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Wisconsin Focus on Energy
2019 Technical
Reference Manual

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The Cadmus Group: Energy Services

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Executive Summary

Under its contract with the Public Service Commission of Wisconsin (the PSC) to evaluate the Wisconsin Focus on Energy programs, the Evaluation Team[1]—in coordination with the Program Administrator, the Program Implementers, and PSC staff—compiled this Technical Reference Manual (TRM). The information contained in this document summarizes the consensus calculations of the electric and natural gas energy savings, and the electric demand reductions, achieved from installing energy efficiency and renewable energy measures that are supported by Focus on Energy programs. This TRM is publicly available online at http://www.focusonenergy.com/about/evaluation-reports.

The values presented in this TRM fall into one of two categories:

- ***Deemed Savings*** are specific per-unit saving or demand reduction values that have been accepted by the Program Administrator, Program Implementers, Evaluator, and the PSC because the measures and the uses for the measures are consistent, and sound research supports the savings achieved.
- ***Savings Algorithms*** are equations for calculating savings or demand reductions based on project- and measure-specific details. This TRM makes these calculations transparent by identifying and justifying all relevant formulas, variables, and assumptions.

This TRM is also a reference guide as to how measures are classified in Focus on Energy's tracking database, SPECTRUM. This document is revised annually to account for changes to programs and measures.

The Evaluation Team leveraged many different primary and secondary sources to derive the calculation algorithms, variable assumptions, and measure descriptions contained in this TRM. These sources include available best practices and industry standards; on-site evaluation, measurement, and verification (EM&V) of savings from Focus on Energy projects; engineering reviews; and reviews of practices used in other jurisdictions. To best represent the Wisconsin climates and demographics, as well as program implementation practices, these energy-savings calculations account for state-specific factors such as climate zones, building codes, and market penetrations.

Update Process

The TRM is updated on a working basis throughout the year, and published twice per year. A fall/winter update incorporates savings updates from evaluation findings that will be effective for the following calendar year. The annual spring update incorporates measures added since fall publication, and reflects savings active for the year of publication. The present edition presents deemed savings and inputs effective for calendar year 2019.

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[1] The Evaluation Team consists of Cadmus, St. Norbert College Strategic Research Institute, Apex Analytics, and REMI.

Annual updates keep the TRM relevant and useful by:

- Presenting validated savings calculations for any new measures Focus on Energy has begun offering through its programs since the last update;
- Eliminating measures that are no longer being offered through Focus on Energy programs; and
- Updating information on existing measures to reflect new research findings and technology changes.

Two processes are in place for updating the TRM and ensuring that those updates are timely, comprehensive, and accurate. All content updates are integrated into the existing document, with changes indicated in the Revision History table included for each measure entry.

1. Updates to savings calculations for existing measures are only made in the fall/winter TRM revision. As part of the annual impact evaluation, the Evaluation Team identifies whether measures' recommended savings could be informed by evaluation findings and/or the presence of new research. The Evaluation Team works with the Program Administrator and the PSC to determine whether the findings are significant enough to merit a full review of the measure savings. Further review is typically pursued for those measure(s) that make a significant contribution to overall program savings, as well as when a lengthy period of time has elapsed since the measure was last reviewed, and/or if there is uncertainty regarding the accuracy of the existing savings calculations.

   In summer of each year, the Evaluation Team issues the results of its review, including any proposed revisions to savings calculations or other aspects of the existing TRM content. Program Implementation staff, the Program Administrator, and PSC staff review the proposed updates to achieve consensus on final revisions for publication in the fall/winter TRM.

   By publishing all changes to existing measures in the fall/winter update, the TRM is able to inform the Program Administrator and Program Implementers in program planning for the upcoming year.

2. Focus on Energy Program Implementers may propose adding new measures or revising the entries for existing measures at any time during the year, by preparing a workpaper that follows the structure of a TRM entry. These workpapers are reviewed by members of the Evaluation Team, the Program Administrator, and PSC staff to ensure that the proposed savings calculations are fully and adequately justified. Workpapers that meet this standard must have the following key criteria:

   a. A clear definition of the measure;
   b. A clear description of how the measure saves energy;
   c. A complete description of the calculation algorithms used to calculate savings, which identifies all variables and, where relevant, identifies the standard values to be used as inputs; and
   d. Citation of all data to valid sources.

The initial workpaper may be revised to ensure that all criteria are met and to achieve consensus on a final savings recommendation. Workpapers that pass all levels of the review receive formal approval from the PSC.

New measures and revised savings calculations take effect for the programs immediately after the workpaper is approved. Similarly, existing measures are deactivated as soon as they are no longer offered. As a result, the published TRM does not have details for all active measures or savings calculations at every point during the year.

Navigating the TRM

Focus on Energy savings and demand reductions are calculated, and incentives are paid, by measure. Measures are defined as a specific product, technology, or service offered through one or more Focus on Energy programs, for which definable savings can be identified. Some TRM entries describe the savings for a single measure. Other entries address a group of related measures whose savings are calculated in a consistent way, such as measures that offer the same type of lighting product in different wattages.

TRM entries are grouped by technology and function, based on the group designations used to classify measures in SPECTRUM. Most groups are based on technology, including a lighting group with subcategories addressing CFLs, LEDs, and other specific lighting technologies. Some measures are grouped by technology end use, such as laundry or food service. These classifications are used for planning purposes and to categorize savings outcomes in evaluation reports.

Measure Detail Structure

Each entry describes the measure and its savings using the following format:

1. An introductory **Measure Detail Table** summarizes the measure savings and characteristics, including the formal measure name and any information necessary to include the measure in SPECTRUM. The measure detail table also identifies two key characteristics that guide how savings are calculated.

   First, the detail table identifies all sectors in which the measure is offered, which include:[2]

   a. Residential single-family homes;
   b. Residential multifamily dwellings (such as apartment buildings and condominiums);
   c. Commercial facilities;
   d. Industrial facilities;
   e. Agriculture facilities; and
   f. School and government facilities.

   In many cases, the energy savings calculated for a measure will be the same for each sector in which it is used. However, this can vary for measures that are used differently by different

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[2] Because measures that are incented through a markdown on the retail price at the store cannot be clearly assigned to a sector, they are assigned to the "upstream" sector based on the program design.

customer sectors. For example, research has confirmed that, on average, homeowners, commercial businesses, and industrial facilities use the same lighting product for different amounts of time and at different times of the day, resulting in different annual electricity savings and demand reductions.

2. Second, the table documents the measure type, which identifies the process by which savings are calculated. Each Focus on Energy measure is one of the following three measure types:
   a. *Prescriptive* measures have a specific deemed savings value that can be applied to each project within a given sector where the measure is used. This measure type is most commonly used for products that are manufactured and used consistently by all participants, such as light bulbs and appliances.
   b. *Custom* measure savings vary by project. This applies to more complex, multifaceted measures with different energy-use factors for each project, such as changes to industrial processes. TRM entries for custom measures do not identify savings values, but instead specify the savings algorithm that should be used to calculate savings and the source and calculation method used for algorithm inputs.
   c. *Hybrid* measure savings, like custom measure savings, vary by project, and are treated like custom measures in the TRM. The distinction between hybrid and custom measures is that the value of custom incentives also varies by project, while hybrid incentives are the same for each project.
3. The next three sections describe the measure(s) and how they achieve energy savings. The **Measure Description** defines the product, technology, or service. The **Description of Baseline Condition** identifies the less efficient product or service the customer could purchase in absence of Focus on Energy programs and incentives, while the **Description of Efficient Condition** identifies how the measure incented through Focus on Energy is more efficient than the baseline. Measures achieve energy savings and/or demand reductions based on the difference in energy use and demand between the baseline and efficient conditions.
4. Formulas are provided to specify the energy savings and demand reduction calculations. The **Annual Energy-Savings Algorithm** identifies how to calculate the electricity and/or natural gas savings achieved per year. The **Summer Coincident Peak Savings Algorithm** identifies the formula used to calculate reductions in electric demand, under the assumption that peak electric demand in Wisconsin occurs weekday afternoons from 1:00 p.m. to 4:00 p.m. in the months of June, July, and August. The **Lifecycle Energy-Savings Algorithm** identifies the formula used to convert annual electricity and/or natural gas savings to the lifecycle savings achieved over the expected useful life (EUL) of the measure. In addition to describing the algorithms used, all three sections specify the values of variables used in the calculation. These inputs may include assumptions about usage behavior or other details obtained through research. For custom and hybrid measures, the algorithms also note which inputs should be calculated on a project-by-project basis, from sources such as engineering reviews, modeling inputs, or on-site measurements.

5. Savings calculated through those formulas are often reported in the Measure Detail Table. However, in some cases—such as when there are calculations for multiple related measures—there is too much detail to concisely include in the Measure Detail Table. In those cases, a **Deemed Savings** section describes all completed savings calculations. In some cases, an **Assumptions** section may also be added to describe the process of selecting and/or calculating algorithm inputs in greater detail.
6. All factual statements and figures throughout the measure description include a superscript citation. The **Sources** section lists those citations numerically. For public sources such as published studies, hyperlinks and publication information are provided for the original source. More details on data cited to internal sources, such as historical Focus on Energy data or measure-specific market research, can be obtained from program staff. Initial inquiries can be directed to Joe Fontaine at the PSC, (608) 266-0910, joe.fontaine@wisconsin.gov.
7. The **Revision History** section has a table with all the revision dates for that TRM entry and briefly describes the changes.

Acknowledgements

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Business (Nonresidential) Measures

Through the Business Portfolio, Wisconsin Focus on Energy delivers energy efficiency and renewable energy programs to nonresidential utility customers in the state. Customers who are eligible to participate in these programs include commercial and industrial firms, agricultural producers, schools, and local governments. With the programs, Focus on Energy aims to help nonresidential customers meet their unique and complex electricity and natural gas needs as efficiently as possible. Focus on Energy accomplishes this by providing information, financial incentives, and support for implementing energy-efficient technologies. These technologies include, but are not limited to, efficient lighting, heating and cooling systems, motors and drives, appliances, renewable energy systems, and custom products specific to key industries, such as food service and agricultural production.

Agriculture

Ag Dairy Refrigeration, Scroll Compressor

	Measure Details
Measure Master ID	Dairy Scroll Compressor Replacement without Pre-Cooler, 3977 Dairy Scroll Compressor Replacement with Pre-Cooler, 3976 Dairy Scroll Compressor Replacement with Pre-Cooler and VFD Milk Pump, 3975
Measure Unit	Per scroll compressor
Measure Type	Prescriptive
Measure Group	Agriculture
Measure Category	Compressor
Sector(s)	Agriculture
Annual Energy Savings (kWh)	1,074 kWh for MMID 3977, 519 kWh for MMID 3976, 328 kWh for MMID 3975
Peak Demand Reduction (kW)	0.0196 kW
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	16,112 kWh for MMID 3977, 7,788 kWh for MMID 3976, 4,914 kWh for 3975
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$400.00[2]

Measure Description

A scroll compressor is a newer, more efficient style of compressor technology used in refrigeration equipment with fewer moving parts and higher reliability compared to a traditional hermetically sealed reciprocating compressor used for dairy milk refrigeration. Most new dairy refrigeration equipment comes standard with scroll compressor technology, so this measure does not apply to new construction projects and is only eligible for dairy farms that need upgraded refrigeration equipment and where the farmer chooses to replace their existing hermetically sealed reciprocating compressor with a new scroll compressor.

Description of Baseline Condition

The baseline condition is a dairy farm operation in which standard hermetically sealed reciprocating compressors are used to power dairy refrigeration equipment.

Description of Efficient Condition

The efficient condition is a dairy farm where the older existing reciprocating compressors are replaced with newer similarly sized scroll-type compressors that power the dairy refrigeration equipment. The deemed replacement size of the compressor is 5 hp, which is one of the most common compressor size ratings from past project submittals.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{RECIP} - kWh_{SCROLL}$

kWh_{RECIP} = lbs of Milk * $C_{P,MILK}$ * ($°F_{IN}$ - $°F_{FINAL}$) * Milking days per year / ($AEER_{RECIP}$ * 1,000)

kWh_{SCROLL} = lbs of Milk * $C_{P,MILK}$ * ($°F_{IN}$ - $°F_{FINAL}$) * Milking days per year / ($AEER_{SCROLL}$ * 1,000)

Where:

lbs of Milk = Estimated daily pounds of milk produced by the dairy operation (= number of milking cows [100; see Assumptions] * 68 pounds of milk per day per cow[3] / 365 days)

$C_{P,MILK}$ = Specific heat of milk (= 0.94 Btu/[lb - °F])[4]

$°F_{IN}$ = Temperature of supplied milk that needs to be mechanically cooled (= 98°F if no pre-cooler is used,[5] = 67°F if a milk pre-cooler unit is used, = 56.3°F if a milk pre-cooler unit and VFD milk pump are used; see Assumptions)

$°F_{FINAL}$ = Final stored temperature of cooled milk (= 38°F)[2]

Milking days per year = 365

$AEER_{RECIP}$ = Annual EER of reciprocating compressor (= 14.48 Btu/watt hour)[3]

$AEER_{SCROLL}$ = Annual EER of scroll compressor (= 16.29 Btu/watt hour)[3]

1,000 = Kilowatt conversion factor

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = 0.1745 kW * CF

Where:

0.1745 kW = Peak kW savings determined from peak kW analysis,[3] with peak compressor power consumption determined from compressor performance data while compressor operated at or near maximum capacity when Wisconsin ambient temperatures were more than 70°F.

CF = Coincidence factor (= 0.1125)[6] Note that only 11.25% of Wisconsin dairy farms have been recorded as milking three or more times per day. Typically, farms milking only twice per day do so during morning and evening hours, outside the Focus on Energy defined peak period. Farms milking three times per day usually have the third milking session during the peak period. (The demand for a long continuous refrigeration compressor run time occurs during the actual milking periods when the freshly extracted milk is directed into the milk storage bulk tank and needs to be cooled as soon as possible.)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

The savings in this workpaper are based on the following assumptions:

- The new scroll compressor is replacing a reciprocating compressor with similarly sized cooling capacity. Calculations are based on between 1 ton and 5 tons of cooling capacity being achieved per compressor in worst case conditions (i.e., hottest ambient temperature days of the year).
- The new scroll compressor is replacing a hermetically sealed reciprocating compressor. According to knowledgeable dairy equipment technician and Trade Ally from Bob's Dairy Supply (Dorchester, Wisconsin), at the vast majority of Wisconsin farms that still have reciprocating compressors, those compressors are hermetically sealed as opposed to semi-hermetic.
- The milk temperature from the output of a pre-cooler is based on a weighted percentage of single and double pass pre-cooler units. Single pass units drop the milk temperature roughly 25°F while double pass units drop the milk temperature roughly 35°F.[2] Based on past project milk pre-cooler application submittals, the latest Wisconsin trend for new pre-cooler installations is 40% single pass pre-cooler and 60% double pass pre-coolers. The estimated temperature drop for a farm with a pre-cooler is 31°F (= 25°F * 0.4 + 35°F * 0.6).[3]
- Compressor operates at a constant 25°F evaporator temperature (which is 10°F to 15°F below final milk storage temperature) and a 20°F condenser split temperature.
- Milking operations occur 365 days per year.[9]
- A well water temperature of 52.3°F is used as milk coolant.[10] It is assumed that the lowest milk temperature that could be achieve is 56.3°F (or 4°F higher than well water coolant temperature),[11] and that the maximum additional cooling for any style of plate cooler in conjunction with a variable speed controlled milk pump is 15°F.[2]
- A single 5 hp compressor/cooling system can handle the milk cooling needs of at least 100 cows (100 cows * 68 pounds per cow per day / 8.6 pounds of milk per gallon = 790 gallons per day).[12] The cooling capacity of a 5 hp compressor should realistically be able to handle the milk cooling

needs of at least 100 cows from one milking session within proper cooling time guidelines. The vast majority of farms have two or three milking sessions per day.

- The milk provided from one milking session of 100 cows represents the maximum capacity that can be cooled by a milk refrigeration system being driven by a single 5 hp scroll compressor; this is a conservative estimate, within the state-mandated time requirements. Except as provided under paragraph (b), milk shall be cooled to 50°F (10°C) or less within four hours after the start of the first milking, and to 45°F (7°C) or less within two hours after the end of milking. The temperature of the blended milk from the first milking and later milking's shall not exceed 50°F (10°C).[13]
- Since the EER of a compressor can vary quite a bit at any one particular operation point, an annual EER[7] is being used to provide a more realistic efficiency value of the compressor based on Wisconsin ambient bin temperature data.
- The scroll compressor models are based on a sample of 12 different compressor models purchased and incentivized through the Focus on Energy Agriculture, Schools, and Government Program. The baseline is from 12 hermetically sealed reciprocating compressor models of similar horsepower ratings from the Emerson website.[8] All compressor performance data is shown and summarized in the 'Compressor Modeling' supporting document.[6]

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   WI Dairy Statistics tab shows annual data from: U.S. Department of Agriculture. "Milk Production Per Cow, Wisconsin." https://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/Dairy/Historical_Data_Series/mkpercow.pdf
   Compressor Modeling tab was created by CESA10 using scroll compressor performance data from past projects submitted to Focus on Energy and Compressor Performance Data sheets from Copeland brand compressors.
   Pre-Cooler Measure Analysis tab shows sample data of 86 pre-cooler projects entered in SPECTRUM from January 2015 through July 2016. The split of single pass to double pass plate coolers installed on Wisconsin dairies was determined from these 86 sample projects.

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    Based on the Farm Inputs tab, Bulk Tank Typical Compressor Sizes table, an 800-gallon bulk tank can handle milk being cooled by a maximum of ~5 hp compressor.
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Revision History

Version Number	Date	Description of Change
01	10/14/2016	Initial release

Heat Recovery Tank, No Heating Element, Electric or Natural Gas

	Measure Details
Measure Master ID	Refrigeration Heat Recovery Unit, No Heating Element, Ag: Natural Gas WH Without Milk Pre-Cooler, 3991 Natural Gas WH With Milk Pre-Cooler, 3990 Natural Gas WH With Milk Pre-Cooler & Milk Pump VFD, 3989 Electric WH Without Milk Pre-Cooler, 3994 Electric WH With Milk Pre-Cooler, 3993 Electric WH With Milk Pre-Cooler & Milk Pump VFD, 3992
Measure Unit	Per milking cow
Measure Type	Hybrid
Measure Group	Agriculture
Measure Category	Energy Recovery
Sector(s)	Agriculture
Annual Energy Savings (kWh)	Varies by number of milking cows and tank size
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by number of milking cows and tank size
Lifecycle Energy Savings (kWh)	Varies by number of milking cows and tank size
Lifecycle Therm Savings (Therms)	Varies by number of milking cows and tank size
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$3,441.45[2]

Measure Description

A refrigeration heat recovery (RHR) unit captures waste heat from the refrigeration system and transfers some of that heat into incoming well water. That captured waste heat pre-heats ground water before it enters the main water heater unit to be heated up to the desired final temperature needed for farm equipment cleaning. The most popular RHR units are comprised of a water tank with a heat exchanger wrapped around the outside of the tank. The hot compressed refrigerant flows through the heat exchanger on its way to the condenser unit. The heat from the refrigerant is transferred through the tank wall into the water. Thermal buoyancy causes the warmest water to rise to the top of the tank. When hot water is used, water flows from the RHR tank into the water heater, while well water flows into the heat recovery tank. These units can typically assist in reducing the water heating energy use by approximately 50%.[3]

It is important to note that if a dairy farm installs a RHR unit and a milk plate cooler, with or without the use of milk pump VFD control, the plate cooler will impact the savings potential of the RHR unit. The use of a plate cooler will reduce the total milk mechanical refrigeration load. Due to this refrigeration load reduction, the amount of heat rejection possible to the RHR system is diminished. Note that there are three different measures listed for each water heater source.

Description of Baseline Condition

The baseline condition is an existing dairy farm with refrigeration equipment and a water heater unit without the use of an RHR unit to feed preheated water to the water heater. Water heater is fed directly with ground water.

Description of Efficient Condition

The efficient condition is farm refrigeration equipment where an RHR tank (without additional heating element) is installed and captures waste refrigerant heat from the refrigeration system compressor and transfers that waste refrigerant heat into an RHR tank, supplied with cool ground water, through a heat exchanger before continuing through the refrigeration system condensing unit. The newly preheated water in the RHR tank is used as input into the farm’s main water heater unit, which now has a smaller temperature differential to overcome to be fully heated, compared to direct ground water.

Annual Energy-Savings Algorithm

The kWh savings are for MMIDs 3992-3994 (RHR unit paired with electric water heater). The therm savings are for MMIDs 3989-3991 (RHR unit paired with natural gas water heater).

$kWh_{SAVED} = Btu_{SAVED} / 3{,}412$

$Therm_{SAVED} = Btu_{SAVED} / 100{,}000$

$Btu_{SAVED} = (Btu_{RECOVERED} / Day * 365) / EF$

$Btu_{RECOVERED}/Day$ = Lesser of: $Btu_{MILK\_POTENTIAL}$ or $Btu_{RHR\_STORAGE}$

$Btu_{MILK\_POTENTIAL}$ = Lbs of Milk * $C_{P,MILK} * \Delta T_{MILK}$ * SF

$Btu_{RHR\_STORAGE}$ = RHR tank size * # of milking’s per day * $C_{P,H2O} * P_{WATER} * \Delta T_{H20}$

Where:

3,412 = Btu per kWh conversion factor

100,000 = Btu per therm conversion factor

365 = Days of milking per year[4]

EF = Energy factor (= 90% for electric standard water heater; = 59% for natural gas standard water heater)[5]

Lbs of Milk = The pounds of milk produced per day that needs to be cooled (= 68 lbs of milk per cow; note that the number of milking cows is user defined)[6]

$C_{P,MILK}$ = Specific heat of milk (= 0.94 Btu/(lb-°F))[8]

ΔT_{MILK} = Change in milk temperature (= $°F_{IN}$ - $°F_{FINAL}$)

  $°F_{IN}$ = Temperature of supplied milk that needs to be mechanically cooled (= 98°F if no pre-cooler is used in operation;[7] = 67°F if a milk pre-cooler unit is used; = 56.3°F if a milk pre-cooler unit and VFD milk pump are used; see Assumptions)

  $°F_{FINAL}$ = Final stored temperature of cooled milk (= 38°F)[7]

SF = Savings factor, the percentage of energy able to be captured from the milk cooling process (= 50%; see Assumptions)[9]

RHR tank size = Size in gallons the RHR tank(s) can hold preheated water per wash cycle (= this is a customer-provided input found on the project invoice; a default value of 100 gallons should be used if RHR tank size cannot be determined from the invoice)

# of milking's per day = Number of times cows are milked per day (= 2.1125; this is based on 11.25%[10] of Wisconsin farms milking more than twice per day. Note that typically, the number of milking's equals the number of equipment wash cycles)

$C_{P,H2O}$ = Specific heat of water (= 1 Btu/lb-°F)

P_{WATER} = Density of water (= 8.34 lbs/gallon)

ΔT_{H20} = Temperature difference (= $Temp_{WARM\_H20}$ – $Temp_{COLD\_H20}$)

  $Temp_{WARM\_H20}$ = Expected temperature an RHR unit can pre-heat well water up to (= 120 °F)[9]

  $Temp_{COLD\_H20}$ = Average well water temperature (= 52.3 °F)[11]

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for RHR units. It is assumed that electric water heaters have a single element and will still be used to heat water up to full temperature, and that the kW rating is unchanged when a RHR unit is added in the water heating loop (resulting in no demand reduction).

Lifecycle Energy-Savings Algorithm

There are kWh savings for measures using electric water heaters, and therm savings for measures using natural gas water heaters.

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

- The percentage range of heat recoverable from milk is 20% to 60%.[9] This workpaper is based on 50% as the deemed savings percentage of recoverable Btus from the milk cooling/heat recovery process, based on engineering judgment.
- This measure assumes that at a minimum, all the preheated water captured in a full RHR tank is ultimately used for cleaning during at least one milk equipment cleaning cycle.
- The RHR unit is assumed to consume no energy itself in order to function (no heating element).
- Based on past project data submitted for the plate-coolers measure, there is roughly a 40%/60% split of single vs. double pass plate coolers,[6] assumed to provide ~25°F/35°F of milk cooling, respectively.[12] This results in a 31°F deemed drop in milk temperature from the inclusion of a pre-cooler to the milk refrigeration system (= [40% * 25°F] + [60% * 35°F]).
- Savings may also result from an increased efficiency of the refrigeration system due to the increased capacity to dissipate heat; however, this workpaper does not account for those savings due to lack of documentation to support the size of those values and claim savings that are conservative in nature.
- The savings are based on the assumption that the maximum hot water temperature from the output of the water heater is 170°F. Therefore, the RHR unit will most likely not achieve total water heating needs on its own.[9]
- The measure savings are based on a well water temperature of 52.3°F for milk coolant.[11] It is assumed that the lowest milk temperature that could be achieved is 56.3°F (or 4°F higher than the well water coolant temperature).[13] The maximum additional cooling for any style of plate cooler in conjunction with a variable speed controlled milk pump would be up to 15°F of additional cooling.[12]
- The user-defined input provided for the number of milking cows is assumed to be the average number of animals being milked throughout the entire year, associated with the refrigeration system(s) using the heat recovery unit.

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Revision History

Version Number	Date	Description of Change
01	10/01/2015	Initial release
02	10/28/2016	Adjusted to include more assumptions and require less customer data, changed unit measure to per milking cow
03	12/2018	Updated cost based on new historical data

High-Speed High-Efficiency Fans, Agriculture

	Measure Details
Measure Master ID	Circulation Fan, HS/HE, 36”-47”, Ag, 4286, 4287 Circulation Fan, HS/HE, 48”-52”, Ag, 4288, 4289 Circulation Fan, HS/HE, ≥53”, Ag, 4290, 4291 Ventilation Fan, HS/HE, 36”-47”, Ag, 4292, 4293 Ventilation Fan, HS/HE, 48”-52”, Ag, 4294, 4295 Ventilation Fan, HS/HE, ≥53”, Ag, 4296, 4297
Measure Unit	Per fan
Measure Type	Prescriptive
Measure Group	Agriculture
Measure Category	Fan
Sector(s)	Agriculture
Annual Energy Savings (kWh)	Varies per fan size
Peak Demand Reduction (kW)	Varies per fan size
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies per fan size
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Circulation fan = 15 (MMIDs 4286–4291), ventilation fan = 16 (MMIDs 4292–4297)[1]
Incremental Cost ($/unit)	$150.00[2]

Measure Description

Agriculture ventilation and exhaust fans are intended to provide minimum ventilation rates and maintain indoor air quality for livestock. The same ventilation and exhaust fans may also be used in greenhouse applications. Agriculture circulation fans are designed to help provide animal comfort, control insects in summer, and maintain dry surfaces. Generally, agricultural-grade air circulating fans are corrosion resistant and designed for easy cleaning. This measure mainly applies to dairy barn fan installations, but can be applied to fan use in other livestock housing areas as well.

Each fan grouping is divided into two efficiency levels based on level of energy efficiency. As a result, program incentives may vary based on the level of fan performance.

Description of Baseline Condition

The baseline condition is an air circulation fan used within an agricultural building. The baseline values for each fan grouping were based on a comparison of actual and certified fan performance information supplied from the Bio-Environmental and Structural System Lab at the University of Illinois (BESS) as of September 29, 2017.[3] The results were sorted into fan size groupings, with single and three phase fans combined. The fan baseline (standard) efficiency and energy consumption values are based on the simple average of each respective value shown for all fan size groupings. The baseline comparison performance criteria for each of the fan size groupings is listed in the Efficiency Level 1 and Efficiency Level 2 Fan Average Power Ratings table below.

Description of Efficient Condition

To qualify for a prescriptive incentive, each circulation or ventilation fan must undergo third-party testing and be rated through the BESS or an accredited Air Movement and Control Association testing facility. The 75th percentile (Efficiency Level 1 of fan size grouping efficiency ratings from testing at BESS labs for both circulation and ventilation fans were used as the initial minimum qualifying efficiency starting point. Next, the actual minimum efficiency requirements were set by slightly adjusting that point up or down as needed to be comparable to past years' fan qualifying standards.

Any single fan size minimum efficiency was not allowed to exceed more than 0.5 units higher than the 2015 minimum qualifying efficacies. Care was also taken not to raise the minimum standard high enough to knock more than 25% of qualifying fans off the 2015 Focus on Energy fan pre-qualified product list (see tables below).

Efficiency Level 1 Exhaust and Ventilation Fans

Fan Diameter (inches)	MMID	75th Percentile (cfm/watt)	2015 Program Requirement (cfm/watt)	2017 Program Requirement (cfm/watt)
36–47	4292	17.0	17.1	17.1
48–52	4294	19.8	20.3	20.3
53+	4296	21.4	20.3	20.3

Efficiency Level 1 Circulation Fans

Fan Diameter (inches)	MMID	75th Percentile (lbf/kW)	2015 Program Requirement (lbf/kW)	2017 Program Requirement (lbf/kW)
36–47	4286	20.0	18.2	18.7
48–52	4288	24.3	22.7	23.1
53+	4290	24.4	22.7	23.1

In 2018, a tiered incentive approach was implemented to award higher incentives for fans performing in the 85th percentile or higher (Efficiency Level 2). Minimum efficiency for Level 1 and 2 fans are listed in the table below.

Energy Savings Minimum Qualifying Fan Efficiency Requirements

Fan Diameter (inches)	MMID (Level 1, Level 2)	Minimum Efficiency for Exhaust and Ventilation Fans at 0.10 Static Pressure (Level 1/Level 2)	Minimum Efficiency for Circulation Fans* (Level 1/Level 2)
36–47	4292, 4293 4286, 4287	17.1/17.5 (cfm/W)	18.7/21.0 (lbf/kW)
48–52	4294, 4295 4288, 4289	20.3/21.6 (cfm/W)	23.1/25.2 (lbf/kW)
53+	4296, 4297 4290, 4291	20.3/22.3 (cfm/W)	23.1/25.0 (lbf/kW)

* lbf = pound force

Annual Energy-Savings Algorithm

Ventilation/Exhaust Fans

$kWh_{SAVED\_VENT} = (Fan_{kW\_BASE\_VENT} – Fan_{kW\_EFF\_VENT}) * HOURS$

Where:

$Fan_{kW\_BASE\_VENT}$ = Ventilation baseline efficiency fan average kW rating at 0.10 static pressure (average of all kW ratings reported from BESS lab tested fans in stated fan size groupings; see Tier 1 and Tier 2 Fan Average Power Ratings table below)[3]

$Fan_{kW\_EFF\_VENT}$ = Ventilation high-efficiency fan average kW rating at 0.10 static pressure (average of all kW ratings at or above the minimum qualifying efficiencies, stated in the Energy Savings Minimum Qualifying Fan Efficiency Requirements table above, from BESS lab tested fans in applicable fan size groupings)[3]

HOURS = Annual hours of operation (= 7,446, which is 8,760 * 0.85; based on the assumption that ventilation fans operate at least 85% of available yearly hours, as a conservative approach to account for barn design (tunnel/cross ventilation, tunnel ventilation with side-wall curtains) and typical control schedules that incorporate number of fans, stages, and temperature setpoints throughout the year)

Circulation Fans

$kWh_{SAVED\_CIRC} = (Fan_{kW\_BASE\_CIRC} - Fan_{kW\_EFF\_CIRC}) * HOURS$

Where:

$Fan_{kW\_BASE\_CIRC}$ = Circulation baseline efficiency fan average kW rating (average of all kW ratings reported from BESS lab tested fans in stated fan size groupings; see Tier 1 and Tier 2 Fan Average Power Ratings table below)[3]

$Fan_{kW\_EFF\_CIRC}$ = Circulation energy-efficient fan average kW rating (average of all kW ratings at or above the minimum qualifying efficiencies, stated in the Energy Savings Minimum Qualifying Fan Efficiency Requirements table above, from BESS lab tested fans in applicable fan size groupings)[3]

HOURS = Annual hours of operation (= 3,864)[4]

According to agriculture, schools, and government program subject matter expert, Terry Laube, farmers in Wisconsin typically turn their circulation fans on when it is 50°F or warmer to improve cow comfort. This HOU assumption holds most true for dairy barn applications; however, it is assumed to reasonably hold true for other uses and for controlling animal comfort.

Tier 1 and Tier 2 Fan Average Power Ratings[3]

Fan Diameter (inches)	MMID (Level 1, Level 2)	Exhaust and Ventilation Fan kW Ratings (Baseline/Level 1/Level 2)	Circulation Fan kW Ratings (Baseline/Level 1/Level 2)
36–47	4292, 4293 4286, 4287	0.7471/0.5469/0.5344	0.5945/0.5393/0.4601
48–52	4294, 4295 4288, 4289	1.2821/1.0059/0.8582	1.0851/0.9849/0.9183
53+	4296, 4297 4290, 4291	1.4201/1.1568/0.9986	1.2058/1.1320/0.9660

Deemed Annual kWh Savings[3]

Fan Diameter (inches)	MMID (Level 1, Level 2)	kWh Savings per Exhaust and Ventilation Fan (Level 1/Level 2)	kWh Savings per Circulation Fan (Level 1/Level 2)
36–47	4292, 4293 4286, 4287	1,490/1,583	213/519
48–52	4294, 4295 4288, 4289	2,057/3,156	387/644
53+	4296, 4297 4290, 4291	1,961/3,138	285/926

* All deemed savings values are rounded to the nearest integer.

Summer Coincident Peak Savings Algorithm

Ventilation/Exhaust Fans

$kW_{SAVED} = (Fan_{kW\_BASE} - Fan_{kW\_EFF}) * CF$

Circulation Fans

$kW_{SAVED} = (Fan_{kW\_BASE} - Fan_{kW\_EFF}) * CF$

Where:

CF = Coincidence factor (= 1.0)

The coincidence factor is based on the assumption that the temperature is above 50°F, and therefore ventilation fans are running during an overwhelming majority of peak hours.

Deemed Demand kW Reduction[4]

Fan Diameter (inches)	MMID (Level 1, Level 2)	Demand kW Reduction per Exhaust and Ventilation Fan (Level 1/Level 2)	Demand kW Reduction per Circulation Fan (Level 1/Level 2)
36–47	4292, 4293 4286, 4287	0.2001/0.2126	0.0552/0.1344
48–52	4294, 4295 4288, 4289	0.2762/0.4238	0.1002/0.1668
53+	4296, 4297 4290, 4291	0.2633/0.4215	0.0738/0.2398

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years for circulation fans, = 16 years for ventilation/exhaust fans)[1]

Deemed Lifecycle Savings (kWh)

Fan Diameter (inches)	MMID (Level 1, Level 2)	Lifecycle kWh Savings per Exhaust and Ventilation Fan (Level 1/Level 2)	Lifecycle kWh Savings per Circulation Fan (Level 1/Level 2)
36–47	4292, 4293 4286, 4287	23,840/25,328	3,195/7,785
48–52	4294, 4295 4288, 4289	32,912/50,496	5,805/9,660
53+	4296, 4297 4290, 4291	31,376/50,208	4,275/13,890

Assumptions

High-speed high-efficiency fans can come with or without guards. Installing a guard on a fan that was originally tested and sold without a guard will decrease the performance of that fan. The deemed savings for fans are based on actual test performance data, assuming that fans are sold and used as tested.

The lifecycle savings are based on agriculture fans and fan housing being cleaned and maintained at least once a year to prevent dust and gunk build-up that would affect fan performance.

When installing fans without guards, be sure they are away from areas that can be reached by people or animals for safety reasons.

Sources

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4. Appendix B: Common Variables, ‘Outside Air Temperature Bin Analysis.’ Average number of hours in Wisconsin at or above 50°F.

Revision History

Version Number	Date	Description of Change
01	08/03/2016	Corrected table headings and typos, added to Assumptions
02	10/02/2017	Created tiered structure for multiple levels of efficiency

Energy Efficient Grain Dryer

	Measure Details
Measure Master ID	Energy Efficient Grain Dryer, 3386 Energy Efficient Grain Dryer, Propane-Fueled, 4868
Measure Unit	Bushels per hour
Measure Type	Hybrid
Measure Group	Agriculture
Measure Category	Grain Dryer
Sector(s)	Agriculture
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies
Annual Propane Savings (Gallons)	Varies
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	Varies
Lifecycle Propane Savings (Gallons)	Varies
Water Savings (gal/yr)	0
Effective Useful Life (years)	20[1,9]
Measure Incremental Cost ($/unit)	$179.00[2]

Measure Description

This incentive offering is for agricultural operations that replace their existing grain drying systems with a more energy-efficient batch or continuous flow grain drying system with a ≤ 1,500 bushels per hour capacity. Although still operational, the efficiency of older equipment becomes obsolete in comparison to newer technology and can be more expensive to operate. Newer grain dryers generally have larger drying capacities, and can process loads faster and at a greater efficiency. Installing a new and more efficient grain dryer will effectively reduce the annual hours of operation by allowing for faster processing of grain through increased efficiency. The purpose of drying grain is to reduce the amount of water contained in the crop after harvest to an acceptable level for marketing, storage, or processing. This incentive will be provided based on the bushel per hour processing capacity of the new grain dryer. In-bin drying and tower grain drying are excluded from this measure and should be handled as custom measures.

While this measure can apply to all types of grain, the main focus of this workpaper is on corn, which is the main use of grain dryers in the state of Wisconsin. This measure is not eligible for new construction, which should be handled as a custom project.

Description of Baseline Condition

The most accurate way to depict an existing grain dryer's previous overall baseline efficiency is to convert one to three years of utility electric and natural gas or propane usage (as metered for the grain dryer in operation) into Btus. This is then divided by the average number of bushels of grain dried in the given year and the initial and post-installation moisture content percentages. This calculates the pounds of water removed, leading to the historical Btu per pound of water removed.

As part of the application, one to three years of grain dryer utility history will be requested and required as part of the supplied documentation for the applied measure.

- In the event that utility data for a grain dryer is not able to be provided for past years, a trade ally analysis of the existing grain dryer efficiency will also be accepted. Most trade ally's grain dryer analyses are propriety in nature, but they help determine an estimate of efficiency based on normal weather temperature/humidity data at the location of grain dryer installation during the time of harvest/drying. Their analysis should also account for the past harvested grain moisture contents, pre- and post-installation, as recorded by the customer, as well as the capacity ratings of the respective dryer (or a dryer similar to the existing dryer if specific information on the actual existing dryer cannot be obtained).
- If neither utility data nor a trade ally analysis can be provided, a default grain dryer efficiency value provided from USDA literature[10] will be used. This third option is a last resort and will most likely be the least accurate baseline comparison.

The efficiency of grain dryers is very dependent on the weather conditions and time of harvest for each year. Unfortunately, there is no simple way to depict this information for each individual project and many assumptions must be made. The several options for providing information to arrive at a baseline efficiency value are provided below to help ensure that the most accurate savings are calculated for Wisconsin Focus on Energy on a project-by-project basis.

Description of Efficient Condition

Per the North Dakota State University Extension Service, the minimum energy required to evaporate water from corn is approximately 1,200 Btu/lb H_2O, and a realistic dryer maximum efficiency is about 1,500 Btu/lb H_2O.[3]

Since this measure is hybrid, the actual drying efficiency will be calculated for the specific efficient grain dryer installed, and to the best level possible based on the information provided by the customer and grain dryer specification sheet. To ensure that the efficient grain dryer is in fact more efficient than the previous dryer before providing the incentive, Wisconsin Focus on Energy requires that the efficient grain dryer use at least 250 Btu/lb H_2O less than the baseline dryer. The minimum level of grain dryer efficiency allowed for approval is to remove $\leq$ 1,950 Btu/lb H_2O. This value was determined based on the USDA's typical grain dryer energy efficiency chart,[10] showing that the typical efficiency value for all high temperature grain dryers was at or above 2,000 Btu/lb H_2O removed. This 2,000 value was adjusted slightly downward to create a conservative baseline value.

The efficiency of a new grain dryer (Btu/lb H_2O removed) can be calculated using the formulas provided in the Annual Energy-Savings Algorithm section, or the efficiency can be provided as trade ally analysis showing all the inputs and outputs used.

The efficient grain dryer is also required to have at least one of the following features specific to being more energy efficient than the previous dryer:

- Staged temperature (higher temperature for wettest grain, lower for nearly dry grain)
- Grain turners or inverters (rotate mostly dry grain away from to wetter grain toward plenum)
- Differential grain speed (column designed to move grain next to the drying plenum faster to reduce excessive grain temperatures and provide a more uniform moisture content)
- Varied width of the drying column (narrower at top where the grain is wettest, allowing humid air to vent to the atmosphere faster)
- Some form of heat recovery (captures excess heat from cooling section of a grain dryer, where applicable, and redirects it to help preheat the incoming burner intake air)

Annual Energy-Savings Algorithm

Initial Calculations[4]

Moisture Shrink (%) = $(MC_{INIT} - MC_{FINAL}) / (1 - MC_{FINAL})$

$lbs_{H2O\_REMOVED}$ = $Bushels_{INITIAL}$ * $lbs/bu_{INITIAL\_MC}$ * Moisture Shrink (%)

The formulas below are used to calculate savings for the proposed grain dryer only.

Grain Dryer Burner Capacity = 1.08 * Airflow CFM * (Plenum temp - Ambient temp)

Gas Usage Rate (therm/hr or gallons propane/hr) = Grain Dryer Burner Capacity / ConvF / burn_eff

Electric Usage Rate (kWh/hr) = Blower Fan hp * 0.746 * Load Factor / motor_eff

$GD_{PROPOSED\_EFF}$ (Btu/lb H_2O) = (Gas Usage Rate * ConvF) + (Electric Usage Rate * 3,412) / (Moisture Shrink % * Bu/hr * final bushel weight)

Where:

Moisture Shrink (%) = The weight reduction factor of wet grain as it is dried (= user-defined input)

MC_{INIT} = Harvested grain moisture content percentage (= from application)

MC_{FINAL} = Dried grain moisture content percentage (= from application)

$lbs_{H2O\_REMOVED}$ = Pounds of water removed from harvest to post grain drying storage (= user-defined input)

$Bushels_{INITIAL}$ = Number of wet bushels of grain to be dried per year (= user-defined input)

$lbs/bu_{INITIAL\_MC}$ = Bushel weight (= determined from grain moisture content percentage and weight per bushel reference tables)[5]

1.08 = Constant for sensible heat equations

Airflow CFM = Rated blower CFM (= derived from dryer specification sheet or user-defined if spec sheet not available)

Plenum temp = Temperature inside dryer at normal operation (= derived from dryer specification sheet or user-defined if spec sheet not available)

Ambient temp = Average ambient temperature of outside air during typical drying times (= varies by city; see table below)

Average Ambient Temperatures in October and November in Various Wisconsin Cities[7]

Wisconsin Cities	October Average	November Average	Total Average
Eau Claire	46°F	33°F	40°F
Green Bay	47°F	34°F	41°F
LaCrosse	48°F	36°F	42°F
Madison	47°F	34°F	40.5°F
Milwaukee	50°F	38°F	44°F

ConvF = Fuel conversion factor (= 100,000 Btu per them, = 91,333 Btu per gallon of propane)[11]

burn_eff = Combustion efficiency of grain dryer burner (= assumed to be 95%)[4]

Blower Fan hp = Main grain dryer blower fan horsepower rating (= derived from dryer specification sheet or user-defined if spec sheet not available)

0.746 = Constant to convert horsepower to kilowatts

Load Factor = Assumed load factor of blower fan (= estimated as 85%)

motor_eff = Efficiency of motor, derived from NEMA-rated fan efficiency tables based on motor horsepower[6]

Bu/hr = Bushels per hour of dryer capacity at 100% operation based on a 5% to 10% moisture content reduction (= derived from dryer specification sheet or user-defined if spec sheet not available)

final bushel weight = Weight of final grain moisture content in lbs/bu[5]

<u>Energy-Savings Calculations:</u>

$\text{kWh}_{\text{SAVED}} = (\text{GD}_{\text{EXISTING\_EFF}} * \text{Lbs}_{\text{H2O\_REMOVED}} * \text{kWh\%\_}_{\text{EXIST}} / 3{,}412) – (\text{GD}_{\text{PROPOSED\_EFF}} * \text{Lbs}_{\text{H2O\_REMOVED}} * \text{kWh\%\_}_{\text{PROP}} / 3{,}412)$

$\text{Gas}_{\text{SAVED}} = (\text{GD}_{\text{EXISTING\_EFF}} * \text{Lbs}_{\text{H2O\_REMOVED}} * \text{Therm\%\_}_{\text{EXIST}} / \text{ConvF}) – (\text{GD}_{\text{PROPOSED\_EFF}} * \text{Lbs}_{\text{H2O\_REMOVED}} * \text{Therm\%\_}_{\text{PROP}} / \text{ConvF})$

Where:

$\text{Gas}_{\text{SAVED}}$ = Therms of natural gas or gallons of propane saved

$\text{GD}_{\text{EXISTING\_EFF}}$ = Existing grain dryer efficiency, or Btu per pound of water removed (= determined from customer utility data and user-defined inputs of bushels dried at specific pre- and post-installation moisture contents)

$\text{Lbs}_{\text{H2O\_REMOVED}}$ = Annual pounds of water removed from grain harvest during drying process (see the Initial Calculations section above)

$\text{kWh\%\_}_{\text{EXIST}}$ = Existing electric use (= average existing utility bill kWh consumption * 3,412 / (average existing utility bill kWh consumption * 3,412 + average user existing utility bill natural gas consumption * ConvF)

3,412 = Constant to convert Btu to kilowatt-hours

$\text{GD}_{\text{PROPOSED\_EFF}}$ = Proposed grain dryer efficiency in Btu per pound of water removed (see the Initial Calculations section above)

$\text{kWh\%\_}_{\text{PROP}}$ = Proposed electric use (= electric usage rate * 3,412 / (electric usage rate * 3,412 + gas usage rate * ConvF)

$\text{Gas\%\_}_{\text{EXIST}}$ = Existing gas use (= 1 - $\text{kWh\%\_}_{\text{EXIST}}$)

$\text{Gas\%\_}_{\text{PROP}}$ = Proposed gas use (= 1 - $\text{kWh\%\_}_{\text{PROP}}$)

Summer Coincident Peak Savings Algorithm

Grain drying does not occur during the summer peak time periods, therefore no peak demand savings can be claimed.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = \Delta kWh/yr * EUL$

Where:

EUL = Effective useful life (= 20 years; sources list measure life of 30 years[1] and 10 to 12 years,[4,9] so 20 years was selected as the midpoint)

Assumptions

The amount of energy savings from grain dryers is based on production, so farms that grow and dry more grain achieve more savings. The amount of grain harvested can be affected by the weather and the number of acres of grain planted in a particular year. The need for drying is also dependent on the weather at the time of harvest, with drier weather requiring less grain drying. To attempt to control for these variables, the number of bushels of grain dried over the past two to three years, as well as the expected future grain drying output, is collected on the application. This helps to control for some of the variability in savings by using grain drying quantities based on past and future planned harvests.

The measure assumes that all grain drying takes place in the late fall months after grain harvest, typically around October and November.[8] While latent heat has a role in the grain drying process, for purposes of simplification the air ‘sensible’ heat transfer formula is used for grain dryer efficiency calculations. The savings assume that blower/dryer fans are running at their full rated speed throughout the entire drying period, as well as that the burner plenum temperature stays constant throughout entire drying period. Specific electric use for grain dryer conveyors or augers/stirrers is not included in the calculation. Finally, grain dryer pricing is based on newer style grain dryers from one manufacturer that are more energy efficient than older models.

The incentive amount is based on the bushels per hour of drying capacity at a 5% moisture content reduction.

This entry includes measures for gas–fired equipment eligible to both natural gas and propane customers. The Code of Federal Regulations,[12] upon which federal efficiency standards are based, defines *gas* as either natural gas or propane (§430.2 for consumer appliances, and §431.2 for commercial and industrial equipment). Thus, it is assumed that equipment efficiencies, costs, etcetera are equal for both fuel types. Any infrastructure or maintenance costs unique to each particular fuel are ignored.

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Revision History

Version Number	Date	Description of Change
01	10/8/2015	Initial release
02	3/2018	Added propane measure

Plate Heat Exchanger and Well Water Pre-Cooler

	Measure Details
Measure Master ID	Plate Heat Exchanger and Well Water Pre-Cooler (< 135 Milking Cows), 3982 Plate Heat Exchanger and Well Water Pre-Cooler (≥ 135 Milking Cows), 3983
Measure Unit	Per milking cow
Measure Type	Prescriptive
Measure Group	Agriculture
Measure Category	Heat Exchanger
Sector(s)	Agriculture
Annual Energy Savings (kWh)	47 kWh
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	705 kWh
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$5,253.00[2]

Measure Description

A well water pre-cooler is a heat exchanger device used to partially cool milk without the need for energy intensive mechanical refrigeration. Cold well water and groundwater, which is around 52.3°F, is pumped through one side of a heat exchanger while cow's milk, at about 98°F, is pumped through the other side of the heat exchanger. Energy savings are calculated based on the amount of milk temperature reduction achieved from the heat exchanger, defined as heat energy that does not have to be removed via mechanical refrigeration. This measure is only eligible for new pre-cooler installations and is not applicable for replacement pre-cooler units. It is assumed that the warmed output water from the plate cooler is reused elsewhere on the farm for either general farm equipment washing or most likely for reuse as animal watering. Little to no water waste should occur of the pre-cooler water output. It is in the farmer's best interest to reuse this output water for general farm use water needs to avoid pumping additional water for farm use.

Description of Baseline Condition

The baseline condition is a dairy operation without the use of a milk pre-cooler. Baseline milk cooling is achieved by using mechanical refrigeration compressors/chillers. Typically scroll or hermetically sealed reciprocating compressors are used to drive the cooling process.

Description of Efficient Condition

The efficient condition is a dairy operation that installs a milk pre-cooler unit to use colder well water as a coolant to pre-cool milk by several degrees prior to the mechanical refrigeration that cools the milk down to a final storage temperature of around 38°F.

Annual Energy-Savings Algorithm

kWh_{SAVED} = lbs of Milk * $C_{P,MILK}$ * ΔT_{MILK} * Milking Days per year / $AEER_{COMPRESSOR}$ / 1,000

Where:

lbs of Milk = Estimated daily pounds of milk produced by the dairy farm that needs to be cooled through use of a milk pre-cooler (= # of milking cows * 68 lbs of milk per day per cow[2,3] / 365 days)

$C_{P,MILK}$ = Specific heat of milk (= 0.94 Btu/(lb-°F))[4]

ΔT_{MILK} = Temperature difference between warm milk incoming into the plate cooler and the cooled milk leaving the plate cooler (= 31°F; see Assumptions)

Milking Days per year = Number of milking days per year (= 365)[5]

$AEER_{COMPRESSOR}$ = Annual energy efficiency ratio of compressor (= 15.39 Btu/watt-hr; see Assumptions)[6]

1,000 = Kilowatt conversion factor

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for well water pre-coolers.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

The savings calculation does not account for the pump energy needed to pump the cold well water through the plate cooler; since the plate cooler output of warmed well water is then used for animal watering, this water pumping would normally occur anyway for animal watering needs. The savings are based on the assumption that all plate cooler water output is reused elsewhere on the farm.

The following assumptions also apply to the savings calculations:

- Milking operations are assumed to occur 365 days per year.[5]
- Savings associated with the reduced runtime of mechanical refrigeration system condenser fans are not included (thus the savings from the measure is conservative).
- A typical water to milk flow ratios of 3:1 or 2:1 is assumed.
- It is assumed that there is a 25°F of milk temperature difference for a single pass plate cooler and a 35°F of temperature difference for a double/multi-pass plate cooler.[7] Recent program trends of plate heat exchanger measures applying for incentives in Wisconsin shows a 40%/60% split[2] of single and double pass plate coolers, respectively. The estimated deemed temperature drop for a farm with a pre-cooler is 31°F (25°F * 0.4 + 35°F * 0.6).
- An even 50/50 split of farms using scroll versus reciprocating compressors to drive the milk cooling process is assumed, using an annual EER of compressor usage based on changing annual ambient temperature conditions.[6]
- Assumes all second-use warmed water from the output of the well water plate cooler will be reused as general wash water to clean farm equipment or help fulfill animal watering needs due to the basis that a dairy cow consumes at least three times more water than they produce as milk.[8]
- User defined input provided for the number of milking cows value is assumed to be the average number of animals being milked throughout the entire year.

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. SPECTRUM. "Dairy Pre-Cooler Supplemental Data Spreadsheet."
   Pre-cooler Measure Analysis' tab shows sample data of 86 pre-cooler projects from January 2015 to July 2016. The split of single pass to double pass plate coolers installed on Wisconsin dairies was determined from the project inputs of these 86 sample projects. Spreadsheet also shows an average of pre-cooler project cost from the 86 recent project samples.
3. U.S. Department of Agriculture. "Milk Production Per Cow." https://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/Dairy/Historical_Data_Series/mkpercow.pdf

4. Hu, Jin. “Determination of Specific Heat of Milk at Different Fat Content Between 1°C and 59°C Using Micro DSC.” Journal of Food Engineering (February 2009): 90(3). p. 395-399.· http://www.researchgate.net/publication/234102534_Determination_of_specific_heat_of_milk_at_different_fat_content_between_1C_and_59C_using_micro_DSC Table 1 Units converted from J/(g*K) to Btu/(lb-°F).
5. Wisconsin Milk Marketing Board. “Did You Know? Website: Milking Every Day.” Accessed December 21, 2015. http://www.dairydoingmore.org/economicimpact/dairyfacts
6. “Dairy Pre-Cooler Supplemental Data.” Compressor Modeling Tab created by CESA10 using compressor model data from past projects submitted to Focus on Energy and Compressor Performance Data sheets from Copeland scroll compressors.
7. Sanford, Scott (University of Wisconsin–Madison). “Energy Efficiency for Dairy Enterprises.” Presentation to Agricultural and Life Sciences Program staff. December 2014. http://farmenergymedia.extension.org/sites/default/files/Dairy%20Energy%20Conservation-2013.pdf
8. Sanford, Scott (University of Wisconsin–Madison). “Well Water Precoolers.” Publication A3784-3. October 2003. http://learningstore.uwex.edu/Assets/pdfs/A3784-03.pdf

Revision History

Version Number	Date	Description of Change
01	09/22/2015	Initial release
02	10/28/2016	Added additional assumptions, updated sources, changed to prescriptive based on number of milking cows

Energy Efficient or Energy Free Livestock Waterer

	Measure Details
Measure Master ID	Waterer, Livestock: < 250 Watts, 2660 Energy Free, 3018
Measure Unit	Per waterer
Measure Type	Prescriptive
Measure Group	Agriculture
Measure Category	Livestock Waterer
Sector(s)	Agriculture
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	0 (winter use only)
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	< 250 watts = $575.35 for retrofit, $566.73 for new construction (MMID 2660);[3] Energy free = $562.89 (MMID 3018)[4]

Measure Description

Electrically heated waterers are commonly used to provide clean water for livestock during winter months when temperatures may drop below freezing. Baseline efficiency waterers typically have no insulation and require large heating elements to prevent water from freezing. Energy-efficient livestock waterers have at least two inches of insulation, which allows for the use of much smaller heating elements (less than 250 watts). Energy-free waterers have at least two inches of insulation and no heating element, as they use ground source water to prevent freezing.

Description of Baseline Condition

The heating element for a baseline unit is typically at least 750 watts, but may be 1,500 watts or larger. Retrofit waterer installations, both energy efficient and energy free, use a baseline of 1,100 watts. New construction waterer calculations use a baseline of 500 watts.

Description of Efficient Condition

Efficient or low energy livestock waterers must have a minimum of two inches of insulation. The heating element for an efficient unit will be a maximum of 250 watts. The energy-free unit may not have an electric heating element installed, but instead uses ground source heating. The new waterer must be able to serve the same herd size as the existing equipment. For new construction, the livestock waterer must be energy free.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Power consumption of baseline measure equipment (= 1,100 watts for retrofit; = 500 watts for new installation)[2]

$Watts_{EE}$ = Power consumption of efficient measure equipment (= 250 watts for energy-efficient retrofit; = 0 watts for energy-free installation)

1,000 = Kilowatt conversion factor

HOU = Average annual run hours of heater (= 3,040; annual operation is used as a conservative estimate of the number of hours below 32°F annually throughout the state of Wisconsin, consistent with TMY3 bin data)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= 0)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Average Annual Deemed Savings

Type	MMID	Sector	kWh
Energy Efficient Livestock Waterer	2660	Agriculture	2,584
Energy Free Retrofit Livestock Waterer	3018	Agriculture	3,344
Energy Free New Construction Livestock Waterer	3018	Agriculture	1,520

Lifecycle Energy Savings

Type	MMID	Sector	kWh
Energy Efficient Livestock Waterer	2660	Agriculture	25,840
Energy Free Retrofit Livestock Waterer	3018	Agriculture	33,440
Energy Free New Construction Livestock Waterer	3018	Agriculture	15,200

Deemed Peak Demand Reduction

Type	MMIDs	kWh
All Livestock Waterers	2660 and 3018	0

Assumptions

No peak demand (kW) reduction is associated with this measure because heaters are generally only used during winter months.

Source

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. EnSave. Energy Efficient Stock Waterers. http://www.usdairy.com/~/media/usd/public/ensaveenergyefficientstockwaterers.pdf
3. Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 131 units over 30 projects from 2016 to 2018 is $788.41. Retrofit baseline cost of $213.06 reflects cost of standard small waterer and 1,000-watt de-icer, derived from five product lookups on www.farmandfleet.com and amazon.com. Retrofit incremental cost is $788.41 - $213.06 = $575.35. New construction baseline cost of $221.68 reflects cost of standard small waterer and 500-watt de-icer, derived from five product lookups on www.chewy.com and amazon.com. Retrofit incremental cost is $788.41 - $221.68 = $566.73.
4. Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 306 units over 49 projects from 2017 to 2018 is $921.46. Baseline cost of $358.57 reflects cost of standard large waterer and 1,000-watt de-icer, derived from five product lookups on www.farmandfleet.com and amazon.com. Incremental cost is $921.46 - $358.57 = $562.89.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	12/2018	Updated cost based on historical program data

Circulation Fan, High Efficiency, Ag

	Measure Details
Measure Master ID	Circulation Fan, High Efficiency, Ag, 2253
Measure Unit	Per fan
Measure Type	Hybrid
Measure Group	Agriculture
Measure Category	Other
Sector(s)	Agriculture
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	Varies
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$150.00[3]

Measure Description

Agriculture circulation fans are designed to destratify air, reduce animal heat stress, control insects, dry surfaces, and cool people and animals. Generally, agricultural-grade air circulating fans are corrosion resistant and designed for easy cleaning.

Description of Baseline Condition

The baseline condition is an air circulation fan used within an agricultural building. Calculations are performed using three separate fan diameter size groupings: 24-35 inches, 36-47 inches, and 48-71 inches. The baseline unit demand is based on the fan size groupings, at 450 watts, 620 watts, and 1,160 watts, respectively.

Description of Efficient Condition

To qualify for a prescriptive incentive, each circulation fan must undergo third-party testing and be rated through the Bioenvironmental and Structural System Lab at the University of Illinois or through the Air Control and Movement Association International Lab.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (CFM_{EE} / VER_{EE} – CFM_{BASE} / VER_{BASE}) * HOU$

Where:

CFM_{EE} = New efficient unit flow at 0.10 static pressure in CFM[2]
VER_{EE} = New unit ventilating efficiency ratio in CFM/watt at 0.10 static pressure
CFM_{BASE} = Baseline unit flow at 0.10 static pressure in CFM
VER_{BASE} = Baseline unit ventilating efficiency ratio in CFM/watt at 0.10 static pressure
HOU = Annual hours of operation (= 2,935)[2]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (CFM_{EE} / VER_{EE} – CFM_{BASE} / VER_{BASE}) * CF$

Where:

CF = Coincidence factor (= 1.0)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 35 units over 31 projects in 2018.
3. “Illinois Technical Reference Manual.” 2013. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf.
Agriculture circulation or exhaust fan incremental cost (all sizes) is $150.00 each.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry

Dairy Refrigeration Tune-Up

	Measure Details
Measure Master ID	Refrigeration System Tune-Up, Agriculture, 4403
Measure Unit	Per milking cow
Measure Type	Prescriptive
Measure Group	Agriculture
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Agriculture
Annual Energy Savings (kWh)	2.5637
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	2.5637
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	1[1]
Incremental Cost ($/unit)	$194.05[2]

Measure Description

This tune-up is designed to assess all refrigeration equipment associated with a commercial-grade dairy farm facility with the intention of reducing electrical consumption.

Description of Baseline Condition

The baseline condition is refrigeration equipment associated with a commercial-grade dairy farm facility that has not been inspected or tuned up in more than 12 months.

Description of Efficient Condition

The efficient condition is refrigeration equipment associated with a commercial-grade dairy farm facility that has been inspected and tuned up by a U.S. EPA 608 Certified Service Provider. The Service Provider must abide by all rules and regulations related to refrigerant testing and safety protocol and must conduct the following tasks: clean and inspect condenser and evaporator coils; clean drain pan; inspect/clean fans, screens, grills, filters, and drier cores; inspect/adjust heat reclaim operation; tighten all line voltage connections; inspect/replace relays and capacitors as needed; and add/remove refrigerant charge as needed.

Annual Energy-Savings Algorithm

Energy savings from the refrigeration equipment tune up/maintenance is 5%.[4]

kWh_{SAVED} = kWh_{SAVED}/day * 365 days

kWh_{SAVED}/day = [lbs milk/day * $C_{P,MILK}$ * (°F_{IN} - °F_{FINAL}) / $AEER_{COMPRESSOR}$ / 1,000] * SF

Where:

365 = Number of days per year cows are milked[5]

lbs milk/day = Pounds of milk produced at farm facility per day (= 68 pounds of milk per cow;[3,5] the number of milking cows is a user-defined input)

$C_{P,MILK}$ = Specific heat of milk (= 0.94 Btu/lb-°F)[6]

°F_{IN} = Temperature of supplied milk that needs to be mechanically cooled (= 71.8°F, or = 98°F if no pre-cooler used in operation;[7] = 67°F if a milk pre-cooler unit is used; = 56.3°F if a milk pre-cooler unit and VFD milk pump are used; see Assumptions)

°F_{FINAL} = Final stored temperature of cooled milk (= 38°F)[7]

$AEER_{COMPRESSOR}$ = Annual energy efficiency ratio of refrigeration compressor (= 15.39 Btu/watt-hour;[4] see Assumptions)

1,000 = Kilowatt conversion factor

SF = Energy savings factor (= 0.05)[4]

Summer Coincident Peak Savings Algorithm

There are no peak coincident savings claimed for this measure. While some level of kilowatt savings is likely to result from a refrigeration system tune up, the amount is anticipated to be small. Also, a large majority of farms in Wisconsin do not actively milk during Focus on Energy–defined peak time periods, due to having only two milking periods per day: this would create a low coincidence factor for any kilowatt savings. Lastly, there is a lack of concrete data readily available on the amount of kilowatt savings that could realistically ensue from a system tune up.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

Where:

EUL = Effective useful life (= 1 year)[1]

Assumptions

The savings factor is a conservative estimate based on a whole refrigeration system tune up. According to Scott Sanford from the University of Wisconsin–Madison, between 3% and 5% electrical savings can be achieved from just cleaning the condenser on an annual basis.[4] In addition to cleaning the condenser, the refrigeration system tune up involves cleaning the evaporator coils, fans, filters, screens, and grills, and inspecting and adjusting or replacing relays, capacitors, and refrigerant charge.

Milk temperature from the output of a pre-cooler is based on a weighted percentage of single and double pass pre-cooler units. Single pass units drop the milk temperature roughly 25°F while double pass units drop the milk temperature roughly 35°F.[9] Based on past project data analysis related to milk pre-cooler application submittals, new pre-cooler installations in Wisconsin are 40% single pass pre-cooler and 60% double pass pre-coolers; therefore, the estimated temperature drop for a farm with a pre-cooler is 31°F (= [25°F * 0.4] + [35°F * 0.6]).[4]

The AEER value is based on an even 50/50 split of farms using scroll versus reciprocating compressors to drive the milk cooling process.[4]

The savings are based on a well water temperature of 52.3°F being used as milk coolant.[4] It is assumed that the lowest milk temperature that could be achieved is 56.3°F (or 4°F higher than the well water coolant temperature).[10] The maximum additional cooling for any style of plate cooler in conjunction with a variable speed controlled milk pump would add up to 15°F of cooling.[4]

The 2017 Focus on Energy Potential Study Site Surveys[4] provide a breakdown of Wisconsin dairy farms with the existing milking equipment scenarios shown in the table below.

Installed Equipment Populations

Existing Milking Equipment Scenario	Percentage of Sites Surveyed
Operation with Milk Pre-Cooler and VFD on Milk Pump	48.4
Operation with Milk Pre-Cooler Only	19.4
Operation without Milk Pre-Cooler	32.3

The user-defined input provided for the number of milking cows is assumed to be the average number of animals being milked throughout the entire year.

Sources

1. Engineering judgement. It is recommended that tune-ups be completed annually.
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 35 units over 31 projects in 2018.
3. U.S. Department of Agriculture. “Milk Production Per Cow, Wisconsin.” WI Dairy Statistics tab. https://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/Dairy/Historical_Data_Series/mkpercow.pdf
4. “Dairy Refrigeration Tune-up, Agriculture Potential Study Data.” Spreadsheet. Potential Study Survey Data tab shows the breakdown of Wisconsin dairy farms with existing milking equipment scenarios based on 2017 Wisconsin Focus on Energy Potential Study results. Compressor Modeling tab created by CESA10 using compressor model data from past projects submitted to Focus on Energy and Compressor Performance Data sheets from Copeland scroll compress. Pre-cooler Measure Analysis tab showing sample data of 86 pre-cooler projects entered in Spectrum from January 2015 to July 2016. The split of single pass to double pass plate coolers installed on Wisconsin dairies was determined from the project inputs of these 86 sample projects.
5. Wisconsin Milk Marketing Board. “Did You Know? Milking Every Day.” Accessed December 21, 2015. http://www.dairydoingmore.org/economicimpact/dairyfacts
6. Hu, Jin. “Determination of Specific Heat of Milk at Different Fat Content Between 1°C and 59°C Using Micro DSC.” Journal of Food Engineering (February 2009): 90(3). p. 395–399.·http://www.researchgate.net/publication/234102534_Determination_of_specific_heat_of_milk_at_different_fat_content_between_1C_and_59C_using_micro_DSC
Table 1 Units converted from J/(g*K) to Btu/(lb-°F).
7. Sanford, Scott (University of Wisconsin–Madison). “Well Water Precoolers.” Publication A3784-3. October 2003. http://learningstore.uwex.edu/Assets/pdfs/A3784-03.pdf
8. Sanford, Scott (University of Wisconsin–Madison). “Energy Efficiency for Dairy Enterprises.” Presentation to Agricultural and Life Sciences Program staff. Slides 16, 21, and 26. December 2014. http://farmenergymedia.extension.org/sites/default/files/Dairy%20Energy%20Conservation-2013.pdf
9. U.S. Department of Energy. “Domestic Hot Water Scheduler.” http://energy.gov/eere/buildings/downloads/dhw-event-schedule-generator
Average water main temperature of all locations measured in Wisconsin by scheduler, weighted by city populations.
10. EnSave. “Milk Pump Variable Speed Drive.” Brochure. 2009. http://www.usdairy.com/~/media/usd/public/ensavemilkpumpvariablespeeddrive.pdf

Revision History

Version Number	Date	Description of Change
01	10/01/2015	Initial TRM entry
02	10/28/2016	Changed EUL and EER values, included three measures to address various system operations, changed unit measure to the number of milking cows
03	10/2017	Updated EUL
04	10/25/2017	Combined three measures into one using Potential Study[4] results to weight existing milking equipment scenarios
05	12/2018	Updated Incremental cost

Boilers and Burners

Boiler, Condensing, ≥ 90% AFUE

	Measure Details
Measure Master ID	Boiler, Hot Water, Modulating: ≥ 90% AFUE, ≤ 300 MBh, 2743 ≥ 90% AFUE, < 300 MBh, 2218 ≥ 90% AFUE, < 300 MBh, Propane-Fueled, 4852 Boiler, Condensing: ≥ 90% AFUE, ≥ 300 MBh, 3276 ≥ 90% AFUE, ≥ 300 MBh, Propane-Fueled, 4866
Measure Unit	Per MBh
Measure Type	Hybrid
Measure Group	Boilers & Burners
Measure Category	Boiler
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Annual Propane Savings (Gallons)	Varies by measure
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure
Lifecycle Propane Savings (Gallons)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	Modulating, ≥ 90% AFUE, < 300 MBh = $10.26 (MMIDs 2218 and 4852)[2] Modulating, ≥ 90% AFUE, < 300 MBh = $12.55 (MMID 2743)[3] Condensing = $8.79 (MMIDs 3276 and 4866)[8]

Measure Description

High-efficiency sealed combustion, condensing, and modulating boilers operate by taking advantage of condensing to lower energy consumption. Condensing boilers are designed to capture the latent heat of condensation in the form of water vapor in the exhaust stream. Capturing this latent heat produces high-efficiency levels. For a boiler to operate in condensing mode, its return water temperature should be kept below 120°F. In order to capture as much latent heat as possible, condensing boilers are made from stainless steel or other corrosion resistant materials. Chimney liners must be installed for boilers that are replacing a naturally drafting unit that was vented through the same flue as a water heater. Flue closure protocols must be followed when the chimney that will used by the replacement unit was not in use for the previous equipment.

Description of Baseline Condition

The baseline measure is an 82% AFUE boiler.[4]

Description of Efficient Condition

The efficient measure meets the following requirements:

- Boiler must be ≥ 90% AFUE
- Boiler must be used in space heating applications
- Boiler must be natural gas– or propane-fueled and produce hot water (those using other fuel types or that generate steam do not qualify)
- Chimney liners must be installed where a high-efficiency natural gas or propane boiler replaces atmospherically drafted equipment that was vented through the same flue as a natural gas or propane water heater
- Redundant or backup boilers do not qualify
- The return water temperature must be cool enough to condense flue gases in order to provide maximum efficiency (if the heating system configuration cannot provide necessary operating conditions to the boiler, selection of a non-condensing or near-condensing boiler may be more appropriate)
- For MMIDs 2743, 2218, and 4852 (< 300 MBh):
  - Must be a sealed combustion unit
  - Must be capable of firing rate modulation
  - Must include outdoor air reset control
  - MMID 4852 is only for when the existing boiler uses fuel oil or propane
- For MMIDs 3276 and 4866 (≥ 300 MBh):
  - Must be capable of capacity modulation
  - Must submit specification sheet with steady state boiler input and output ratings and AFUE
  - When replacing a natural gas–fueled boiler system with both condensing (> 90% AFUE) and near-condensing (85% AFUE to 89% AFUE), use the Hybrid Hot Water Boiler Plant measure (MMID 3275)
  - MMID 4866 is only for when the existing boiler uses fuel oil or propane, and is not eligible for use with the Hybrid Hot Water Boiler Plan measure

Annual Energy-Savings Algorithm

$Gas_{SAVED} = BC * OF * EFLH * ISR * (1 / AFUE_{BASE} – 1 / AFUE_{EFF}) / ConvF$

Where:

BC = Boiler rated capacity (MBtu/hr)

OF = Oversizing factor (= varies by measure; see table below)

Oversize Factor by Measure

Description	MMID	Oversize Factor[6]
Boiler, Hot Water, Modulating, ≥ 90% AFUE, ≤ 300 MBh	2743	172%
Boiler, Hot Water, Modulating, ≥ 90% AFUE, < 300 MBh	2218, 4852	215%
Boiler, Condensing, ≥ 90% AFUE, ≥ 300 MBh	3276, 4866	119%

EFLH = Effective full-load hours (= 1,890)[5]

ISR = In-service rate (= 95% for MMIDs 3276 and 4866; = 100% for MMIDs 2743, 2218, and 4852)[7]

$AFUE_{BASE}$ = Boiler baseline thermal efficiency (= 82%)[4]

$AFUE_{EFF}$ = Boiler proposed thermal efficiency (= 95%)[7]

ConvF = Conversion factor (= 100 MBtu per therm, = 91.3 MBtu per gallon propane)[9]

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Gas_{LIFECYCLE} = Gas_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 20 years)[1]

Deemed Savings

Gas Savings (per MBh)

Description	MMID	therms		Gallons Propane	
		Annual	Lifecycle	Annual	Lifecycle
Boiler, Hot Water, Modulating, ≥ 90% AFUE, ≤ 300 MBh	2743	5.22	104.49	-	-
Boiler, Hot Water, Modulating, ≥ 90% AFUE, < 300 MBh	2218	6.50	129.98	-	-
Boiler, Hot Water, Modulating, ≥ 90% AFUE, < 300 MBh, Propane-Fueled	4852	-	-	7.12	142.39
Boiler, Condensing, ≥ 90% AFUE, ≥ 300 MBh	3276	3.42	68.40	-	68.40
Boiler, Condensing, ≥ 90% AFUE, ≥ 300 MBh, Propane-Fueled	4866	-	-	3.75	74.92

Assumptions

This entry includes measures for gas–fired equipment eligible to both natural gas and propane customers. The Code of Federal Regulations,[10] upon which federal efficiency standards are based, defines *gas* as either natural gas or propane (§430.2 for consumer appliances, and §431.2 for commercial/industrial equipment). Thus it is assumed that equipment efficiencies, costs, and other variables are equal for both fuel types. Any infrastructure or maintenance costs unique to each particular fuel are ignored.

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy historical project data obtained from SPECTRUM. January 1, 2016 to June 30, 2018. Average cost of 456 boilers over 237 projects is $37.16/MBh. August 2018 online lookups of 18 baseline and 22 efficient boiler models less than 300 MBh on www.supplyhouse.com and www.grainger.com reveal an efficient cost that is 27.6% higher than the baseline cost. The incremental cost is therefore 27.6% * $37.16 = $10.26/MBh.
3. Wisconsin Focus on Energy historical project data obtained from SPECTRUM. January 1, 2016 to June 30, 2018. Average cost of 203 boilers over 168 projects is $45.45/MBh. August 2018 online lookups of 18 baseline and 22 efficient boiler models less than 300 MBh on www.supplyhouse.com and www.grainger.com reveal an efficient cost that is 27.6% higher than the baseline cost. The incremental cost is therefore 27.6% * $45.45 = $12.55/MBh.

4. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review.” Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf

   Energy Efficiency and Renewable Energy Office. “2008-07-28 Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Furnaces and Boilers; Final Rule; Technical Amendment.” Federal standard for residential boilers. Effective August 27, 2008. https://www.regulations.gov/document?D=EERE-2006-STD-0102-0009
5. U.S. Environmental Protection Agency and U.S. Department of Energy. “Life Cycle Cost Estimate for ENERGY STAR Qualified Air Source Heat Pump(s).” April 2009. https://www.energystar.gov/sites/default/uploads/buildings/old/files/ASHP_Sav_Calc.xls

   Several Cadmus metering studies revealed that the ENERGY STAR calculator EFLH values are overestimated by 25%. The heating EFLH were adjusted by population-weighted heating degree days and typical meteorological year values, then averaged for the state of Wisconsin.
6. Cadmus. “Focus on Energy Boiler Measure Study.” 2016.

   The study determined realized savings from billing data for sites that had applied for boiler incentives during the 2012–2014 program years. The oversize factors in this workpaper align each measure’s calculated savings, in conjunction with assumed EFLH and AFUE values, with the savings calculated from billing data results for 26 sites for MMID 2218 and 33 sites for MMID 3276.
7. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. August 31, 2017. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf
8. Wisconsin Focus on Energy historical project data obtained from SPECTRUM. 2016 to 2018. Average cost of 90 boilers over 50 projects is $23.06/MBh. August 2018 online lookups of four baseline and 19 efficient boiler models over 300 MBh on www.supplyhouse.com and www.grainger.com reveal an efficient cost that is 38.1% higher than the baseline cost. The incremental cost is therefore 38.1% * $23.06 = $8.79/MBh.
9. U.S. Energy Information Administration. “Energy Units and Calculators Explained.” Accessed December 2018. https://www.eia.gov/energyexplained/?page=about_energy_units
10. Electronic Code of Federal Regulations. §430-431. Accessed February 2019. https://www.ecfr.gov/cgi-bin/text-idx?gp=&SID=92c3f99c51e1124fcc790d11c93e04af&mc=true&tpl=/ecfrbrowse/Title10/10CIIsubchapD.tpl

Revision History

Version Number	Date	Description of Change
01	01/2013	Updated baseline efficiency from 80% to 82% (MMID 2743).
02	08/2016	Added MMIDs 2218 and 3276, which were not previously documented. Merged boiler measures into one workpaper for consistency. Updated the oversizing factor based on the 2016 Boiler Measure study by Cadmus and consolidated EFLH to one value for the state of Wisconsin.
03	05/2018	Updated efficient AFUE and added ISR.
04	12/2018	Updated incremental cost, EFLH, and savings algorithm.
05	03/2019	Added propane measures.

Boiler, Near Condensing, ≥ 85% AFUE

	Measure Details
Measure Master ID	Boiler, Hot Water, Near Condensing, ≥ 85% AFUE, ≥ 300 MBh, 3277 Boiler, Hot Water, Near Condensing, ≥ 85% AFUE, ≥ 300 MBh, Propane-Fueled, 4867
Measure Unit	Per MBh
Measure Type	Hybrid
Measure Group	Boilers & Burners
Measure Category	Boiler
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	1.61
Annual Propane Savings (Gallons)	1.77
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	32.2
Lifecycle Propane Savings (Gallons)	35.5
Water Savings (gal/year)	0
Effective Useful Life (years)	20[1]
Incremental Cost	$4.56[2]

Measure Description

Mid-efficiency boilers use forced draft or induced draft power burners, instead of atmospheric draft, to push or pull gases through the firebox and heat exchanger. Because these boilers have relatively high efficiencies and relatively low flue gas temperatures, they are often constructed with stainless steel or other corrosion-resistant materials to tolerate condensation in the boiler. These boilers are typically used in applications where high-efficiency sealed combustion, condensing, and modulating boilers cannot be vented or where they will not have low enough return water temperatures to condense the water vapor in the flue gas.

Description of Baseline Condition

The baseline measure is an 82% AFUE boiler.[3]

Description of Efficient Condition

The efficient condition is one that meets several requirements:

- Boiler must be ≥ 85% AFUE
- Boiler must be used in space heating applications
- Boiler must be natural gas– or propane-fired and must produce hot water (those using other fuels or to generate steam do not qualify)
- Chimney liners must be installed where a high-efficiency natural gas or propane boiler replaces atmospherically drafted equipment that was vented through the same flue as a natural gas or propane water heater
- Redundant or backup boilers do not qualify
- Condensing boilers (≥ 90% AFUE or thermal efficiency) will provide maximum efficiency only if the return water temperature is cool enough to condense flue gases (if the heating system configuration cannot provide necessary operating conditions to the boiler, the savings are calculated based on a non-condensing or near-condensing boiler)
- Boiler must be capable of capacity modulation
- Specification sheet must be submitted with steady state boiler input and output ratings and AFUE
- When replacing a natural gas–fueled boiler system with both condensing (≥ 90% AFUE) and near-condensing (85% AFUE to 89% AFUE), savings are calculated based on MMID 3275
- MMID 4867 is only used when the existing boiler uses fuel oil or propane. MMID 4867 is not eligible for use of the hybrid hot water boiler plant measure.

Annual Energy-Savings Algorithm

$Gas_{SAVED} = BC * OF * EFLH * (1 / AFUE_{BASE} – 1 / AFUE_{EFF}) / ConvF$

Where:

BC = Boiler rated capacity (MBtu per hour)

OF = Oversizing factor (= 77%)[4]

EFLH = Effective full-load hours (= 1,890)[5]

$AFUE_{BASE}$ = Boiler baseline thermal efficiency (= 82%)[3]

$AFUE_{EFF}$ = Boiler proposed thermal efficiency (= 91%)[6]

ConvF = Fuel conversion factor (= 100 MBtu per therm, = 91.3 MBtu per gallon propane)[7]

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Gas_{LIFECYCLE} = Gas_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 20 years)[1]

Assumptions

This entry includes measures for natural gas–fired equipment eligible to both natural gas and propane customers. The Code of Federal Regulations,[8] upon which federal efficiency standards are based, defines *gas* as either natural gas or propane (§430.2 for consumer appliances, and §431.2 for commercial and industrial equipment). Thus it is assumed that equipment efficiencies, costs, and the like are equal for both fuel types. Any infrastructure or maintenance costs unique to each particular fuel are ignored.

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 67 boilers over 36 projects from 2016 to 2018 is $11.96/MBh. August 2018 online lookups of four baseline and 19 efficient boiler models over 300 MBh on www.supplyhouse.com and www.grainger.com reveal an efficient cost that is 38.1% higher than the baseline cost. The incremental cost is therefore 38.1% * $11.96 = $4.56/MBh.
3. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review.” Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
Energy Efficiency and Renewable Energy Office. “2008-07-28 Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Furnaces and Boilers; Final Rule; Technical Amendment.” Federal standard for residential boilers. Effective August 27, 2008. https://www.regulations.gov/document?D=EERE-2006-STD-0102-0009
4. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Table 3-2 Lighting Hours of Use in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

5. U.S. Environmental Protection Agency and U.S. Department of Energy. “Life Cycle Cost Estimate for ENERGY STAR Qualified Air Source Heat Pump(s).” April 2009. https://www.energystar.gov/sites/default/uploads/buildings/old/files/ASHP_Sav_Calc.xls Several Cadmus metering studies reveal that the ENERGY STAR calculator EFLH values are overestimated by 25%. The heating EFLH were adjusted by population-weighted HDD and TMY3 values, then averaged for the state of Wisconsin.
6. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. August 31, 2017. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf
7. U.S. Energy Information Administration. “Energy Units and Calculators Explained.” Accessed December 2018. https://www.eia.gov/energyexplained/?page=about_energy_units
8. Electronic Code of Federal Regulations. §430-431. Accessed February 2019. https://www.ecfr.gov/cgi-bin/text-idx?gp=&SID=92c3f99c51e1124fcc790d11c93e04af&mc=true&tpl=/ecfrbrowse/Title10/10CIIsubchapD.tpl

Revision History

Version Number	Date	Description of Change
01	01/2013	Updated baseline efficiency from 80% to 82% AFUE (MMID 2743)
02	08/2016	Consolidated EFLH to one value for the state of Wisconsin
03	05/2018	Updated efficient AFUE, added ISR
04	12/2018	Updated incremental cost, EFLH, and savings algorithm
05	03/2019	Added propane measure

Boiler Plant Retrofit

	Measure Details
Measure Master ID	Boiler Plant Retrofit, Hybrid Plant, ≥1 MMBh, 3275
Measure Unit	Per MBh
Measure Type	Hybrid
Measure Group	Boilers & Burners
Measure Category	Boiler
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	1.43 per MBh
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	28.63 per MBh
Water Savings (gal/year)	0
Effective Useful Life (years)	20[1]
Incremental Cost	$6.60[2]

Measure Description

High-efficiency sealed combustion, condensing, and modulating boilers operate by taking advantage of condensing in an effort to decrease energy consumption. Condensing boilers are designed to capture latent heat by condensing water vapor in the exhaust stream. For a boiler to properly condense, its return water temperature should be kept below 120°F. In order to capture as much latent heat as possible, condensing boilers are made from stainless steel or other corrosion-resistant materials.

Mid-efficiency boilers use forced draft or induced draft power burners, instead of atmospheric draft, to push or pull gases through the firebox and heat exchanger. Because these boilers have relatively high efficiencies and relatively low flue gas temperatures, they are often constructed with stainless steel or other corrosion-resistant materials to tolerate condensation in the boiler.

This measure applies to the entire boiler plant. The summation of the capacity for all heating equipment must be greater than 1,000 MBh. This measure combines high- and mid-efficiency boilers in a boiler plant to take advantage of both condensing boilers (when return water temperatures are low enough for condensing) and mid-efficiency boilers (when return water temperatures do not allow for condensing). The upgraded plant must have at least 50% high-efficiency boilers.

Description of Baseline Condition

The baseline measure is an 82% AFUE boiler.[3]

Description of Efficient Condition

The efficient condition is one which meets the following requirements:

- Boiler must be ≥ 85% AFUE
- Boiler must be used in space heating applications
- Boiler must be natural gas (those using other fuels or to generate steam do not qualify)
- Chimney liners must be installed where a high-efficiency natural gas boiler replaces atmospherically drafted equipment that was vented through the same flue as a gas water heater
- Redundant or backup boilers do not qualify
- Condensing boilers (≥ 90% AFUE or thermal efficiency) will provide maximum efficiency only if the return water temperature is cool enough to condense flue gases (if the heating system configuration cannot provide necessary operating conditions to the boiler, calculate the savings based on a non-condensing or near-condensing boiler)
- Summation of plant heating capacity must be ≥ 1,000 MBh excluding backup and redundant boilers
- Must include both condensing (≥90% AFUE) and near-condensing (≥85% AFUE) boilers, and be capable of capacity modulation
- Plant must have at a minimum 50% of total heating capacity served by ≥ 90% AFUE boilers
- Plant must have controls to operate condensing boilers when return water temperature allows condensing operation
- Plant must have indoor/outdoor reset and staging controls
- Specification sheet must exist with steady state boiler input and output ratings and AFUE

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}} = \text{BC} * \text{OF} * \text{EFLH} * (\text{AFUE}_{\text{EE}} / \text{AFUE}_{\text{BASE}} - 1) / 100$

Where:

BC = Boiler rated input capacity (MBtu per hour)

OF = Oversizing factor (= 123%)[4]

EFLH = Effective full-load hours (= 1,890)[5]

$\text{AFUE}_{\text{BASE}}$ = Boiler baseline thermal efficiency (= 82%)[3]

$AFUE_{EFF}$ = Boiler proposed thermal efficiency (= 87%)

100 = Conversion factor from MBtu to therm

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = DS * EUL$

Where:

EUL = Effective useful life (= 20 years)[1]

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 20 boilers over 11 projects from 2016 to 2018 is $17.33/MBh. August 2018 online lookups of four baseline and 19 efficient boiler models over 300 MBh on www.supplyhouse.com and www.grainger.com reveal an efficient cost that is 38.1% higher than the baseline cost. The incremental cost is therefore 38.1% * $17.33 = $6.60/MBh.
3. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation ACES: Default Deemed Savings Review." Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
Energy Efficiency and Renewable Energy Office. "2008-07-28 Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Furnaces and Boilers; Final rule; technical amendment." Federal standard for residential boilers. Effective August 27, 2008. https://www.regulations.gov/document?D=EERE-2006-STD-0102-0009
4. Cadmus. "Focus on Energy Boiler Measure Study." 2016.
In this study, Cadmus determined realized savings from billing data for sites that had applied for boiler incentives during the 2012-2014 program years. The oversize factor in this workpaper

aligns the calculated savings, in conjunction with assumed EFLH and AFUE values, with the savings calculated from billing data results. Billing data was analyzed for a total of nine sites.

5. U.S. Environmental Protection Agency and U.S. Department of Energy. "Life Cycle Cost Estimate for ENERGY STAR Qualified Air Source Heat Pump(s)." April 2009. https://www.energystar.gov/sites/default/uploads/buildings/old/files/ASHP_Sav_Calc.xls Several Cadmus metering studies reveal that the ENERGY STAR calculator EFLH values are over-estimated by 25%. The heating EFLH were adjusted by population-weighted HDD and TMY3 values, then they were averaged for the state of Wisconsin.

Revision History

Version Number	Date	Description of Change
01	1/2013	Updated baseline efficiency from 80% to 82% (MMID 2743)
02	8/2016	Updated oversizing factor based on the 2016 boiler measure study by Cadmus. Consolidated EFLH to one value for the state of Wisconsin.
03	12/2018	Updated incremental cost, EFLH, and savings algorithm

Boiler Control, Outside Air Temperature Reset/Cutout Control

	Measure Details
Measure Master ID	Boiler, Outside Temperature Reset/Cutout Control, 2221
Measure Unit	Per MBh
Measure Type	Prescriptive
Measure Group	Boilers & Burners
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, and Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by sector and location
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by sector and location
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$612.00[2]

Measure Description

Boiler reset controls automatically control the boiler water temperature based on outdoor temperature. This allows the water to run a little cooler during the fall and spring, and a little hotter during the coldest parts of the winter, improving boiler efficiency and indoor comfort by providing a better match between boiler output and space heating needs. Boiler cutout controls prevent a boiler from firing at a predetermined outside temperature setpoint to prevent overheating.

Description of Baseline Condition

The baseline condition is no input/output reset with an 84% boiler.

Description of Efficient Condition

Outside air temperature reset or cutout control incentives are for existing space heating boilers only. A new boiler with integrated boiler reset controls is not eligible. New boilers not equipped with these controls are eligible for retrofit. The system must be set so that the minimum temperature is not more than 10°F above the manufacturer’s recommended minimum return temperature, unless unusual circumstances require a higher setting. The system must have an outdoor air temperature sensor in a shaded location on the north side of the building. For controls on multiple boilers to qualify, a control strategy must stage the lag boiler(s) only after the first boiler stage(s) fail to maintain the boiler water temperature called for by the reset control.

Annual Energy-Savings Algorithm

$Therm_{SAVED} = BC * EFLH_{HEAT} / (Eff * 100) * SF$

Where:

BC = Boiler input capacity in MBh (= 1)

$EFLH_{HEAT}$ = Equivalent full-load heating hours (= 1,890 for Residential- multifamily; = varies by city for Commercial, Industrial, Agriculture, and Schools & Government sectors, see table below)

Equivalent Full-Load Heating and Cooling Hours by City

City	$EFLH_{HEAT}$[3]
Green Bay	1,852
La Crosse	1,966
Madison	1,934
Milwaukee	1,883
Wisconsin Average	1,909
Weighted Average	**1,890**

Eff = Combustion efficiency of the boiler (= 84%)[4]

100 = Conversion factor from therm to MBtu

SF = Savings factor (= 8%)[5]

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)[1]

Deemed Savings

Evaluated Therm Savings for Boiler Control Measure

Measure Name	MMID	Sector, City	Energy Savings (therms per MBh)	
			Annual	Lifetime
Boiler, Outside Temperature Reset/Cutout Control	2221	Multifamily, All	1.800	9.000
		Nonres, Green Bay	1.764	8.819
		Nonres, La Crosse	1.872	9.362
		Nonres, Madison	1.842	9.210
		Nonres, Milwaukee	1.793	8.967

Sources

1. Average of Cadmus database March 2013 and Fannie Mae Estimated Useful Life Table: https://www.fanniemae.com/content/guide_form/4099f.pdf
2. *Illinois Technical Reference Manual*. p. 187. 2013. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf
   Boiler outside air reset/cutout controls cost is $612.00 per set of controls.
3. Several Cadmus metering studies revealed that the ENERGY STAR calculator EFLH values are overestimated by 25%. The heating EFLH were adjusted by population-weighted heating degree days and typical meteorological year values, then averaged for the state of Wisconsin.
4. Cadmus. *2016 Potential Study for Focus on Energy.*
   Data maintained by Cadmus and Wisconsin PSC.
   Based on 43 boilers at school, office, restaurant, and retail sites.
5. Michigan Energy Measures Database. http://www.michigan.gov/mpsc/0,1607,7-159-52495_55129---,00.html

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	01/2015	Changed savings from per unit to per MBh
03	05/2018	Updated based on Potential Study data
04	12/2018	Updated multifamily EFLH

Process Boiler Burner, 10:1 High Turn Down

	Measure Details
Measure Master ID	Process Boiler Burner, 10:1 High Turn Down, 4760
Measure Unit	Per boiler horsepower
Measure Type	Hybrid
Measure Group	Boilers and Burners
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	$65.22[2]

Measure Description

Boilers typically have an operating turndown of 3:1 or 4:1. Installing a high turndown burner with 10:1 (or better) turndown capability reduces burner starts, provides better load control, saves wear-and-tear on the burner, reduces refractory wear, reduces purge-air requirements, and provides fuel savings.

Description of Baseline Condition

The baseline condition is a boiler burner with 3:1 or 4:1 turndown capability.

Description of Efficient Condition

The efficient condition is a burner system with 10:1 turndown capability. High turndown burners require linkageless and oxygen trim controls in order to be the most efficient.

Annual Energy-Savings Algorithm

$Therm_{SAVED} = BHP * 33{,}476 * LF * HOU / 100{,}000 * (1 / Eff_{BASE} – 1 / Eff_{PROPOSED})$

Where:

BHP = Boiler horsepower (= user input)

33,476 = Conversion factor from BHP to MBh

LF = Boiler load factor (= user input)

HOU = Annual hours of operation (= user input)

100,000 = Conversion factor from Btu to therms

Eff_{BASE} = Boiler efficiency baseline (= user input)

$Eff_{PROPOSED}$ = Boiler efficiency with proposed burner (= user input)

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 20 years)[1]

Deemed Savings

Savings vary by application. This is a hybrid measure that uses inputs from the application that are then entered into the savings algorithm above to generate the therm savings.

Assumptions

Boiler horsepower, boiler load factor, and operating hours are all provided by the end user on the application form. The HOU value should reflect the yearly hours of use, with the load factor representing the average boiler load fraction throughout the hours of use.

The boiler efficiency baseline uses the combustion efficiency provided by the end user on the application form. It assumes that this efficiency will remain at the user-specified level at 80% load and above, that the boiler efficiency is 5% less than this at 10% load, and that the boiler efficiency varies linearly between 80% and 10% load. These assumptions are based on a bulletin from Cleaver Brooks.[3]

Boiler manufacturers claim that a high turndown burner can add savings of 2% to 3%.[3,4,5] It is assumed that a high turndown burner produces an efficiency gain of 0.5% at 80% load and 2% at 10% load, and that the gain varies linearly between 80% load and 10% load.[3]

The value for the boiler efficiency with a proposed burner equals the boiler efficiency baseline plus the gain in efficiency at the specified average load factor. Typical gains in efficiency range from 0.6% to 1.4%.

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf Value for boilers used.
2. Wisconsin Focus on Energy. Historical project data for MMID 2203 obtained from SPECTRUM. Average cost of 25 units over 19 projects from 2016 to 2018.
3. Cleaver Brooks. *Discover How to Save Fuel with Turndown and High Efficiency across the Firing Range*. Accessed October 2018. http://cleaverbrooks.com/products-and-solutions/boilers/firetube/cbex-elite/Burner%20Efficiency%20and%20Firing%20rate.pdf
4. U.S. Department of Energy, Energy Efficiency and Renewable Energy Advanced Manufacturing Office. Steam Tip Sheet #24. *Upgrade Boilers with Energy-Efficiency Burners.* January 2012. https://www.energy.gov/sites/prod/files/2014/05/f16/steam24_burners.pdf
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Revision History

Version Number	Date	Description of Change
01	02/2019	Initial TRM entry

Boiler Control, Linkageless

	Measure Details
Measure Master ID	Boiler Control, Linkageless, 2205 Process Boiler Control, Linkageless, 4761
Measure Unit	Per boiler horsepower
Measure Type	Boiler Control = Prescriptive (MMID 2205) Process Boiler Control = Hybrid (MMID 4761)
Measure Group	Boilers and Burners
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure (see savings algorithms below)
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure (see savings algorithms below)
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$79.61[2]

Measure Description

Traditional boiler combustion controls consist of a single servo motor and a series of linkages to control the airflow and fuel flow into the combustion chamber. The linkage connections are susceptible to hysteresis, which limits the accuracy of the control. In addition, linkage controls are unable to match the combustion curve for airflow and fuel flow across a range of burn rates. Therefore, combustion efficiency is not optimized. Linkageless controls eliminate these issues and can improve the efficiency of the boiler.

Description of Baseline Condition

The baseline condition is a single servo motor with linkages to control airflow and fuel flow to the combustion chamber.

Description of Efficient Condition

The efficient condition is linkageless controls to control airflow and fuel flow to the combustion chamber.

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}}$ = BHP * 33,476 * LF * HOU / (Eff * 100,000) * SF

Where:

BHP = Boiler horsepower (= user input)

33,476 = Conversion factor from BHP to Btu/h

LF = Boiler load factor (= 100% for MMID 2205, see Assumptions; = actual for MMID 4761)

HOU = Annual hours of operation (= 1,890 for MMID 2205;[3] = actual for MMID 4761)

Eff = Boiler efficiency (= 85% for MMID 2205;[4] = actual for MMID 4761)

100,000 = Conversion factor from Btu to therms

SF = Savings fraction (= 3%, see Assumptions)

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}} = \text{Therm}_{\text{SAVED}}$ * EUL

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Savings for Linkageless Controls, Therms per Boiler Horsepower

Measure	MMID	Annual Savings	Lifecycle Savings
Boiler Control, Linkageless	2205	22	330
Process Boiler Control, Linkageless	4761	Varies	Varies

Assumptions

The savings above are based on linkageless controls only. Oxygen trim controls are a separate measure.

For the space heating boiler measure (MMID 2205), the HOU value of 1,890 reflects the equivalent full-load hours and the load factor is not needed and is therefore 100%. For the process boiler measure (MMID 4761), the HOU value should reflect the yearly hours of use, with the load factor representing the average boiler load fraction throughout the hours of use.

The savings fraction is deemed to be 3%, which is the value historically used for Focus on Energy, outlined in the 2010 *Deemed Savings Manual*.[5] The manual cites a number of sources that are now unavailable, showing savings factors ranging from 1% to 6%. The one currently available source[6] indicates roughly 3.3% (Figure 2). That source also indicates 5% to 15% in text, though this range is likely very optimistic and exists only for poorly tuned boiler burners and boilers normally operated at a small fraction of design load. A more recent case study[7] indicates 1.1% to 1.4%, though this was compared against well-tuned linkage burners that may not reflect the actual field baseline. Another recent case study[8] indicates roughly 1.1% for a single site, based on the average differences in efficiency (Table 5). Because the latter two studies may not represent the field as a whole, and engineering judgement indicates that savings are probably in fact higher than their findings on average, the savings fraction is deemed to remain at 3%. This percentage may merit further review as new data becomes available.

Sources

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3. U.S. Environmental Protection Agency and U.S. Department of Energy. “Life Cycle Cost Estimate for ENERGY STAR Qualified Air Source Heat Pump(s).” April 2009. https://www.energystar.gov/sites/default/uploads/buildings/old/files/ASHP_Sav_Calc.xls

   Several Cadmus metering studies reveal that the ENERGY STAR calculator EFLH values are over-estimated by 25%. The heating EFLH were adjusted by population-weighted HDD and TMY3 values, then averaged for the state of Wisconsin.
4. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. p. 34. August 31, 2017. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf
5. PA Consulting Group Inc. *State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
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Revision History

Version Number	Date	Description of Change
01	02/2019	Initial TRM entry

Boiler Oxygen Trim Controls

	Measure Details
Measure Master ID	Boiler Oxygen Trim Controls, 2206 Process Boiler, Oxygen Trim Combustion Controls, 4762
Measure Unit	Per boiler horsepower
Measure Type	Oxygen Trim Controls = Prescriptive (MMID 2206) Oxygen Trim Combustion Controls = Hybrid (MMID 4762)
Measure Group	Boilers and Burners
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure (see savings algorithms below)
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure (see savings algorithms below)
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$55.54[2]

Measure Description

Although boilers require some excess oxygen to ensure the complete combustion of fuel, too much excess oxygen decreases boiler efficiency. An increase in excess oxygen requires an increase in combustion air. The higher volume of combustion air will heat up during combustion and this heat energy is lost up the stack. Installing a system to monitor excess oxygen in the flue allows excess air to be reduced to optimal levels. This improves the efficiency of the boiler.

Description of Baseline Condition

The baseline condition is dual-point (linkageless) controls with no system in place to monitor oxygen levels in flue gases.

Description of Efficient Condition

The efficient condition is to install oxygen monitoring in the flue gas to control oxygen to optimal levels.

Annual Energy-Savings Algorithm

$Therm_{SAVED}$ = BHP * 33,476 * LF * HOU / (Eff * 100,000) * SF

Where:

BHP = Boiler horsepower (= user input)

33,476 = Conversion factor from BHP to MBh

LF = Boiler load factor (= 100% for MMID 2206, see Assumptions; = actual for MMID 4762)

HOU = Annual hours of operation (= 1,890 for MMID 2206;[3] = actual for MMID 4762)

Eff = Boiler efficiency (= 85% for MMID 2206;[4] = actual for MMID 4762)

100,000 = Conversion factor from Btu to therms

SF = Savings fraction (= 1.1%, see Assumptions)

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE}$ = $Therm_{SAVED}$ * EUL

Where:

EUL = Effective useful life (= 5 years)[1]

Deemed Savings

Savings for Oxygen Trim Controls, Therms per Boiler Horsepower

Measure	MMID	Annual Savings	Lifecycle Savings
Boiler Oxygen Trim Controls	2206	8	40
Process Boiler, Oxygen Trim Combustion Controls	4762	Varies	Varies

Assumptions

For the space heating boiler measure (MMID 2206), the HOU value of 1,890 reflects the equivalent full-load hours and the load factor is not needed and is therefore 100%. For the process boiler measure (MMID 4762), the HOU value should reflect the yearly hours of use, with the load factor representing the average boiler load fraction throughout the hours of use.

The savings fraction is deemed to be 1.1%, which is the value historically used for Focus on Energy, outlined in the 2010 *Deemed Savings Manual*.[5] The manual refers to a 2002 report from Oak Ridge National Laboratory[6] and a 2001 Environmental Protection Agency brief,[7] and shows a short analysis based on these two reports.

Two additional studies suggest savings ranging from 0.5% to 5%[8] and 5%.[9] However, additional (January 2019) analysis was conducted using data from Table 5 of an ACEEE paper[10] and Table B.1 from the Oak Ridge National Laboratory report[6] supporting a savings fraction of around 1% for a linkageless controls baseline. Therefore, the existing 1.1% savings factor is maintained.

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." Appendix B. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 459 units over 44 projects from 2012 to 2018.
3. U.S. Environmental Protection Agency and U.S. Department of Energy. "Life Cycle Cost Estimate for ENERGY STAR Qualified Air Source Heat Pump(s)." April 2009. https://www.energystar.gov/sites/default/uploads/buildings/old/files/ASHP_Sav_Calc.xls

   Several Cadmus metering studies reveal that the ENERGY STAR calculator EFLH values are over-estimated by 25%. The heating EFLH were adjusted by population-weighted HDD and TMY3 values, then averaged for the state of Wisconsin.
4. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. p. 34. August 31, 2017. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf
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Revision History

Version Number	Date	Description of Change
01	02/2019	Initial TRM entry

Radiant Tube Inserts

	Measure Details
Measure Master ID	Radiant Tube Inserts, 2507
Measure Unit	Per insert
Measure Type	Hybrid
Measure Category	Boilers & Burner
Measure Group	Industrial Ovens and Furnaces
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies
Lifecycle Electricity Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Measure Incremental Cost ($/unit)	$368.64[2]

Measure Description

Radiant tube heaters are typically used in metal heat-treating furnaces. The heaters are long tubes, often in a U-shape, and have natural gas–fired burners at one end of the burner leg to produce a flame and heated gas that flows through the tube to produce heat for conditioning metals. Ceramic inserts with a twisted shape are available for the inside of the tubes that enhance the radiant heat transfer from the exhaust gases in the burner to the heat-treating furnace. This reduces heat exhaust and the natural gas usage of the heat treat system.

Description of Baseline Condition

The baseline condition is a traditional radiant tube with no heat transfer assisting devices in the exhaust leg of the radiant tube.

Description of Efficient Condition

The efficient condition is a radiant tube with new radiant inserts applied to a natural gas furnace used for heat treating.

Annual Energy-Savings Algorithm

$\text{Therms}_{\text{SAVED}} = \text{Capacity}_{\text{FURNACE}} * \text{Hours} * \text{SF} / 100{,}000$

Where:

$\text{Capacity}_{\text{FURNACE}}$ = Input capacity of heat treat furnace in Btu/hr (= actual)

Hours = Annual operating hours (= actual)

SF = Savings fraction for radiant tube inserts (= 15%)[3,4]

100,000 = Btu to therms conversion factor

Summer Coincident Peak Savings Algorithm

There are no peak demand savings for this measure.

Lifecycle Energy-Savings Algorithm

$\text{Therms}_{\text{LIFECYCLE}} = \text{Therms}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (= 5 years)[1]

Assumptions

Savings calculations are extremely difficult to provide due to the complexity of heat transfer. Therefore, case studies are cited for savings estimates. One paper reports that the savings from several case studies have varied between 5% and 25%,[3] depending upon the existing furnace: if the furnace is relatively new and equipped with a recuperator, savings may be 5%, but if installed in an older furnace, savings can be up to 25%. The DOE EERE Advanced Manufacturing Office indicates a savings range of 15% to 20%.[4] A 2007 Focus on Energy report[5] indicates savings of 15% and 11% for two separate units under controlled test conditions. Another 2007 report[6] indicates savings of 18% and 29% for two separate units under controlled test conditions. Based on this information, a 15% savings fraction was deemed, which is the mid to low end of these ranges.

The savings calculated is for the retrofit of one complete furnace, while the incentive is paid based on number of individual radiant tube inserts.

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” Appendix B. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 330 units over six projects from 2012 to 2015.

3. Goetzler, William, Craig McDonald, and Ganesh Venkat. "Energy Efficiency Portfolio of the Future." ACEEE Summer Study on Energy Efficiency in Buildings, 2008. http://aceee.org/files/proceedings/2008/data/papers/7_212.pdf
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Revision History

Version Number	Date	Description of Change
01	09/08/2017	Initial TRM workpaper
02	12/2018	Updated incremental cost

Steam Fittings and Pipe Insulation

	Measure Details
Measure Master ID	Insulation, Steam Fitting, Removable, Natural Gas, 2429, 4543 Insulation, Steam Piping, Natural Gas, 2430, 4544
Measure Unit	Per linear foot (pipe insulation) Per fitting (fitting insulation)
Measure Type	Prescriptive
Measure Group	Boilers & Burners
Measure Category	Insulation
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	11.38 (per linear foot pipe insulation) 40.44 (per fitting insulation)
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	113.8 (per linear foot pipe insulation) 404.4 (per fitting insulation)
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	Steam fitting = $37.63 (MMID 2429)[4] Steam piping = $8.40 (MMID 2430)[5]

Measure Description

Uninsulated steam lines and fittings are a constant source of wasted energy. Adding insulation can typically reduce energy losses by 90% and will help ensure proper steam pressure and temperatures where needed. This measure is only for steam pipes in unconditioned spaces, including unconditioned basements and crawlspaces that are insulated from the conditioned space of the building.

Description of Baseline Condition

The baseline measure is an existing, non-insulated steam pipe or fittings that is part of an HVAC steam distribution system, with 80% boiler efficiency.

Description of Efficient Condition

Insulation must meet all federal and local safety standards and be rated for the temperature of the pipe on which it will be applied. Incentives are not intended for replacing existing pipe, insulation but only for insulating existing bare pipe.

The pipe being insulated must be at least 0.5-inches in diameter and must carry steam as part of an HVAC steam distribution system. The insulation thickness must meet 2009 IECC standards,[2] as outlined in section 5.3.2.8. For steam pipe with a 1.5-inch NPS or smaller, insulation must be at least 1.5 inches thick. For steam pipe with an NPS greater than 1.5 inches, insulation must be at least 3.0-inches thick. This is based on insulation with a K-value that does not exceed 0.27 Btu per inch/h * foot^2*°F. Installation must include a protective jacket around the insulation.

Annual Energy-Savings Algorithm

Savings were calculated using the assumptions listed below and 3E Plus v4.0 software, distributed by NAIMA (North American Insulation Manufacturers Association).[3] The 3E Plus software was used to calculate heat loss rates for bare and insulated pipe thickness per foot. The difference in heat loss is multiplied by the assumed hours of operation and divided by the boiler efficiency and Btu to therm conversion to calculate annual natural gas therm savings.

$\text{Therm}_{\text{SAVED\_PIPE}} = \text{PipeInsul}_{\text{SAVED}} * \text{LF}$

$\text{PipeInsul}_{\text{SAVED}} = \text{Pipe}_{\text{BARE}} - \text{Pipe}_{\text{INSUL}}$

Where:

$\text{PipeInsul}_{\text{SAVED}}$ = Annual energy savings through insulating in therms per linear foot of pipe (= 11.38)

LF = Total linear feet of pipe (= 1)

$\text{Pipe}_{\text{BARE}}$ = Annual energy consumption for uninsulated pipe calculated with 3E Plus software

$\text{Pipe}_{\text{INSUL}}$ = Annual energy consumption for insulated pipe calculated with 3E Plus software

$\text{Therm}_{\text{SAVED\_FITTING}} = \text{FittingInsul}_{\text{SAVED}} * \text{NF}$

$\text{FittingInsul}_{\text{SAVED}} = \text{Fitting}_{\text{BARE}} - \text{Fitting}_{\text{INSUL}}$

Where:

$\text{FittingInsul}_{\text{SAVED}}$ = Annual energy savings through insulating in therms per fitting (= 40.44)

NF = Number of fittings (= 1)

$Fitting_{BARE}$ = Annual energy consumption for uninsulated fitting calculated with 3E Plus software

$Fitting_{INSUL}$ = Annual energy consumption for uninsulated fitting calculated with 3E Plus software

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Assumptions

The pipe or fitting will be hot for 4,000 hours per year.

The NPS is 2 inches. A fitting is equivalent to approximately 3.55 feet of 2-inch pipe.

The system application for this calculation is Pipe – Horizontal/Vertical, with the dimensional standard of ASTM C 585 Rigid/Flexible.

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Table 3-2 Lighting Hours of Use in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
2. 2009 IECC standards.
3. This program is available through NAIMA (North American Insulation Manufacturers Association) at http://www.pipeinsulation.org/.
4. Actual Program Data, 2015-2016. 20 projects with average actual cost of $37.63 per fitting.
5. Actual Program Data, 2015-2016. 18 projects with average actual cost of $8.40 per foot

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry

Boiler Tune-Up

	Measure Details
Measure Master ID	Boiler Tune-Up, 2744, 4419
Measure Unit	Per MBh
Measure Type	Prescriptive
Measure Group	Boilers & Burners
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0.339
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	0.339
Water Savings (gal/year)	0
Effective Useful Life (years)	1[1]
Incremental Cost ($/unit)	$0.83[2]

Measure Description

Tune-ups are required for boilers to maintain optimal combustion efficiency. Boiler tune-ups must be completed according to the boiler tune-up checklist. This measure applies to non-process-related boilers. A boiler tune-up includes reducing excess air and stack temperature; cleaning burners, burner nozzles, combustion chamber, and boiler tubes; sealing the combustion chamber; and recalibrating boiler controls.

The inspector also checks combustion air intake. The proper combustion air-to-fuel ratio directly affects combustion efficiency. Inadequate air supply yields unburned combustibles (fuel, soot, smoke, and carbon monoxide) while excess air causes heat loss from increased flue gas flow, which lowers the boiler efficiency.

Description of Baseline Condition

The baseline measure is 84% boiler efficiency.

Description of Efficient Condition

The incentive is available once in a 12-month period. The service provider must perform before and after combustion efficiency tests and record the results on the boiler tune-up incentive application. The burner must be adjusted to improve combustion efficiency as needed. The incentives are only available for space and water heating equipment.

Annual Energy-Savings Algorithm

$Therm_{SAVED}$ = BOF * CAP * SF * HDD * 24 / [(T_{INDOOR} – $T_{OUTDOOR}$) * $AFUE_{PRE}$ * 100]

Where:

BOF = Boiler oversize factor (= 77%, deemed)
CAP = Size of the boiler being tuned (= 1 MBh)
SF = Savings factor (= 1.6%, deemed)[3]
HDD = Heating degree days (= 7,699)[3]
T_{INDOOR} = Indoor design temperature (= 65°F)[3]
$T_{OUTDOOR}$ = Outdoor design temperature (= -15°F)[3]
$AFUE_{PRE}$ = AFUE of boiler prior to tune-up (= 84% for multifamily; = 84% for small business)[4]
100 = Conversion factor from MBh to therm

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE}$ = $Therm_{SAVED}$ * EUL

Where:

EUL = Effective useful life (= 1 year)[1]

Sources

1. PA Consulting Group Inc. “Public Service Commission of Wisconsin Focus on Energy Evaluation: Business Programs Measure Life Study. Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Illinois Technical Reference Manual. p. 185. 2013. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf

3. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. Cadmus. *2016 Potential Study for Focus on Energy.*
   Data maintained by Cadmus and Wisconsin PSC.
   Based on 18 boilers at office, restaurant, and retail sites and 23 boilers at multifamily sites.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	04/2017	Added MMID 4058
03	05/2018	Updated based on *Potential Study* data
04	10/2018	Removed MMID 4058, added MMID 4419, changed EUL to one year, removed average boiler size

Building Shell

Spring-Loaded Garage Door Hinge

	Measure Details
Measure Master ID	Spring-Loaded Garage Door Hinge: 55 Degree Indoor Temperature Setpoint, 3680, 4614 60 Degree Indoor Temperature Setpoint, 3681, 4615 65 Degree Indoor Temperature Setpoint, 3682, 4616 70 Degree Indoor Temperature Setpoint, 3683, 4617
Measure Unit	Per garage door
Measure Type	Hybrid
Measure Group	Building Shell
Measure Category	Air Sealing
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/Year)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	$228.00[9]

Measure Description

Overhead doors do not always seal well against weather stripping and gaps may occur that lead to the loss of energy if the inside space is heated. These gaps can be exacerbated by wind and/or deterioration of weather stripping with age.

Spring-loaded garage door hinges reduce air infiltration around overhead doors by employing spring-loaded assemblies that keep overhead door sections pressed tightly against the seals. This eliminates the loss of energy.

The heavy-duty 12-gauge steel hinges fit most existing commercial doors. Individual door panels can be custom-adjusted to overcome poor track positioning and warped walls. The measure can be installed as a retrofit or on new construction.

Description of Baseline Condition

Infiltration is the uncontrolled leakage of air into a building. Air leaking can increase both heating and cooling costs. The rate of infiltration is driven by how well a building is sealed, the difference in temperature between the inside of the building and outside air, and the wind speed. Generally, the greatest temperature differences and wind speeds occur in winter. Sealed leaks will produce heating savings. The calculations below estimate heating savings.

The baseline condition is a 1/8-inch gap between the door and the weather stripping on the two vertical dimensions and one horizontal dimension. The bottom of the door is assumed sealed.

Description of Efficient Condition

The efficient condition is having installed the spring-loaded hinges, and the gap is assumed to be zero resulting in a net sealed dimension of 1/8 inch.

Annual Energy-Savings Algorithm

Reduced Infiltration (CFM) = $A_L * [(C_s * \Delta T) + (C_w * W_s^2)]^{0.5}$

Where:

A_L = Effective leakage area reduced, in square inches (= 51; average door assumed to be 10 feet wide and 12 feet tall; perimeter of top and two sides is 408 inches; with 1/8-inch gap reduced)

C_s = Stack coefficient (= 0.0299 $CFM^2/(in^4 * °F$; determined from building height in stories with average of 2 stories assumed)[3]

ΔT = Indoor temperature setpoint minus average outside temperature during heating season (= 35°F; average outside temperature across Wisconsin during the heating season, for four locations)[4]

C_w = Wind coefficient (= 0.0086 $CFM^2/ in^4 mph^2$; determined from how sheltered the building is from the wind)[5]

W_s = Average heating season wind speed (= 11 mph)[2,6]

Hourly Heat Load Reduced (Btu/hour) = Reduced Infiltration (CFM) * (60 Min/Hr) * (0.08 Lb/CF) * (0.24 Btu/lb) * ΔT

Where:

0.08 = Average heating season air density in Wisconsin (lb/CF)[7]

0.24 = Specific heat of air (Btu/lb)[8]

Hourly Natural Gas Reduced (therms/hour) = (Reduced Heat Load Btu/hour)/(Heating Efficiency)/(100,000 Btu/therm)

Where:

Heating Efficiency = Typical non-condensing heating efficiency (= 0.80)[9]

Annual Natural Gas Use Reduced (therms/year) = Hourly Natural Gas Reduced (therms/hour) * (Heating hours/year)

Where:

Heating Hr/Yr = Hours in typical September to April heating season (= 5,840)

Deemed Savings Results

MMID	Indoor Temperature Setpoint (°F)	Deemed Savings/Door (Therms/Year)
3680	55	110
3681	60	143
3682	65	179
3683	70	217

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}}$ = Therms/year * EUL

Where:

EUL = Effective useful life (= 20 years)[1]

Assumptions

The baseline condition is having a 1/8-inch gap between the garage door and the weather stripping on the two vertical dimensions and one horizontal dimension. The bottom of the door is assumed to be sealed. After installing the spring-loaded hinges, the gap is assumed to be zero resulting in a net sealed dimension of 1/8 inch. Interior space must be heated with natural gas.

The infiltration calculation is based on an ASHRAE model noted in the sources.

Infiltration in residential buildings has been studied extensively, and several calculation techniques have been produced to estimate annual infiltration rates. However, infiltration in commercial buildings has not been studied to the same detail, and standard calculations have not been developed for annual commercial infiltration rates. Therefore, the calculations assume residential-like infiltration.

The interior temperature setpoint is based on individual customer, and will be input by the customer who selects one of the four options (55°F, 60°F, 65°F, or 70°F). Deemed energy savings will vary according to the Deemed Savings Results table above. The incentive will not vary by setpoint, so there is no gain for a customer to report an inaccurate number.

The average garage door is 10 feet wide by 12 feet tall, based on Wisconsin Focus on Energy installations done to date.

The EUL is 20 years.[1] Initial installations of the Green Hinge product have been in the market for at least five years, and the trade ally claims there have been no failures in that time. The company provides a lifetime guarantee thus if there is a failure, the customer would likely replace it in kind. The spring supplier certifies that the spring is good for > 10,000,000 cycles. Conventional garage door hinges routinely last 20+ years.

The average installation cost is based on the average door size of 10 feet wide by 12 feet tall, with six panels and five sets of hinges at $28.00/set (trade ally website quote) plus an estimated installation of $200.00 per door.

Sources

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Revision History

Version Number	Date	Description of Change
01	8/2016	Added workpaper

Compressed Air, Vacuum Pumps

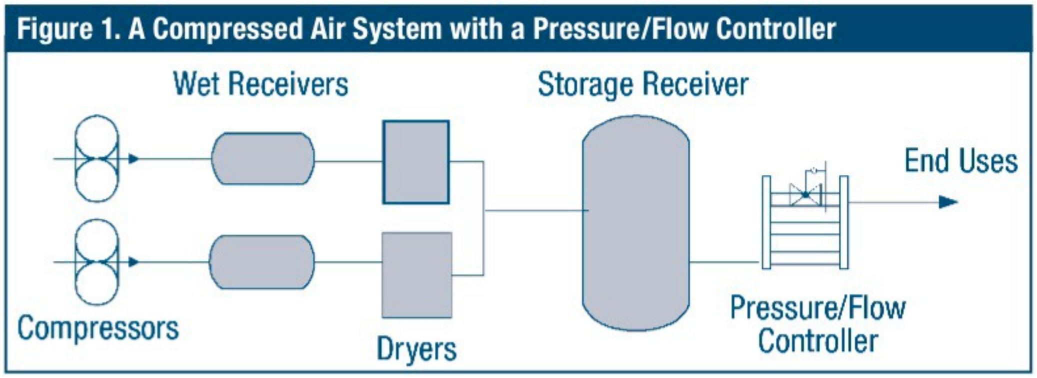
Compressed Air Controller, Pressure/Flow Controller

	Measure Details
Measure Master ID	Compressed Air Controller, Pressure/Flow Controller, 2255, 4493
Measure Unit	Per horsepower
Measure Type	Prescriptive
Measure Group	Compressed Air, Vacuum Pumps
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	199
Peak Demand Reduction (kW)	0.035
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	2,989
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$26.46/hp[7]

Measure Description

A pressure/flow controller can greatly increase the control of an air storage system. These units, also called demand valves, precision flow controllers, or pilot-operated regulators, are precision pressure regulators that allow the airflow to fluctuate while maintaining a constant pressure to the facility's air distribution piping network.

Compressed Air System with a Pressure/Flow Controller[2]



Installing a pressure/flow controller on the downstream side of an air storage receiver creates a pressure differential entering and leaving the vessel. This pressure differential stores energy in the form of readily available compressed air, which can be used to supply the peak air demand for short-duration events, in place of using more compressor horsepower to feed this peak demand.

The benefits of having a pressure/flow controller include:

- Reducing the kilowatts of peak demand, especially with multiple compressor configurations.
- Saving kilowatt-hours by allowing the compressor to run at most efficient loads, then turn itself off in low demand and no demand periods.
- Saving kilowatt-hours by reducing plant air pressure to the minimum allowable. This leads to reduced loads on the electric motors and greater system efficiency. For every 2 psi reduced in the system, 1% of energy is saved.
- Maintaining a reduced, constant pressure in the facility wastes less air due to leakage, and less volume is required by the compressor.
- Ensuring quality control of the process by the constant pressure: machines can produce an enhanced product quality when the pressure is allowed to fluctuate.

Description of Baseline Condition

The baseline condition is having no existing pressure/flow controller and an existing compressed air system with a total compressor motor capacity ≥ 50 hp.

Description of Efficient Condition

To qualify for an incentive, the facility must have a compressed air system with motor capacity ≥ 50 hp and a pressure/flow controller must be installed on the main pressure header. This measure is not replacing drop-line regulators or filter-regulator lubricators.

Annual Energy-Savings Algorithm

kWh_{SAVED} = hp * 0.746 / Motor Eff. * Load Factor * HOU * % decrease

Where:

hp = Compressor motor size in horsepower
0.746 = Conversion factor from kilowatts to horsepower
Motor Eff. = Compressor motor efficiency (= 95%)[3]
Load Factor = Average load on compressor motor (= 89%)[3]
HOU = Average annual run hours (= 5,702)[4]
% decrease = Percentage decrease in power input (= 5%)[5]

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = hp * 0.746 / Motor Eff. * Load Factor * % decrease * CF

Where:

CF = Coincidence factor (= 1)[6]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

Where:

EUL = Effective useful life (= 15 years)[1]

Sources

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4. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. August 31, 2017. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf
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6. Army Corps of Engineers. *Compressed Air System Survey at Sierra Army Depot, CA*. Mike C.J. Lin, Ahmad R. Ganji, Shy-Sheng Liou, and Bryan Hackett. November 2000. www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA384166
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Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	05/2018	Updated HOU
03	12/2018	Updated incremental cost

Compressed Air, Cycling Thermal Mass Air Dryers

	Measure Details
Measure Master ID	Compressed Air, Cycling Thermal Mass Air Dryers, 2264, 4483
Measure Unit	Per CFM
Measure Type	Prescriptive
Measure Group	Compressed Air, Vacuum Pumps
Measure Category	Dryer
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	1,604 per 100 CFM
Peak Demand Reduction (kW)	0.281 per 100 CFM
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	24,062 per 100 CFM
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$6.00[7]

Measure Description

When air is compressed, it is typically saturated with moisture, which may cause corrosion or contamination if it condenses in a compressed air system. Compressed air dryers remove moisture from the compressed air system. Refrigerated dryers are the most common,[2] which remove moisture by cooling the air and causing water vapor to condense. Cycled refrigerated dryers turn on and off or use a VFD to operate only as needed. Non-cycling dryers will continue to consume energy when drying is not needed.

Description of Baseline Condition

The baseline for this measure is a non-cycling refrigerated thermal mass air dryer.

Description of Efficient Condition

New dryers must be properly sized to meet the needs of the compressed air system in order to qualify. New dryers must be cycling or VFD-controlled refrigerated dryers. This measure is only for the replacement of non-cycled refrigerated dryers with cycled refrigerated dryers. The addition of controls to existing dryers does not qualify. The replacement of desiccant, deliquescent, heat-of-compression, membrane, or other types of dryers does not qualify.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = SF * LF * CFM * HOU$

Where:

SF = Savings factor in kilowatts per CFM (= varies by dryer capacity; see table below)

LF = Load factor (= 89%)[4]

CFM = Cubic feet per minute; the actual rated capacity of air dryer

HOU = Average annual run hours (= 5,702)[5]

Savings Factor by Dryer Capacity

Dryer Capacity in CFM	Savings Factor (kW/CFM)[3]
< 100	0.00474
≥ 100 and < 200	0.00359
≥ 200 and < 300	0.00316
≥ 300 and < 400	0.00290
≥ 400	0.00272

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = SF * LF * CFM * CF$

Where:

CF = Coincidence factor (= 1)[6]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Sources

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2. United States Department of Energy. Compressed Air Challenge, Improving Compressed Air System Performance: A Sourcebook for Industry. p. 11. November 2003.

3. *Massachusetts Technical Resource Manual for Estimating Savings from Energy Efficiency Measures*. Average of values, p. 217. October 2010.
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Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	05/2018	Updated HOU

Dew Point Controls for Desiccant Dryers

	Measure Details
Measure Master ID	Dew Point Controls for Desiccant Dryers, 4363, 4481
Measure Unit	Per CFM
Measure Type	Hybrid
Measure Group	Compressed Air, Vacuum Pumps
Measure Category	Dryer
Sector(s)	Commercial, Industrial
Annual Energy Savings (kWh)	Varies by air compressor type, horsepower, and air dryer type
Peak Demand Reduction (kW)	Varies by air compressor type, horsepower, and air dryer type
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by air compressor type, horsepower, and air dryer type
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$4,000 per system[2]

Measure Description

Desiccant dryers are used in compressed air systems where air needs to be dried to a lower dew point (down to -40°F) than refrigerated-type dryers can provide (35–39°F). A desiccant dryer consists of two towers containing a desiccant medium. One of these towers dries the air, while the other purges compressed air to regenerate the desiccant medium. When the drying tower is saturated, the towers swap functions. This regeneration is typically accomplished by one of several mechanisms: compressed air purging, heated compressed air purging, or heated blower air.

Desiccant dryers that use compressed air purging to regenerate the desiccant towers typically operate by purging a fixed amount of compressed air at regular intervals, regardless of the amount of air being dried at the time. This situation leads to over-purging compressed air, increasing the energy consumption of the air compressor. Installing dewpoint-dependent switching controls will monitor the dewpoint within the dryer and only purge compressed air when necessary, potentially reducing the annual operating costs of the desiccant dryer by up to 60%.[3]

Description of Baseline Condition

The baseline equipment is a desiccant air dryer that purges periodically based on a timer control. Modulation-controlled air compressor systems are not qualified for this measure.

Description of Efficient Condition

The efficient condition is a dew-point sensor control, which can measure the amount of humidity within the desiccant tower and will purge only when required. This control will reduce the amount of purge energy (compressed air, heater and blower power) required by the air dryer during part-load operation.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = CFM * (PR_{BASE} - PR_{EE}) * HOURS$

$PR_{BASE} = Eff * \%Power_{BASE} + HD_{BASE} + BD_{BASE}$

$PR_{EE} = Eff * \%Power_{EE} + HD_{EE} + BD_{EE}$

Where:

CFM = Cubic feet per minute; the actual rated capacity of air compressor that the air dryer serves

PR_{BASE} = Power requirement of baseline system in kW/cfm

PR_{EE} = Power consumption of efficient dew-point sensor controlled system in kW/cfm

HOURS = Average annual run hours (= 5,702)[4]

Eff = Efficiency of standard air compressor (varies by air compressor type; see table below)[5]

$\%Power_{BASE}$ = Percentage of rated power at baseline condition (= varies by air compressor control type and dryer type; see table below)

HD_{BASE} = Heater demand of the dryer at baseline condition (= varies by dryer type; see table below)

BD_{BASE} = Blower demand of the dryer at baseline condition (= varies by dryer type; see table below)

$\%Power_{EE}$ = Percentage of rated power with dew point control (= varies by air compressor control type and dryer type; see table below)

HD_{EE} = Heater demand of the dryer with dew point control (= varies by dryer type; see table below)

BD_{EE} = Blower demand of the dryer with dew point control (= varies by dryer type; see table below)

Efficiency of Standard Air Compressor (Eff)

Air Compressor Type	Eff (kW/cfm)[5]
Single-acting, air-cooled reciprocating	0.22
Double-acting, water-cooled reciprocating	0.15
Single-stage, lubricant-injected rotary screw	0.18
Two-stage, lubricant-injected rotary screw	0.16
Lubricant-free rotary screw	0.18
Centrifugal	0.16
Other	0.18

Power by Air Compressor Control Type and Dryer Type[6,8]

Air Compressor Control Type	Dryer Type	$\%Power_{BASE}$	$\%Power_{EE}$
Variable Speed Drive	Heatless	65.0%	57.5%
	Heated	57.0%	53.5%
	Blower Purge	50.8%	50.8%
Load/Unload	Heatless	83.2%	78.3%
	Heated	78.0%	75.5%
	Blower Purge	72.9%	72.9%
Variable Displacement	Heatless	73.1%	67.3%
	Heated	66.9%	64.2%
	Blower Purge	61.5%	61.5%
Inlet Modulation	Heatless	89.5%	87.3%
	Heated	87.1%	86.1%
	Blower Purge	85.0%	85.0%

Heater Demand and Blower Demand by Dryer Type

Dryer Type	Heater Demand (kW/CFM)[6]		Blower Demand (kW/CFM)[6]	
	HD_{BASE}	HD_{EE}	BD_{BASE}	BD_{EE}
Heatless Dryer	0	0	0	0
Heated Dryer	0.012	0.006	0	0
Blower Purge Dryer	0.019	0.010	0.003	0.0015

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = CFM * (PR_{BASE} - PR_{EE}) * CF$

Where:

CF = Coincidence factor (= 1)[7]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

The %Power depends on air compressor control type and load factor. The total load of the air compressor is the sum of loads from end uses and the amount of purge air required by dryer. The average load factor of air compressor end uses was obtained through a survey of 12 custom compressed air projects (within Michigan and Ohio) where older, traditional controlled air compressors were replaced with similar sized VSD air compressors. The total power consumption was metered over a seven-day period both before and after replacement, and the average power draw (kW) for each project was analyzed. Using this data, the percentage volume flow rate (CFM) loading of all the VSD compressors was found using the manufacturer's specification sheets. The study revealed that, on average, these compressors were loaded to 47% of their full-load CFM. The post-replacement data was analyzed because the profile with these compressors gives the most accurate prediction of the facility's actual air demand, assuming the facility's air demand did not change from pre- to post-replacement.

The purge air demands were obtained through a survey of 82 dryers from the following manufacturers: Ingersoll Rand, Quincy, Parker-AIRTEK, and Parker-DOMNICK HUNTER.[6] The heatless dryers and heated dryers require 15% and 7% capacity respectively for purge air, respectively. Blower purge dryers do not need purge air from the air compressor: with the help of dew point control, the purge air demand can be reduced to match the compressed air demand at end use. Because the average load factor from end use is close to 50%, we assumed the dew point controls can reduce purge air by 50% for all cases. The baseline total load factors and dew point control total load factors are summarized in the following table. Finally, the %Powers were determined for different types of air compressors using typical air compressor performance curves.[9]

Total Load Factors of Different System Types

Dryer Types	Baseline	Dew Point Control
Heatless Dryer	65%	57.5%
Heated Dryer	57%	53.5%
Blower Purge Dryer	50%	50%

The baseline average power demands for heaters and blowers was obtained based on a survey of 76 dryers from the following manufacturers: Ingersoll Rand, Quincy, Parker-AIRTEK and Parker-DOMNICK HUNTER. With the help of dew point control, the heater demand and blower demand can be reduced to match the compressed air demand at end use. Because the average load from end use is close to 50%, it is assumed both heater demand and blower demand can be reduced by 50% for all cases with dew point controls.

Sources

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Revision History

Version Number	Date	Description of Change
01	10/11/2017	Initial TRM entry

Compressed Air and Vacuum Pump Heat Recovery, Space Heating

	Measure Details
Measure Master ID	Compressed Air Heat Recovery, Space Heating, 2257, 4494 Vacuum Pump Heat Recovery, Space Heating, 3928, 4629
Measure Unit	Per horsepower
Measure Type	Prescriptive
Measure Group	Compressed Air, Vacuum Pumps
Measure Category	Energy Recovery
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	73.39
Lifecycle Electricity Savings (kWh)	0
Lifecycle Therm Savings (Therms)	954.07
Water Savings (gal/year)	0
Effective Useful Life (years)	13[1]
Incremental Cost ($/unit)	$112.41[5]

Measure Description

The majority of the energy consumed by industrial air compressors and vacuum pumps is converted to heat, which can be recovered. Air compressor and vacuum pump heat recovery systems are designed to capture waste heat and use it for space heating, water heating, or process heating. These systems can be installed on both air- and water-cooled compressors and vacuum pumps. For air-cooled compressors and vacuum pumps, ductwork and fans may be installed to send cool air across the unit’s after-cooler and oil cooler. The cool air absorbs heat from the compressor or vacuum pump and gets ducted to where it is needed. For water-cooled compressors and vacuum pumps, a water-to-air or water-to-water heat exchanger may be used.

Heat recovery systems installed for backup or redundant air compressors and vacuum pumps do not qualify. The project must result in an estimated net reduction in facility Btus to be eligible. The static pressure in the area where the compressor or vacuum pump is enclosed must remain the same, since a reduction in static pressure may reduce compressor efficiency. If outside air is used, anti-freeze protection must be considered.

Description of Baseline Condition

The baseline condition is a compressor or vacuum pump without a heat recovery system, but with natural gas space heating.

Description of Efficient Condition

The efficient condition is a compressor or vacuum pump with a heat recovery system for natural gas space heating.

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}}$ = hp * Load Factor * 2,545 * HR * HOU / 100,000

Where:

hp = Compressor or vacuum pump motor horsepower size
Load Factor = Average load on compressor or vacuum pump motor (= 89%)[2]
2,545 = Conversion factor from horsepower to Btu/hr
HR = Heat recoverable as a percentage of brake horsepower (= 85%)[3]
HOU = Average annual run hours of the compressor or vacuum pump (= 3,812)[4]
100,000 = Conversion from Btus to therms

Summer Coincident Peak Savings Algorithm

There are no peak coincident savings for this measure.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}} = \text{Therm}_{\text{SAVED}}$ * EUL

Where:

EUL = Effective useful life (= 13 years)[1]

Assumptions

The percentage of recoverable heat reference[3] states that between 80% and 90% of heat is recoverable from air cooled air compressors, so the savings in this workpaper are based on the midpoint of 85%. Historical project data for Focus on Energy indicates that all or nearly all heat recovery projects have been for air-cooled air compressors.

Based on engineering judgement, the heating season is assumed to be October through March, which is six months or 50% of the year.

Sources

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5. Historical project data. 105 applications across 2015 and 2016.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	09/2016	Expanded scope to include compressed air and vacuum pump heat recovery
03	10/2017	Updated EUL
04	05/2018	Updated HOU

Compressed Air Mist Eliminators

	Measure Details
Measure Master ID	Compressed Air Mist Eliminators, 2258, 4495
Measure Unit	Per horsepower
Measure Type	Prescriptive
Measure Group	Compressed Air, Vacuum Pumps
Measure Category	Filtration
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	80
Peak Demand Reduction (kW)	0.014
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	New construction = 400; retrofit = 240
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	New construction = 5; retrofit= 3[1]
Incremental Cost ($/unit)	$28.24[7]

Measure Description

Large compressed air systems require air filtration for proper operation. These filters remove oil mist from the supply air of lubricated compressors, protecting the distribution system and end-use devices. While these filters are important to the operation of the system, they do have a pressure drop across them, and thus require a slightly higher operating pressure. Typical coalescing oil filters will operate with a 2 psig to 10 psig pressure drop. Mist eliminator air filters operate at a 0.5 psig pressure drop that increases to 3 psig over time before replacement is recommended.

This reduction in pressure drop allows the compressed air system to operate at a reduced pressure and, in turn, reduces the energy consumption of the system. In general, the energy consumption will decrease by 1% for every 2 psig the operating pressure is reduced.[2] Lowering the operating pressure has the secondary benefit of decreasing the demand of all unregulated usage, such as leaks and open blowing.

The equipment is mist eliminator air filters. The compressed air system must be greater than 50 hp to qualify, and the mist eliminator must have less than a 1 psig pressure drop and replace a coalescing filter.

Description of Baseline Condition

The baseline measure is a standard coalescing filter.

Description of Efficient Condition

The efficient condition is a mist eliminator air filter that replaces a standard coalescing filter.

Annual Energy-Savings Algorithm

kWh_{SAVED} = hp * 0.746 / Motor Eff. * Load Factor * HOU * % Savings

% Savings = $Total_{PR}$ * RS

Where:

hp = Compressor motor size horsepower
0.746 = Conversion factor from horsepower to kilowatts
Motor Eff. = Compressor motor efficiency (= 95%)[2]
Load Factor = Average load on compressor motor (= 89%)[2]
HOU = Average annual run hours (= 5,702)[3]
% Savings = Percentage of energy saved (= 2%)[4]
$Total_{PR}$ = Total pressure reduction from replacing filter (= 4 psig)[4]
RS = Percentage of energy saved for each psig reduced (= 0.5%)[5]

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = hp * 0.746 / Motor Eff. * Load Factor * % Savings * CF

Where:

CF = Coincidence factor (= 1; compressed air systems run during peak demand)[6]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

Where:

EUL = Effective useful life (= 5 years for new construction; = 3 years for retrofit)[1]

Sources

1. *Massachusetts Technical Reference Manual*. 2013. http://ma-eeac.org/wordpress/wp-content/uploads/TRM_PLAN_2013-15.pdf
   Savings based on low pressure mist eliminator filters and on typical replacement schedules for low pressure filters (NSTAR staff estimates)

2. Cascade Energy. *Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors.* November 5, 2012.
3. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. August 31, 2017. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf
4. Sullair Corporation. *Compressed Air Filtration and Mist Eliminators Datasheet*. http://www.amcompair.com/products/brochures/sullair_brochures/_Sullair%20filtration.pdf.
5. United States Department of Energy. *Improving Compressed Air System Performance: A Sourcebook for Industry*. p. 20. November 2003.
6. Army Corps of Engineers. *Compressed Air System Survey at Sierra Army Depot, CA.* Mike C.J. Lin, Ahmad R. Ganji, Shy-Sheng Liou, and Bryan Hackett. November 2000. www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA384166
7. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 135 units over 59 projects from 2016 to 2018.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	05/2018	Updated HOU
03	12/2018	Updated incremental cost

Compressed Air Nozzles, Air Entraining

	Measure Details
Measure Master ID	Compressed Air Nozzles, Air Entraining, 2259, 4496
Measure Unit	Per nozzle
Measure Type	Prescriptive
Measure Group	Compressed Air, Vacuum Pumps
Measure Category	Nozzle
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	4,800
Peak Demand Reduction (kW)	1.8
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	72,000
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$35.49[6]

Measure Description

Engineered nozzles, also known as air entraining nozzles, reduce the amount of compressed air required for cleaning, cooling, drying, and blowoff applications. These nozzles use the coanda effect to pull in free air and accomplish tasks with up to 70% less compressed air. Engineered nozzles often replace simple copper tubes, and have the added benefits of reducing noise due to the use of laminar airflow and producing a safer workplace due to the elimination of potential skin contact with high pressure air.

Description of Baseline Condition

The baseline condition is a standard efficiency compressed air system operating at an efficiency of 0.16 kW/scfm[2] for a minimum of 2,000 hours per year. Compressed air pipe flow rates are standard.[3]

Description of Efficient Condition

Nozzles must be engineered and usage must be 2,000 hours or greater to qualify.

Annual Energy-Savings Algorithm

kWh_{SAVED} = Eff * (Open Flow – Eng. Flow) * HOU

Where:

Eff = Efficiency of standard air compressor (= 0.16 kW/scfm)
Open Flow = Flow of copper pipe nozzle (= 21 scfm)

Eng. Flow = Flow of engineered nozzle (= 6 scfm)
HOU = Average annual run hours (= 2,000)

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = Eff * (Open Flow – Eng. Flow) * CF

Where:

CF = Coincidence factor (= 0.75)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

The nozzle flow rates are averages based on available published data from engineered nozzle manufacturers. The savings assume a 1/8-inch diameter open tube.[3]

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. United States Department of Energy. *Improving Compressed Air System Performance*. Pgs. 48-49.
3. Franklin Energy Services, LLC. Personal communications regarding engineering approximation based on field observation.
4. Technical Reference Manual for Ohio Senate Bill 221 Energy Efficiency and Conservation Program and 09-512-GE-UNC. October 15, 2009.
5. The 2,000 hours is the minimum (and most conservative) run hours needed to qualify for this measure and agreed upon by the PSC, Cadmus, Administrator, and Implementers.
6. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 228 units over 16 projects from 2012 to 2017.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	12/2018	Updated incremental cost

Compressed Air System Leak Survey and Repair

	Measure Details
Measure Master ID	Compressed Air System Leak Survey and Repair, 4766 Compressed Air System Leak Survey and Repair-Agriculture, 4767
Measure Unit	Per horsepower
Measure Type	Hybrid
Measure Group	Compressed Air, Vacuum Pumps
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by capacity and leak size
Peak Demand Reduction (kW)	Varies by capacity and leak size
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by capacity and leak size
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	2[1]
Incremental Cost ($/unit)	$4.83[2]

Measure Description

For the compressed air system survey and repair measure, the facility's compressed air system is analyzed and areas are identified with opportunity to reduce leakage and energy consumption and gain efficiency through an improved equipment control strategy or equipment replacement.

Description of Baseline Condition

The baseline condition is determined by surveying the existing compressed air system. This involves identifying the number and types of compressors used; their nominal hp, scfm, or psig; and the controls associated with each compressor. The most common method of surveying the compressed air system is a leak survey with an ultrasonic instrument.

Description of Efficient Condition

To qualify for an incentive, the customer must repair one leak for every five connected compressor horsepower. If less than one leak per every five horsepower is identified, then all identified leaks must be repaired. The customer can provide a written explanation for a leak that cannot be repaired and may still qualify for an incentive. The customer must provide a leak log in the form of a spreadsheet so that the number of repairs and associated savings can verified using the algorithm provided below. Customers must leave leak tags in place for at least four months after submitting an application to allow for verification if needed.

Annual Energy-Savings Algorithm

kWh_{SAVED} = CFM Reduction / (CFM/BHP) * 0.746 * HOU / Eff

Where:

CFM Reduction = Total CFM reduction in entire compressed air system (= directly from the leak log survey (preferred) or estimated using other reported leak log data the table below

CFM/BHP = Average amount of CFM per brake horsepower (= 4.2)[3]

0.746 = Motor brake horsepower to kilowatt conversion factor

HOU = Average annual compressor run hours (= user input)

Eff = Air compressor deemed motor efficiency (= 90%)

CFM Discharge Rates by Leak Decibel Readings and Pressure Levels[3,4]

Digital Reading	System Air Pressure						
	10 PSIG	25 PSIG	50 PSIG	75 PSIG	100 PSIG	125 PSIG	150 PSIG
	Estimated CFM Equivalent Values						
10 dB	0.05	0.10	0.20	0.30	0.40	0.40	0.60
20 dB	0.20	0.30	0.50	0.70	0.90	1.10	1.30
30 dB	0.50	0.70	1.00	1.30	1.60	1.90	2.20
40 dB	0.80	1.20	1.60	2.10	2.50	2.80	3.20
50 dB	1.30	1.80	2.30	2.90	3.40	3.80	4.30
60 dB	2.00	2.60	3.10	3.80	4.30	4.80	5.40
70 dB	2.70	3.50	4.00	4.80	5.40	5.90	6.60
80 dB	3.60	4.50	5.00	5.80	6.50	7.10	7.80
90 dB	4.60	5.60	6.10	6.90	7.60	8.30	9.10
100 dB	5.70	6.90	7.30	8.10	8.80	9.60	10.40

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 2 years)[1]

Assumptions

The savings assume that the air compressor unit is not variable speed controlled.

Historical project data from January 2016 through June 30, 2018 was used to determine the incremental cost. Data from all sectors was included in the analysis. There were 97 projects for MMID 2261, 43 projects for MMID 2262, 50 projects for MMID 2263, and 111 projects for MMID 3598. The average actual measure cost and average actual unit of measure (hp) across all four MMIDs was used to calculate the average dollar per horsepower incremental cost.

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
   Each tune-up should last two years.
2. Historical Focus on Energy project data, January 1, 2016 to June 30, 2018.
   For 301 projects across previous compressed air leak survey and repair measures MMID 2261, MMID 2262, MMID 2263, and MMID 3598, the average cost is $4.83/hp.
3. UE Systems, Inc. *Compressed Air Ultrasonic Leak Detection Guide*.
   http://www.uesystems.com/wp-content/uploads/2012/08/compressed_air_guide.pdf
4. UE Systems, Inc. “Compressed Air Loss Guesstimator for Digital Ultraprobes.” Accessed January 30, 2017. http://www.uesystems.com/resources/charts-and-graphs/compressed-air-loss-guesstimator-for-digital-ultraprobes

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	10/14/2016	Updated savings algorithm
03	10/17/2018	Updated to one measure rather than separate measures for years 1 through 4

Compressed Air Condensate Drains, No Loss Drain

	Measure Details
Measure Master ID	Compressed Air Condensate Drains, No Loss Drain, 2254, 4492
Measure Unit	Per drain
Measure Type	Prescriptive
Measure Group	Compressed Air, Vacuum Pumps
Measure Category	Other
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	1,711
Peak Demand Reduction (kW)	0.24
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	34,200
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	$448.93[5]

Measure Description

Air condensate drains, also referred to as traps, allow for water in the form of condensation to be removed from compressed air systems. Undrained water may interfere with the flow of compressed air and may also corrode the piping or tank.

Manual or automatic drains may be used. A manual drain is typically a simple valve that is opened by an operator. Level-operated mechanical drains are automatic and should not waste air if properly maintained, but they do require maintenance. Electrically operated solenoid drains use a timing device to open an orifice for a programmed amount of time, regardless of the level of condensate. Each of these types of drains may waste compressed air, and each can be replaced with no air-loss drains that automatically remove condensate without waste.

Description of Baseline Condition

The baseline measure is a timed solenoid drain.

Description of Efficient Condition

The efficient condition is a no loss air drain used in a system with load/no-load, variable speed, variable displacement, or centrifugal compressors. Load/no-load compressors must have adequate storage for drains to be eligible. Manual drains, lever-operated mechanical drains, and solenoid drains are not eligible for incentives. No loss drains must be rated to remove the necessary amount of condensate without any loss of compressed air.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = SF * HOU$

Where:

SF = Saving factor in kilowatts per drain (= 0.3)[2]

HOU = Average annual run hours (= 5,702)[3]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = SF * CF$

Where:

CF = Coincidence factor (= 0.80)[2]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 20 years)[1]

Sources

1. *2011 Xcel Colorado DSM Plan*. https://www.xcelenergy.com/staticfiles/xe/Regulatory/Regulatory%20PDFs/2011-CO-DSM-Plan.pdf.
2. TecMarket Works. *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs*. pp. 193 and 194. October 15, 2010.
3. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. August 31, 2017. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf
4. TecMarket Works. *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs*. p. 13. October 15, 2010.
5. Historical project data from 2016 and 2017. Average cost for 118 projects is $448.93 per drain.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	05/2018	Updated HOU

Controls

7 Outlet Advanced Power Strip, Business, Pack Based

	Measure Details
Measure Master ID	7 Outlet Advanced Power Strip, Business, Pack Based, 4684
Measure Unit	Per power strip
Measure Type	Prescriptive
Measure Group	Vending & Plug Loads
Measure Category	Controls
Sector(s)	Commercial, Industrial
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	8[1]
Incremental Cost ($/unit)	$13.50[2]

Measure Description

Advanced power strips have multiple plugs and the ability to automatically disconnect specific connected loads depending on the power draw of a control load, also plugged into the strip. Power is disconnected from the switched (controlled) outlets when the control load power draw is reduced below a certain adjustable threshold, thus turning off the appliances plugged into the switched outlets. Savings generally occur during off hours, when connected equipment would have previously continued to consume electricity while in standby mode or when off.

Description of Baseline Condition

The baseline condition is a standard power strip that does not control connected loads (only has a manual switch for control).

Description of Efficient Condition

The efficient condition is an advanced power strip that has a load-sensing master plug and at least two controlled plugs.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = [kW_{WkDay} * (Hours_{WkDay} – HOU_{WkDay}) + kW_{WkEnd} * (Hours_{WkEnd} – HOU_{WkEnd})] * Weeks * ISR$

Where:

kW_{WkDay} = Standby power consumption of connected electronic on weekday off-hours (= 0.0315 kW)[4]

$Hours_{WkDay}$ = Total hours during the work week, from Monday at 7:30 a.m. to Friday at 5:30 p.m. (= 106 hours)

HOU_{WkDay} = Number of hours the business is open during the work week (= varies by sector; see table below and Assumptions)

kW_{WkEnd} = Standby power consumption of connected electronics on weekend off-hours (= 0.00617 kW)[4]

$Hours_{WkEnd}$ = Total hours during the weekend, from Friday at 5:30 p.m. to Monday at 7:30 a.m. (= 62 hours)

HOU_{WkEnd} = Number of hours the business is open during the weekend (= varies by sector; see table below and Assumptions)

Hours of Use by Sector

Sector	Annual Lighting Hours[5]	Weekly Lighting Hours	HOU_{WkDay}	HOU_{WkEnd}
Commercial	3,730	71.54	60	11.54
Industrial	4,745	91.00	80	11.00

Weeks = Number of weeks per year (= 52.14)

ISR = In-service rate (= 0.77 for pack-based measures)[3]

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 8 years)[1]

Deemed Savings

Annual and Lifecycle Deemed Savings by Sector

Sector	kWh_{SAVED}	$kWh_{LIFECYCLE}$
Commercial	71	568
Industrial	46	368

Assumptions

The standby power consumption for the weekday and weekend were assumed to be 0.0315 kW and 0.00617 kW, respectively.[4]

The total open business hours were based off lighting hours of use for each sector.[5] Commercial sector weekday hours of operation were assumed to be 60, based on 12 hours per weekday. Industrial sector weekday hours of operation were assumed to be 80, based on 16 hours per weekday (two 8-hour shifts). The weekend hours were assumed to be the remaining hours needed to total the lighting annual hours of use by sector.

Sources

1. Southern California Edison. “Smart Power Strips.” Work Paper SCE13CS002. Rev 3. January 25, 2016. http://deeresources.net/workpapers
2. Quote from Resource Action Programs, January 16, 2018.
3. Navigant. *ComEd Rural Small Business Energy Efficiency Kits IPA Program Impact Evaluation Report*. August 1, 2018. Table 7-5. http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY9_Evaluation_Reports_Final/ComEd_PY9_Rural_SB_EE_Kits_IPA_Program_Impact_Evaluation_Report_2018-08-01.pdf
4. Illinois Statewide Technical Reference Manual for Energy Efficiency. Version 6.0. pp. 498–500. February 8, 2017. http://www.ilsag.info/il_trm_version_6.html
5. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Updated March 22, 2010. Table 3.2 Lighting Hours of Use in Commercial Applications. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	03/14/2018	Initial TRM entry

Domestic Hot Water

Agriculture Water Heaters

	Measure Details
Measure Master ID	Natural Gas to Natural Gas Commercial Water Heater Storage, 3995 Propane Commercial Water Heater Storage, 4877 Electric to Electric Commercial Water Heater (< 150 Milking Cows), 3996 Electric to Electric Commercial Water Heater (≥ 150 Milking Cows), 3997
Measure Unit	Per cow
Measure Type	Hybrid
Measure Group	Domestic Water Heater
Measure Category	Water Heater
Sector(s)	Agriculture
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Annual Propane Savings (Gallons)	Varies by measure
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure
Lifecycle Propane Savings (Gallons)	Varies by measure
Annual Water Savings (gallons)	0
Effective Useful Life (years)	15[1]
Measure Incremental Cost ($/unit)	Natural gas to natural gas or Propane = $3,521.92 (MMIDs 3995 and 4877),[8] Electric to electric = $631.98 (MMIDs 3996 and 3997)[2]

Measure Description

This measure is replacing a less efficient water heater with a newer high-efficiency model that is code-compliant and delivers hot water at the same temperature and flow rate as the baseline water heater, but using less energy. A dairy farm is typically encouraged to have a commercial-sized water heater to meet the farming hot water needs; however, residential-sized units that are capable of reaching the needed water heating temperatures may be appropriate for smaller farms. This does not include measures for switching to electric tankless water heaters. AHRI listings will be used as the valid form of third-party verification to ensure water heater quality and efficiency standards.

Description of Baseline Condition

New water heater units are intended to be installed when the existing unit has failed or is judged to have reached its end of life. Therefore, the baseline unit is a new conventional electric, natural gas, or propane storage water heater intended for service in commercial and industrial buildings. Per the

"Market Transformation Efforts for Water Heating Efficiency" report from ACEEE,[3] the following baseline efficiency energy factor ratings are assumed:

- Electric Water Heater: 0.90 EF
- Natural Gas Water Heater: 0.59 EF

Description of Efficient Condition

The minimum requirements for the new replacement water heaters must be as follows:

- ***Gas Storage to High-Efficiency Gas Storage:*** New natural gas or propane water heater must have a thermal efficiency of ≥ 90% as rated by AHRI.
- ***Gas Storage to High-Efficiency Tankless Gas:*** New natural gas or propane water heater must have a thermal efficiency of ≥ 90% as rated by AHRI.
- ***Electric Storage to High-Efficiency Electric Storage:*** Electric commercial-rated water heaters must have a thermal efficiency of ≥ 98% and a standby loss of ≤ 0.64% per hour as rated by AHRI. Electric residential-rated water heaters must have an AHRI rated energy factor of ≥ 0.93 and a storage volume of ≥ 80 gallons.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = Btu_{SAVED} / 3{,}412$

$Gas_{SAVED} = Btu_{SAVED} / ConvF$

$Btu_{SAVED} = GPY * \rho_{WATER} * C_{P,H2O} * \Delta T * [(1/EF_{BASELINE}) - (1/EF_{EFFICIENT})]$

Where:

Gas_{SAVED} = Therms of natural gas or gallons of propane saved

GPY = Annual hot water usage (= GPD * 365)

  GPD = Average gallons of hot water usage per day (= 2.75 gallons per cow per day[5] * number of milking cows being served by water heater (as defined by user), or * maximum amount of hot water that can be supplied by the total number of purchased water heaters during two one-hour milking sessions;[5] see Assumptions; Note that for hybrid calculations, use the lesser of these two approaches to determine the annual water usage)

  365 = Number of days in a year

ρ_{WATER} = Density of water (= 8.34 lbs/gallon)[6]

$C_{P,H2O}$ = Specific heat of water (=1 Btu/lb-°F)

ΔT = Change in temperature (= $\text{Temp}_{\text{HOT\_H20}} - \text{Temp}_{\text{COLD\_H20}}$)

Where:

$\text{Temp}_{\text{HOT\_H20}}$ = Average dairy farm water heater setpoint temperature (= 170°F)[5,7]

$\text{Temp}_{\text{COLD\_H20}}$ = Assumed starting water temperature (= 103°F; see Assumptions)

$\text{EF}_{\text{BASELINE}}$ = Efficiency metric for baseline water heater (= 0.90 EF for electric storage, = 0.59 EF for natural gas storage;[3] see Assumptions)

$\text{EF}_{\text{EFFICIENT}}$ = Efficiency metric for efficient water heater (for commercial-rated water heaters = $M * C_{P,H2O} * \Delta T / Q_{in}$; for residential-rated water heaters = AHRI rated EF value of purchased unit)[4]

Where:

M = Mass of hot water being used per day (= GPD * 8.34 lbs/gal)

Q_{in} = Daily Btu consumption of water heater (= $\text{GPD} * \rho_{\text{WATER}} * C_{P,H2O} * \Delta T / \eta_{RE} * (1 - \text{Standby Loss} / P_{in}) + 24 * \text{Standby Loss}$)[4]

Where:

η_{RE} = Recovery efficiency of water heater (%), assumed to be equivalent to the AHRI-rated thermal efficiency of the new commercial water heater

Standby Loss = Standby heat loss value (Btu/hour = %/hr * P_{in}) as rated by the AHRI certificate of the new commercial water heater (conversion for commercial electric water heater ratings must be performed based on the AHRI-stated percentage of loss per hour rating)

P_{in} = AHRI-rated input power of water heater (for commercial electric resistance conversion, Btu/hour = 3,412 * element kW rating)

24 = Number of hours in a day

3,412 = Conversion factor from Btu to kWh

ConvF = Fuel conversion factor (= 100 MBtu per therm, = 91.3 MBtu per gallon of propane)[9]

Summer Coincident Peak Savings Algorithm

There are no peak coincident savings for the electric water heater measures due to an assumption (based on past program experience) that a majority of water heater upgrades will not feature a lower kilowatt element rating. This is a conservative judgement and may be reviewed for future workpaper updates.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Gas_{LIFECYCLE} = Gas_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

- The actual water heater unit volume rating will be used, or a default of approximately 100 gallons[2] if not otherwise known. This is the amount of water that is ready and at full hot water capacity prior to the start of each milking session.
- It is assumed that the cleaning of dairy pipeline equipment takes place within one hour after the milking session is complete to prevent the growth of bacteria. It is also assumed that the main water heating demand will take place within one hour after each milking session.
- Engineering judgement is being used to justify the use of ACEEE Report A121’s baseline residential rated energy factor standard as a baseline for mainly commercial water heater units, which will be the bulk of water heaters being applied for this measure. The baseline energy factors are assumed to be similar for both residential and commercial use.
- This workpaper is making a flat assumption based on field experience from AgSG program Energy Advisors that approximately 75% of Wisconsin dairy farms use a refrigeration heat recovery unit that pre-heats well water from the refrigeration system’s waste heat and feeds it to the main water heater. Preheated refrigeration heat recovery output water is around a conservative 120°F[8] and average well water temperature is 52.3°F,[9] and a 75/25 split of those two temperatures is assumed to get a mixed deemed average of approximately 103°F incoming water heater temperature.
- Estimating the actual dairy hot water usage on a farm is quite volatile depending heavily on farm management and farm size. Several sources were evaluated and through an engineering judgement, a realistic estimated average of 2.75 gallons of hot water used per cow per day was used for this analysis.[5]

- A user-defined input is provided for the number of milking cows, assumed to be the average number of animals being milked throughout the entire year that are being served by the water heaters.
- This entry includes measures for gas–fired equipment eligible to both natural gas and propane customers. The Code of Federal Regulations,[10] upon which federal efficiency standards are based, defines *gas* as either natural gas or propane (§430.2 for consumer appliances, and §431.2 for commercial and industrial equipment). Thus, it is assumed that equipment efficiencies, costs, etcetera are equal for both fuel types. Any infrastructure or maintenance costs unique to each particular fuel were ignored.

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. “Historical Data for Ag HW Measures.”
   Water Heater Costs tab shows historical SPECTRUM data of 59 agricultural water heater project costs for the two workpaper measures. Project dates ranges from June 2012 through August 2016. The water heater size in gallons of past projects is also reported in this file.
   HW Use tab shows sample data of 33 refrigeration heat recovery per water heater projects entered in SPECTRUM from April 2015 through July 2016. These projects were hybrid in nature and the hybrid calculations provided an estimated hot water usage in gallons per day, hot water temperature, and number of milking cows per farm. The projects’ hot water usage was combined with the recorded number of milking cows on the farm to determine an estimated how water usage per cow per day. Six additional sources also provided estimates of hot water usage per cow per day, ranging between 0.73 and 4.75 gallons. A conservative engineering judgement of 2.75 gallons of hot water per cow per day was used. The projects’ recorded hot water temperatures averaged close to 170°F.
   Water Recharge Calculation tab has additional support about the hybrid method to determine maximum water supply provided for specific water heaters purchased for individual milking session cleaning needs.
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Revision History

Version Number	Date	Description of Change
01	10/27/2016	Initial release
02	12/2018	Updated incremental cost
03	3/2018	Added propane measure

Water Heater, High Usage, ≥ 90% TE Gas Storage / ≥ 2 EF Electric Heat Pump

	Measure Details
Measure Master ID	Water Heater, High Usage: ≥ 90% TE, K-12 School, 3684 ≥ 90% TE, Natural Gas, 3045 ≥ 0.82 EF, Tankless, Natural Gas, 3046 ≥ 2 EF, Heat Pump Storage, Electric, 3047
Measure Unit	Per heater
Measure Type	Hybrid
Measure Group	Domestic Hot Water
Measure Category	Water Heater
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by facility type
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by facility type
Lifecycle Energy Savings (kWh)	Varies by facility type
Lifecycle Therm Savings (Therms)	Varies by facility type
Water Savings (gal/year)	0
Effective Useful Life (years)	≥ 90% TE = 15 (MMIDs 3684 and 3045)[1] ≥ 0.82 EF = 20 (MMID 3046)[1] ≥ 2 EF = 13 (MMID 3047)[2]
Incremental Cost ($/unit)	≥ 90% TE, K-12 School = $1,135.00 (MMID 3684)[11] ≥ 90% TE, Natural Gas = $1,176.21 (MMID 3045)[12] ≥ 0.82 EF = $605.00 (MMID 3046)[13] ≥ 2 EF = $2,893.00 (MMID 3047)[14]

Measure Description

This measure is installing a new high-efficiency water heater unit in new construction or in place of an older existing water heater. The new high-efficiency water heater delivers the same amount of hot water at the same temperature as the existing or baseline unit.

Description of Baseline Condition

The baseline condition is a new conventional electric or natural gas storage water heater intended for service in commercial and industrial buildings (as new DHW heaters are only installed when the existing unit has failed or is judged to have reached its end-of-life condition). Per the ACEE “Market

Transformation Efforts for Water Heating Efficiency" report,[3] the following efficiency ratings are assumed:

- Electric DHW Heater: 0.90 EF
- Natural Gas DHW Heater: 0.59 EF
- Natural Gas DHW Heater: ≥ 0.67 EF

High usage applications are required to meet the annual operation and usage requirements for one or more of the categories shown in the table below.

Annual Operation and Usage in High Usage Applications

Category	Subcategory	Annual Operation (Minimum Days/Year)	Usage (Minimum)
Food Service	Full Service Restaurant Fast Food	≥ 300	Meals/Day (≥ 300)
	Cafeteria	≥ 175	Meals/Day (≥ 300)
Lodging	Dormitory	≥ 200	Beds (≥ 50)
	Hotel/Motel	≥ 300	Rooms or Beds (≥ 30)
Healthcare	Hospital	≥ 300	Beds (≥ 30)
	Nursing Home	≥ 300	Beds (≥ 30)
Laundry	Laundromat	≥ 300	Washes/Day (≥ 30)
Food Sales	Super Market	≥ 300	N/A
Education	K-12 Schools	≥ 180	Students/Building (≥ 300)
Prisons	Housing	≥ 200	Housed Inmates (≥ 50)

Description of Efficient Condition

The efficient condition is one of the following types of new energy-efficient DHW heaters:

Qualifying Natural Gas Equipment:

- ***0.82 EF Natural Gas Tankless Water Heaters:*** To be able to heat water 70°F or more virtually instantaneously, most natural gas tankless water heaters have an input of 100,000 Btu/hour or higher. Their major advantage is having no standby heat losses, which have to be made up by the heater firing whenever the water temperature drops below a setpoint. In addition, these heaters are typically installed close to the location where hot water is needed, which minimizes losses from the hot-water delivery piping.
- ***90% Thermal Efficiency[8] Condensing Natural Gas Storage Water Heaters:*** Condensing natural gas storage water heaters are designed to capture the latent heat from water vapor created when natural gas is burned. Conventional natural gas storage water heaters allow water vapor

to leave the device, and therefore the latent heat is not captured: this means condensing natural gas heaters have a higher efficiency. Because flue gases have been significantly cooled, condensing natural gas water heaters require the use of a fan to propel combustion products gases through the exhaust flue.

<u>Qualifying Electric Equipment:</u>

- 2.0 EF ENERGY STAR–Qualified Integrated Heat Pump Water Heaters
- 2.0 EF Add-On Heat Pump Water Heaters

The EF rating for residential water heaters was developed per a U.S. DOE rulemaking process, and is therefore based on a test profile that represents the water usage pattern in a typical residence. There is a general consensus that this profile is not appropriate for rating the newer types or storage types of DHW heaters, and a U.S. DOE–sponsored committee is developing a better test procedure and profile.

High usage, condensing, natural gas storage water heaters are not EF rated. For calculation purposes, an EF of 0.8 is used for condensing storage water heaters in high usage applications.[8]

Annual Energy-Savings Algorithm

$Btu_{SAVED} = GPY * 8.33 * 1.0 * \Delta T * [(1 / EF_{BASELINE}) – (1 / EF_{EFFICIENT})]$

For electric water heaters: $kWh_{SAVED} = Btu_{SAVED} / 3,412$

For natural gas water heaters: $Therm_{SAVED} = Btu_{SAVED} / 100,000$

Where:

GPY = Gallons per year of DHW usage (= derived from days per year of operation and gallons per day shown in table below)

8.33 = Density of water in pounds per gallon

1.0 = Specific heat of water in Btu per (pound-°F temperature change)

ΔT = Water temperature change produced by the DHW heater (= 52.3°F as user-defined on application;[5] If actual water heater setpoint temperature is unknown, = 130°F as the default[10])

$EF_{BASELINE}$ = Efficiency metric for baseline DHW heater

$EF_{EFFICIENT}$ = Efficiency metric for efficient DHW heater

3,412 = Conversion factor for Btu per kWh

100,000 = Conversion factor for Btu per therm

Average Daily Gallons by Facility Type

Facility Type	Average Daily Gallons	Source[4]
Schools Elementary School Jr./Sr. High School	0.6 gal/student 1.8 gal/student	ASHRAE HVAC Applications 2011, Chapter 50, Table 7
Motels and Hotels ≤ 20 rooms/suites 21 to 99 rooms/suites ≥ 100 rooms/suites	20 per room 14 per room 10 per room	ASHRAE HVAC Applications 2011, Chapter 50, Table 7
Dormitories	12.7 per student	ASHRAE HVAC Applications 2011, Chapter 50, Table 7 (average of 13.1 for male dormitory and 12.3 for female dormitory)
Prison Housing	12.7 per housed inmate	ASHRAE HVAC Applications 2011, Chapter 50, Table 7 (average of 13.1 for male dormitory and 12.3 for female dormitory; *prison housing water usage is assumed to be similar to the dormitories category)*
Hospital	50 per bed	http://smud.apogee.net/comsuite/content/ces/?id=971 (lists a range of 25 to 90 gallons/day/bed, used 50, which is conservative of 57.5 midpoint)[5]
Nursing Homes	18.4 per bed	ASHRAE HVAC Applications 2011, Chapter 50, Table 7
Food Service Full Service Restaurant Cafeteria Fast Food	2.4 per meal 2.4 per meal 350 per day	Full Service and cafeteria: ASHRAE HVAC Applications 2011, Chapter 50, Table 7 Fast food: ASHRAE HVAC Applications 2011, Chapter 50, page 50.15 (lists range of 250 to 500, use 350 as under midpoint of the range)
Supermarket	650 per day	ASHRAE HVAC Applications 2011, Chapter 50, page 50.15 (lists range of 300 to 1,000, use average of 650)
Laundry	21 per wash	ASHRAE HVAC Applications 2011, Chapter 50, page 50.12 (for low-flow clothes washer)

Summer Coincident Peak Savings Algorithm

Demand reduction is a function of building type because it is a function of whether—at the time of interest—the units are operating intermittently to compensate for heat losses through the tank and surrounding insulation, or if they are operating at a constant level to heat the incoming water that is replacing hot water being used at a high rate. A careful study to analyze demand reduction in various facility types has not been performed, largely because it is recognized that the amount of reduction will be quite small. For this reason, and because the power rating of storage type electric water heaters is the same for the baseline and efficient models, zero demand reduction is assumed for all storage type heaters. For heat pump DHW heaters, there will be savings due to different power ratings.

Electric and Natural Gas Storage DHW Heaters

There are no summer coincident peak savings for storage DHW heaters.

Electric Heat Pump DHW Heaters

$kW_{SAVED} = CF * FUF * kW_{BASELINE} * [(1/EF_{BASELINE}) – (1/EF_{EFFICIENT})]$

Where:

CF = Coincidence factor, or ratio of expected power demand at utility peak system demand to the maximum connected load of an item of equipment (= varies by facility type, see table below)

FUF = Facility utilization factor, or ratio of facility utilization at the time of utility peak system demand to the maximum facility utilization. This parameter is a function of facility type. For dormitories, it should reflect summer occupancy relative to maximum occupancy. Similarly for other facility types, it should account for summer weekday occupancy factors that affect DHW usage (= project-specific values; otherwise use the set of typical FUF values shown in table below)

$kW_{BASELINE}$ = Power rating of the baseline DHW heater

Coincidence Factors and Facility Utilization Factors

Facility Type	CF	FUF[7]
Dormitories	0.25	0.30
Schools		
Elementary	0.10	0.10
Junior / Middle / High	0.25	0.40
Motels and Hotels*	0.25	1.00
Nursing Homes	0.35	1.00
Hospital (assume same values as nursing home)	0.35	1.00
Office Buildings	0.15	0.90
Food Service	0.40	1.00
Apartment Houses	0.25	0.90
Supermarkets	0.15	1.00
Laundry	0.50	1.00

* Excludes restaurants, kitchens, and laundries.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years for natural gas storage and freestanding water heaters;[1] = 20 years for natural gas tankless water heaters;[1] = 13 years for electric heat pump)[2]

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    Data maintained by Cadmus and Wisconsin PSC.
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Revision History

Version Number	Date	Description of Change
01	01/01/2013	Revised measure
02	11/07/2014	Added building categories
03	09/25/2015	Added categories for K-12 schools and prisons
04	12/29/2015	Updated incremental cost data
05	10/2017	Updated EUL 3045 and 3046
06	10/2017	Updated EUL 3047
07	05/2018	Updated based on Potential Study data
08	12/2018	Updated costs for MMIDs 3045 and 3047

Pre-Rinse Sprayer, 1.1 GPM, Electric or NG, Pack Based

	Measure Details
Measure Master ID	Pre-Rinse Sprayer, 1.1 GPM, Electric or Natural Gas, Pack Based, 4693
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Pre-Rinse Sprayer
Sector(s)	Commercial, Industrial
Annual Energy Savings (kWh)	28
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	2.69
Lifecycle Energy Savings (kWh)	140
Lifecycle Therm Savings (Therms)	13.45
Water Savings (gal/yr)	684
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$26.25[6]

Measure Description

The measure replaces existing higher-flow pre-rinse sprayers used in commercial kitchens with low-flow pre-rinse sprayers. Installing these devices is an inexpensive and lasting approach to water conservation. These products save energy by reducing the amount of energy needed to process, move, and heat water. The annual energy savings come from replacing a standard pre-rinse sprayer head with a low-flow pre-rinse sprayer.

Description of Baseline Condition

The federal standard for commercial pre-rinse sprayers is 1.6 GPM or lower; 1.6 GPM is the baseline efficiency level.[2]

Description of Efficient Condition

The efficient condition is replacing a standard pre-rinse sprayer with a pre-rinse sprayer rated at 1.1 GPM.[9]

Annual Energy-Savings Algorithm

The savings from the measure were calculated internally, using data from an evaluation report for a similar measure from the California Urban Water Conservation Council.[1]

$$\text{Gallons}_{\text{SAVED}} = \{(\text{GPM}_{\text{BASELINE}} * \text{HPD}_{\text{BASELINE}}) - (\text{GPM}_{\text{EE}} * \text{HPD}_{\text{EE}})\} * \text{DPY} * 60 * \text{ISR}$$

$$\text{kWh}_{\text{SAVED}} = \{(\text{GPM}_{\text{BASELINE}} * \text{HPD}_{\text{BASELINE}}) - (\text{GPM}_{\text{EE}} * \text{HPD}_{\text{EE}})\} * \left\{\frac{\text{DPY} * 60 * (\text{T}_{\text{OUT}} - \text{T}_{\text{IN}}) * 8.33}{\eta * 3{,}412}\right\} * \text{ISR} * \text{WFS}$$

$$Therm_{SAVED} = \{(GPM_{BASELINE} * HPD_{BASELINE}) - (GPM_{EE} * HPD_{EE})\} * \left\{\frac{DPY * 60 * (T_{OUT} - T_{IN}) * 8.33}{\eta * 100{,}000}\right\} * ISR * WFS$$

Where:

$GPM_{BASELINE}$ = Baseline gallons per minute (= 1.6)[2]

$HPD_{BASELINE}$ = Baseline hours used per day (= 0.44)[1]

GPM_{EE} = Gallons per minute with low-flow pre-rinse sprayer (= 1.1)[9]

HPD_{EE} = Hours used per day with low-flow pre-rinse sprayer (= 0.60)[1]

DPY = Days used per year (= 312; see Assumptions)

60 = Number of minutes in an hour

ISR = In-service rate (= 0.83 for pack-based measures)[7]

T_{OUT} = End-use water temperature (= 101°F; see Assumptions)

T_{IN} = Inlet water temperature (= 52.3°F)[5]

8.33 = Conversion factor (= 8.33 density of water in lbs/gal * 1.0 specific heat capacity of water in Btu/lb°F; Btu/gallon/°F)

η = Water heater conversion efficiency (= 92% if electric; = 70% if gas)[4]

3,412 = Conversion factor for Btus per kilowatt-hour

WFS = Weighted fuel share (= 32% for electric; = 68% for natural gas)[8]

100,000 = Conversion factor, Btus per therm

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)[1]

Assumptions

The days used per year equals 312 based on assuming six days per week for 52 weeks per year.[10] The average end-use water temperature is assumed to be 101°F; this is an equally weighted average of cold (72.3°F), mixed (105.0°F), and hot (125.6°F) water temperatures.[1]

Sources

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Revision History

Version Number	Date	Description of Change
01	03/09/2018	Initial TRM entry

Kitchen and Bathroom Aerators, Business, Electric or Natural Gas, Pack Based

	Measure Details
Measure Master ID	Kitchen Aerator: 1.5 GPM, Small Office, Electric or Natural Gas, Pack Based, 4688 1.5 GPM, Restaurant, Electric or Natural Gas, Pack Based, 4689 Bathroom Aerator: 1.0 GPM, Small Office, Electric or Natural Gas, Pack Based, 4690 1.0 GPM, Restaurant, Electric or Natural Gas, Pack Based, 4691 1.0 GPM, Retail, Electric or Natural Gas, Pack Based, 4692
Measure Unit	Per aerator
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Aeration
Sector(s)	Commercial, Industrial
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	Varies by measure
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	Kitchen Aerator: $1.44 (MMID 4688, 4689)[2] Bathroom Aerator: $1.46 (MMID 4690, 4691, 4692)[2]

Measure Description

This measure is the installation of low-flow aerators in the kitchens and bathrooms of small offices, restaurants, and retail commercial buildings. These low-flow aerators conserve water by reducing the flow rate as compared to the 2.2 gallons per minute (gpm) standard aerators. Not only are there savings in water consumption, but also in electricity and natural gas usage because low-flow aerators reduce the demand to heat and transport as much water. These devices are an affordable, easily installed, long-lasting solution to save water and energy.

Description of Baseline Condition

The baseline condition is a standard aerator with a flow rate of 2.2 gpm.[3]

Description of Efficient Condition

The efficient condition is replacing a standard aerator with a low-flow aerator with a flow rate of 1.5 gpm for kitchen aerators and 1.0 gpm for bathroom aerators.[4]

Annual Energy-Savings Algorithm

$$kWh_{SAVED} = Gallons_{SAVED} * 8.33 * C * (T_{POINT\ OF\ USE} - T_{ENTERING}) / (EF_{ELECTRIC} * 3{,}412) * WFS_{ELECTRIC}$$

$$Therm_{SAVED} = Gallons_{SAVED} * 8.33 * C * (T_{POINT\ OF\ USE} - T_{ENTERING}) / (EF_{GAS} * 100{,}000) * WFS_{GAS}$$

$$Gallons_{SAVED} = (GPM_{EXISTING} - GPM_{NEW}) / GPM_{EXISTING} * Usage * ISR$$

Where:

$Gallons_{SAVED}$ = First-year water savings in gallons

8.33 = Density of water, lbs/gallon

C = Specific heat of water (= 1 Btu/lb °F)

$T_{POINT\ OF\ USE}$ = Temperature of water at point of use (= 86°F for bathrooms,[11] = 93°F for office and retail kitchens,[11] = 101°F for restaurant kitchens;[10] see Assumptions)

$T_{ENTERING}$ = Temperature of water entering water heater (= 52.3°F)[7]

$EF_{ELECTRIC}$ = Energy factor of electric water heater (= 93%)[9]

3,412 = Conversion factor for Btus per kilowatt-hour

$WFS_{ELECTRIC}$ = Assumed fraction of participating sites with electric hot water (= 60%)[8]

EF_{GAS} = Energy factor of natural gas water heater (= 77%)[9]

100,000 = Conversion factor for Btus per therm

WFS_{GAS} = Assumed fraction of participating sites with natural gas hot water (= 40%)[8]

$GPM_{EXISTING}$ = Baseline flow rate (= 2.2 gpm)[3]

GPM_{NEW} = Efficient flow rate (= 1.5 gpm for kitchens, = 1.0 gpm for bathrooms)[4]

Usage = Estimated usage of mixed water (= 2,500 gallons per year for small office, = 3,650 gallons per year for retail, = 12,675 gallons per year for restaurants; see Assumptions)[5]

ISR = In-service rate (= varies, see table below)

Aerator In-Service Rates

Facility Type	In-Service Rate[6]	
	Bath Aerator	Kitchen Aerator
Small Office	41%	39%
Restaurant	81.5%	81.5%
Retail	69%	N/A

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Deemed Savings for Aerators

Facility Type	Aerator Location	MMID	Annual Gallons	Lifecycle Gallons	Annual kWh	Lifecycle kWh	Annual Therms	Lifecycle Therms
Small Office	Bathroom	4690	559	5,590	30	300	0.82	8.2
	Kitchen	4688	310	3,100	20	200	0.55	5.5
Restaurants	Bathroom	4691	5,634	56,340	299	2,990	8.22	82.2
	Kitchen	4689	3,287	32,870	252	2,520	6.93	69.3
Retail	Bathroom	4692	1,374	13,740	73	730	2.00	20.0

Assumptions

The average end-use temperature for bathrooms is assumed to be 86°F and the average end-use temperature for kitchens at small office and retail sites is assumed to be 93°F. This matches the assumptions for residential sites.[11] The average restaurant kitchen end-use is assumed to be 101°F. This matches the assumption for pre-rinse sprayers (MMID 4693) and is an equally weighted average of cold (72.3°F), mixed (105.0°F), and hot (125.6°F) water temperatures obtained from a study on pre-rinse sprayers.[10]

For restaurant usage, a 50/50 average of sit-down and fast food values, from the Illinois TRM,[5] is used (the average of 9,581 and 15,768 is 12,675).

Sources

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Revision History

Version Number	Date	Description of Change
01	03/2018	Initial TRM entry

Food Service

Salamander Broiler, Infrared

	Measure Details
Measure Master ID	Salamander Broiler, Infrared, Nautral Gas, Per input MBh, 4359, 4661
Measure Unit	Per input MBh of efficient broiler
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Broiler
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	5.82
Lifecycle Electricity Savings (kWh)	0
Lifecycle Therm Savings (Therms)	69.84
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	$1,000.00[2]

Measure Description

A salamander broiler is a self-contained appliance intended for a range of culinary functions such as toasting, finishing, or browning of dishes and melting cheese to intense searing of food products. Salamanders are an efficient alternative to broiling in a standard oven as the smaller heating element in a salamander broiler can provide more precise control of the cooking compared to a broiler oven that heats a larger amount of air.

Radiant broilers typically have cast-iron burners that heat ceramic bricks to cook food product with a mix of radiant and convective heat transfer. Infrared broilers use a different burner and ceramic brick design that increases radiant heat transfer and reduces convective heat transfer for a given Btu of input. This not only increases the effectiveness of the broiler for certain tasks, but also increases the overall efficiency of the broiler in terms of heat delivered to food per Btu of input.

Description of Baseline Condition

The baseline condition is a natural gas–fired radiant salamander broiler.

Description of Efficient Condition

This incentive applies toward the installation of newly purchased natural gas–fired salamander broiler with infrared burners.

Annual Energy-Savings Algorithm

$Therms_{SAVED} = MBh_{INPUT} * [(1 / EffRatio) – 1] * DC * HOU / 100$

Where:

MBh_{INPUT} = Input capacity in MBh of the efficient salamander broiler (= actual capacity of the efficient salamander broiler)
EffRatio = Ratio of radiant to infrared broiler efficiency (= 75%, see Assumptions)
DC = Duty cycle (= 70%)[4]
HOU = Annual hours of use based on eight hours per day, six days per week, 52 weeks per year (= 2,496 hours)[4]
100 = MBh to therms conversion factor

Lifecycle Energy-Savings Algorithm

$Therms_{LIFECYCLE} = Therms_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 12 years)[1]

Assumptions

An infrared broiler is assumed to consume 25% less energy per unit of food cooked than a radiant broiler. This mimics the assumption used in the Missouri TRM,[3] which assumes that the difference in baseline and efficient consumption for a salamander broiler matches that of a char broiler, and therefore it receives typical char broiler values from the Food Service Technology Center's Life-Cycle Cost Calculator.[5] This also matches information from a Food Arts magazine article,[6] which mentions that radiant broilers typically consume "roughly 25 to 30 percent less heat-on-meat per BTU."

Sources

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Revision History

Version No.	Date	Description of Change
01	09/29/2017	Initial TRM entry

Dishwasher, ENERGY STAR Commercial

	Measure Details
Measure Master ID	Dishwasher: Low Temp: Door Type, ENERGY STAR, 2280, 4497 (Electric) and 2293, 4510 (Natural Gas) Multi Tank Conveyor, ENERGY STAR, 2294, 4511 (Electric) and 4512 (Natural Gas) Single Tank Conveyor, ENERGY STAR, 2296, 4513 (Electric) and 4514 (Natural Gas) Under Counter, ENERGY STAR, 2298, 4515 (Electric) and 2299, 4516 (Natural Gas) Pots/Pans Type, ENERGY STAR, 4599 (Electric) and 4600 (Natural Gas) High Temp, Electric Booster: Door Type, ENERGY STAR, 2281, 4498 (Electric) and 2282, 4499 (Natural Gas) Multi Tank Conveyor, ENERGY STAR, 2283, 4500 (Electric) and 2284, 4501 (Natural Gas) Single Tank Conveyor, ENERGY STAR, 2285, 4502 (Electric) and 2286, 4503 (Natural Gas) Under Counter, ENERGY STAR, 2287, 4504 (Electric) and 2288, 4505 (Natural Gas) Pots/Pans Type, ENERGY STAR, 3136, 4596(Electric) and 3137, 4597 (Natural Gas) High Temp, Natural Gas Booster: Door Type, ENERGY STAR, 2289, 4506 (Natural Gas) Multi Tank Conveyor, ENERGY STAR, 2290, 4507 (Natural Gas) Single Tank Conveyor, ENERGY STAR, 2291, 4508 (Natural Gas) Under Counter, ENERGY STAR, 2292, 4509 (Natural Gas) Pots/Pans Type, ENERGY STAR, 3138, 4598 (Natural Gas)
Measure Unit	Per dishwasher
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Dishwasher, Commercial
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	Varies by measure
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	Varies by measure, see Appendix D

Measure Description

On average, ENERGY STAR-qualified commercial dishwashers are 25% more efficient than conventional dishwashers in both energy and water use. The reduction in water use results in additional water-heating energy savings.

The ENERGY STAR rating applies to commercial under-counter dishwashers; single-tank door type dishwashers; pot, pan, and utensil dishwashers; single- and multiple-tank conveyor dishwashers; and flight-type dishwashers. To meet ENERGY STAR criteria, commercial dishwashers must meet certain idle energy use rates and volume of water consumed per rack.

Dishwasher measures are for higher temperature and lower temperature machines in door type, multitank conveyor, single-tank conveyor, and under-counter machines. Water heater configurations are for electric water heaters with an electric booster heater, natural gas water heaters with an electric booster heater, and natural gas water heaters with a natural gas booster heater. This measure does not apply to flight-type dishwashers, as these units are custom.

Description of Baseline Condition

The baseline condition for commercial dishwashers is based on values in the ENERGY STAR commercial kitchen equipment calculator;[2] these values were based on the U.S. EPA 2013 FSTC research on available commercial dishwasher models.[3]

Description of Efficient Condition

The efficient condition for commercial dishwashers is defined by the ENERGY STAR v2.0 *Requirements for Commercial Dishwashers*.[2]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = \Delta kWh/yr_{WATER\ HEATER} + \Delta kWh/yr_{BOOSTER\ HEATER} + \Delta kWh/yr_{IDLE}$

$Therm_{SAVED} = \Delta Therms/yr_{WATER\ HEATER} + \Delta Therms/yr_{BOOSTER\ HEATER}$

$Gallons_{SAVED} = Gallons/yr_{BASE} – Gallons/yr_{EE}$

Energy-Savings Algorithms by Fuel and Machine Type

Fuel Type	Machine Type	Algorithm
Electric	Water Heater	$\Delta kWh/yr_{WATER\ HEATER} = Gallons_{SAVED} * kWh/gallon_{WATER\ HEATER}$
	Booster Heater	$\Delta kWh/yr_{BOOSTER\ HEATER} = Gallons_{SAVED} * kWh/gallon_{BOOSTER\ HEATER}$
Natural Gas	Water Heater	$\Delta Therms/yr_{WATER\ HEATER} = Gallons_{SAVED} * Therms/gallon_{WATER\ HEATER}$
	Booster Heater	$\Delta Therms/yr_{BOOSTER\ HEATER} = Gallons_{SAVED} * Therms/gallon_{BOOSTER\ HEATER}$

Energy Usage by Fuel and Machine Type

Fuel Type	Machine Type	Energy Use
Electric	Water Heater	$kWh/gallon_{WATER\ HEATER} = \Delta T_{WH} * C_{WATER} * \rho_{WATER} / \eta_{ELECTRIC} / 3{,}412$
	Booster Heater	$kWh/gallon_{WATER\ HEATER} = \Delta T_{BH} * C_{WATER} * \rho_{WATER} / \eta_{ELECTRIC} / 3{,}412$
Natural Gas	Water Heater	$Therms/gallon_{WATER\ HEATER} = \Delta T_{WH} * C_{WATER} * \rho_{WATER} / \eta_{GAS} / 100{,}000$
	Booster Heater	$Therms/gallon_{BOOSTER\ HEATER} = \Delta T_{WH} * C_{WATER} * \rho_{WATER} / \eta_{GAS} / 100{,}000$

Where:

ΔT_{WH} = Temperature rise delivered by water heater (= 70°F)[2]
C_{WATER} = Specific heat of water (= 1 Btu/pound/°F)
ρ_{WATER} = Density of water (= 8.33 lbs/cubic foot)
$\eta_{ELECTRIC}$ = Electric conversion efficiency (= 98%)[4]
3,412 = Conversion factor from Btu to kWh
ΔT_{BH} = Temperature rise delivered by booster heater (= 40°F)[2]
η_{GAS} = Natural gas conversion efficiency (= 76%)[4]
100,000 = Conversion factor from Btu to therms

$$\Delta kWh/yr_{IDLE} = (kW_{BASE\ IDLE} * DY * (HD - RD * WT_{BASE} / 60)) - (kW_{EE\ IDLE} * DY * (HD - RD * WT_{EE} / 60))$$

$$Gallons/yr_{BASE} = GPR_{BASE} * DY * RD$$

$$Gallons/yr_{EE} = GPR_{EE} * DY * RD$$

Where:

$kW_{BASE\ IDLE}$ = Baseline consumption when on but not in wash cycle (= varies by measure; see table below)[2]
DY = Days per year of dishwasher operation (= 365)[2]
HD = Hours per day of dishwasher operation (= 18)[2]
RD = Number of racks of dishes washed each day (= varies by measure; see table below)[2]
WT_{BASE} = Wash time (= length of wash cycles in minutes; varies by measure, see table below)[2]
60 = Minutes per hour
$kW_{EE\ IDLE}$ = Efficient equipment consumption when on but not in wash cycle (= varies by measure; see table below)[2]

WT_{EE} = Wash time efficient equipment (= varies by measure; see table below)

GPR_{BASE} = Gallons per rack of baseline equipment (= varies by measure; see table below)[2]

GPR_{EE} = Gallons per rack of ENERGY STAR equipment (= varies by measure; see table below)[2]

Variable Values by Measure Type

Measure Type	GPR_{BASE}	GPR_{EE}	$kW_{BASE\ IDLE}$	$kW_{EE\ IDLE}$	WT_{BASE}	WT_{EE}	RD
Low Temperature							
Under Counter	1.73	1.19	0.50	0.50	2.0	2.0	75
Stationary Single-Tank Door	2.10	1.18	0.60	0.60	1.5	1.5	280
Single-Tank Conveyor	1.31	0.79	1.60	1.50	0.3	0.3	400
Multiple Tank Conveyor	1.04	0.54	2.00	2.00	0.3	0.3	600
High Temperature							
Under Counter	1.09	0.86	0.76	0.50	2.0	2.0	75
Stationary Single-Tank Door	1.29	0.89	0.87	0.70	1.0	1.0	280
Single-Tank Conveyor	0.87	0.70	1.93	1.50	0.3	0.3	400
Multiple Tank Conveyor	0.97	0.54	2.59	2.25	0.2	0.2	600
Pot, Pan, and Utensil	0.70	0.58	1.20	1.20	3.0	3.0	280

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = DRed_{DW} * CF$

Where:

$DRed_{DW}$ = Summer demand reduction per purchased ENERGY STAR dishwasher (= 0.0225)[5]

CF = Coincident factor (= 1; this is already embedded in the summer peak demand reduction estimate as $DRed_{DW}$)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

$Gallons_{LIFECYCLE} = Gallons_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Savings with Electric Water Heater and Booster Heater

	MMID	Baseline		ENERGY STAR		Savings	
		Electric (kWh)	Natural Gas (therm)	Electric (kWh)	Natural Gas (therm)	Electric (kWh)	Natural Gas (therm)
Low Temperature							
Under Counter	2298 (Electric) 2299 (Natural Gas)	11,085	0	8,508	0	2,577	0
Stationary Single-Tank Door	2280 (Electric) 2293 (Natural Gas)	39,824	0	23,433	0	16,392	0
Single-Tank Conveyor	2296 (Electric)	42,687	0	28,868	0	13,819	0
Multitank Conveyor	2294 (Electric)	50,656	0	31,567	0	19,090	0
High Temperature (with electric booster heater)							
Under Counter	2287 (Electric) 2288 (Natural Gas)	12,474	0	9,278	0	3,196	0
Stationary Single-Tank Door	2281 (Electric) 2282 (Natural Gas) 2761 (Pots/Pans)	40,351	0	28,325	0	12,027	0
Single-Tank Conveyor	2285 (Electric) 2286 (Natural Gas)	46,069	0	36,758	0	9,311	0
Multitank Conveyor	2283 (Electric) 2284 (Natural Gas)	73,321	0	45,538	0	27,784	0
Pot, Pan, and Utensil	3137	21,351	0	17,991	0	3,360	0
High Temperature (with natural gas booster heater)							
Under Counter	2292	9,502	131	6,933	103	2,569	28
Stationary Single-Tank Door	2289	27,218	578	19,264	399	7,954	179
Single-Tank Conveyor	2291	33,415	557	26,577	448	6,838	109
Multitank Conveyor	2290	52,159	931	33,757	518	18,403	413
Pot, Pan, and Utensil	3138	14,224	314	12,086	260	2,138	54

Savings with Natural Gas Water Heater and Booster Heater

	MMID	Baseline		ENERGY STAR		Savings	
		Electric (kWh)	Natural Gas (therm)	Electric (kWh)	Natural Gas (therm)	Electric (kWh)	Natural Gas (therm)
Low Temperature							
Under Counter	2298 (Electric) 2299 (Natural Gas)	2,829	363	2,829	250	0	113
Stationary Single-Tank Door	2280 (Electric) 2293 (Natural Gas)	2,409	1,647	2,409	925	0	721
Single-Tank Conveyor	2296 (Electric) 2297 (Natural Gas)	9,344	1,467	8,760	885	584	582
Multitank Conveyor	2294 (Electric) 2295 (Natural Gas)	10,950	1,747	10,950	907	0	840
High Temperature (with electric booster heater)							
Under Counter	2287 (Electric) 2288 (Natural Gas)	7,272	229	5,174	181	2,098	48
Stationary Single-Tank Door	2281 (Electric) 2282 (Natural Gas) 2761 (Pots/Pans)	17,368	1,012	12,468	698	4,900	314
Single-Tank Conveyor	2285 (Electric) 2286 (Natural Gas)	23,925	975	18,941	784	4,984	190
Multitank Conveyor	2283 (Electric) 2284 (NG)	36,288	1,630	24,921	907	11,367	723
Pot, Pan, and Utensil	3137	8,879	549	7,657	455	1,222	94
High Temperature (with natural gas booster heater)							
Under Counter	2292	4,300	360	2,829	284	1,471	76
Stationary Single-Tank Door	2289	4,234	1,590	3,407	1,097	827	493
Single-Tank Conveyor	2291	11,271	1,531	8,760	1,232	2,511	299
Multitank Conveyor	2290	15,126	2,561	13,140	1,426	1,986	1,135
Pot, Pan, and Utensil	3138	1,752	863	1,752	715	0	148

Annual Water Savings

	MMID	Baseline (Gallons/yr)	ENERGY STAR (Gallons/yr)	Savings (Gallons/yr)
Low Temperature				
Under Counter	2298 (Electric) 2299 (Natural Gas)	47,359	32,576	14,783
Stationary Single-Tank Door	2280 (Electric) 2293 (Natural Gas)	214,620	120,596	94,024
Single-Tank Conveyor	2296 (Electric) 2297 (Natural Gas)	191,260	115,340	75,920
Multitank Conveyor	2294 (Electric) 2295 (Natural Gas)	227,760	118,260	109,500
High Temperature				
Under Counter	Electric Booster Heater: 2287 (Electric) 2288 (Natural Gas) Natural Gas Booster Heater: 2292	29,839	23,543	6,296
Stationary Single-Tank Door	2281 (Electric) 2282 (Natural Gas) 2761 (Pots/Pans)	131,838	90,958	40,880
Single-Tank Conveyor	Electric Booster Heater: 2285 (Electric) 2286 (Natural Gas) Natural Gas Booster Heater: 2291	127,020	102,200	24,820
Multitank Conveyor	Electric Booster Heater: 2283 (Electric) 2284 (Natural Gas)	212,430	118,260	94,170
Pot, Pan, and Utensil	Electric Booster Heater: 3137 Natural Gas Booster Heater: 3138	71,540	59,276	12,264

Assumptions

For peak demand reduction, the HOU is assumed to be the total HOU and is not differentiated from the percentage of time during idle state versus washing.

Sources

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Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	01/2019	Removed MMIDs 2295, 2297, 3139, and 3140

Fryer, ENERGY STAR

	Measure Details
Measure Master ID	Fryer, ENERGY STAR, Electric, 2337 Fryer, ENERGY STAR, NG, 2338, 4538
Measure Unit	Per fry pot
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Fryer
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1,2]
Measure Incremental Cost ($/unit)	MMID 2337: $276[2] MMID 2338: $1,860[2]

Measure Description

This measure is installing a standard ENERGY STAR electric or natural gas fryer (with a vat that measures ≥14 inches and <18 inches wide, and a shortening capacity of ≥25 pounds and <60 pounds). One fry pot unit is considered as one unit.

Description of Baseline Condition

Baseline equipment is assumed to be a new electric or natural gas fryer that does not meet ENERGY STAR performance specification.

Description of Efficient Condition

The efficient condition is an electric or natural gas fryer that is on the ENERGY STAR Fryer qualified products list. ENERGY STAR fryers include advanced burner and heat exchanger designs to achieve savings while cooking, as well as insulation to achieve savings when idle or during periods of low use.

ENERGY STAR lists individual units with one fry pot as fryers on their qualified products list, and essentially treats one fry pot as one fryer. In practice, manufacturers will often take two or three individual fry pots and package them together as one unit.

Annual Energy-Savings Algorithm

Energy savings result from installing a more efficient unit than the standard efficiency on the market. The amount of savings depends on the type of unit install: ENERGY STAR electric or ENERGY STAR natural gas.

Savings estimates are based on savings equations and assumptions provided to Pacific Gas and Electric by the Food Service Technology Center and shared with Focus on Energy through the Consortium on Energy Efficiency. Fryer performance is determined by applying ASTM F1361-05, the Standard Test Method for the Performance of Open Deep Fat Fryers. The savings estimates are reported per fry pot. Therefore, if a fryer has more than one fry pot, savings should be multiplied accordingly.

The energy consumption equation for electric fryers (kWh) and natural gas fryers (Btu) is of the same form, with only the units of the variables changed. The form of the equation shows that the energy consumption of a fryer is equal to the sum of energy used for cooking, energy used at idle, and energy used to preheat.

$$E_{DAY} = \frac{LB_{FOOD} * E_{FOOD}}{Efficiency} + IdleRate * \left(OpHrs - \frac{LB_{FOOD}}{PC} - \frac{T_{PreHt}}{60}\right) + E_{PreHt}$$

Where:

E_{DAY} = Daily energy consumption per fry pot, in kWh for electric and in Btu for natural gas (= calculated)

LB_{FOOD} = Pounds of food cooked per day (= 150 lb/day)[3,4,5]

E_{FOOD} = ASTM energy to (= 0.167 kWh/lb for electric; 570 Btu/lb for nautral gas)[6]

Efficiency = ASTM heavy load cooking energy efficiency percentage (= varies by measure and sector; see table in Assumptions section)[3]

IdleRate = Idle energy rate, in kW for electric and in Btu/hr for natural gas; see table in Assumptions section)[4,5]

OpHrs = Operating hours per day (= 12 hours for the commercial, industrial, and agriculture sectors;[3] = 9 hours for the schools/government sector; see the Assumptions section[8])

PC = Production capacity in lb/hr (= varies by measure and sector; see table in Assumptions section)[4,5]

T_{PreHt} = Preheat time (= 15 minutes)[6]

60 = Minute to hour conversion factor

E_{PreHt} = Preheat energy in kWh for electric and in Btu for natural gas (= varies by measure and sector; see table in Assumptions section)[4,5]

In order to estimate annual savings, the daily energy consumption baseline and qualifying units are calculated using the above equation, and the latter is subtracted from the former. The resulting daily savings value is multiplied by operating days per year to yield annual savings.

$kWh_{SAVED} = (E_{DAY,B} – E_{DAY,Q}) * OpDay$

$Therm_{SAVED} = (E_{DAY,B} – E_{DAY,Q}) * OpDay / 100{,}000$

Where:

$E_{DAY,B}$ = Daily energy use of a baseline unit in kWh or Btu

$E_{DAY,Q}$ = Daily energy use of a qualifying unit in kWh or Btu

OpDay = Number of operating days per year (= 365 days for commercial, industrial, and agriculture sectors;[3,4,5] = 282.5 days for schools/government sector; see the Assumptions section[8])

100,000 = Btu to therm conversion factor

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} * CF / (OpHrs * OpDay)$

Where:

CF = Coincidence factor (=0.9)[7]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therms_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (=12 years)[1]

Deemed Savings

Annual Deemed Savings

MMID	Measure	Sector	kW	kWh	Therms
2337	Fryer, ENERGY STAR, Electric	Agriculture, Commercial, Industrial	0.4223	2,055	-
		Schools & Government	0.4610	1,302	-
2338	Fryer, ENERGY STAR, NG	Agriculture, Commercial, Industrial	-	-	629
		Schools & Government	-	-	397

Lifecycle Deemed Savings

MMID	Measure	Sector	kWh	Therms
2337	Fryer, ENERGY STAR, Electric	Agriculture, Commercial, Industrial	24,660	-
		Schools & Government	15,628	-
2338	Fryer, ENERGY STAR, NG	Agriculture, Commercial, Industrial	-	7,548
		Schools & Government	-	4,765

Assumptions

Below is a discussion of each parameter and its basis, following by a table with the values for each parameter by fryer type. The preheat energy, idle energy rate, and production capacity are based on the Food Service Technology Calculators.[4,5]

Efficiency values for fryers are based on the ENERGY STAR Commercial Kitchen Equipment Calculator.[3] Electric fryers are deemed to be 75% efficient for the baseline and 80% efficient for the ENERGY STAR rated products. These are conservative values since this workpaper does not classify fryers as large or standard vat fryers, as ENERGY STAR lists. The ENERGY STAR efficiency values for electric fryers by vat size are outlined in the table below.

Efficiency Values for Electric Fryers[3]

Standard Vat		Large Vat		Assumed Efficiency	
Baseline	ENERGY STAR	Baseline	ENERGY STAR	Baseline	ENERGY STAR
75%	83%	70%	80%	75%	80%

Operating Hours (OpHrs). The operating hours per day is determined to be 12 hours for all fryers. The Food Service Technology Center lists annual operating hours at 14 hours.[4,5] The ENERGY STAR Commercial Kitchen Equipment Calculator lists 16 hours for standard vat fryers and 12 hours for large vat fryers.[3] The most conservative value was used in energy savings calculations.

Operating Days (OpDay). The calculation assumes that the fryers operate 365 days per year.[3,4,5]

For the schools and government sector, schools have a lower hours per day (6 hours)[8] and days per year (200 days).[8] Since school and government facilities are not broken out into their own sectors, a straight average (of 9 hours per day, 282.5 days per year) was used.

ASTM Parameters. ASTM parameters are those that were determined by Food Service Technology Center by applying ASTM F1361-05, the Standard Test Method for the Performance of Deep Fat Fryers.[6]

Pounds of Food per Day (LB_{Food}). This variable was determined to be 150 pounds of food cooked per day for all fryer types.[3,4,5]

Preheat Time (T_{PreHt}). A preheat time of 15 minutes is used in the savings equation for each fryer.[6]

The assumed parameter values for electric fryers are presented in the table below.

Parameter Values for Electric Fryers

Parameter	Baseline Model	Energy Efficient Model
Preheat Energy (kWh)	2.4[5]	1.9[5]
Idle Energy Rate (kW)	1.2[5]	0.86[5]
Cooking Energy Efficiency	75%[3]	80%[3]
Production Capacity (lbs/hr)	65[5]	71[5]
ASTM Energy to Food (kWh/lb)	0.167[6]	0.167[6]
Pounds of Food Cooked per Day (lb/day)	150[3,4,5]	150[3,4,5]
Preheat Time (min)	15[6]	15[6]
Operating Hours (hr/day)	12[3]	12[3]
Operating Days (day/yr)	365[3,4,5]	365[3,4,5]

The assumed parameter values for natural gas fryers are presented in the table below.

Parameter Values for Natural Gas Fryers

Parameter	Baseline Model	Energy Efficient Model
Preheat Energy (kWh)	18,500[4]	16,000[4]
Idle Energy Rate (kW)	17,000[4]	6,371[4]
Cooking Energy Efficiency	35%[3]	50%[3]
Production Capacity (lbs/hr)	60[4]	67[4]
ASTM Energy to Food (kWh/lb)	570[6]	570[6]
Pounds of Food Cooked per Day (lb/day)	150[3,4,5]	150[3,4,5]
Preheat Time (min)	15[6]	15[6]
Operating Hours (hr/day)	12[3]	12[3]
Operating Days (day/yr)	365[3,4,5]	365[3,4,5]

Sources

1. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." EUL Table. 2014. http://www.deeresources.com
2. ENERGY STAR. "Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment." Calculator. October 2016 Version. www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx
3. ENERGY STAR Commercial Kitchen Equipment Calculator. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx
4. Food Service Technology Center. "Gas Fryer Life-Cycle Cost Calculator." https://fishnick.com/saveenergy/tools/calculators/gfryercalc.php
5. Food Service Technology Center. "Electric Fryer Life-Cycle Cost Calculator." https://fishnick.com/saveenergy/tools/calculators/efryercalc.php
6. Pacific Gas and Electric. "Commercial Fryers, Food Service Equipment." Workpaper PGECOFST102 R5. 2014. http://deeresources.net/workpapers
7. *2004-2005 Database for Energy Efficiency Resources (DEER) Update Study Final Report*. pp. 3-15 to 3-18, table 3-14. http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf
8. Engineering judgement from AgSG program for typical school operating hours per day (6 hours) and days per year (200 days).

Revision History

Version Number	Date	Description of Change
01	09/08/2017	Initial TRM entry

Griddle, ENERGY STAR

	Measure Details
Measure Master ID	Griddle, ENERGY STAR, Electric, 2371 Griddle, ENERGY STAR, NG, 2372, 4539
Measure Unit	Per linear foot
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Griddle
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1]
Measure Incremental Cost ($/unit)	MMID 2371: $860[2] MMID 2372: $1,250[2]

Measure Description

This measure applies to electric- and natural gas–fired high-efficiency griddles installed in a commercial kitchen. Commercial griddles that are ENERGY STAR qualified are about 10% to 11% more energy efficient than standard models, due to the use of highly conductive or reflective plate materials, improved thermostatic controls, and strategic placement of thermocouples.[3]

Description of Baseline Condition

Baseline equipment is assumed to be a new electric or natural gas griddle that does not meet ENERGY STAR performance specification.

Description of Efficient Condition

The efficient condition is either an electric or natural gas griddle that is on the ENERGY STAR *Griddle Qualified Products List*.

Annual Energy-Savings Algorithm

Energy savings result from installing a more efficient unit than the standard efficiency on the market. Savings estimates are based on savings equations and assumptions provided to Pacific Gas and Electric by the Food Service Technology Center (FSTC) and shared with Focus on Energy through the Consortium on Energy Efficiency.

For electric griddles, kilowatt savings are not determined by a savings equation. Rather, they are reported based on metered data. All savings are per linear foot of griddle.

The equation for energy consumption for electric griddles is similar to the equation for natural gas griddles, with only the units of the variables changed. The form of the equation shows that the energy consumption of a griddle is equal to the sum of energy used for cooking, idle, and preheating.

$$E_{DAY} = \frac{LB_{FOOD} * E_{FOOD}}{Efficiency} + IdleRate * \left(OpHrs - \frac{LB_{FOOD}}{PC} - \frac{T_{PREHT}}{60}\right) + E_{PREHT}$$

Where:

E_{DAY} = Daily energy consumption in kWh/linear ft or Btu/linear ft

LB_{FOOD} = Pounds of food cooked per day per linear foot (= varies by sector; see table in the Assumptions section)

E_{FOOD} = ASTM energy to food in kWh/lb or Btu/lb (= varies by sector; see table in the Assumptions section)

Efficiency = ASTM heavy load cooking energy efficiency percentage (= varies by sector; see table in the Assumptions section)

IdleRate = Idle energy rate per linear foot in kW/ft or Btu/hr/ft (= varies by sector; see table in the Assumptions section)

OpHrs = Operating hours per day (= varies by sector; see Operating Schedule by Sector table below)

PC = Production capacity per linear foot in lb/hr/ft (= varies by sector; see table in the Assumptions section)

T_{PREHT} = Preheat time (= 15 minutes; see the Assumptions section)

60 = Minute to hour conversion

E_{PREHT} = Preheat energy per linear foot in kWh/ft or Btu/ft (= varies by sector; see table in the Assumptions section)

In order to estimate annual savings, the consumption of the baseline and qualifying units are calculated using the above equation, and the latter is subtracted from the former. The resulting daily savings value is multiplied by operating days per year to yield annual savings.

$kWh_{SAVED} = (E_{DAY,B} - E_{DAY,Q}) * OpDay$

Where:

$E_{DAY,B}$ = Daily energy use of baseline unit per linear foot in kWh/ft or Btu/ft
$E_{DAY,Q}$ = Daily energy use of qualifying unit per linear foot in kWh/ft or Btu/ft
OpDay = Number of operating days per year (see Operating Schedule by Sector table below)

$Therm_{SAVED} = (E_{Day,B} - E_{Day,Q}) * OpDay / 100{,}000$

Where:

$E_{Day,B}$ = Daily energy use of baseline unit per linear foot (kWh/ft or Btu/ft)
$E_{Day,Q}$ = Daily energy use of qualifying unit per linear foot (kWh/ft or Btu/ft)
OpDay = Number of operating days per year (= varies by sector; see Operating Schedule by Sector table below)
100,000 = Btu to therms conversion

Operating Schedule by Sector

Sector	Hours per Day (OpHrs)	Days per Year (OpDay)
Agriculture[4,5]	12	365
Commercial[4,5]	12	365
Industrial[4,5]	12	365
Schools & Government[10] (see the Assumptions section)	9	282.5

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} * CF / (OpDay * OpHrs)$

Where:

CF = Coincidence factor (= 0.9)[9]

OpDay = Number of operating days per year (= varies by sector; see Operating Schedule by Sector table above)

OpHrs = Operating hours per day (= varies by sector; see Operating Schedule by Sector table above)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (=12 years)[1]

Deemed Savings

Annual Deemed Kilowatt and Kilowatt-Hour Savings

MMID	Measure Description	Commercial		Industrial		Agriculture		Schools & Gov	
		kW	kWh	kW	kWh	kW	kWh	kW	kWh
2371	Griddle, ENERGY STAR, Electric	0.2384	1,160	0.2384	1,160	0.2384	1,160	0.2535	716

Annual Deemed Therm Savings

MMID	Measure Description	Commercial	Industrial	Agriculture	Schools & Gov
2372	Griddle, ENERGY STAR, Natural Gas	100	100	100	53

Lifecycle Deemed Kilowatt-Hour Savings

MMID	Measure Description	Commercial	Industrial	Agriculture	Schools & Gov
2371	Griddle, ENERGY STAR, Electric	13,920	13,920	13,920	8,592

Lifecycle Deemed Therm Savings

MMID	Measure Description	Commercial	Industrial	Agriculture	Schools & Gov
2372	Griddle, ENERGY STAR, Natural Gas	1,200	1,200	1,200	636

Assumptions

Many of the parameter values used in the savings estimate were determined by FSTC according to ASTM F1275, the Standard Test Method for Performance of Griddles.[6] These were originally prepared for Pacific Gas and Electric and were provided to the program through the Consortium on Energy Efficient Kitchens when the measure was deemed in 2007. ENERGY STAR subsequently began qualifying griddles, and savings estimates have been updated to match ENERGY STAR data and criteria. All values are discussed below, and summarized in the Griddle Parameters by Model and Fuel table below.

- ***Pounds of Food per Day, LB_{FOOD}.*** The deeming calculation assumes that 33.3 pounds of food are cooked per day per linear foot by natural gas and electric standard efficiency and ENERGY STAR griddles. The FSTC assumes that 100 lb/hr were cooked per day by each griddle. The deemed value is obtained by dividing 100 lb/hr by three feet, which is the rounded average length from ENERGY STAR *Qualified Products List*.[8]
- ***Energy to Food, E_{FOOD}.*** Energy to food is deemed to be 0.139 kWh/lb for electric griddles and 475 Btu/lb for natural gas griddles. These values are the original values provided by FSTC.[7]
- ***Efficiency.*** The deemed ASTM heavy load cooking energy efficiency values used in this calculation are the values provided by FSTC. For baseline units, deemed values are 30% for natural gas griddles and 60% for electric griddles.[7] For ENERGY STAR units, the deemed values are 38% for natural gas griddles and 70% for electric griddles. These values are the minimum efficiency values to be ENERGY STAR qualified.[3]
- ***Idle Energy Rate, IdleRate.*** The deemed idle energy rates for baseline models are 7,000 Btu/hr/ft for natural gas griddles and 0.800 kW/ft for electric griddles. These are based on FSTC provided values of 3,500 Btu/hr/ft^2 for natural gas griddles and 0.4 kW/ft^2 for electric griddles.[4,5] The deemed idle energy rate for ENERGY STAR models are 4,136 Btu/hr/ft for natural gas griddles and 0.586 kW/ft for electric griddles. These are based on FSTC provided values of 2,068 Btu/hr/ft^2 for natural gas griddles and 0.293 kW/hr/ft^2 for electric griddles.
- ***Production Capacity, PC.*** The deemed production capacity values for baseline models are 8.4 lb/hr/ft for natural gas griddles and 11.6 lb/hr/ft for electric griddles. These are based on FSTC provided values of 4.2 lb/hr/ft^2 for natural gas griddles and 5.8 lb/hr/ft^2 for electric griddles.[4,5] The deemed production capacity for ENERGY STAR models are 16.4 lb/hr/ft for natural gas griddles and 16.4 lb/hr/ft for electric griddles. These are based on FSTC provided values of 8.2 lb/hr/ft^2 for natural gas griddles and 8.2 lb/hr/ft^2 for electric griddles.[4,5]
- ***Preheat Time, T_{PREHT}.*** Preheat time is the deemed amount of time it takes a griddle to reach operating temperature after being turned on. This is deemed to be 15 minutes from an FSTC workpaper.[7]
- ***Preheat Energy, E_{PREHT}.*** The deemed preheat energy for baseline models are 7,000 Btu/ft for natural gas griddles and 1.33 kWh/ft for electric models. These are based on values from the

FSTC provided values of 3,500 Btu/ft^2 for natural gas griddles and 0.667 kWh/ft^2 for electric gridles.[4,5] The deemed preheat energy for ENERGY STAR models are 5,000 Btu/ft for natural gas units and 0.667 kWh/ft^2 for electric units. These are based on FSTC provided values of 2,500 Btu/ft^2 for natural gas griddles and 0.333 kWh/ft^2 for electric griddles.[4,5]

- ***Idle Energy Rate, Production Capacity, and Preheat Energy.*** The base values for these variables were provided in terms of square feet. These base values were multiplied by two feet, as this was the rounded average depth from ENERGY STAR *Qualified Products List*.[8]
- ***Deemed Effective Useful Life***. This is 12 years, erring on a more conservative value from the FSTC calculator default value.[4,5]

Savings are based on the assumption that kilowatts were metered while the unit or units were firing. The peak period kilowatt savings are defined as the average kilowatts from 1 p.m. to 4 p.m., Monday through Friday, June through August. So, using these metered kilowatt values tacitly assumes that the unit is firing throughout the peak period.

For the schools and government sector, schools have a lower hours per day (six hours)[10] and days per year (200 days).[10] Since school and government facilities are not broken out into individual sectors, a straight average of the lower hours per day and days per year for schools and the values for government facilities[4,5] was used. These values are substituted into the savings equation to yield the savings values reported in the Annual Energy-Savings Algorithm and Lifecycle Energy-Savings Algorithm sections. The values are reported in the table below.

Griddle Parameters by Model and Fuel

Fuel Type	Parameter	Baseline Model	ENERGY STAR Model
Electric or Natural Gas	Preheat Time (min)	15	15
	Pounds of Food per Day (lb/day/ft)	33.3	33.3
Electric	Preheat Energy (kWh/ft)	1.33	0.67
	Idle Energy Rate (kW/ft)	0.8	0.586
	Efficiency	60%	70%
	Production Capacity (lb/h/ft)	11.6	16.4
	ASTM Energy to Food (kWh/lb)	0.139	0.139
Natural Gas	Preheat Energy (Btu/ft)	7,000	5,000
	Idle Energy Rate (Btu/h/ft)	7,000	4,136
	Efficiency	30%	38%
	Production Capacity (lb/h/ft)	8.4	16.4
	ASTM Energy to Food (Btu/lb)	475	475

Sources

1. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. EUL for commercial cooking equipment measure. http://www.deeresources.com
2. ENERGY STAR. "Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment." Calculator. October 2016 Version. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx
3. ENERGY STAR. "Commercial Griddles." Energy Efficient Commercial Griddles. Accessed December 19, 2017. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_griddles
4. "Commercial Foodservice Equipment Life-cycle Cost Calculator - Electric Griddle." Accessed September 5, 2017. https://fishnick.com/saveenergy/tools/calculators/egridcalc.php
5. "Commercial Foodservice Equipment Life-cycle Cost Calculator - Gas Griddle." Accessed September 5, 2017. https://fishnick.com/saveenergy/tools/calculators/ggridcalc.php
6. ENERGY STAR. "Commercial Griddles Key Product Criteria." Products. Accessed September 5, 2017. https://www.energystar.gov/index.cfm?c=griddles.pr_crit_comm_griddles
7. Pacific Gas and Electric. "Commercial Griddle – Electric and Gas." Food Service Equipment Workpaper PGECOFST103 R7. 2016. http://deeresources.net/workpapers
8. "ENERGY STAR Commercial Griddles Qualified Product List." Accessed January 19, 2018. https://www.energystar.gov/productfinder/product/certified-commercial-griddles/results
9. *Database for Energy Efficiency Resources*. Update Study Final Report, p. 3-15 to 3-18, Table 3-14. http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf
   Table lists coincidence factor for other similar commercial cooking equipment.
10. Engineering judgement from AgSG program for typical school operating hours per day (six hours) and days per year (200 days).

Revision History

Version Number	Date	Description of Change
01	09/05/2017	Initial TRM entry
02	11/13/2017	Updated to address comments from other implementers

Hot Food Holding Cabinets

	Measure Details
Measure Master ID	Hot Food Holding Cabinet, V = 13-28 cu. ft., ENERGY STAR, 2677, 4583 Hot Food Holding Cabinet, V < 13 cu. ft., ENERGY STAR, 2678, 4584 Hot Food Holding Cabinet, V ≥ 28 cu. ft., ENERGY STAR, 2679, 4585
Measure Unit	Per cabinet
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Hot Holding Cabinet
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	$902[2]

Measure Description

This measure is an ENERGY STAR hot food holding cabinet, which is designed to keep cooked or baked foods warm and fresh until ready for serving customers.

Description of Baseline Condition

The baseline equipment is an electric hot food holding cabinet that is not ENERGY STAR certified.

Description of Efficient Condition

The efficient condition is an electric hot food holding cabinet that is ENERGY STAR certified. ENERGY STAR certified hot food holding cabinets include better insulation to reduce heat loss, provide better temperature uniformity within the cabinet from top to bottom (less stratification), and may include magnetic door gaskets or auto-door closures.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * OpHrs * OpDays / 1,000$

Where:

$Watts_{BASE}$ = Power consumption of baseline cabinet (= varies by volume; see table below)

$Watts_{EE}$ = Power consumption of efficient cabinet (= varies by volume; see table below)

OpHrs = Average hours of operation per day (= varies by sector; see table below)

OpDays = Average days of operation per year (= varies by sector; see table below)

1,000 = Kilowatt conversion factor

$Watts_{BASE}$ and $Watts_{EE}$ are based on the cabinet's interior volume, V. Interior volumes are referenced using the ENERGY STAR *Certified Commercial Products List,* then categorized as ½, ¾, or full size based on ENERGY STAR Version 2.0 *Requirements for Commercial Hot Food Holding Cabinets*.[6] The average volume, V_{AVG}, is determined by cabinet description and used in calculating $Watts_{BASE}$ and $Watts_{EE}$.

For $Watts_{BASE}$, the average volume is multiplied by the maximum idle energy rate to determine wattage. The maximum idle energy rate, 40 watts per cu. ft., is a manufacturer's requirement for all hot food holding cabinets sold in California.[5]

For $Watts_{EE}$, the average volume is multiplied by the ENERGY STAR *Maximum Idle Energy Consumption Rate*.[6] The interior volume is an averaged value from the ENERGY STAR *Certified Commercial Hot Food Holding Cabinet List* as of September 14, 2017.[7]

Parameters by Cabinet Description

MMID	Cabinet Description	Interior Volume (cu ft)	Average Interior Volume (cu ft)	Maximum Idle Energy Consumption Rate (watts)
2677	¾ Size	$13 \le V < 28$	21.14	$\le 2.0 * V_{AVG} + 254.0$
2678	½ Size	$0 < V < 13$	7.78	$\le 21.5 * V_{AVG}$
2679	Full Size	$28 \le V$	53.40	$\le 3.8 * V_{AVG} + 203.5$

Power Consumption by Cabinet Description

MMID	Cabinet Description	$Watts_{BASE}$	$Watts_{EE}$
2677	¾ Size	846	296
2678	½ Size	311	167
2679	Full Size	2,136	406

Operating Schedule by Sector

Sector	Hours per Day	Days per Year
Agriculture[2]	15	365
Commercial[2]	15	365
Industrial[2]	15	365
Schools & Government[2,3] (see the Assumptions section)	10.5	282.5

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) * CF / 1{,}000$

Where:

CF = Coincidence factor (= 0.9)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 12 years)[1]

Assumptions

Schools operate for fewer hours per day (six hours)[3] and fewer days per year (200 days)[3] than other sectors. Since school and government facilities are part of a single sector, a straight average of the lower hours per day and days per year for schools (six hours/day and 200 days/year) and the values for government facilities (15 hours/day and 365 days/year)[2] was used to calculate savings for that sector.

Deemed Savings

Annual Deemed Savings

MMID	Measure Description	Commercial		Industrial		Agriculture		Schools & Gov	
		kW	kWh	kW	kWh	kW	kWh	kW	kWh
2677	Hot Food Holding Cabinet, V = 13-28 cu. ft., ENERGY STAR	0.495	3,011	0.495	3,011	0.495	3,011	0.495	1,631
2678	Hot Food Holding Cabinet, V < 13 cu. ft., ENERGY STAR	0.130	788	0.130	788	0.130	788	0.130	427
2679	Hot Food Holding Cabinet, V ≥ 28 cu. ft., ENERGY STAR	1.557	9,472	1.557	9,472	1.557	9,472	1.557	5,132

Lifecycle Deemed Savings (kWh)

MMID	Measure Description	Commercial	Industrial	Agriculture	Schools & Gov
2677	Hot Food Holding Cabinet, V = 13-28 cu. ft., ENERGY STAR	36,132	36,132	36,132	19,572
2678	Hot Food Holding Cabinet, V < 13 cu. ft., ENERGY STAR	9,456	9,456	9,456	5,124
2679	Hot Food Holding Cabinet, V ≥ 28 cu. ft., ENERGY STAR	113,664	113,664	113,664	61,584

Sources

1. *Database for Energy Efficiency Resources*. Version 2008.2.05. "Effective/Remaining Useful Life Values." October 10, 2008. http://www.deeresources.com/files/deer0911planning/downloads/EUL_Summary_10-1-08.xls
2. ENERGY STAR. *Commercial Kitchen Equipment Calculator*. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx
   Used for both incremental cost and calculation inputs (hours per day and days per year)
3. Engineering judgement from AgSG program for typical school operating hours per day (six hours) and days per year (200 days).
4. *Database for Energy Efficiency Resources Update Study Final Report*. p. 3-15 to 3-18, Table 3-14. 2004-2005. http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf
5. Pacific Gas & Electric. *Insulated Holding Cabinet*. Food Service Equipment Workpaper PGECOFST105 R5. 2016. http://deeresources.net/workpapers
6. "ENERGY STAR Version 2.0 Requirements for Commercial Hot Food Holding Cabinets." https://www.energystar.gov/products/commercial_food_service_equipment/commercial_hot_food_holding_cabinets/partners
7. ENERGY STAR Commercial Hot Food Holding Cabinets. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_hot_food_holding_cabinets

Revision History

Version Number	Date	Description of Change
01	09/20/2017	Initial TRM entry
02	11/13/2017	Updated to address comments from other implementers

ENERGY STAR Commercial Combination Ovens (Natural Gas or Electric)

	Measure Details
Measure Master ID	Oven, Combination, ENERGY STAR, Electric, 3118 , 4594 Oven, Combination, ENERGY STAR, Natural Gas, 3119, 4595
Measure Unit	Per oven
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Oven
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	15,096
Peak Demand Reduction (kW)	3.446
Annual Therm Savings (Therms)	1,103
Lifecycle Energy Savings (kWh)	181,146
Lifecycle Therm Savings (Therms)	13,237
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	$0.00[6]

Measure Description

A combination oven is a self-contained device that functions as a hot air convection (oven mode), saturated and superheated steam heating (steam mode), and combination convection/steam mode for moist heating. The convection/stem mode performs steaming, baking, roasting, rethermalizing, and proofing of various food products. The combination oven can also be referred to as a combination oven/steamer, combi, or combo.

Description of Baseline Condition

Baseline equipment is assumed to be a new combination oven that does not meet ENERGY STAR v2.0 performance specification. Data analysis were provided by the CEE and a dataset was provided by the EPA FSTC and manufacturers from December 2011 through July 2012.

Description of Efficient Condition

The efficient condition is any commercial combination oven that is on the ENERGY STAR Commercial Combination Ovens qualified products list,[2] per the ENERGY STAR v2.0 performance specifications for natural gas and electric combination ovens.[2]

Annual Energy-Savings Algorithms

Electric Combination Oven:

$$kWh_{\text{SAVED}} = (Wh/day_{\text{BASELINE}} - Wh/day_{\text{EE}}) * DPY / 1{,}000$$

$$Wh/day_{\text{BASELINE}} = Wh/day_{\text{CONVECTION, BASELINE}} + Wh/day_{\text{STEAM, BASELINE}} + Wh/day_{\text{PREHEAT, BASELINE}}$$

$$Wh/day_{\text{CONVECTION, BASELINE}} = (1-\%_{\text{STEAM}}) *\{(m * E_{\text{CONVECTION}}) / \eta_{\text{CONVECTION, BASELINE}} + [E_{\text{IDLE-CONVECTION, BASELINE}} * (t_{\text{DAY}} - m/PC_{\text{CONVECTION, BASELINE}} - nP * t_{\text{PREHEAT}}/60)]\}$$

$$Wh/day_{\text{STEAM, BASELINE}} = \%_{\text{STEAM}} * \{(m* E_{\text{STEAM}}) / \eta_{\text{STEAM,BASELINE}} + [E_{\text{IDLE-STEAM, BASELINE}} * (t_{\text{DAY}} - m/PC_{\text{STEAM,BASELINE}} - nP * t_{\text{PREHEAT}}/60)]\}$$

$$Wh/day_{\text{PREHEAT, BASELINE}} = E_{\text{PREHEAT, BASELINE}} * nP$$

$$Wh/day_{\text{EE}} = Wh/day_{\text{CONVECTION, EE}} + Wh/day_{\text{STEAM, EE}} + Wh/day_{\text{PREHEAT, EE}}$$

$$Wh/day_{\text{CONVECTION, EE}} = (1-\%_{\text{STEAM}}) * \{(m * E_{\text{CONVECTION}}) / \eta_{\text{CONVECTION, EE}} + [E_{\text{IDLE-CONVECTION, EE}} * (t_{\text{DAY}} - m/PC_{\text{CONVECTION, EE}} - nP * t_{\text{PREHEAT}}/60)]\}$$

$$Wh/day_{\text{STEAM, EE}} = \%_{\text{STEAM}} * \{(m * E_{\text{STEAM}}) / \eta_{\text{STEAM,EE}} + [E_{\text{IDLE-STEAM, EE}} * (t_{\text{DAY}} - m/PC_{\text{STEAM, EE}} - nP * t_{\text{PREHEAT}}/60)]\}$$

$$Wh/day_{\text{PREHEAT, EE}} = E_{\text{PREHEAT, EE}} * nP$$

Natural Gas Combination Oven:

$$Therm_{\text{SAVED}} = (Btu/day_{\text{BASELINE}} - Btu/day_{\text{EE}}) * DPY / 100{,}000$$

$$Btu/day_{\text{BASELINE}} = Btu/day_{\text{CONVECTION, BASELINE}} + Btu/day_{\text{STEAM,BASELINE}} + Btu/day_{\text{PREHEAT, BASELINE}}$$

$$Btu/day_{\text{CONVECTION, BASELINE}} = (1-\%_{\text{STEAM}}) * \{(m * E_{\text{CONVECTION}}) / \eta_{\text{CONVECTION, BASELINE}} + [E_{\text{IDLE-CONVECTION, BASELINE}} * (t_{\text{DAY}} - m/PC_{\text{CONVECTION, BASELINE}} - nP * t_{\text{PREHEAT}}/60)]\}$$

$$Btu/day_{\text{STEAM, BASELINE}} = \%_{\text{STEAM}} * \{(m* E_{\text{STEAM}}) / \eta_{\text{STEAM, BASELINE}} + [E_{\text{IDLE-STEAM, BASELINE}} * (t_{\text{DAY}} - m/PC_{\text{STEAM,BASELINE}} - nP * t_{\text{PREHEAT}}/60)]\}$$

$$Btu/day_{\text{PREHEAT, BASELINE}} = E_{\text{PREHEAT,BASELINE}} * nP$$

$$Btu/day_{\text{EE}} = Wh/day_{\text{CONVECTION, EE}} + Wh/day_{\text{STEAM, EE}} + Wh/day_{\text{PREHEAT, EE}}$$

$$Wh/day_{\text{CONVECTION, EE}} = (1-\%_{\text{STEAM}}) * \{(m* E_{\text{CONVECTION}}) / \eta_{\text{CONVECTION, EE}} + [E_{\text{IDLE-CONVECTION, EE}} * (t_{\text{DAY}} - m/PC_{\text{CONVECTION, EE}} - nP * t_{\text{PREHEAT}}/60)]\}$$

$Wh/day_{STEAM,\ EE} = \%_{STEAM} * \{(m * E_{STEAM}) / \eta_{STEAM,\ EE} + [E_{IDLE\text{-}STEAM,\ EE} * (t_{DAY} - m/PC_{STEAM,\ EE} - nP * t_{PREHEAT}/60)]\}$

$Wh/day_{PREHEAT,\ EE} = E_{PREHEAT,EE} * nP$

Where:

DPY = Days of operation per year (= 365)[3]

1,000 = Kilowatt conversion factor

$\%_{STEAM}$ = Percentage of time in steam mode (= 50%)[3]

m = Estimated mass of food cooked per day, in pounds (= 250)[3]

$E_{CONVECTION}$ = Energy absorbed by food product: cooking by convection (= 73.2 Wh/lb; = 250 Btu/lb)[4]

$E_{IDLE\text{-}CONVECTION,\ BASELINE}$ = Baseline idle energy rate (= varies by unit type; see table below)[3]

t_{DAY} = Estimated operating time per day, in hours (= 12)[3]

$PC_{CONVECTION,\ BASELINE}$ = Production capacity of baseline equipment in pounds per hour (= varies by unit type; see table below)[3]

nP = Estimated number of preheats per day (= 1)[3]

$t_{PREHEAT}$ = Estimated preheat time in minutes per preheat (= 15)[3]

60 = Minutes in an hour

E_{STEAM} = Energy absorbed by food product: cooking by steam (= 30.8 Wh/lb; = 105 Btu/lb)[4]

100,000 = Conversion factor from Btu to therms

$\eta_{STEAM,BASELINE}$ = Cooking energy efficiency of baseline unit (= varies by unit type; see table below)[4]

$\eta_{CONVECTION,\ BASELINE}$ = Energy efficiency of baseline unit (= varies by unit type; see table below)[4]

$E_{IDLE\text{-}STEAM,\ BASELINE}$ = Baseline energy absorbed by food product: cooking by steam (= varies by unit type; see table below)[3]

$PC_{STEAM,BASELINE}$ = Production capacity of baseline cooking by steam

$E_{PREHEAT,\ BASELINE}$ = Measured energy used per preheat for baseline unit (= varies by unit type; see table below)[3]

$\eta_{CONVECTION,\ EE}$ = Cooking energy efficiency of efficient unit

$E_{IDLE\text{-}CONVECTION,\ EE}$ = ENERGY STAR idle rate of efficient equipment (= varies by unit type; see table below)[4]

$PC_{CONVECTION, EE}$ = Production capacity of efficient equipment in pounds per hour (= varies by unit type; see table below)[3]

$\eta_{STEAM, EE}$ = Cooking energy efficiency of efficient unit, cooking by steam (= varies by unit type; see table below)[4]

$E_{IDLE\text{-}STEAM, EE}$ = ENERGY STAR idle rate of efficient equipment, cooking by steam (= varies by unit type; see table below)[4]

$PC_{STEAM,EE}$ = Production capacity of energy efficient equipment, cooking by steam

$E_{PREHEAT, EE}$ = Measured energy used per preheat from efficient equipment (= varies by unit type; see table below)[3]

Production Capacity by Unit Type

	Baseline	EE
$PC_{CONVECTION}$	100	125
PC_{STEAM}	150	200

Cooking Energy Efficiency by Unit Type

	Electric		Natural Gas	
	Baseline	EE	Baseline	EE
$\eta_{CONVECTION}$	65%	70%	35%	44%
η_{STEAM}	40%	50%	20%	38%

Measured Energy Used per Preheat by Unit Type

	Baseline	EE
$E_{PREHEAT, ELECTRIC}$ (Watts)	3,750	2,000
$E_{PREHEAT, STEAM}$ (Btu)	22,000	16,000

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} * (CF / HOU)$

Where:

CF = Coincidence factor (= 1)[5]

HOU = Annual hours of use (= 4,380)[3]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 12 years)[1]

Assumptions

The default values given in calculators from the ENERGY STAR FSTC were used for savings calculation variables.

Sources

1. Similar MMIDs 2485-2488. EUL derived from Food Service Technology Center. Gas Convection Oven Life-Cycle Cost Calculator.
2. United States Department of Energy. ENERGY STAR Product Finder: Commercial Combination Ovens.
3. United States Department of Energy. Version 2.0 ENERGY STAR Performance Specification for Gas and Electric Combination Ovens.
4. Food Service Technology Center. "Life-Cycle & Energy Cost Calculator: Combination Ovens." http://www.fishnick.com/saveenergy/tools/calculators/
5. The Summer Peak Coincidence Factor is assumed to equal 1.0, since the annual kWh savings is divided by the total annual hours (8760), effectively resulting in the average kW reduction during the peak period.
6. ENERGY STAR® Commercial Kitchen Savings Calculator. Accessed March 11, 2016. All Rack Ovens Incremental Cost=$0.00. https://www.energystar.gov/products/commercial_food_service_equipment

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry

Oven, Convection, ENERGY STAR, Electric

	Measure Details
Measure Master ID	Oven, Convection, ENERGY STAR, Electric, 2485, 4545
Measure Unit	Per oven
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Oven
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	2,083
Peak Demand Reduction (kW)	0.48
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	24,998
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	$388.00[5]

Measure Description

A convection oven is a self-contained device that functions as a hot air convection (oven mode), saturated and superheated steam heating (steam mode), and combination convection/steam mode for moist heating. The convection/stem mode performs steaming, baking, roasting, rethermalizing, and proofing of various food products. Savings adjustment for existing active measure based on ENERGY STAR Version 2.1 specification taking effect January 1, 2014.[3]

Description of Baseline Condition

The baseline condition is an electric full-size convection ovens that has an average cooking energy efficiency of 65% and an average idle rate of 2 kW.[4]

Description of Efficient Condition

The efficient condition is the minimum cooking energy efficiency of an ENERGY STAR electric full-size convection ovens of 71%, with a maximum idle rate of 1.6 kW.[4]

Annual Energy-Savings Algorithm

Per the energy formula on page 4-48 of the Deemed Savings Manual 1.0:[2]

$$kWh_{SAVED} = (E_{DAY,\ BASELINE} – E_{DAY,\ ENERGY\ STAR}) * OpDay$$

$$E_{DAY} = [(LB_{FOOD} * E_{FOOD})/Efficiency] + IdleRate * [OpHrs – (LB_{FOOD}/PC) – (T_{PREHT}/60)] + E_{PREHT}$$

Where:

OpDay = Operating days per year (= varies by model and fuel type; see table below)

E_{DAY} = Daily energy consumption (kWh or Btu)

LB_{FOOD} = Pounds of food cooked per day (= varies by model and fuel type; see table below)

E_{FOOD} = ASTM Energy to Food (kWh/lb or Btu/lb; = varies by model and fuel type, see table below)

Efficiency = ASTM Heavy Load Cooking Energy Efficiency percentage (= varies by model and fuel type; see table below)

IdleRate = Idle energy rate (kW or Btu/hr; = varies by model and fuel type, see table below)

OpHrs = Operating hours per day (= varies by model and fuel type; see table below)

PC = Production capacity in pounds per hour (= varies by model and fuel type; see table below)

T_{PREHT} = Preheat time in minutes (= varies by model and fuel type; see table below)

60 = Conversion from minutes to hours

E_{PREHT} = Preheat energy (kWh or Btu; = varies by model and fuel type, see table below)

Parameter Values by Model and Oven Fuel

Oven Fuel	Parameter	Baseline Model	ENERGY STAR Model	Source
Electric or Natural Gas	Preheat Time (min)	15	15	Deemed
	Operating Hours/Day	12	12	4
	Operating Days/Year	365	365	4
	Pounds of Food Cooked per Day	100	100	4
Electric	Production Capacity (lb/h)	90	90	4
	Preheat Energy (kWh)	1.5	1	4
	Idle Energy Rate (kW)	2	1.6	4
	Cooking Energy Efficiency (%)	65%	71%	4
	ASTM Energy to Food (kWh/lb)	0.0732	0.0732	4
Natural Gas	Production Capacity (lb/h)	83	86	4
	Preheat Energy (Btu)	19,000	11,000	4
	Idle Energy Rate (Btu/h)	15,100	12,000	4
	Cooking Energy Efficiency (%)	44%	46%	4
	ASTM Energy to Food (Btu/lb)	250	250	4

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (E_{DAY, BASELINE} – E_{DAY, ENERGY STAR}) / OpHrs$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 12 years)^4

Sources

1. Food Service Technology Center. Convection Oven Life-Cycle Cost Calculator.
2. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3-2 Lighting Hours of Use in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
3. ENERGY STAR Commercial Ovens Program Requirements, Version 2.1.
4. ENERGY STAR Commercial Kitchen Equipment Calculator.
5. ENERGY STAR. "Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment." 2016. https://www.energystar.gov/sites/default/files/asset/

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	12/2018	Updated incremental cost

Oven, Convection, ENERGY STAR, Natural Gas

	Measure Details
Measure Master ID	Oven, Convection, ENERGY STAR, Natural Gas, 2486, 4546
Measure Unit	Per full size oven
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Oven
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	156
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	1,872
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	$170.00[5]

Measure Description

A convection oven is a self-contained device that functions as a hot air convection (oven mode), saturated and superheated steam heating (steam mode), and combination convection/steam mode for moist heating. The convection/stem mode performs steaming, baking, roasting, rethermalizing, and proofing of various food products.

Description of Baseline Condition

The average cooking energy efficiency of a natural gas full-size convection oven is 44%, with an average idle rate of 15,100 Btu per hour.[4]

Description of Efficient Condition

The minimum cooking energy efficiency of ENERGY STAR full-size convection ovens is 46%, with a maximum idle rate of 12,000 Btu per hour.[4]

Annual Energy-Savings Algorithm

$$kWh_{SAVED} = (E_{DAY,\ BASELINE} - E_{DAY,\ ENERGY\ STAR}) * OpDay * (1/100{,}000)$$

$$E_{DAY} = [(LB_{FOOD} * E_{FOOD})/Efficiency] + IdleRate * [OpHrs - (LB_{FOOD}/PC) - (T_{PREHT}/60)] + E_{PREHT}$$

Where:

E_{DAY} = Daily energy consumption (kWh or Btu)

OpDays = Operating days per year (= varies by model and fuel type; see table below)

1/100,000 = Btu to therms conversion

LB_{FOOD} = Pounds of food cooked per day (= varies by model and fuel type; see table below)

E_{FOOD} = ASTM Energy to Food (kWh/lb or Btu/lb; = varies by model and fuel type, see table below)

Efficiency = ASTM Heavy Load Cooking Energy Efficiency percentage (= varies by model and fuel type; see table below)

IdleRate = Idle energy rate (kW or Btu/hr; = varies by model and fuel type, see table below)

OpHrs = Operating hours per day (= varies by model and fuel type; see table below)

PC = Production capacity (lb/hr; = varies by model and fuel type, see table below)

T_{PREHT} = Preheat time in minutes (= varies by model and fuel type; see table below)

60 = Conversion from minutes to hours

E_{PREHT} = Preheat energy (kWh or Btu; = varies by model and fuel type, see table below)

Parameter Values by Model and Oven Fuel

Oven Fuel	Parameter	Baseline Model	ENERGY STAR Model	Source
Electric or Natural Gas	Preheat Time (min)	15	15	Deemed
	Operating Hours/Day	12	12	3
	Operating Days/Year	365	365	3
	Pounds of Food Cooked per Day	100	100	3
Electric	Production Capacity (lb/h)	90	90	3
	Preheat Energy (kWh)	1.5	1	4
	Idle Energy Rate (kW)	2	1.6	3
	Cooking Energy Efficiency (%)	65%	71%	3
	ASTM Energy to Food (kWh/lb)	0.0732	0.0732	3
Natural Gas	Production Capacity (lb/h)	83	86	3
	Preheat Energy (Btu)	19,000	11,000	4
	Idle Energy Rate (Btu/h)	15,100	12,000	3
	Cooking Energy Efficiency (%)	44%	46%	3
	ASTM Energy to Food (Btu/lb)	250	250	3

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}} = \text{Therm}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (= 12 years)[1]

Sources

1. Food Service Technology Center. Gas Convection Oven Life-Cycle Cost Calculator.
2. ENERGY STAR Commercial Ovens Program Requirements, Version 2.1.
3. ENERGY STAR Commercial Kitchen Equipment Calculator.
4. Food Service Technology Center. Electric Convection Oven Life-Cycle Cost Calculator.
5. ENERGY STAR. “Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.” 2016. https://www.energystar.gov/sites/default/files/asset/

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	12/2018	Updated incremental cost

Oven, Rack Type, ENERGY STAR, Natural Gas

	Measure Details
Measure Master ID	Oven, Rack Type, ENERGY STAR, Natural Gas: Single Compartment, 2488, 4548 Double Compartment, 2487, 4547
Measure Unit	Per oven
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Oven
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1,2]
Incremental Cost ($/unit)	$0.00[3]

Measure Description

Rack ovens have a high capacity, are able to produce steam internally, and are fitted with a motor-driven mechanism for rotating multiple pans inserted into one or more removable or fixed pan racks within the oven cavity. A single rack oven is able to accommodate one removable single rack of standard sheet pans measuring 18 x 26 x 1-inch, while a double rack oven is able to accommodate two removable single racks of standard sheet pans measuring 18 x 26 x 1-inch, or one removable double-width rack.

Description of Baseline Condition

The baseline condition is an average natural gas single rack oven with cooking energy efficiency of 43.5% and an average idle rate of 24,451 Btu per hour.[4]

The baseline condition could also be an average natural gas double rack oven with cooking energy efficiency of 50.5% and an average idle rate of 37,971 Btu per hour.[4]

Description of Efficient Condition

The minimum cooking energy efficiency for a single rack oven to qualify for ENERGY STAR is 48%, with a maximum idle rate of 25,000 Btu per hour.[5] The average cooking energy efficiency of available ENERGY STAR-qualified natural gas single rack ovens is 48.9% with an average idle rate of 21,009 Btu per hour.[4]

The minimum cooking energy efficiency for a double rack oven to qualify for ENERGY STAR is 52%, with a maximum idle rate of 30,000 Btu per hour.[5] The average cooking energy efficiency of available ENERGY STAR-qualified natural gas double rack ovens is 53.9% with an average idle rate of 24,128 Btu per hour.[4]

Annual Energy-Savings Algorithm

$$\text{Therm}_{\text{SAVED}} = (\text{E}_{\text{DAY, BASELINE}} - \text{E}_{\text{DAY, ENERGY STAR}}) * \text{OpDay} * (1/100{,}000)$$

$$\text{E}_{\text{DAY}} = [(\text{LB}_{\text{FOOD}} * \text{E}_{\text{FOOD}})/\text{Efficiency}] + \text{GasIdleRate} * [\text{OpHrs} - (\text{LB}_{\text{FOOD}}/\text{PC}) - (\text{T}_{\text{PREHT}}/60)] + \text{E}_{\text{PREHT}}$$

$$\text{kWh}_{\text{SAVED}} = \text{kWh}_{\text{ANNUAL, BASELINE}} - \text{kWh}_{\text{ANNUAL, ENERGY STAR}}$$

$$\text{kWh}_{\text{ANNUAL}} = \text{ElecIdleRate} * \text{OpDay} * [\text{OpHrs} - (\text{LB}_{\text{FOOD}}/\text{PC})]$$

Where:

E_{DAY} = Daily energy consumption (Btu)

OpDays = Operating days per year (= varies by model; see table below)

1/100,000 = Btu to therms conversion

LB_{FOOD} = Pounds of food cooked per day (= varies by model; see table below)

E_{FOOD} = ASTM Energy to Food (Btu/lb; = varies by model, see table below)

Efficiency = ASTM Heavy Load Cooking Energy Efficiency (%; = varies by model, see table below)

GasIdleRate = Gas Idle energy rate (Btu/hr; = varies by model, see table below)

OpHrs = Operating hours per day (= varies by model; see table below)

T_{PREHT} = Preheat time in minutes (= varies by model; see table below)

60 = Conversion from minutes to hours

E_{PREHT} = Preheat energy (Btu; = varies by model, see table below)

ElecIdleRate = Electric Idle energy rate (kW; = varies by model, see table below)

PC = Production capacity (lb/hr; = varies by model, see table below)

Parameter Values by Model

Parameter	Single Rack		Double Rack		Source
	Baseline	ENERGY STAR	Baseline	ENERGY STAR	
Preheat Energy (Btu; E_{PREHT})	50,000	44,000	100,000	85,000	4
Gas Idle Energy Rate (Btu/hr; GasIdleRate)	24,451	21,009	37,971	24,128	4
Electric Idle Energy Rate (kW; ElecIdleRate)	0.80	0.51	1.55	1.14	4
Heavy-Load Energy Efficiency (%; Efficiency)	43.5%	48.9%	50.5%	53.9%	4
ASTM Energy to Food (Btu/lb; E_{FOOD})	250	250	250	250	6
Production Capacity (lbs/hr; PC)	141	137	268	281	4
Operating Hours per Day (OpHrs)	12	12	12	12	4
Operating Days per Year (OpDays)	365	365	365	365	4
Preheat time in minutes (T_{PREHT})	15	15	15	15	7
Lbs of Food Cooked per Day (LB_{FOOD})	600	600	1,200	1,200	4

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = ElecIdleRate_{BASELINE} – ElecIdleRate_{ENERGY\ STAR}$

Where:

$ElecIdleRate_{BASELINE}$ = Electric Idle energy rate (kW; = varies by model, see table above)

$ElecIdleRate_{ENERGY\ STAR}$ = Electric Idle energy rate (kW; = varies by model, see table above)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 12 years)[1,2]

Deemed Savings

Natural Gas and Electricity Deemed Savings per ENERGY STAR, Natural Gas, Rack Type Oven

Measure	MMID	Annual kWh	Annual Therms	Peak kW	Lifecycle kWh	Lifecycle Therms
Single Compartment	2488	828	255	0.29	9,936	3,060
Double Compartment	2487	1,002	529	0.41	12,024	6,348

Sources

1. Food Service Technology Center. *Gas Rack Oven Life-Cycle Cost Calculator.* www.fishnick.com/saveenergy/tools/calculators/grackovencalc.php
2. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” June 2, 2008. http://www.deeresources.com/
3. ENERGY STAR® Commercial Kitchen Savings Calculator. Accessed March 11, 2016. All Rack Ovens Incremental Cost = $0.00. https://www.energystar.gov/products/commercial_food_service_equipment
4. Commercial Ovens Draft 2 Version 2.2 Plots, ENERGY STAR website for development of Commercial Ovens Specification Version 2.2. http://www.energystar.gov/products/spec/commercial_ovens_specification_version_2_2_pd. *(Implementer had personal communication with Consortium for Energy Efficiency staff to obtain the data tables used to generate these public plots of rack oven performance).*
5. ENERGY STAR Commercial Ovens Program Requirements, Version 2.2. www.energystar.gov/sites/default/files/Commercial%20Ovens%20Final%20Version%202.2%20Specification.pdf
6. ENERGY STAR Commercial Kitchen Equipment Calculator (used convection ovens value since a separate value for rack ovens is not yet available). www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx
7. *Wisconsin Focus on Energy Technical Reference Manual.* October 22, 2015. (Preheat time listed as 15 minutes and “deemed” for convection ovens (MMID 2485, 2486) and combination ovens (MMID 3118, 3119).

Revision History

Version Number	Date	Description of Change
01	11/11/2015	Updated from Wisconsin Focus on Energy QPL to ENERGY STAR
02	01/22/2016	Updated per comments

Commercial Freezers, ENERGY STAR

	Measure Details
Measure Master ID	Freezer, Chest, Glass Door: < 15 cu ft, ENERGY STAR, 4522 15-29 cu ft, ENERGY STAR, 2322, 4523 30-49 cu ft, ENERGY STAR, 2323, 4524 50+ cu ft, ENERGY STAR, 2324, 4525 Freezer, Chest, Solid Door: < 15 cu ft, ENERGY STAR, 2325, 4526 15-29 cu ft, ENERGY STAR, 2326, 4527 30-49 cu ft, ENERGY STAR, 2327, 4528 50+ cu ft, ENERGY STAR, 4529 Freezer, Vertical, Glass Door: < 15 cu ft, ENERGY STAR, 4530 15-29 cu ft, ENERGY STAR, 2330, 4531 30-49 cu ft, ENERGY STAR, 2331, 4532 50+ cu ft, ENERGY STAR, 2332, 4533 Freezer, Vertical, Solid Door: < 15 cu ft, ENERGY STAR, 2333, 4534 15-29 cu ft, ENERGY STAR, 2334, 4535 30-49 cu ft, ENERGY STAR, 2335, 4536 50+ cu ft, ENERGY STAR, 2336, 4537
Measure Unit	Per freezer
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Refrigerator / Freezer - Commercial
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by size and door type
Peak Demand Reduction (kW)	Varies by size and door type
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by size and door type
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	$0 for solid door (MMIDs 2325–2327 and 2333–2336)[1] $1,240 for glass door (MMIDs 2322–2324 and 2330–2332)[1]

Measure Description

This measure is installing refrigeration equipment that meets ENERGY STAR Version 4.0 performance specification, effective March 27, 2017.[2] ENERGY STAR commercial solid door and glass door freezers are more energy efficient than standard units, and use higher efficiency ECM evaporator and condenser fan motors, a hot natural gas anti-sweat heater, or high-efficiency compressors.

Description of Baseline Condition

The baseline condition is a unit meeting U.S. Department of Energy commercial refrigeration equipment maximum energy usage standards for equipment sold in the United States, effective March 27, 2017.[3]

Description of Efficient Condition

The efficient condition is certified ENERGY STAR Version 4.0, effective March 27, 2017, for vertical and horizontal closed-door freezers.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (kWh_{BASELINE} - kWh_{ENERGY\ STAR}) * Days$

Where:

$kWh_{BASELINE}$ = Daily baseline unit consumption (= varies by unit; see table below)

$kWh_{ENERGY\ STAR}$ = Daily qualifying unit consumption (= varies by unit; see table below)

Days = Annual days of operation, deemed (= 365)

Parameter Values by Unit Type

Unit Type	Door Type	Size (cu. ft.)	Daily Baseline Consumption, DOE 2017	Daily Qualifying Consumption, ENERGY STAR Specification 4.0
Vertical Closed Freezers	Solid	0 < V < 15	0.22V + 1.38	0.21V + 0.9
		15 ≤ V < 30	0.22V + 1.38	0.12V + 2.428
		30 ≤ V < 50	0.22V + 1.38	0.285V - 2.703
		50 ≤ V	0.22V + 1.38	0.142V + 4.445
	Transparent	0 < V < 15	0.29V + 2.95	0.232V + 2.36
		15 ≤ V < 30	0.29V + 2.95	0.232V + 2.36
		30 ≤ V < 50	0.29V + 2.95	0.232V + 2.36
		50 ≤ V	0.29V + 2.95	0.232V + 2.36
Horizontal Closed Freezers	Solid	All volumes	0.06V + 1.12	0.057V + 0.55
	Transparent		0.75V + 4.10	

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / HOURS$

Where:

HOURS = Hours of use, deemed (= 8,760)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 12 years)[1]

Deemed Savings

Deemed Savings Values by Measure

Measure Master Name	MMID	Average Volume Based on Measure	Daily Baseline Consumption, DOE 2017	Daily Qualifying Consumption, ENERGY STAR Specification 4.0	Deemed Savings		
					Annual kWh	LC kWh	kW
Freezer, Chest, Glass Door							
15-29 cu ft, ENERGY STAR	2322	22	0.08V + 1.23	0.057V + 0.55	433	5,196	0.049
30-49 cu ft, ENERGY STAR	2323	39.5	0.08V + 1.23	0.057V + 0.55	580	6,960	0.066
50+ cu ft, ENERGY STAR	2324	65	0.08V + 1.23	0.057V + 0.55	794	9,528	0.091
Freezer, Chest, Solid Door							
< 15 cu ft, ENERGY STAR	2325	7.5	0.06V + 1.12	0.057V + 0.55	216	2,592	0.025
15-29 cu ft, ENERGY STAR	2326	22	0.06V + 1.12	0.057V + 0.55	232	2,784	0.026
30-49 cu ft, ENERGY STAR	2327	39.5	0.06V + 1.12	0.057V + 0.55	251	3,012	0.029
Freezer, Vertical, Glass Door							
15-29 cu ft, ENERGY STAR	2330	22	0.29V + 2.95	0.232V + 2.36	681	8,172	0.078
30-49 cu ft, ENERGY STAR	2331	39.5	0.29V + 2.95	0.232V + 2.36	1,052	12,624	0.12
50+ cu ft, ENERGY STAR	2332	65	0.29V + 2.95	0.232V + 2.36	1,591	19,092	0.182
Freezer, Vertical, Solid Door							
< 15 cu ft, ENERGY STAR	2333	7.5	0.22V + 1.38	0.21V + 0.9	203	2,436	0.023
15-29 cu ft, ENERGY STAR	2334	22	0.22V + 1.38	0.12V + 2.428	420	5,040	0.048
30-49 cu ft, ENERGY STAR	2335	39.5	0.22V + 1.38	0.285V - 2.703	553	6,636	0.063
50+ cu ft, ENERGY STAR	2336	65	0.22V + 1.38	0.142V + 4.445	732	8,784	0.084

Assumptions

It is assumed that the smallest internal volume of freezers is one cubic foot and the greatest internal volume of freezers (per certified products in ENERGY STAR) is 80 cubic feet. These numbers are used to provide the average internal volume of the measures, specifically those under 15 cu ft and 50 or more cu ft.

Sources

1. ENERGY STAR. *Program Calculator for Commercial Refrigerators and Freezers*. October 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx
2. ENERGY STAR. *Program Requirements for Commercial Refrigerators and Freezers*. Version 4.0. https://www.energystar.gov/sites/default/files/asset/document/Commercial%20Refrigerators%20and%20Freezers%20V4%20Spec%20Final%20Version_0.pdf
3. U.S. Department of Energy. *Commercial Refrigeration Equipment Standards.* Effective March 27, 2017. https://www.ecfr.gov/cgi-bin/text-idx?SID=ea9937006535237ca30dfd3e03ebaff2&mc=true&node=se10.3.431_166&rgn=div8

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	10/2017	Updated baseline and qualifying unit specifications
03	01/2019	Removed MMIDs 2321, 2328, and 2329

Commercial Refrigerator, ENERGY STAR

	Measure Details
Measure Master ID	Refrigerator, Chest, Glass Door: < 15 cu ft, ENERGY STAR, 4551 15-29 cu ft, ENERGY STAR, 2522, 4552 30-49 cu ft, ENERGY STAR, 2523, 4553 50+ cu ft, ENERGY STAR, 2524, 4554 Refrigerator, Chest, Solid Door: < 15 cu ft, ENERGY STAR, 2525, 4555 15-29 cu ft, ENERGY STAR, 2526, 4556 30-49 cu ft, ENERGY STAR, 2527, 4557 50+ cu ft, ENERGY STAR, 2528, 4558 Refrigerator, Vertical, Glass Door: < 15 cu ft, ENERGY STAR, 2529, 4559 15-29 cu ft, ENERGY STAR, 2530, 4560 30-49 cu ft, ENERGY STAR, 2531, 4561 50+ cu ft, ENERGY STAR, 2532, 4562 Refrigerator, Vertical, Solid Door: < 15 cu ft, ENERGY STAR, 2533, 4563 15-29 cu ft, ENERGY STAR, 2534, 4564 30-49 cu ft, ENERGY STAR, 2535, 4565 50+ cu ft, ENERGY STAR, 2536, 4566
Measure Unit	Per refrigerator
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Refrigerator / Freezer - Commercial
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by size and door type
Peak Demand Reduction (kW)	Varies by size and door type
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by size and door type
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	$1,440 for solid door (MMIDs 2525–2528 and 2533–2536); $470 for glass door (MMIDs 2522–2524 and 2529–2532)[1]

Measure Description

This measure is installing refrigeration equipment that meets ENERGY STAR Version 4.0 performance specification, effective March 27, 2017.[2] ENERGY STAR commercial solid and glass door refrigerators are designed to be more energy efficient than standard units and use higher-efficiency ECM evaporator and condenser fan motors, a hot natural gas anti-sweat heater, or high-efficiency compressors.

Description of Baseline Condition

The baseline condition is a unit meeting U.S. Department of Energy commercial refrigeration equipment maximum energy usage standards for equipment sold in the United States, effective March 27, 2017.[3]

Description of Efficient Condition

The efficient equipment is certified ENERGY STAR Version 4.0, effective March 27, 2017, for vertical and horizontal closed-door refrigerators.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (kWh_{BASELINE} - kWh_{ENERGY\ STAR}) * Days$

Where:

$kWh_{BASELINE}$ = Daily baseline unit consumption (= varies by unit; see table below)
$kWh_{ENERGY\ STAR}$ = Daily qualifying unit consumption (=varies by unit; see table below)
Days = Annual days of operation, deemed (= 365)

Parameter Values by Unit Type

Unit Type	Door Type	Size (cu. ft.)	Daily Baseline Consumption, DOE 2017	Daily Qualifying Consumption, ENERGY STAR Specification 4.0
Vertical Closed Refrigerators	Solid	0 < V < 15	0.05V + 1.36	0.022V + 0.97
		15 ≤ V < 30	0.05V + 1.36	0.066V + 0.31
		30 ≤ V < 50	0.05V + 1.37	0.04V + 1.09
		50 ≤ V	0.05V + 1.38	0.024V + 1.89
	Transparent	0 < V < 15	0.1V + 0.86	0.095V + 0.445
		15 ≤ V < 30	0.1V + 0.86	0.05V + 1.12
		30 ≤ V < 50	0.1V + 0.86	0.076V + 0.34
		50 ≤ V	0.1V + 0.86	0.105V - 1.111
Horizontal Closed Refrigerators	Solid	All volumes	0.05V + 0.91	0.05V + 0.28
	Transparent		0.06V + 0.37	

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / HOU$

Where:

HOU = Hours of use, deemed (= 8,760)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 12 years)[4]

Deemed Savings

Deemed Savings Values by Measure

Measure Master Name	MMID	Average Volume Based on Measure	Daily Baseline Consumption	Daily Qualifying Consumption	Deemed Savings		
					Annual kWh	LC kWh	kW
Refrigerator, Chest, Glass Door							
15-29 cu ft, ENERGY STAR	2522	22	0.06V + 0.37	0.05V + 0.28	113	1,356	0.013
30-49 cu ft, ENERGY STAR	2523	39.5	0.06V + 0.37	0.05V + 0.28	177	2,124	0.02
50+ cu ft, ENERGY STAR	2524	65	0.06V + 0.37	0.05V + 0.28	270	3,240	0.031
Refrigerator, Chest, Solid Door							
< 15 cu ft, ENERGY STAR	2525	7.5	0.05V + 0.91	0.05V + 0.28	230	2,760	0.026
15-29 cu ft, ENERGY STAR	2526	22	0.05V + 0.91	0.05V + 0.28	230	2,760	0.026
30-49 cu ft, ENERGY STAR	2527	39.5	0.05V + 0.91	0.05V + 0.28	230	2,760	0.026
50+ cu ft, ENERGY STAR	2528	65	0.05V + 0.91	0.05V + 0.28	230	2,760	0.026
Refrigerator, Vertical, Glass Door							
< 15 cu ft, ENERGY STAR	2529	7.5	0.1V + 0.86	0.095V + 0.445	165	1,980	0.019
15-29 cu ft, ENERGY STAR	2530	22	0.1V + 0.86	0.05V + 1.12	307	3,684	0.035
30-49 cu ft, ENERGY STAR	2531	39.5	0.1V + 0.86	0.076V + 0.34	536	6,432	0.061
50+ cu ft, ENERGY STAR	2532	65	0.1V + 0.86	0.105V - 1.111	601	7,212	0.069

Measure Master Name	MMID	Average Volume Based on Measure	Daily Baseline Consumption	Daily Qualifying Consumption	Deemed Savings		
					Annual kWh	LC kWh	kW
Refrigerator, Vertical, Solid Door							
< 15 cu ft, ENERGY STAR	2533	7.5	0.05V + 1.36	0.022V + 0.97	219	2,628	0.025
15-29 cu ft, ENERGY STAR	2534	22	0.05V + 1.36	0.066V + 0.31	255	3,060	0.029
30-49 cu ft, ENERGY STAR	2535	39.5	0.05V + 1.37	0.04V + 1.09	243	2,916	0.028
50+ cu ft, ENERGY STAR	2536	65	0.05V + 1.38	0.024V + 1.89	423	5,076	0.048

Assumptions

It is assumed that the smallest internal volume of refrigerators is one cubic foot and the greatest internal volume of refrigerators (per certified products in ENERGY STAR) is 80 cubic feet. These numbers are used to provide the average internal volume of the measures, specifically those less than 15 cu ft and 50 or more cu ft.

Sources

1. ENERGY STAR. *Program Calculator for Commercial Refrigerators and Freezers*. October 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx
2. ENERGY STAR. *Program Requirements for Commercial Refrigerators and Freezers*. Version 4.0. https://www.energystar.gov/sites/default/files/asset/document/Commercial%20Refrigerators%20and%20Freezers%20V4%20Spec%20Final%20Version_0.pdf
3. U.S. Department of Energy. *Commercial Refrigeration Equipment Standards*. Effective March 27, 2017. https://www.ecfr.gov/cgi-bin/text-idx?SID=ea9937006535237ca30dfd3e03ebaff2&mc=true&node=se10.3.431_166&rgn=div8

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	10/2017	Updated baseline and qualifying unit specifications
03	01/2019	Removed MMID 2521

Steamer, ENERGY STAR

	Measure Details
Measure Master ID	Steamer, ENERGY STAR, Electric, 4710 Steamer, ENERGY STAR, NG, 4711
Measure Unit	Per pan
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Steamer
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	Varies by measure
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	Electric = $755.56 (MMID 4710), NG = $504.44 (MMID 4711)[2]

Measure Description

This measure consists of installing an ENERGY STAR electric or natural gas commercial steamer. ENERGY STAR steamers consume less energy than standard steamers because of improved insulation and a more efficient steam delivery system. To qualify, ENERGY STAR steamers must meet a minimum cooling efficiency and a maximum idle energy rate.

Description of Baseline Condition

The baseline condition is a non-ENERGY STAR commercial steamer.

Description of Efficient Condition

The efficient condition is an ENERGY STAR–certified commercial steamer.

Annual Energy-Savings Algorithm

Energy savings result from installing a more efficient unit than the standard efficiency on the market, and the amount of savings depends on the quantity of pans.

Savings estimates are based on savings equations and assumptions provided to Pacific Gas and Electric by the Food Service Technology Center (FSTC) and shared with Focus on Energy through the Consortium on Energy Efficiency. Steamer performance was determined by FSTC according to ASTM F1484, the Standard Test Method for Performance of Steam Cookers.

The energy consumption equation for electric steamers (kWh) and natural gas steamers (Btu) is of the same form, with only the units of the variables changed. The form of the equation shows that the daily energy consumption of a steamer is equal to the sum of cooking, idle, steam, and preheat energy:

$$E_{DAY} = \left(\frac{LB_{FOOD} * E_{FOOD}}{Efficiency}\right) + (1 - \%Steam) * IdleRate * \left(OpHrs - \frac{LB_{FOOD}}{PC} - \frac{T_{PreHt}}{60}\right) + \%Steam * \left(OpHrs - \frac{LB_{FOOD}}{PC} - \frac{T_{PreHt}}{60}\right) * \left(\frac{PC * E_{FOOD}}{Efficiency}\right) + E_{PreHt}$$

Where:

E_{DAY} = Daily energy consumption (kWh or Btu; calculated)

LB_{FOOD} = Pounds of food per day (lb/day; see table in Assumptions)[2]

E_{FOOD} = ASTM Energy to Food (= 0.0308 kWh/lb for electric; = 105 Btu/lb for natural gas)[2]

Efficiency = ASTM heavy load cooking energy efficiency (%; see table in Assumptions)[2]

%Steam = Percentage of time in constant steam mode (%; see table in Assumptions)[2]

IdleRate = Idle energy rate (kW or Btu/hr; see table in Assumptions)[3,4]

OpHrs = Operating hours per day (= 12 for the commercial, industrial, and agriculture sectors;[2] = 9 for the schools and government sector;[2,5] see Assumptions)

PC = Production capacity (lb/hr; see table in Assumptions)[2]

T_{PreHt} = Preheat time (= 15 minutes)[6]

60 = Minute to hour conversion

E_{PreHt} = Preheat energy (kWh or Btu; see table in Assumptions)[3,4]

To estimate annual savings, the consumption of the baseline and qualifying units are calculated using the above equation, and the latter is subtracted from the former. The resulting daily savings value is multiplied by operating days per year to yield annual savings:

$kWh_{SAVED} = (E_{DAY,B} - E_{DAY,Q}) * OpDay$

$Therm_{SAVED} = (E_{DAY,B} - E_{DAY,Q}) * OpDay / 100{,}000$

$Gallons_{SAVED} = (GPH_{BASE} - GPH_{Q}) * OpHrs * OpDay$

Where:

$E_{DAY,B}$ = Daily energy use of a baseline unit (kWh or Btu)

$E_{DAY,Q}$ = Daily energy use of a qualifying unit (kWh or Btu)

OpDay = Number of operating days per year (= 365 for the commercial, industrial, and agriculture sectors;[2] = 282.5 for the schools and government sector;[2,5] see Assumptions)

100,000 = Btu to therm conversion

GPH_{BASE} = Gallons per hour water use for a baseline unit (= varies by measure; see table below and Assumptions)

GPH_{Q} = Gallons per hour water use for a qualifying unit (= varies by measure; see table below)

Gallons of Water Use for Baseline and Qualifying Units

MMID	Fuel Source	Baseline Water Consumption Per Pan (Gallons/Hour)[7]	Average ENERGY STAR Model Water Consumption Per Pan (Gallons/Hour)[8]
4710	Electric	5.83	0.40
4711	Natural Gas	5.83	0.51

Annual Deemed Savings Per Pan

MMID	Sector	kW	kWh	Therms	Water Savings (gal)
Steamer, ENERGY STAR, Electric					
4710	Agriculture, Commercial, Industrial	4.34	2,827	--	24,445
	Schools & Government	4.34	1,663	--	14,190
Steamer, ENERGY STAR, Natural Gas					
4711	Agriculture, Commercial, Industrial	--	--	205	23,301
	Schools & Government	--	--	121	13,526

Summer Coincident Peak Savings Algorithm

The summer coincident peak savings for electric steamers are not determined using a savings equation, but are reported based on metered data.[6] Further details can be found in the Assumptions.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Gallons_{LIFECYCLE} = Gallons_{SAVED} * EUL$

Where:

EUL = Effective useful life (=12 years)[1]

Lifecycle Deemed Savings Per Pan

MMID	Sector	kWh	Therms	Water Savings (gal)
Steamer, ENERGY STAR, Electric				
4710	Agriculture, Commercial, Industrial	33,926	--	293,340
	Schools & Government	19,961	--	170,280
Steamer, ENERGY STAR, Natural Gas				
4711	Agriculture, Commercial, Industrial	--	2,464	279,612
	Schools & Government	--	1,457	162,312

Assumptions

Savings are based on the per-pan weighted average of the savings calculated from multiple pan steamers. Per-pan weighted averages were calculated with the weightings from the three, four, five, and six-pan electric steamers and five and six-pan natural gas steamers listed on the ENERGY STAR Qualified Product List as of January 23, 2018, as shown in the table below.

Weighting Per Pan

# of Pans	Weighting[8]
Steamer, ENERGY STAR, Electric, 4710	
3	26%
4	1%
5	10%
6	63%
Steamer, ENERGY STAR, Natural Gas, 4711	
5	12.5%
6	87.5%

Values for ASTM parameters for baseline and energy-efficient cases were determined by FSTC according to ASTM F1484, the Standard Test Method for Performance of Steam Cookers. These parameters are based on measured data under preheat, idle, and heavy-load cooking conditions:

- ***Pounds of Food per Day, LB_{FOOD}.*** An estimate of the average pounds of food steamed per day.
- ***Energy to Food, E_{FOOD}.*** The amount of energy absorbed by food during cooking, per pound of food.
- ***Heavy Load Cooking Efficiency.*** The minimum qualifying value for each steamer measure. This ASTM parameter value is not based on an average of tested steamers. The minimum qualifying values of 38% for natural gas steamers and 50% for electric steamers are used as the efficiencies of the qualifying steamers in the savings calculations.
- ***Percentage of Time in Constant Steam Mode, %Steam.*** The steamer's constant steam setting that keeps the steamer operating at maximum input even when not cooking. The setting is controlled by the operator.
- ***Idle Energy Rate, IdleRate.*** The energy rate consumed by the steamer when on but not cooking and not set to constant steam.
- ***Operating Hours, OpHrs.*** The number of hours the steamer is on per day, whether cooking or idle.
- ***Production Capacity, PC.*** The amount of food a given steamer can cook per hour.
- ***Preheat Time, T_{PreHt}.*** The amount of time for a steamer to reach operating temperature when turned on.
- ***Preheat Energy, E_{PreHt}.*** The amount of energy the steamer consumes daily to reach operating temperature.
- ***Operating Days, OpDay.*** The number of days the steamer is on per year, whether cooking or idle.

For the schools and government sector, schools have fewer hours per day (six hours)[5] and fewer days per year (200 days)[5] than government facilities. Since school and government facilities are not broken out into their own sectors, a straight average (nine hours per day, 282.5 days per year) of the lower hours per day and days per year for schools (six hours per day and 200 days per year) and the values for government facilities (12 hours per day and 365 days per year) was used.

The values used in the savings equations and the resulting consumptions and savings are presented in the tables below.

Electric Steamer Assumptions That Are Constant with Respect to Number of Pans

Parameter	Baseline Model	Energy-Efficient Model
Pounds of Food per Day (lb/day)[2]	100	100
ASTM Energy to Food (kWh/lb)[2]	0.0308	0.0308
Cooking Energy Efficiency (%)[2]	30	50
Constant Steam (%)[2]	40	40
Preheat Time (min)[6]	15	15
Preheat Energy (kWh)[3]	1.5	1.5
Operating Hours (hr/day) for Agriculture, Commercial, and Industrial Sectors[2]	12	12
Operating Hours (hr/day) for Schools & Government Sector[2,5]	9	9
Operating Days (day/yr) for Agriculture, Commercial, and Industrial Sectors[2]	365	365
Operating Days (day/yr) for Schools & Government Sector[2,5]	282.5	282.5

Electric Steamer Assumptions Per Pan

Fuel Source	Parameter	Baseline Model	Energy-Efficient Model
Electric	Idle Energy Rate per Pan (kW)[3]	0.17	0.04
	Production Capacity per Pan (lb/hr)[2]	23.3	16.7

Using the above values, daily kilowatt-hour consumptions for the baseline and energy-efficient models were calculated, and the difference between these was multiplied by annual operating days to yield the values in the Annual Deemed Savings Per Pan table.

Steamers were initially deemed as having a demand reduction of 6.201 kW. These initial findings were later reduced by 30%, as it was determined to be more representable of actual savings. Therefore, the savings are 4.341 kW for all electric steamers, as was shown in the Annual Deemed Savings Per Pan table above. These values are based on metering studies conducted by FSTC.[6]

Natural Gas Steamer Assumptions That Are Constant with Respect to Number of Pans

Parameter	Baseline Model	Energy-Efficient Model
Pounds of Food per Day (lb/day)[2]	100	100
ASTM Energy to Food (Btu/lb)[2]	105	105
Cooking Energy Efficiency (%)[2]	18	38
Constant Steam (%)[2]	40	40
Preheat Time (min)[6]	15	15
Preheat Energy (Btu)[4]	20,000	20,000
Operating Hours (hr/day) for Agriculture, Commercial, and Industrial Sectors[2]	12	12
Operating Hours (hr/day) for Schools & Government Sector[2,5]	9	9
Operating Days (day/yr) for Agriculture, Commercial, and Industrial Sectors[2]	365	365
Operating Days (day/yr) for Schools & Government Sector[2,5]	282.5	282.5

Natural Gas Steamer Assumptions Per Pan

Fuel Source	Parameter	Baseline Model	Energy-Efficient Model
Natural Gas	Idle Energy Rate per Pan (Btu/hr)[3]	2,500	486
	Production Capacity per Pan (lb/hr)[2]	23.3	20

Using the above values, the daily Btu consumptions for the baseline and energy-efficient models were calculated, and the difference between them was multiplied by annual operating days to yield deemed savings in Btu. That result was divided by 100,000 to convert deemed reduction estimates to the therm values shown in the Annual Deemed Savings per Pan table above.

For water savings, the baseline was set at 35 gallons per hour, which is the midpoint of the range (30 to 40 gallons per hour) provided by ENERGY STAR[7] for a six-pan steamer. Dividing 35 gallons per hour by six yields the baseline water use per pan of 5.83 gallons per hour.

For incremental cost, the ENERGY STAR savings calculator[2] lists $3,400 for electric steamers and $2,270 for gas steamers, but does not differentiate by number of pans. The cost is applied equally to 3, 4, 5, and 6 pan steamers. Therefore, to convert that cost to a per-pan cost, the cost was divided by the average of the number of pans (4.5).

Sources

1. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” EUL for commercial cooking equipment measure. June 2, 2008. http://www.deeresources.com
2. ENERGY STAR. “Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.” Calculator. October 2016 version. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx
3. ENERGY STAR. “Program Requirements for Commercial Steam Cookers.” Accessed September 20, 2018 https://www.energystar.gov/ia/partners/product_specs/program_reqs/commer_steamer_prog_req.pdf
4. California Energy Wise. Electric Steamer Energy Savings Calculator. Accessed September 21, 2018. https://caenergywise.com/calculators/electric-steamers/#calc
5. Engineering judgement from AgSG program for typical school operating six hours per day and 200 days per year.
6. Pacific Gas and Electric. “Commercial Steam Cookers, Food Service Equipment Workpaper PGECOFST104 R6.” 2016. http://deeresources.net/workpapers
7. Fisher Nickel Inc. “Best Practices – How to Achieve the Most Efficient Use of Water in Commercial Food Service Facilities.” February 2005. https://www.energystar.gov/ia/business/healthcare/fisher_nickel_feb_2005.pdf
8. ENERGY STAR. “Commercial Steam Cookers Qualified Products List.” Accessed January 23, 2018. www.energystar.gov/productfinder/product/certified-commercial-steam-cookers/results

Revision History

Version Number	Date	Description of Change
01	09/08/2017	Initial TRM entry
02	09/21/2018	Updated unit of measure and condensed measures into two MMIDs

HVAC

Advanced Rooftop Unit Controller

	Measure Details
Measure Master ID	Advanced Rooftop Unit Controller, 3964, 4646
Measure Unit	Per ton
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	Varies
Annual Therm Savings (Therms)	Varies
Lifecycle Electricity Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	Varies
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$530.10[3]

Measure Description

The Pacific Northwest National Laboratory estimates that 90% of the installed base of rooftop units are constant volume systems with single speed supply fans.[4] Advanced rooftop controllers convert these units to variable speed systems that can better optimize performance for varying loads and that incorporate additional features such as demand control ventilation (DCV) and improved economizer controls.

Description of Baseline Condition

The baseline condition is a rooftop unit with direct expansion cooling and natural gas heat, a constant speed supply fan, a functional economizer, and no carbon dioxide–based ventilation controls. The rooftop unit must also have ≥ 7 tons nominal cooling capacity and have a ≥ 1 hp supply fan.

Description of Efficient Condition

The efficient condition is an advanced rooftop controller, defined as a digital controller for retrofit applications that improves the rooftop unit’s ability to optimize for heating, cooling, and ventilation load based on temperature, humidity, or occupancy through enhanced control of airflow and variable or multispeed control. The advanced rooftop unit controller must meet several characteristics to qualify for an incentive:

- Multi-speed or variable speed control of the supply fan with, at a minimum, reduced fan speed operation for first stage cooling and ventilation modes.
- Modulating outdoor air damper control to maintain proper ventilation rates according to ASHRAE Standard 62.1 under different fan speeds.
- DCV, in which the breathing zone airflow shall be reset in response to current occupancy and shall be no less than the building component of the DCV zone. The ventilation system shall be controlled such that at steady state it provides each zone with no less than the breathing zone outdoor airflow for the current zone population.
    - Carbon dioxide sensors shall be used as to determine occupancy; these sensors may be placed in either the return air ducts of the single zone systems or in the zones themselves. The outdoor air damper must adjust proportionally so that the ventilation rate varies continuously between the minimum ventilation setpoint and the design ventilation setpoint of the affected space based on the occupancy at any given time.
    - Time of day schedules may not be used to determine occupancy in the affected space.
    - Economizer operation should override DCV control.
- Integrated economizer, whereby the compressor will stage on and off as needed to make up the additional cooling load required when 100% outside air is not capable of providing the entire cooling load. When the outside air conditions are not suitable for free cooling or integrated economizer operation, the economizer dampers are positioned to provide only the required amount of ventilation airflow.

Annual Energy-Savings Algorithm

The amount of energy savings for advanced rooftop unit controllers is based on hourly calculations that compare baseline and proposed heating and cooling requirements and fan energy use while the building is designated as occupied. The difference between baseline and proposed is the resulting savings for this measure.[5,6]

$$kWh_{SAVED} = (FanEnergy_{BASELINE} + CoolingEnergy_{BASELINE} + ElecHeatingEnergy_{BASELINE}) - (FanEnergy_{PROPOSED} + CoolingEnergy_{PROPOSED} + ElecHeatingEnergy_{PROPOSED})$$

$$FanEnergy_{BASELINE} = \Sigma\,(hp * 0.746 * LoadFactor / MotorEff * OccStatus * 1\ hour)$$

$$CoolingEnergy_{BASELINE} = \Sigma\,(1.08 * CFM * \Delta T / (1{,}000 * EER) * OccStatus * 1\ hour)$$

$$ElecHeatingEnergy_{BASELINE} = \Sigma\,(1.08 * CFM * \Delta T / (ElecHtgEff * 3{,}412) * OccStatus * 1\ hour)$$

$$FanEnergy_{PROPOSED} = \Sigma\ ([FanPower40\% + FanPower75\% + FanPower90\%] * OccStatus * 1\ hour)$$

$$CoolingEnergy_{PROPOSED} = \Sigma\ (1.08 * CFM * \Delta T / (1{,}000 * EER) * OccStatus * 1\ hour)$$

$$ElecHeatingEnergy_{PROPOSED} = \Sigma\ (1.08 * CFM * \Delta T / (ElecHtgEff * 3{,}412) * OccStatus * 1\ hour)$$

$$Therm_{SAVED} = HeatingEnergy_{BASELINE} - HeatingEnergy_{PROPOSED}$$

$$HeatingEnergy_{BASELINE} = \Sigma\ (1.08 * CFM * \Delta T / (HtgEff * 100{,}000) * OccStatus * 1\ hour)$$

$$HeatingEnergy_{PROPOSED} = \Sigma\ (1.08 * CFM * \Delta T / (HtgEff * 100{,}000) * OccStatus * 1\ hour)$$

Where:

hp = Fan horsepower of the rooftop unit

0.746 = Conversion from horsepower to kilowatts

LoadFactor = Fan motor load factor (= actual if known, otherwise 75%)

MotorEff = Fan motor efficiency (= actual if known, otherwise 90%)

OccStatus = Indicator of whether the building is occupied at the specific hour for the calculation (= 0 if unoccupied, = 1 if occupied)

1.08 = Constant for sensible heat load equation

CFM = Airflow in CFM of the rooftop unit (= actual if known, otherwise 400 CFM/ton cooling capacity)

ΔT = Temperature difference (°F) between the outside air and either the building heating or cooling setpoint

1,000 = Conversion from watts to kilowatts (EER units are Btuh per watt)

EER = Cooling efficiency of the rooftop unit (= actual if known, otherwise use IECC 2006 minimum efficiency for retrofit projects and IECC 2009 minimum efficiency for new construction projects, see Assumptions)

3,412 = Conversion from Btu/h to kW

FanPower40% = Fan power while operating at 40% load (using fan laws with 2.5 exponent and $FanEnergy_{BASELINE}$)

FanPower75% = Fan power while operating at 75% load (using fan laws with 2.5 exponent and $FanEnergy_{BASELINE}$)

FanPower90% = Fan power while operating at 90% load (using fan laws with 2.5 exponent and $FanEnergy_{BASELINE}$)

HtgEff = Gas heating efficiency (= actual if known, otherwise 80%)

ElecHtgEff = Electric heating efficiency (= actual if known, otherwise 1.0 COP for electric resistance heating)

100,000 = Conversion from Btu to therms

Summer Coincident Peak Savings Algorithm

The amount of demand reduction is the reduction in fan power energy from operating at 100% speed (baseline) to operating at 90% speed (proposed). The cooling load for the baseline and proposed is assumed to be the same.

$kW_{SAVED} = hp * 0.746 * LoadFactor / MotorEff * (1 – 0.9^{2.5})$

Where:

0.9 = Maximum fan motor percentage of speed under the proposed conditions

2.5 = Fan affinity law exponent

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (=10 years)[1]

Assumptions

- Customer cannot apply for a rebate for both this measure and for a DCV (MMID 3266) or a VFD (MMID 2643).
- If advanced rooftop unit controllers are installed on an existing rooftop unit that needs to be replaced within 10 years, it is expected that the advanced rooftop unit controller will be transferred and re-programmed to the new rooftop unit. The new rooftop unit under this scenario is not eligible for an additional advanced rooftop unit controller incentive.
- Rooftop unit equipment for this measure will usually have just a supply fan. If a rooftop unit has both a supply fan and a return fan, it is assumed that variable speed controls would also be added to the return fan to maintain appropriate building pressurization. In those cases, the supply and return fan horsepower would be added together and used as the horsepower in the savings calculation.

- The rooftop unit EER for retrofit projects is estimated to equal IECC 2006 minimum requirements, which are:
    - 10.3 EER for units ≥ 65,000 and < 135,000 Btu (≥ 5.42 and < 11.25 tons)
    - 9.7 EER for units ≥ 135,000 and < 240,000 Btu (≥ 11.25 and < 20 tons)
    - 9.5 EER for units ≥ 240,000 and < 760,000 Btu (≥ 20 and < 63.3 tons)
    - 9.2 EER for units ≥ 760,000 Btu (≥ 63.3 tons)
- The rooftop unit EER for new construction projects is estimated to equal IECC 2009 minimum requirements, which are:
    - 11.2 EER for units ≥ 65,000 to 135,000 Btu (≥5.42 < 11.25 tons)
    - 11.0 EER for units ≥ 135,000 to 240,000 Btu (≥ 11.25 < 20 tons)
    - 10.0 EER for units ≥ 240,000 to 760,000 Btu (≥ 20 < 63.3 tons)
    - 9.7 EER for units ≥ 760,000 Btu (≥ 63.3 tons)
- Advanced rooftop unit controls incorporate variable speed fans, DCV, and economizer improvements. Nearly all the savings comes from the variable speed fan and DCV. Therefore, the measure life for advanced rooftop unit controls was assumed to match that of the individual measures for variable speed fan (MMID 2643) and DCV (MMID 3266).
- Cadmus conducted a metering study over the summer of 2017[7] to examine 54 rooftop units across 16 Wisconsin sites, which were mostly convenience stores, drugstores, and supermarkets. This study revealed that rooftop units generally do not heat above 50°F or cool below 55°F. The calculation tool for this measure[5] therefore assumes no need for heating or cooling between 50°F and 55°F. To complete the load profile, it then allows the user to specify the heating and cooling design temperatures, and assumes 80% of heating load and 90% of cooling load at those temperatures.

Sources

1. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." EUL Table. 2014. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx
2. Minnesota Department of Commerce Division of Energy Resources. "State of Minnesota Technical Reference Manual for Energy Conservation Improvement Programs." Version 1.3. http://mn.gov/commerce-stat/pdfs/trm-version-1.3.pdf
   Illinois Energy Efficiency Stakeholder Advisory Group. "Illinois Statewide Technical Reference Manual." http://www.ilsag.info/technical-reference-manual.html
   Federal Energy Management Program. *Demand-Controlled Ventilation Using CO2 Sensors*. March 2004. http://infohouse.p2ric.org/ref/43/42844.pdf

3. Average historic project cost for MMID 3651 completed under special offer for advanced rooftop unit controllers in 2015, plus historical project cost under MMID 3964 for projects completed in 2017 and January through March 2018 (35 applications for a total of 68 rooftop units; total of 1,500 tons). Note that no measures were completed under MMID 3650 for the advanced rooftop unit controller special offer, so that MMID was excluded.
4. Pacific Northwest National Laboratory. "Advanced Rooftop Control Retrofit: Field-Test Results." p. 1. July 2013. https://www.pnnl.gov/main/publications/external/technical_reports/pnnl-22656.pdf
5. Wisconsin Focus on Energy. "2018-Advanced RTU Controls.xltx"
6. National Renewable Energy Laboratory "National Solar Radiation Data Base, 1991- 2005 Update: Typical Meteorological Year 3." http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html
7. Cadmus. Summer 2017 Rooftop Unit Metering Study. Data maintained by Cadmus.

Revision History

Version Number	Date	Description of Change
01	11/2016	Initial TRM entry (measure was previously a special offer)
02	10/2017	Updated EUL
03	11/2018	Added electric heating savings

Demand Control Ventilation for Air Handling Units

Measure Master ID	Demand Control Ventilation for Air Handling Units, 2853
Measure Unit	Per CFM of outside air controlled
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Calculated
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Calculated
Lifecycle Energy Savings (kWh)	Calculated
Lifecycle Therm Savings (Therms)	Calculated
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$1.34/CFM[2]

Measure Description

Commercial spaces are required to provide ventilation based on a minimum flow rate of outside air, as calculated using the area of conditioned space and number of occupants. Standard systems are unable to measure the number of occupants and must default to a maximum occupancy based ventilation rate. Demand control ventilation measures that carbon dioxide is in the space as a proxy for occupants, and allows the occupant-based portion of ventilation to be reduced below the maximum, resulting in heating and cooling savings.

Description of Baseline Condition

The baseline equipment is a packaged, split, or built-up air handler with an economizer that does not provide ventilation during unoccupied operation. Heating is assumed to be provided by natural gas equipment with an operating efficiency of 80%. Cooling efficiencies are estimated at code requirements according to the table below.

Cooling Efficiency Code Requirements

IECC 2009 Table 503.2.3(1)	Minimum Efficiency
Standard AC Unit < 65 kBtu/h (5.42 tons)	13.0 SEER
Standard AC Unit ≥ 65 and < 135 kBtu/h (5.42 to 11.25 tons)	11.0 EER
Standard AC Unit ≥ 135 and < 239 KBtu/h (11.25 to 20 tons)	10.8 EER
Standard AC Unit ≥ 240 and < 759 kBtu/h (20 to 63.33 tons)	9.8 EER
Standard AC Unit ≥ 760 kBtu/h (63.33 tons)	9.5 EER

Description of Efficient Condition

The efficient equipment includes packaged, split, or built up air handlers that control outside air by monitoring carbon dioxide conditions in the space and adjusting ventilation to meet the occupancy based space requirement while not falling below the conditioned area requirement.

Annual Energy-Savings Algorithm

$$kWh_{SAVED} = (4.5 * CFM * \Delta h) * (EFLH_{COOL} * 12 / EER) * SF_{COOL} / 3{,}412 * (HOU/HOU_{COOL})$$

$$Therm_{SAVED} = (1.08 * CFM) * HOU * HDD / \eta / 100{,}000 * SF_{HEAT}$$

Where:

4.5 = Conversion factor for flow rate and specific volume of air for enthalpy based cooling calculation

CFM = Outside airflow in cubic feet per minute, provided by customer

Δh = Difference in enthalpy (Btu/lbm) between the design day outside air conditions and the return air conditions; lbm is pounds per mass.

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= varies by building type; see table below)[6]

12 = Conversion factor from EER to kW/ton

EER = Energy efficiency ratio of the existing equipment, assumed to be code (= varies by unit size; see table above)

SF_{COOL} = Deemed cooling savings factor (= varies by building type; see table below)[6]

3,412 = Conversion factor from Btu to kWh

HOU = Hours of operation per day, provided by customer

HOU_{COOL} = Default hours of operation per day used in $EFLH_{COOL}$ (= varies by building type; see table below)[6]

1.08 = Conversion factor for flow rate and specific volume of air for dry bulb heating calculation

HDD = Heating degree days (using base 65; = see table below)

η = Heating efficiency (= assumed to be 0.83)

SF_{HEAT} = Deemed heating savings factor (= varies by building type; see table below)[6]

Enthalpies, HDD, and Incremental Costs

	Design Cooling h (Btu/lbm)	Cooling Return h (Btu/lbm)	HDD
Weighted Wisconsin Average	32.15	28.86	7,616

Cooling and Heating Savings Factors and Equivalent Full-Load Hours by Building Type

Building Type	SF_{COOL}	SF_{HEAT}	$EFLH_{COOL}$	HOU_{COOL}
Food Sales	0.34	0.40	749	17.25
Food Service	0.34	0.40	578	11.50
Health Care	0.34	0.40	803	24.00
Hotel/Motel	0.15	0.18*	663	24.00
Office	0.15	0.18	578	11.50
Public Assembly	0.34	0.40	535	11.50
Public Services (non-food)	0.34	0.40	535	11.50
Retail	0.34	0.40	567	11.50
Warehouse	0.31	0.36	358	11.50
School	0.34	0.40	439	13.00
College	0.34	0.40	877	13.20
Other	0.15	0.18	589	11.50

* This value is applicable to common areas and conference rooms, but not to sleeping areas.

Summer Coincident Peak Savings Algorithm

There are no peak savings associated with this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

$EFLH_{COOL}$ data based on DOE2/EQuest building simulation. The prototype building models are based on the California DEER study prototypes, modified for local construction practices and code. Simulations were run using TMY3 weather data.

Assumed ventilation rates complied following the requirements of ASHRAE standard 62.1 - 2004.

Incremental costs include controls and programming, and assumes a similar cost between Direct Expansion and water-cooled equipment.

Savings assume a constant volume air system.

Savings assume existing economizer operation, and that economizer operation is given preference over a demand control ventilation strategy.

Assumes savings in hospitals and clinics is limited to areas without a code required ACH of fresh air.

Sources

1. 2013 Connecticut TRM. http://www.energizect.com/sites/default/files/2013%20PSD_ProgramSavingsDocumentation-Final110112.pdf
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 23 projects from 2017 to 2018.
3. "ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment."
4. Trane. "Psychometric Chart at Barometric Pressure 29.921 Inches of Mercury." and ASHRAE 2009 Fundamentals. Cooling DB/MCWB @ 0.4% averaged for state.
5. Franklin Energy Services. Assumed cooling setpoint of 74°F with 50% relative humidity and a 2°F temperature rise in the return plenum.
6. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3-2 Lighting Hours of Use in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
7. Franklin Energy Services. Calculated through energy modeling with certain building type square footage modified based on economizer operation hours. Savings limited to 40% based on professional experience due to concerns for negative building pressurization and minimum outside air requirements per square footage of occupied facility. Higher values may be obtained, requiring custom calculations.

Revision History

Version Number	Date	Description of Change
01	01/01/2013	Revised measure
02	12/2018	Updated incremental cost

Parking Garage Ventilation Controls

	Measure Details
Measure Master ID	Parking Garage Ventilation Controls, 3016 Parking Garage Ventilation Controls with Heating, 3493
Measure Unit	Per exhaust fan system
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Controls = 0 (MMID 3016), Controls with Heating = Varies (MMID 3493)
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	Controls = 0 (MMID 3016), Controls with Heating = Varies (MMID 3493)
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$827.88[2]

Measure Description

The proposed measure requires controlling ventilation airflow in enclosed parking garages based on carbon monoxide concentrations, while maintaining code required run hours.[3] By controlling airflow based on need rather than running it constantly, the system will save energy and maintain a safe environment. The measure with heating applies only to garages with heated exhaust air—not to heated garages in general, which generally meet space heating needs via separate unit heaters.

Description of Baseline Condition

The baseline condition is 24-hour garage exhaust fan operation.

Description of Efficient Condition

The efficient condition is garage exhaust fan(s) that are controlled by carbon monoxide sensor(s) with a minimum five hours of daily operation.[3]

Annual Energy-Savings Algorithm

$$kWh_{SAVED} = kWh_{BASE} - kWh_{EE}$$

$$kWh_{BASE} = hp_{FAN} * 0.746 * HOU_{BASE} * 365$$

$kWh_{EE} = hp_{FAN} * 0.746 * HOU_{EE} * 365$

$Therm_{SAVED} = Therm_{BASE} - Therm_{EE}$

$Therm_{BASE} = CFM * 1.08 * (T_{IN} - T_{OUT}) * HOU_{BASE} * DAY_{HEAT} / (100{,}000 * Eff)$

$Therm_{EE} = CFM * 1.08 * (T_{IN} - T_{OUT}) * HOU_{EE} * DAY_{HEAT} / (100{,}000 * Eff)$

Where:

kWh_{BASE} = Annual electricity consumption of baseline fan control system

kWh_{EE} = Annual electricity consumption of carbon monoxide fan control system

hp_{FAN} = Total horsepower of garage ventilation fan motor(s) (= user input)

0.746 = Kilowatts per horsepower

HOU_{EE} = Average daily exhaust fan run hours with carbon monoxide control system (= 7; see Assumptions)

365 = Days per year

$Therm_{BASE}$ = Annual natural gas consumption of baseline fan control system

$Therm_{EE}$ = Annual natural gas consumption of efficient fan control system

CFM = Airflow in cubic feet per minute of air handling unit (= user input)

1.08 = Sensible heat constant in Btu/hr-CFM-°F

T_{IN} = Makeup air setpoint temperature (= user input; if unknown use 50°F)

T_{OUT} = Average outdoor heating temperature (= varies by location; see Assumptions)

HOU_{BASE} = Daily run hours for base case (= 24)

DAY_{HEAT} = Average days per year requiring heat (= varies by location; see Assumptions)

100,000 = Conversion from Btu to therms

Eff = Heating efficiency (user input; if unknown use 80%)

Summer Coincident Peak Savings Algorithm

There are no coincident peak savings associated with this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = (kWh_{BASE} - kWh_{EE}) * EUL$

Where:

EUL = Effective useful life (= 5 years)[1]

Assumptions

General space heating needs for a heated garage are assumed to be met by separate unit heaters. The measure version with heating only applies to garages with heated makeup air. For these garages, the air is heated from the outside temperature to the makeup air setpoint.

It is assumed that the heating season for garages is from November 1 to March 31, and that heating only occurs when the outdoor temperature is under 50°F. Therefore, the average outdoor heating temperature is the average temperature below 50°F from November 1 to March 31 using TMY3 weather data[4] for the nearest city. Similarly, DAY_{HEAT} is the average number of days per year (hours / 24) meeting these conditions. The table below contains these values.

The average daily exhaust fan run hours with a carbon monoxide control system was set to seven hours to account for the five-hour minimum[3] plus additional carbon monoxide sensing run time based on engineering judgement.

The value for T_{IN} reflects the setpoint for the makeup air heat, if the makeup air is heated. This is a user input, but can be assumed to be 50°F if unknown.

Weather-Related Data by Location

City	DAY_{HEAT}[4]	T_{OUT}[4]	Weighting by Participant[5]
Green Bay	149.5	24.5°F	22%
La Crosse	146.6	25.5°F	3%
Madison	143.6	23.6°F	18%
Milwaukee	145.0	26.3°F	48%
Wisconsin Average	146.2	25.0°F	9%
Weighted Average	**145.9**	**25.3**	

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” Ventilation Controls Installed, p. 69. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 16 units over three projects from 2013 to 2014.
3. Wisconsin Legislature SPS 364.0404 - minimum enclosed garage ventilation. http://docs.legis.wisconsin.gov/code/admin_code/sps/safety_and_buildings_and_environment/361_366/364.pdf
4. National Renewable Energy Laboratory. “National Solar Radiation Data Base, 1991-2005 Update: Typical Meteorological Year 3.” https://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html
5. Cadmus. *Focus on Evaluated Energy Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

Revision History

Version Number	Date	Description of Change
01	12/31/2012	Initial TRM entry
02	10/11/2018	Added MMID 3493 for heated garages, updated algorithm

Unit Heaters, ≥ 90% Thermal Efficiency

	Measure Details
Measure Master ID	Unit Heater, ≥ 90% Thermal Efficiency, Heating: Setpoint = 70°F, 4753 Setpoint = 65°F, 4754 Setpoint = 60°F, 4755 Setpoint = 55°F, 4756 Unit Heater, ≥ 90% Thermal Efficiency, Heating, Propane-Fueled: Setpoint = 70°F, 4878 Setpoint = 65°F, 4879 Setpoint = 60°F, 4880 Setpoint = 55°F, 4881
Measure Unit	Per MBh input capacity
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Unit Heater
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies
Annual Propane Savings (Gallons)	Varies
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies
Lifecycle Propane Savings (Gallons)	Varies
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$15.56[2]

Measure Description

Condensing natural gas– or propane-fired unit heaters with at least 90% thermal efficiency have higher thermal efficiencies than heaters with code-minimum efficiency and save energy by consuming less fuel.

Description of Baseline Condition

The baseline equipment is assumed to be any non-condensing unit heater with a thermal efficiency of 80%. The standard measures must be used when replacing a natural gas–fired heater. The propane measures must be used when replacing a fuel oil- or propane-fired heater.

Description of Efficient Condition

Qualified units must be condensing natural gas– or propane-fired unit heaters, with capacities up to 300 MBh and thermal efficiency of at least 90%. Higher efficiencies are achieved by passing the flue gas through a secondary heat exchanger to extract more heat.

Annual Energy-Savings Algorithm

$\text{Gas}_{\text{SAVED}} = \text{CAP}_{\text{EE}} * \text{LF} * (\text{Eff}_{\text{EE}} / \text{Eff}_{\text{BASE}} - 1) * \text{EFLH}_{\text{HEAT}} / \text{ConvF}$

Where:

$\text{Gas}_{\text{SAVED}}$ = Therms of natural gas or gallons of propane saved

CAP_{EE} = Efficient unit heater input capacity in MBh (= user input)

LF = Load factor (= 0.7245; see Assumptions)

Eff_{EE} = Thermal efficiency of new unit heaters (= 0.90)

Eff_{BASE} = Thermal efficiency of baseline unit heaters (= 0.80)[3]

$\text{EFLH}_{\text{HEAT}}$ = 24 * HDD / ΔT in hours

Where:

24 = Conversion factor from days to hours

HDD = Heating degree days (= varies by balance point inside temperature; see Assumptions)

ΔT = $\text{T}_{\text{INSIDE}} - (\text{T}_{\text{OUTSIDE}} + \text{T}_{\text{DR}} / 2)$

Where:

T_{INSIDE} = Design balance point inside temperature (= varies with internal loads; see Assumptions)

$\text{T}_{\text{OUTSIDE}}$ = Design outside temperature (deemed; = -15°F)[4]

T_{DR} = Average winter diurnal temperature range (= 18°F; see Assumptions)

ConvF = Fuel conversion factor (= 100 MBtu per therm, = 91.3 MBtu per gallon propane)[7]

There are no electrical savings for this measure.

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Gas_{LIFECYCLE} = Gas_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

The savings per MBh input is presented in the table below.

Gas Savings per MBh by Thermostat Setpoint

Thermostat Setpoint	Therms Savings per MBh Input		Gallons Propane Savings per MBh Input	
	Annual	Lifecycle	Annual	Lifecycle
$\geq$ 70°F	2.36	35.4	2.59	38.8
65°F	2.09	31.3	2.29	34.3
60°F	1.83	27.5	2.00	30.1
$\leq$ 55°F	1.58	23.6	1.73	25.9

Assumptions

Baseline equipment costs were obtained from an equipment supplier website[2] that sells non-condensing unit heaters from multiple manufacturers. Capacities ranged from 30 MBh to 400 MBh. The average baseline equipment cost was $7.08 per MBh for non-condensing unit heaters. Condensing unit heaters cost an average of $22.64 per MBh based on historical Focus on Energy project data from 2015 to June 2018. This resulted in an incremental cost of $15.56 per MBh input.

Heating degree days were calculated using temperature bin data (1-degree bins) from TMY3 weather files for 20 Wisconsin locations. This statewide bin dataset was created by averaging the hours for the 20 sites for each temperature bin.

To account for internal heat gains (lights, people, computers, machinery, etcetera), the base temperature for heating degree days was assumed to be 5°F below the thermostat setpoint.

The outside temperature associated with heating degree days is the average outside temperature for the day. The data in the table below show that during the winter in Wisconsin, the diurnal temperature range—the difference between the maximum temperature and the minimum temperature for the day—averages approximately 18 degrees.

Average Winter Diurnal Temperature in Wisconsin[6]

Location	Month	Temperature		
		Maximum	Minimum	Difference
Ashland	December	26.1	7.9	18.2
	January	22.1	0.1	22.0
	February	27.3	3.4	23.9
Green Bay	December	27.7	12.6	15.1
	January	22.8	5.7	17.1
	February	27.1	9.5	17.6
Madison	December	29.8	13.5	16.3
	January	24.8	7.2	17.6
	February	30.0	11.1	18.9
Medford	December	23.5	6.1	17.4
	January	19	-1.7	20.7
	February	24.6	1.2	23.4
Milwaukee	December	31.3	17.4	13.9
	January	26.1	11.7	14.4
	February	30.0	16.0	14.0
LaCrosse	December	28.0	12.6	15.4
	January	23.5	5.4	18.1
	February	29.7	10.0	19.7
Average				**18.0**

The design outside temperature associated with heating degree days is then -15°F + (18°F / 2) = -15°F + 9°F = -6°F.

The equivalent full-load heating hours are presented in the table below. A load factor of 0.7245 was selected, which brings the produces an overall $\text{EFLH}_{\text{HEAT}}$ of 1,890 hours at a 70°F setpoint. This is consistent with the average commercial $\text{EFLH}_{\text{HEAT}}$ used elsewhere in this technical manual.

Equivalent Full-Load Heating Hours by Thermostat Setpoint

Thermostat Setpoint Temperature	HDD Base Temperature, T_{INSIDE}	ΔT	HDD	$\text{EFLH}_{\text{HEAT}}$	$\text{EFLH}_{\text{HEAT}}$ * LF
70°F	65°F	77°F	7,718	2,609	1,890
65°F	60°F	66°F	6,342	2,306	1,671
60°F	55°F	61°F	5,136	2,021	1,464
55°F	50°F	56°F	4,058	1,739	1,260

This entry includes measures for natural gas–fired equipment eligible to both natural gas and propane customers. The Code of Federal Regulations,[8] upon which federal efficiency standards are based, defines *gas* as either natural gas or propane (§430.2 for consumer appliances, and §431.2 for commercial and industrial equipment). Thus, it is assumed that equipment efficiencies, costs, etcetera are equal for both fuel types. Any infrastructure or maintenance costs unique to each particular fuel were ignored.

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Historical Focus on Energy project data. 2015 to June 2018.
   For 29 projects and 100 total unit heaters, the average unit heater cost is $22.64/MBh, less the baseline unit heater cost of $7.08/MBh from review of www.supplyhouse.com pricing (Accessed June 2018) for Reznor and Modine unit heaters. See 2018 Focus on Energy *Incremental Measure Cost* study for details.
3. International Code Council. *2015 International Energy Conservation Code*. Table 403.2.3(4). https://codes.iccsafe.org/public/document/IECC2015/chapter-4-ce-commercial-energy-efficiency
4. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Section 3.4, p. 3–14. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. U.S. Energy Information Administration. "Energy Units and Calculators Explained." Accessed December 2018. https://www.eia.gov/energyexplained/?page=about_energy_units
6. Climatemps.com. Accessed May 2018. http://www.usa.climatemps.com/
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8. Electronic Code of Federal Regulations. §430-431. Accessed February 2019. https://www.ecfr.gov/cgi-bin/text-idx?gp=&SID=92c3f99c51e1124fcc790d11c93e04af&mc=true&tpl=/ecfrbrowse/Title10/10CIIsubchapD.tpl

Revision History

Version Number	Date	Description of Change
01	10/10/2018	Initial TRM entry
02	3/2018	Added propane measures

Infrared Heating Units, High or Low Intensity

	Measure Details
Measure Master ID	Infrared Heating Units, High or Low Intensity, 2422
Measure Unit	Per MBh
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Infrared Heater
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	1.06
Lifecycle Electricity Savings (kWh)	0
Lifecycle Therm Savings (Therms)	15.90
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$15.56[2]

Measure Description

This measure applies to natural gas–fired high- and low-intensity infrared heaters with an electronic ignition that uses non-conditioned air for combustion.

Description of Baseline Condition

The baseline condition is a natural gas–fired unit heater with a code minimum thermal efficiency of 80%. Air in rooms with high ceilings is often stratified. Air near the roof is many degrees warmer than air at the thermostat level, so more heat is lost through roof conduction in rooms with stratified air than in rooms where the air is not as stratified.

Description of Efficient Condition

The efficient condition is a natural gas–fired infrared radiant heater with electronic ignition that uses non-conditioned air for combustion. Energy is saved in three possible ways:

1. First, radiant heat provides the same level of comfort at lower air temperatures than non-radiant systems, so the thermostat is set lower and conduction heat transfer is lower.
2. Secondly, the radiant heat warms up the floor of a room which destratifies the air, so compared to non-radiant systems the air near the ceiling is cooler and conduction heat transfer through the roof is lower.
3. Third, the thermal efficiency of the radiant heater may be slightly higher than the thermal efficiency of the baseline unit heater.

Both high- and low-intensity units qualify.

Annual Energy-Savings Algorithm

$Therm_{SAVED} = Therm_{BASE} - Therm_{EE}$

$Therm_{BASE} = LF * (1{,}000 * Cap) * EFLH_{HEAT} * (T_{CEILING,BASE} – T_{OUTSIDE}) / [100{,}000 * Eff_{BASE} * (T_{INSIDE,BASE} – T_{OUTSIDE})]$

$Therm_{EE} = LF * (1{,}000 * Cap) * EFLH_{HEAT} * (T_{CEILING,EE} – T_{OUTSIDE}) / [100{,}000 * Eff_{EE} * (T_{INSIDE,EE} – T_{OUTSIDE})]$

Where:

LF = Load factor (= 0.77)[3]
Cap = Input capacity for new infrared radiant heater in MBh (= user input)
$EFLH_{HEAT}$ = Equivalent full-load heating hours (= 1,890; see Assumptions)
$T_{CEILING,BASE}$ = Inside air temperature near the ceiling with the baseline unit heater (= 75°F; see Assumptions)
$T_{OUTSIDE}$ = Design outside temperature (= -15°F)[3]
100,000 = Btu to therms conversion factor
Eff_{BASE} = Efficiency of baseline unit heater (= 0.80)[4]
$T_{INSIDE,BASE}$ = Inside air temperature, which is the thermostat setpoint, with the baseline unit heater (= 65°F; see Assumptions)
$T_{CEILING,EE}$ = Inside air temperature near the ceiling with the infrared radiant heater (= 65°F; see Assumptions)
Eff_{EE} = Efficiency of infrared radiant heater (= 0.80)[4]
$T_{INSIDE,EE}$ = Inside air temperature, which is the thermostat setpoint, with the infrared radiant heater (= 60°F; see Assumptions)

There are no electrical savings for this measure.

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak demand savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

The inside air temperature at the ceiling is assumed to be in contact with a majority of the building envelope, except the middle and lower sections of walls. This lower wall area is assumed to be small relative to the area of the roof and higher parts of walls.

The building envelope R-value and area are not explicitly in the savings calculation because the heater capacity is assumed to be sized for the envelope insulation and envelope area of the space being heated.

The inside air temperature near the roof is assumed to be 10°F warmer than the air at the thermostat in the baseline condition and is assumed to be 5°F warmer with the infrared heater, based on measured stratified temperatures with a 25-foot ceiling.[5]

The calculation methodology for this measure assumes, based on engineering judgment, that the space thermostat setpoint can be lowered by 5°F while maintaining occupant comfort levels.

Since the thermostat setting can be lower with an infrared heater, the heat load calculation with a lower inside temperature would result in a slightly smaller heater. However, this size difference is negligible. If the infrared radiant heater is sized for an inside design temperature of 60°F and the equivalent baseline heater is sized for an inside design temperature of 65°F, the baseline unit heater would be larger by 7% [(65° - -15°) / (60° - -15°) = 80 / 75 = 1.0667]

No electrical savings are claimed because the combustion air fans in the infrared radiant heaters have roughly equivalent power to the propeller fans in the baseline unit heaters. This is based on data from four infrared heater manufacturers (Modine, Reznor, Space-ray, and Schwank) and three unit heater manufacturers (Modine, Reznor, and Trane) in April 2018. Any difference is negligible.

The impact of whether most of the heating load is from infiltration versus conduction was considered. The savings for 100% infiltration was 7% larger than for 100% conduction. This difference is negligible. Even though the algorithm uses the conduction formula, the results are applicable to a system with no envelope exposure and sized for infiltration. The inputs for this comparison are shown in the table below.

Assumptions for Comparing Infiltration and Conduction

Value	Baseline	Proposed
Heater Efficiency	80%	80%
Inside Design Temperature	70°F	65°F
Balance Point Temperature	65°F	65°F
Ceiling Temperature	80°F	70°F

Data for determining the equivalent full-load heating hours are presented in the table below.

Supporting Inputs for Equivalent Full-Load Heating Hours by City for Business[6]

Location	$EFLH_{HEAT}$	Weighting by Participant
Green Bay	1,852	22%
Lacrosse	1,966	3%
Madison	1,934	18%
Milwaukee	1,883	48%
Wisconsin Average	1,909	9%
Weighted Average	**1,890**	**100%**

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” Appendix B. August 25, 2009.
   https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Historical Focus on Energy project data. 2016 to June 2018.
   Eighty-nine projects, 262 total unit heaters. Average unit heater cost is $22.64/MBh, minus the baseline unit heater cost of $7.08/MBh (based on a review of www.supplyhouse.com pricing, accessed June 2018, for Reznor and Modine unit heaters. See the 2018 Focus on Energy *Incremental Measure Cost* study for details.
3. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0. p. 4-12 for load factor, p. 4-133 for outside design temperature. March 22, 2010.
   https://www.focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
   Similar to MMIDs 2744, 3277, 4058, and 4659.

4. International Code Council. *2015 International Energy Conservation Code*. Table 403.2.3(4). https://codes.iccsafe.org/public/document/IECC2015/chapter-4-ce-commercial-energy-efficiency
5. Kosar, Doug. "1026: Destratification Fans – Public Project Report." Nicor Gas, Emerging Technology Program. October 6, 2014.https://www.nicorgasrebates.com/-/media/Files/NGR/PDFs/ETP/1026%20Thermal%20Equalizer%20Destratification%20Fans%20Public%20Project%20Report%20APPROVED%20FINAL%20to%20Nicor%20Gas%2010062014%20REV%202.pdf
6. Several Cadmus metering studies reveal that the ENERGY STAR EFLHs calculator are overestimated by 25%. $EFLH_{HEAT}$ was adjusted by population-weighted heating degree days and TMY3 values.

Revision History

Version Number	Date	Description of Change
01	10/10/2018	Initial TRM entry

Smart Thermostats and Communicating Thermostats for Business

	Measure Details
Measure Master ID	Smart Thermostat: Natural Gas Boiler, 4375 Natural Gas Furnace with AC, 4376 Natural Gas Rooftop Unit, 4377 Communicating Thermostat: Natural Gas Boiler, 4372 Natural Gas Furnace with AC, 4373 Natural Gas Rooftop Unit with AC, 4374
Measure Unit	Per MBh for MMIDs 4372 and 4375 Per thermostat for MMIDs 4373, 4374, 4376, and 4377
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies
Lifecycle Electricity Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	Varies
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	Smart thermostats = $173.89 (MMIDs 4375–4377)[2] Communicating thermostats = $90.89 (MMIDs 4372–4374)[3]

Measure Description

Standard programmable thermostats allow customers to adjust temperature setpoints at different times of the day, changing temperatures during unoccupied periods to allow for energy savings. Communicating thermostats provide this base level of functionality but can be programmed remotely through Wi-Fi. Compared to standard programmable thermostats, smart thermostats provide enhanced functionality:

- More simple use and programming, both on the thermostat and remotely via smartphone apps and web portals
- Occupancy sensing that enables energy savings from automatic setbacks during unoccupied periods (occupancy sensing may use sensors in the thermostat or a smartphone app's capability to track the resident's location)

- Learning capability or automatic schedule generation or modification by dynamically adjusting or constructing a program schedule based on actual occupancy patterns, eliminating the need for programming
- Intelligent control of HVAC equipment, including minimizing the amount of energy expended for recovery from setback, intelligent control of two-stage HVAC sources, and minimizing the use of inefficient electric-resistance heat associated with most heat pumps
- Use of outside temperature and other weather data to better ensure comfort and minimize energy use
- Encourage the use of more energy-efficient set temperatures, such as a leaf icon that appears when the set temperature is moved in the direction of less energy use
- Algorithms that make frequent, subtle set temperature changes to save energy

Description of Baseline Condition

The baseline condition is a manual or standard programmable thermostat installed in a business with a natural gas furnace with air conditioning, natural gas rooftop unit with air conditioning, or natural gas boiler (no cooling).

Description of Efficient Condition

The efficient condition is a smart or communicating thermostat installed in a small business to replace the existing thermostat.

To qualify as *communicating*, the thermostat must be Wi-Fi capable (with the Wi-Fi connection established by the customer), but not certified as an ENERGY STAR Connected Thermostat, and not included as a qualifying smart thermostat measure prior to 2018.

To qualify as *smart*, the thermostat must be certified as an ENERGY STAR Connected Thermostat or be included on the Focus on Energy business smart thermostat qualified products list, which requires the thermostat to have occupancy sensing, learning capability, or other features above and beyond Wi-Fi connectivity, as outlined in the Measure Description section. The Focus on Energy qualified products list serves as an alternate to ENERGY STAR, since the list of ENERGY STAR-qualified thermostats only includes 26 models from eight manufacturers (as of May 2, 2018).

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}} = \text{EFLH}_{\text{HEAT}} * \text{CAP}_{\text{HEAT}} / (\text{EFF}_{\text{HEAT}} * 100) * \text{ESF}_{\text{HEAT}}$

$\text{kWh}_{\text{SAVED}} = \text{EFLH}_{\text{COOL}} * \text{CAP}_{\text{COOL}} / \text{EFF}_{\text{COOL}} * \text{RLF}_{\text{COOL}} * \text{ESF}_{\text{COOL}}$

Where:

$\text{EFLH}_{\text{HEAT}}$ = Equivalent full-load heating hours (= 1,890 average for Wisconsin commercial buildings, see table below)

Equivalent Full-Load Heating Hours by City

Location	$\text{EFLH}_{\text{HEAT}}$[9]	Weighting by Participant
Green Bay	1,852	22%
Lacrosse	1,966	3%
Madison	1,934	18%
Milwaukee	1,883	48%
Wisconsin Average	1,909	9%
Weighted Average	**1,890**	**100%**

CAP_{HEAT} = Heating system capacity (= user input for boilers; see Heating Capacity Info table in Assumptions for furnaces and rooftop units)

EFF_{HEAT} = Efficiency of the heating system (= 89.6% for furnaces, = 80.3% for rooftop units, = 85.5% for boilers; see Efficiency Info table in Assumptions)

100 = Conversion factor from MBh to therms

ESF_{HEAT} = Heating energy savings fraction (for smart thermostats: = 4.6% for furnaces and rooftop units and = 5.0% for boilers; for communicating thermostats: = 2.8% for furnaces and rooftop units and = 3.0% for boilers, see Assumptions)

$\text{EFLH}_{\text{COOL}}$ = Equivalent full-load cooling hours (= 599 average for Wisconsin commercial buildings, see table below)

Equivalent Full-Load Cooling Hours by Building Type

Building Type	$EFLH_{COOL}$[10]
College	877
Food Sales	749
Food Service	578
Healthcare	803
Hotel/Motel	663
Industrial	519
Office	578
Other	589
Public Assembly	535
Public Services (non-food)	535
Retail	567
School	439
Warehouse	358
Average	**599**

CAP_{COOL} = Cooling system capacity in MBh (= see Cooling Capacity Info table in Assumptions section)

EFF_{COOL} = Cooling system efficiency (= 0 for boilers, = 13 SEER for furnaces with AC,[8] = 11.4 EER for rooftop units;[6] see Efficiency Info table in Assumptions)

RLF_{COOL} = Rated load factor for cooling; the peak cooling load/nameplate capacity. This factor compensates for oversizing the air conditioning unit (= 0.90 for rooftop units, see Assumptions; = 1.0 for all other)

ESF_{COOL} = Cooling energy savings fraction (= 20.5% for smart thermostats, = 12.4% for communicating thermostats, see Assumptions)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure. It is assumed that businesses will be occupied during this time, and therefore no programmed or automatic setbacks will be occurring.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Annual and Lifecycle Savings by Measure

Measure	MMID	Peak kW	Annual kWh	Lifecycle kWh	Annual therms	Lifecycle therms	Unit
Smart Thermostat, Business Heated by							
Natural Gas Boiler	4375	0	0	0	1.105	11.05	per MBh controlled
Natural Gas Furnace with AC	4376	0	418	4,180	84	840	per smart thermostat
Natural Gas Rooftop Unit	4377	0	1,417	14,170	184	1,840	
Communicating Thermostat, Business Heated by							
Natural Gas Boiler	4372	0	0	0	0.66	6.60	per MBh controlled
Natural Gas Furnace with AC	4373	0	253	2,530	51	510	per smart thermostat
Natural Gas Rooftop Unit with AC	4374	0	857	8,570	112	1,120	

Assumptions

It is difficult to conduct billing analyses to derive advanced thermostat savings for commercial populations, and there is currently not a single standard method for calculating such savings. A 2017 examination of seven other programs (in Illinois, Iowa, Massachusetts, Minnesota, Montana, New York, and Rhode Island) reveals an array of approaches, but many of these programs employ savings fractions or fixed savings values derived from proprietary sources, and many use approaches or savings values that are not ideal for the Focus on Energy program. The New York program[11] simply applies the same savings fractions for commercial and residential thermostats. There are many reasons that savings fractions for residential and commercial thermostats may be different, such as different occupancy behavior, different manual and programmable setback practices, and different communicating and smart setback practices. However, with a lack of valid alternatives, this workpaper used the approach of the New York program.

For the 2016 Focus on Energy evaluation, Cadmus conducted a billing analysis to examine savings for participants who installed smart thermostats as part of MMIDs 3609, 3610, and 3611 (updated to MMIDs 4301, 4302, and 4303). The 2016 *Focus on Energy Evaluation Report*[12] discusses these findings, and results from that billing analysis are analyzed further in the updated workpaper for these MMIDs. This study did not examine communicating thermostats, but it did produce savings factors for smart thermostats, as described in the workpaper for MMIDs 4301, 4302, and 4303.

Values for energy savings factors for communicating thermostats were derived by extrapolating data from the Minnesota TRM.[13] This TRM finds a heating and cooling energy savings factor of 5.4% for communicating thermostats and of 8.9% for smart thermostats. Therefore, this TRM shows that energy savings factors for communicating thermostats are 60.7% of those for smart thermostats. That ratio was applied to the energy savings factors for communicating thermostats in this workpaper, using the energy savings factors for smart thermostats found from the 2016 Cadmus billing analysis. Details are shown in the table below.

Energy Savings Factors

Parameter	Thermostat Type	Furnace	Boiler
ESF_{THERM}	Smart	4.6%	5.0%
	Communicating	2.8%	3.0%
ESF_{COOL}	Smart	20.5%	20.5%
	Communicating	12.4%	12.4%
ESF_{HEAT}	Smart	14.2%	N/A
	Communicating	8.6%	N/A

Rooftop unit energy savings factors are assumed to match furnace energy savings factors.

The heating and cooling efficiencies for each measure were obtained from *Potential Study* data,[6] which was from site visits to retail, restaurant, school, and small offices. Average efficiencies and site counts for each type of system are presented in the table below.

Efficiency Info

Parameter	System	Sites	Average Value
EFF_{HEAT}	Boilers	43	85.5%
	Furnaces	37	89.6%
	Rooftop Units	121	80.3%
EFF_{COOL}	Rooftop Units	68	11.4 SEER

The cooling capacities for the furnace and rooftop unit measures were obtained by examining system sizes for an existing measure in historical project data.[4] Results from this examination are shown in the table below. A default value of 0.90 was assumed for the rated load factor for rooftop unit cooling consumption, which aligns with MMIDs 4368 through 4371 for split systems greater than or equal to 5.42 tons.

Cooling Capacity Info

HVAC System	MMID	MMID of Measure Used to Derive Capacity	Programs Examined	Number of Projects	Average Cooling Capacity (MBh)
Furnace	4376	3022 (business AC split system)	BIP, CSF (≤ 5.4 tons)	141	44.3
Rooftop Unit	4377		BIP, CSF (> 5.4 tons, ≤ 20 tons)	151	146.2

The heating capacities for furnaces were also obtained by analyzing project data from other measures.[4] Heating capacity for rooftop units was obtained by examining common heating sizes matched to a cooling capacity of 146.2 MBh for three manufacturers.[5] Findings are presented in the table below.

Heating Capacity Info

HVAC System	MMID	MMIDs/Measures Used to Derive Capacity	Programs Examined	Number of Projects	Average Heating Capacity (MBh)
Boiler	4375	Boilers may have multiple zones, with each zone controlled by an individual thermostat			User input for MBh controlled by thermostat
Furnace	4376	3491, 3492 (furnaces ranging from 39 to 331 MBh)	Commercial, Agriculture, Industrial, Schools & Government (includes new construction for each)	268	87
Rooftop Unit	4377	Analysis of three rooftop unit manufacturers to determine heating MBh for 146.2 MBh cooling capacity rooftop unit			170

Sources

1. GDS Associates. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*. Table 1, HVAC Controls. June 2007. http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. July 1, 2017 through December 1, 2017. Average cost of 2,585 smart thermostat projects (MMIDs 3609, 3610, and 3611). Minus the cost of a manual thermostat, which is $39.11 based on online lookups from July 2018.

3. Online retail research, February 2017. Average cost of communicating thermostats is $130. Minus the cost of a manual thermostat, which is $39.11 based on online lookups from July 2018.
4. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. January 1, 2016 through October 31, 2017.
5. Trane, model YH*150G3,4,W – 12.5 ton cooling capacity, 150 MBh heating capacity
   Carrier, model 48HCDD14 – 12.5 ton cooling capacity, 180 MBh heating capacity
   Johnson Controls, model J12ZF – 12.5 ton cooling capacity, 180 MBh heating capacity
   Average heating capacity of 170 MBh.
6. Cadmus. *2016 Potential Study for Focus on Energy.* Data maintained by Cadmus and Public Service Commission of Wisconsin. Commercial site visits from the summer of 2016 to retail, restaurant, and small office sites.
7. International Energy Conservation Code. Table 503.2.3(4). 2009.
8. Appliance Standards Awareness Project. “Central Air Conditioners and Heat Pumps.” http://www.appliance-standards.org/product/central-air-conditioners-and-heat-pumps
9. Several Cadmus metering studies reveal that the ENERGY STAR calculator EFLH are over-estimated by 25%. The $EFLH_{HEAT}$ were adjusted by population-weighted HDD and TMY3 values.
10. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” June 2, 2008. http://www.deeresources.com/
    DEER model runs that were weather normalized for statewide use by population density.
11. New York State Department of Public Service. *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs, Version 4*. April 29, 2016. http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/72c23decff52920a85257f1100671bdd/$FILE/ATTESQKL.pdf/TRM%20-%20Version%204.0-April%202016.pdf
12. Cadmus. *Focus on Energy Calendar Year 2016 Evaluation Report, Volume II*. May 19, 2017. https://focusonenergy.com/sites/default/files/WI%20FOE%20CY%202016%20Volume%20II%20-%20%28Low%20Res%29.pdf
13. Minnesota Department of Commerce, Division of Energy Resources. *State of Minnesota Technical Reference Manual for Energy Conservation Improvement Programs, Version 2.0*. April 2016. http://mn.gov/commerce-stat/pdfs/mn-trm-v2.0-041616.pdf

Revision History

Version Number	Date	Description of Change
01	05/02/2018	Initial TRM entry
02	12/2018	Added communicating thermostats, updated costs

Surgery Occupancy, HVAC Controls

	Measure Details
Measure Master ID	HVAC Controls, Surgery Occupancy, 3632
Measure Unit	Per upgrade
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Commercial, Schools & Government
Annual Energy Savings (kWh)	Varies by type of savings
Peak Demand Reduction (kW)	Varies by type of savings
Annual Therm Savings (Therms)	Varies by type of savings
Lifecycle Energy Savings (kWh)	Varies by type of savings
Lifecycle Therm Savings (Therms)	Varies by type of savings
Water Savings (gal/year)	0
Effective Useful Life (years)	5[7]
Incremental Cost ($/unit)	$5,500.00[6]

Measure Description

The savings expected to be realized in the business commercial sector, specifically within hospital air handlers serving surgery spaces. These air handlers currently operate continuously at a minimum of 20 Air Changes per Hour (ACH), and 4 ACH of outside air. After Building Automation Systems are upgraded to an extended architecture, the capability to reduce airflow to operating rooms when unoccupied may be obtained. However, space pressure relationships between an operating room and adjoining spaces are critical and steps must be taken to prevent an operating room from having negative pressure when airflow is reduced. Typically, these steps involve installing additional equipment on the return and/or supply ductwork serving the operating room. Once the equipment and controls changes have been made, an airflow reduction to 6 ACH, 1.6 ACH OA is feasible. The cost of these upgrades varies widely, depending on the existing equipment. However, if a base system of building automation system is present, the additional controls and possible VFD cost is within expected program range of one to 10 years.

Description of Baseline Condition

Baseline equipment includes an air handler with Supply/Return fans served by Variable Speed Drives, chilled water cooling coils, hot water heating coils, and economizer operation. Cooling energy is provided by a chilled water loop, typically served by a chiller paired with a cooling tower. Heating energy is provided by a hot water loop, typically served by an atmospheric boiler.

Air handlers typically serve multiple spaces, so the portion of air flow and supply/return fan horsepower energy that should be attributed to the surgery rooms is calculated by the following inputs:

- Number of surgery rooms
- Total square footage of surgery rooms
- Total square footage of non-surgery rooms served by associated AHU
- Average volume of rooms
- Reheat Type, Natural Gas or Electric
- Existing air changes per hour
- Surgery room temperature and humidity requirements during occupied and unoccupied modes
- Estimated schedule of unoccupied controls to be implemented (e.g. 6pm to 6am, 7 days/week)
- Surgery Room space pressure setpoint relative to adjacent spaces
- Proposed Control Strategy Type (described in description of efficient condition)

Based on these inputs, a baseline condition of Supply CFM, OA CFM, and Fan Power kW is calculated. CFM calculations are based on the size of the room and assumptions of 20 ACH Supply, 4 ACH OA Supply. Fan power is calculated as CFM*Static Pressure/(6,356*Total Fan Efficiency).

With these calculated values, BIN Data and typical AHU setpoints are used to calculate savings on cooling kWh, heating therms, reheat therms, and fan kWh. Assumptions are used for Cooling kW/Ton, Boiler efficiency, Return Air Temperature, Supply Air Temperature, Fan efficiency, fan static pressure, and return/exhaust fan load relative to supply fan.

Description of Efficient Condition

The Efficient Condition allows for operation in a similar manner to the proposed condition, except the total supply CFM has been reduced to 6 ACH with proportional OA cfm reduction. The Efficient Condition is expected to operate as one of the three possible controls strategies:

- A two-position (min/max) variable air volume (VAV) box is installed on the supply air source. Supply airflow is controlled to setpoint. Shut-off dampers are installed in the return ductwork equal to the amount of the setback volume. The VAV box and dampers are balanced to the maximum and minimum volumes for occupied and unoccupied modes. When the VAV box switches to the unoccupied mode, the return dampers (controlling the setback volume) close.
- Pressure-independent valves are placed on the supply and return ductwork (and potentially on ductwork serving surrounding spaces). The supply airflow is controlled to setpoint. The valves, calibrated to the maximum and minimum volumes for occupied and unoccupied modes, maintain the desired offset.

- A modulating control dampers is installed in the return duct and controlled by a room pressure sensor. The damper modulates to maintain a positive relative room pressure during both occupied and unoccupied modes. A standard terminal box controls the supply airflow to setpoint for each sequence.

Annual Energy-Savings Algorithm

Heating Load Savings (therms/year)

If bin data recorded is between schedule of unoccupied controls: (Total CFM Existing - Total CFM Proposed) * Sensible Heat Constant * (T_supply - T_MA)

Cooling Load Savings (kWh/year)

Total Energy Cooling Load of outside Air: (Outside Air CFM Existing-Outside Air CFM Proposed) * Total Heat Constant * (Enthalpy_OA - Enthalpy_DA)

Sensible Energy Cooling Load of Return Air: If T_OA > T_supply: (Return Air CFM Existing - Return Air CFM Proposed) * Sensible Heat Constant * (T_return - T_supply)

Fan Power Savings (kWh/year)

(Total Air CFM Existing - Total AIR CFM Proposed) * (Pressure_fan static / 6,356 / Efficiency_fan) * kW/bhp * RF + EF_Multiplier * hours/yr unoccupied

Reheat Savings (therms/year)

Sensible Heat Constant * (Total CFM Existing - Total CFM Proposed) * (T_VAV_Supply_Existing - T_VAV_Supply_Proposed) * (Total Hours - Occupied Hours)

Where:

Total CFM Existing = Actual total building airflow
Total CFM Proposed = Proposed total building airflow
Sensible Heat Constant = (lb/cubic feet air * Btu/lb air * minute/hour = 1.08
T_supply = Supply temperature of air handling unit (= 52°F)
T_MA = Mixed air temperature, calculated based on percentage of outside air vs. return air (based on ideal economizer schedule)
Outside Air CFM Existing = Actual outside air supply airflow
Outside Air CFM Proposed = Proposed outside air supply airflow
Total Heat Constant = (60 min/hr) / (density of standard air = 0.075) = 4.5

Enthalpy_OA = Enthalpy of outside air= [A * RH_OA + B (Curve fit equation to psych chart, accurate within 0.7% between 40°F ≤ T_OA ≤ 80°F)]

A = 0.007468 * DB^2 - 0.4344 * DB + 11.1769

RH_OA = Outside air relative humidity, TMY3 bin data B = 0.2372 * DB + 0.1230

Enthalpy_DA = Enthalpy of discharge air, 52°F at saturated conditions in 0-foot elevation (= 21.45)

Return Air CFM Existing = Actual return air supply airflow

Return Air CFM Proposed = Proposed return air supply airflow

T_return = Return temperature of air handling unit (= assumed 3°F above T_setpoint)

Total Air CFM Existing = Actual total airflow

Total Air CFM Proposed = Proposed total airflow

Pressure_fan static = Total static pressure of supply fan (= assumed 4 inches Water Gauge)

6,356 = Horsepower conversion factor

Efficiency_fan = Overall supply fan efficiency (= assumed 75, including fan, motor, and VFD efficiencies)

kW/bhp = Conversion from horsepower to watts (= 0.746)

RF+ EF_Multiplier = Total energy consumption of all fans is 175% of the energy consumption of just the supply fan. (= assumed 1.75)

hours/yr unoccupied = Unoccupied hours per year (=6,140)

T_VAV_Supply_Existing = Actual supply temperature of the air after passing through the VAV box

T_VAV_Supply_Proposed = Proposed supply temperature of the air after passing through the VAV box

Total Hours = Number of hours per year, per bin

Occupied Hours = Number of hours facility is occupied

Summer Coincident Peak Savings Algorithm

There are no peak savings from this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)

Sources

1. Grumman Butkus. “Greening the OR Symposium.” Presentation. September 11, 2014.
2. The American Society for Healthcare Engineering. Operating Room HVAC Setback Strategies. 2011. http://www.ashe.org/resources/management_monographs/pdfs/mg2011love.pdf
3. ANSI/ASHRAE/ASHE 170-2008 Ventilation of Healthcare Facilities
4. ASHRAE 90.1-2007 Energy Standard for Buildings Except Low-Rise Residential Buildings
5. ASHRAE 62.1-2007 Ventilation for Acceptable Indoor Air Quality
6. Historical Program Data- four similar projects done under other measure names

Historical Focus on Energy Surgery HVAC Projects

App ID	Project Cost	Square Footage
249844	$29,980.00	1,800
74147	$25,050.00	3,912
118592	$29,514.00	3,600
199725	$75,640.00	4,520

7. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
8. Roberts, John, B. Tso. "Do Savings from Retrocommissioning Last? Results from an Effective Useful Life Study." 2010 ACEEE Summer Study on Energy Efficiency in Buildings. (2010). http://aceee.org/files/proceedings/2010/data/papers/1990.pdf

Revision History

Version Number	Date	Description of Change
01	03/2015	Initial TRM entry
02	10/2017	Updated EUL

Energy Recovery Ventilator

	Measure Details
Measure Master ID	Energy Recovery Ventilator, 2314, 4521
Measure Unit	Per CFM
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Energy Recovery
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	72
Peak Demand Reduction (kW)	9.43
Annual Therm Savings (Therms)	13,576
Lifecycle Energy Savings (kWh)	1,080
Lifecycle Therm Savings (Therms)	203,640
Water Savings (gal/year)	0
Effective Useful Life (years)	15[3]
Incremental Cost ($/unit)	$6.63[4]

Measure Description

This measure is installing an Energy Recovery Ventilator (ERV) on an HVAC system that provides both heating and cooling to occupied space. ERV systems exchange heat (often both sensible heat and water vapor) between outgoing exhaust air and incoming ventilation air. Under appropriate conditions, this allows for reducing the capacity of the HVAC system, which creates energy savings. Heat and energy recovery wheels are the most commonly applied ERV systems.

Description of Baseline Condition

The baseline is determined from the facility operating hours, current heating/cooling equipment efficiencies, and ERV supply airflow CFM.

Description of Efficient Condition

The efficient condition is an ERV installed on the HVAC system. The system must both heat and cool the space, with minimum cooling hours from 1:00 p.m. to 4:00 p.m., June through August, and with heating occurring in the winter. In addition, the following specifications must be met:

- The leaving supply airflow matches AHRI standard 1060-2005.
- Equipment is AHRI certified to standard 1060-2005 and bear the AHRI certification symbol for the air-to-air recovery ventilation equipment certification program based on AHRI 106.
- Qualifying equipment is independently tested and reported per ASHRAE standard 84-1991.

Annual Energy-Savings Algorithm

Savings were calculated as the sum of iterations over the full range of temperatures (-30°F to 100°F), broken into five-degree intervals. The total savings account for the distribution of the number of hours for each temperature interval.

When in cooling, the savings for each temperature interval are calculated as:[1]

$$kWh_{SAVED} = \Sigma (\Delta kWh_{TEMP\text{-}INTERVAL})$$

$$\Delta kWh_{TEMP\text{-}INTERVAL} = [(1/\rho_{AIR} * 60 * V_{SUPPLY} * \eta_{HX\text{-}SUMMER} * (H_{OUT} - H_{RETURN}) / 12{,}000 * \eta_{COOLING}) - kW_{FAN}] * t_{TEMP\text{-}INTERVAL}$$

$$kW_{FAN} = V_{SUPPLY} * (\Delta P_{HX} + \Delta P_{OTHERS}) / (33{,}013 / 5.202) / \eta_{FANMECH.} / \eta_{FANMOTOR} * 0.746$$

When in heating, the savings for each temperature interval are calculated as:

$$Therm_{SAVED} = \Sigma (\Delta Therms_{TEMP\text{-}INTERVAL})$$

$$\Delta Therm_{TEMP\text{-}INTERVAL} = ((1.08 * V_{SUPPLY} * \eta_{HX\text{-}WINTER} * (T_{HEATED\ SPACE} - T_{OUTSIDE}) / 100{,}000) / \eta_{HEATING}) * t_{TEMP\text{-}INTERVAL}$$

Where:

$1/\rho_{AIR}$ = Specific volume of air (ρ_{AIR} = 0.075 lb/cubic foot at 1 atm and 68°F)
60 = Conversion factor from hours to minutes
V_{SUPPLY} = Volume of supply air (= actual; otherwise use default value of 7,200 CFM)
$\eta_{HX\text{-}SUMMER}$ = Efficiency of summer heat exchanger (= actual; otherwise use default value of 74%)
H_{OUT} = Enthalpy of outside air in Btu per pound, based on temperature interval
H_{RETURN} = Enthalpy of inside air at 75°F, 50% RH (= 28.3 Btu/lb)
12,000 = Conversion from Btu to tons (of cooling)
$\eta_{COOLING}$ = Efficiency of cooling system (= 1.20 kW/ton)
$t_{TEMP\text{-}INTERVAL}$ = Number of hours the system operates in the particular temperature interval
ΔP_{HX} = Pressure drop across the heat exchanger (= 0.29 inches of water)
ΔP_{OTHERS} = Pressure drop across the filter, louver, inlet, and outlet (= 0.80 inches of water)
33,013 = Conversion factor from horsepower to foot pounds per minute
5.202 = Conversion factor from inches of water to pounds per square foot

$\eta_{FANMECH}$ = Fan mechanical efficiency (= actual; otherwise use default value of 65%)

$\eta_{FANMOTOR}$ = Fan motor efficiency (= actual; otherwise use default value of 89.5% for 5 hp fan motor)

0.746 = Conversion factor from horsepower to kilowatts

1.08 = Conversion factor of pounds of air per hour multiplied by heat capacity of air in Btu per pound, which allows the enthalpy to be determined using the volumetric flowrate of air in CFM and the temperature difference

$\eta_{HX\text{-}WINTER}$ = Efficiency of summer heat exchanger (= actual; otherwise use default value of 73%)

$T_{HEATED\ SPACE}$ = Temperature inside heated space (= 68°F)

$T_{OUTSIDE}$ = Midpoint of the temperature interval outside in Fahrenheit, based on temperature interval

100,000 = Btu to therm conversion

$\eta_{HEATING}$ = Efficiency of heating system (= 85%)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / HOU_{COOLING}$

Where:

kWh_{SAVED} = Annual savings during cooling season, based on temperature interval (= 9,615 kWh)

$HOU_{COOLING}$ = Number of operating hours during cooling (= 1,258)[2]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[3]

Deemed Savings

Deemed Energy Savings by Heating or Cooling

	Annual Energy Savings	Peak Demand Reduction	Lifecycle Energy Savings
Yearlong	72 kWh	-	1,080 kWh
	13,576 therms	-	203,640 therms
Cooling	11,867 kWh	9.43 kW	178,005 kWh
	-	-	-
Heating	-11,795 kWh	-	176,925 kWh
	13,576 therms	-	203,640 therms

There are negative kWh savings from operating the fan (kWh_{FAN}); when the system is in heating mode, heating savings come from natural gas savings, whereas the electric energy use increases due to the kWh consumed by the fan. However, the overall Btu savings is net positive.

Assumptions

Deemed savings values were calculated for a system with a 7,200 CFM supply fan.

All the assumptions used in the savings calculations, as listed in the definition of terms, are from the Focus on Energy Program Energy Recovery Ventilator Calculation input.[1]

The weather intervals and corresponding operating hours in the following tables were used to calculate the deemed savings values.[2]

Weather Intervals and Corresponding Operating Hours

	Temperature Range (°F)	Range Midpoint (°F)	Hours Operating in Each Temperature Interval (hours)	Enthalpy (Btu/lb)
Cooling	95 to 100	97.5	4.18	42.12
	90 to 95	92.5	20.56	40.57
	85 to 90	87.5	70.72	39.45
	80 to 85	82.5	266.68	35.13
	75 to 80	77.5	421.24	32.40
	70 to 75	72.5	474.69	30.69
Heating	65 to 70	67.5	698.74	28.33
	60 to 65	62.5	877.28	25.22
	55 to 60	57.5	574.89	21.97
	50 to 55	52.5	642.02	19.17
	45 to 50	47.5	466.10	17.11

	Temperature Range (°F)	Range Midpoint (°F)	Hours Operating in Each Temperature Interval (hours)	Enthalpy (Btu/lb)
	40 to 45	42.5	639.90	15.06
	35 to 40	37.5	859.58	12.95
	30 to 35	32.5	730.96	10.99
	25 to 30	27.5	429.07	9.13
	20 to 25	22.5	507.80	7.61
	15 to 20	17.5	388.02	5.87
	10 to 15	12.5	229.07	4.04
	5 to 10	7.5	147.38	2.53
	0 to 5	2.5	95.69	1.30
	-5 to 0	-2.5	93.43	0.08
	-10 to -5	-7.5	79.95	-1.39
	-15 to -10	-12.5	27.69	-2.52
	-20 to -15	-17.5	9.57	-3.90
	-25 to -20	-22.5	3.49	-4.86
	-30 to -25	-27.5	1.31	-6.22

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Focus on Energy Program, Energy Recovery Ventilator Calculator prepared by Franklin Energy.
3. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
4. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 151 projects from 2016 to 2018.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	12/2018	Updated incremental cost

Agriculture High Volume Low Speed Fans

	Measure Details
Measure Master ID	Fans, High Volume Low Speed (HVLS), General, 3998
Measure Unit	Per foot, fan diameter
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Fan
Sector(s)	Agriculture
Annual Energy Savings (kWh)	815
Peak Demand Reduction (kW)	0.2110
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	12,225
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$51.48[2]

Measure Description

Keeping livestock cool during the summer months is an important factor in breeding, milk production, and general good health. Traditionally, farmers use several high-speed circulation fans (typically less than 54 inches in diameter) with a 1 hp to 1.5 hp motor per fan that move approximately 29,000 cubic feet of air per minute (CFM) to keep the livestock cool. High volume low speed (HVLS) fans with diameters of eight to 24 feet typically use 1 hp to 2 hp motors per fan and move between 140,000 CFM and 300,000 or more CFM.[3] HVLS fans between 16-feet and 24-feet are eligible for incentives.

Description of Baseline Condition

Dairy farms typically have a freestall barn with one or two rows of high speed fans per group of animals, where one row is along the feed alley blowing over the animals' backs and one row is over the cow beds in the center of the group. Usually, 48-inch to 50-inch high speed fans are installed every 30 feet to 40 feet. The baseline condition for other livestock barns is similar, in that multiple high-speed fans are placed to keep the animals cool.

Description of Efficient Condition

For dairy farms, a freestall barn would generally have one row of HVLS fans installed down the center of the barn over the feed alley to meet the air circulation needs of the barn livestock. The efficient condition for other types of livestock barns is similar, in that fewer HVLS fans will be installed compared to baseline to achieve the same or similar amount of circulating air flow.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{HIGH\ SPEED} - Watts_{HVLS}) / 1{,}000 * HOU$

Where:

$Watts_{HIGH\ SPEED}$ = Power consumption of baseline high speed fan system (= varies by fan diameter; see table below)

$Watts_{HVLS}$ = Power consumption of HVLS fan (= varies by fan diameter; see table below)

Default Values for High Speed and HVLS Fan Wattages

HVLS Fan Diameter Size	One HVLS Fan is Equivalent to 48-inch High Speed Circulation Fan[5]	$W_{HIGH\ SPEED}$*	W_{HVLS}[5]
16 feet	4.0	4,124	761
18 feet	4.5	4,640	850
20 feet	5.0	5,155	940
22 feet	5.5	5,670	940
24 feet	6.0	6,186	1,119

* A 48-inch diameter circulation fan average uses 1,031 watts.[4] Therefore, a 16-foot HVLS fan has a $W_{HIGH\ SPEED}$ equivalent to 4.0 * 1,031 watts = 4,124 watts.

1,000 = Kilowatt conversion factor

HOU = Average annual run hours (= 3,864)[6]

Deemed HVLS Fan kWh Savings

HVLS Fan Diameter Size	kWh_{SAVED}	kWh_{SAVED}/foot	Fan Size Distribution[2]
16 feet	12,995	812	5%
18 feet	14,645	814	5%
20 feet	16,287	814	53%
22 feet	18,277	831	2%
24 feet	19,579	816	35%
Weighted Average		**815 kWh_{SAVED}/foot**	

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{HIGH\ SPEED} - Watts_{HVLS}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= 1.0; see Assumptions)

Deemed HVLS Fan kW Savings

HVLS Fan Diameter Size	kW_{SAVED}	kW_{SAVED}/foot	Fan Size Distribution[2]
16 feet	3.3631	0.2102	5%
18 feet	3.7901	0.2106	5%
20 feet	4.2151	0.2108	53%
22 feet	4.7301	0.2150	2%
24 feet	5.0670	0.2111	35%
Weighted Average		**0.2110 kW_{SAVED}/foot**	

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

This measure is based on the assumption that HVLS fans have wider applications than just dairy barns, and that savings will be similar in other livestock barns such as those for poultry or swine. HVLS fans are most likely to be used in dairy barn applications based on Agriculture, Schools, and Government Program experience.

As the HVLS fan diameter increases, more 48-inch diameter circulation fans would be required to meet the same circulation needs of the facility (see the Default Values for High Speed and HVLS Fan Wattages table).

According to professional experience of program subject matter expert Terry Laube, farmers in Wisconsin typically turn their circulation fans on when it is 50°F or warmer to improve cow comfort. This HOU holds most true for dairy barn applications; however, the HOU rating is deemed reasonable to hold true for uses other than dairy barns, as well for control of animal comfort.

The fan size distribution was determined by analyzing historical program data from January 2012 through August 2016: it is estimated that the 22-foot fans will account for 2% of total, and that the newly eligible 16-foot and 18-foot fan options will account for 10% (5% each) of the total. Since the deemed savings is based on fan diameter foot, this is a conservative estimate. It is also estimated that the 20-foot and 24-foot fans will account for 53% and 35% of the total, respectively. These percentages were adjusted to reflect the historical split between the two fan sizes. Fan distribution will be re-evaluated in a couple of years and deemed savings will be adjusted as needed.

The coincidence factor equals 1.0, as all hours during the peak window are assumed to be above 50°F.

Sources

1. Cadmus. Database. March 2013.
   PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 17 units over eight projects from 2017 to 2018 is $332.36/foot. Base cost of $280.88 is also based on historical data, examining MMID 3768 (Circulation Fan, HS/HE, 48"-52", Ag), average cost of 122 units over 12 projects from 2016 to 2018 and normalizing per foot. Incremental cost is $332.36 - $280.88 = $51.48.
3. Kammel, D.W., M.E. Raabe, and J.J. Kappelman (University of Wisconsin-Madison). "Design of High Volume Low Speed Fan Supplemental Cooling System in Dairy Free Stall Barns." Accessed September 29, 2015. http://www.uwex.edu/energy/pubs/HVLSFreestallDesign.pdf
4. Bioenvironmental and Structural System Laboratory at The University of Illinois at Urbana-Champaign. "Fan Database." http://bess.illinois.edu/
5. KEMA. "2009 Evaluation of IPL Energy Efficiency Programs." Appendix H, Group I Programs, Volume 2. Tables H-16 and H-17. http://www.alliantenergy.com/wcm/groups/wcm_internet/@int/documents/document/mdaw/mtix/~edisp/121605.pdf
6. Appendix B: Common Variables, 'Outside Air Temperature Bin Analysis' average number of hours in Wisconsin at or above 50°F.

Revision History

Version Number	Date	Description of Change
01	10/01/2015	Initial TRM entry
02	10/01/2016	Changed measure unit from per fan to per fan diameter (foot) and updated deemed savings source
03	12/2018	Updated incremental cost

ECM HVAC Fan Motors

	Measure Details
Measure Master ID	ECM HVAC Fan Motors, Heating, 3910, 4625 ECM HVAC Fan Motors, Cooling, 3911, 4626 ECM HVAC Fan Motors, Occupied Ventilation, 3912, 4627 ECM HVAC Fan Motors, 24/7 Ventilation, 3913, 4628
Measure Unit	Per horsepower
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Motors and Drives
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	18[1,2]
Incremental Cost ($/unit)	$120.00 per motor[3]

Measure Description

This measure is for the installation of an electronically commutated motor (ECM) with ≥1 hp on air handling equipment such as exhaust fans, fan coil units, VAV boxes, and cabinet heaters. These are typically induction motors and are covered by NEMA standards. Residential type furnaces with an ECM are excluded from this measure, as they are covered by other measures (MMIDs 1981, 2764, 3491, and 3492). Single package vertical units for multifamily (MMIDs 3693, 3694) are also excluded.

Description of Baseline Condition

The baseline condition is an existing shaded pole (SP) or permanent split capacitor (PSC) motor that is 1 hp or less.

Description of Efficient Condition

The efficient condition is an ECM that is an equivalent size to the motor being replaced.

Annual Energy-Savings Algorithm

Savings are determined by converting the motor horsepower to kW, multiplying by inverse of the difference in motor efficiencies, and multiplying by the hours of use for the specific type of equipment.

This will allow a "units of measure" question to be used to enter the motor horsepower and generate accurate savings for the variety of motor sizes available for this technology.

$kWh_{SAVED} = hp * 0.746 * (1/Eff_{BASE} – 1/Eff_{EE}) * HOU$

Where:

hp = Horsepower of the motor being replaced (= customer provided)
0.746 = Conversion factor from horsepower to kW
Eff_{BASE} = Motor efficiency of baseline technology (= 36.25%)[3]
Eff_{EE} = Motor efficiency for the ECM (= 70.0%)[3]
HOU = Average annual hours of operation (= varies by motor application and sector; see table below)

Hours of Use by Fan Type and Sector

Fan Type	Sector	Hours of Use
Heating Fan[4]	All	2,285
Cooling Fan[4]	All	678
Occupied Ventilation	Commercial[5]	3,730
	Industrial[5]	4,745
	Agriculture[5]	4,698
	Schools and Government[5]	3,239
	Residential-Multifamily (common areas)[6]	5,950
24/7 Ventilation	All	8,760

Summer Coincident Peak Savings Algorithm

$kW_{SAVED}= hp * 0.746 * (1/Eff_{BASE} – 1/Eff_{EE}) * CF$

Where:

CF = Coincidence factor (= varies by fan type; see table below)

Coincidence Factor by Fan Type

Fan Type	Coincidence Factor
Heating Fan[7]	0.0
Cooling Fan[6]	0.8
Occupied Ventilation[8]	0.9
24/7 Ventilation[9]	1.0

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 18 years)[1,2]

Deemed Savings

For select standard fractional horsepower motors, the amount of savings from upgrading to an ECM are outlined in the following tables.

Demand Reduction by Fan Type

Baseline Horsepower	Proposed Horsepower	Heating Fan kW Reduced	Cooling Fan kW Reduced	Occupancy Vent kW Reduced	24/7 Vent kW Reduced
1.0	1.0	0.000	0.7938	0.8930	0.9922

Annual Energy Savings by Fan Type

Baseline hp	Proposed hp	Fan kWh Saved		Occupancy Vent kWh Saved					24/7 Vent kWh Saved
		Heating	Cooling	Comm	Indust	Ag	S&G	MF	
1.0	1.0	2,267	673	3,701	4,708	4,661	3,214	5,904	8,692

Lifecycle Energy Savings by Fan Type

Baseline hp	Proposed hp	Fan kWh Saved		Occupancy Vent kWh Saved					24/7 Vent kWh Saved
		Heating	Cooling	Comm	Indust	Ag	S&G	MF	
1.0	1.0	40,810	12,109	66,617	84,745	83,906	57,848	106,266	156,453

Assumptions

A 50%/50% average of SP efficiency (30%) and PSC efficiency (42.5%) was used for the baseline motor efficiency (i.e., 36.25%), based on engineering judgment. Program project data collection will include motor type and size, which will be used to adjust this assumption, if appropriate.

Heating fan includes cabinet heaters, unit heaters, and heating-only fan coil units.

Cooling fan includes cooling-only fan coil units.

Occupied ventilation includes any equipment that is normally on during occupied hours all year, regardless of season. This includes fan powered VAV boxes, fan coil units that provide both heating and cooling, and exhaust fans with timer controls to only run during occupied hours.

24/7 ventilation includes any items that run continuously year round. Typically this would be exhaust fans without controls, but may also include fan powered VAV boxes and fan coil units for facilities that operate 24/7.

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Sachs, Harvey and S. Smith. "Saving Energy with Efficient Residential Furnace Air Handlers: A Status Report and Program Recommendations." ACEEE report A033. p. 9. May 1, 2003. http://aceee.org/research-report/a033
3. Navigant Consulting Inc. "Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment." Table 2.1, p. 5, Section 2.4.3, p. 16, and Table 4.10, p. 49. Prepared for U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. December 4, 2013. http://energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf
   SP efficiency is the midpoint of 20 – 40% range listed in Table 2.1.
   PSC efficiency is the midpoint of 35 – 50% range listed in Section 2.4.3.
   ECM efficiency is the fractional horsepower efficiency of 70% listed in Section 2.4.3.
4. Appendix B: Common Variables, Heating and Cooling Degree Days. p. 647. *Converted HDD to hours using process on page 18 for MMID 3275, and CDD to hours using process on page 204 for MMIDs 3494 to 3505.*
5. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3.2 Lighting Hours of Use in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
   The savings are based on the assumption that lighting hours equal building occupancy hours when ventilation would also be needed.
6. Tetra Tech. "ACES Deemed Savings Desk Review." November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf

7. Engineering judgement.
   By definition of the measure, the motor only operates during the heating season, making the peak demand coincidence factor = 0.
8. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com/
   DEER model runs were weather normalized for statewide use by population density.
9. Engineering judgement.
   By definition of the measure, the motor operates continuously, making the peak demand coincidence factor = 1.0.

Revision History

Version Number	Date	Description of Change
01	09/13/2016	Initial TRM entry

A/C Split or Packaged System, High Efficiency

	Measure Details
Measure Master ID	A/C Split or Packaged System, High Efficiency: ≥ 5.42 to < 11.25 tons, 4368 ≥ 11.25 to < 20.00 tons, 4369 ≥ 20.00 to < 63.33 tons, 4370 ≥ 63.33 tons, 4371
Measure Unit	Per DX Cooling Unit
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Rooftop Unit / Split System AC
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	Varies
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$1,025.44 (MMID 4368)[2,8] $1,749.75 (MMID 4369)[2,8] $1,083.06 (MMID 4370)[2,8] $2,742.68 (MMID 4371)[2,8]

Measure Description

This measure is installing high-efficiency, unitary packaged, and split air conditioning equipment that is ≥ 65,000 Btu/hr (5.42 tons). This measure applies to replacing an existing unit at the end of its useful life or installing a new unit in a new or existing building.

Description of Baseline Condition

The baseline equipment for new construction or where new equipment is required by code is a standard efficiency packaged or split air conditioner that meets the 2015 IECC energy efficiency requirements. The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

Baseline Equipment for New Construction

Size of Standard AC Unit	Minimum Efficiency[3]			
	Electric Resistance Heat		All Other Heat (including natural gas)	
≥ 65 and < 135 kBtu/hour (≥ 5.42 to < 11.25 tons)	11.2 EER	12.8 IEER	11.0 EER	12.6 IEER
≥ 135 and < 240 kBtu/hour (≥ 11.25 to < 20.00 tons)	11.0 EER	12.4 IEER	10.8 EER	12.2 IEER
≥ 240 and < 760 kBtu/hour (≥ 20.00 to < 63.33 tons)	10.0 EER	11.6 IEER	9.8 EER	11.4 IEER
≥ 760 kBtu/hour (≥ 63.33 tons)	9.7 EER	11.2 IEER	9.5 EER	11.0 IEER

The baseline equipment for existing buildings is a standard efficiency packaged or split air conditioner that meets the 2012 IECC energy efficiency requirements. The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

Baseline Equipment for Existing Building

Size of Standard AC Unit	Minimum Efficiency[4]			
	Electric Resistance Heat		All Other Heat (including Natural Gas)	
≥ 65 and < 135 kBtu/hour (≥ 5.42 to < 11.25 tons)	11.2 EER	11.4 IEER	11.0 EER	11.2 IEER
≥ 135 and < 240 kBtu/hour (≥ 11.25 to < 20.00 tons)	11.0 EER	11.2 IEER	10.8 EER	11.0 IEER
≥ 240 and < 760 kBtu/hour (≥ 20.00 to < 63.33 tons)	10.0 EER	10.1 IEER	9.8 EER	9.9 IEER
≥ 760 kBtu/hour (≥ 63.33 tons)	9.7 EER	9.8 IEER	9.5 EER	9.6 IEER

Description of Efficient Condition

The efficient equipment is a high-efficiency packaged air conditioner that exceeds the CEE Tier 1 energy efficiency requirements listed in the table below.

Efficient Equipment Requirements

Size of High-Efficiency AC Unit	Minimum to Qualify[5]
≥ 65 and < 135 kBtu/hour (≥ 5.42 to < 11.25 tons)	12.0 EER and 13.8 IEER
≥ 135 and < 240 kBtu/hour (≥ 11.25 to < 20.00 tons)	12.0 EER and 13.0 IEER
≥ 240 and < 760 kBtu/hour (≥ 20.00 to < 63.33 tons)	10.3 EER and 12.1 IEER
≥ 760 kBtu/hour (≥ 63.33 tons)	9.7 EER and 11.4 IEER

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (CAP * 12) * (1 / IEER_{BASE} – 1 / IEER_{EE}) * EFLH_{COOL}$

Where:

CAP = Rated cooling capacity of the energy-efficient unit (tons)

12 = Conversion factor from tons to MBh

$IEER_{BASE}$ = Integrated energy efficiency ratio of standard efficiency code baseline unit in Btu/watt-hour

$IEER_{EE}$ = Integrated energy efficiency ratio of efficient unit in Btu/watt-hour

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 410 for multifamily; = 599 for commercial, industrial, agriculture, and schools & government; see tables below)

Multifamily Equivalent Full-Load Cooling Hours by Location

Location	$EFLH_{COOL}$[6]	Weighting by Participant
Green Bay	344	22%
La Crosse	323	3%
Madison	395	18%
Milwaukee	457	48%
Wisconsin Average	380	9%
Overall	**410**	

Commercial, Industrial, Agriculture, and Schools & Government Equivalent Full-Load Cooling Hours by Building Type

Building Type	$EFLH_{COOL}$[7]
College	877
Food Sales	749
Food Service	578
Healthcare	803
Hotel/Motel	663
Industrial	519
Office	578
Other	589
Public Assembly	535
Public Services (non-food)	535
Retail	567
School	439
Warehouse	358
Average	**599**

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (CAP * 12) * (1 / EER_{BASE} – 1 / EER_{EE}) * CF$

Where:

CF = Coincidence factor (= 80%)[6]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=15 years)[1]

Deemed Savings

The measure is hybrid and savings will vary; the tables below list reference savings values for various capacities. The data below are based on the assumption that equipment has natural gas heat for baseline EER value. Actual savings will vary.

Reference Savings Values by Capacity: Multifamily New Construction, Natural Gas Heat

Capacity (Btu/hour)	EER$_{BASE}$	EER$_{EE}$	IEER$_{BASE}$	IEER$_{EE}$	MMID	kWh$_{SAVED}$	kW$_{SAVED}$	kWh$_{LIFECYCLE}$
100,000	11.0	12.0	12.6	13.8	4368	255	0.61	3,820
187,000	10.8	12.0	12.2	13.0	4369	349	1.39	5,235
500,000	9.8	10.3	11.4	12.1	4370	936	1.98	14,044
800,000	9.5	9.7	11.0	11.4	4371	942	1.39	14,124

Reference Savings Values by Capacity: Multifamily Retrofit, Natural Gas Heat

Capacity (Btu/hour)	EER$_{BASE}$	EER$_{EE}$	IEER$_{BASE}$	IEER$_{EE}$	MMID	kWh$_{SAVED}$	kW$_{SAVED}$	kWh$_{LIFECYCLE}$
100,000	11.0	12.0	11.2	13.8	4368	621	0.61	9,311
187,000	10.8	12.0	11.0	13.0	4369	968	1.39	14,515
500,000	9.8	10.3	9.9	12.1	4370	3,388	1.98	50,826
800,000	9.5	9.7	9.6	11.4	4371	4,855	1.39	72,829

Reference Savings Values by Capacity:
Commercial, Industrial, Agriculture, and Schools & Government New Construction, Natural Gas Heat

Capacity (Btu/hour)	EER$_{BASE}$	EER$_{EE}$	IEER$_{BASE}$	IEER$_{EE}$	MMID	kWh$_{SAVED}$	kW$_{SAVED}$	kWh$_{LIFECYCLE}$
100,000	11.0	12.0	12.6	13.8	4368	372	0.61	5,581
187,000	10.8	12.0	12.2	13.0	4369	510	1.39	7,648
500,000	9.8	10.3	11.4	12.1	4370	1,368	1.98	20,518
800,000	9.5	9.7	11.0	11.4	4371	1,376	1.39	20,635

Reference Savings Values by Capacity:
Commercial, Industrial, Agriculture, and Schools & Government Retrofit, Natural Gas Heat

Capacity (Btu/hour)	EER$_{BASE}$	EER$_{EE}$	IEER$_{BASE}$	IEER$_{EE}$	MMID	kWh$_{SAVED}$	kW$_{SAVED}$	kWh$_{LIFECYCLE}$
100,000	11.0	12.0	11.2	13.8	4368	907	0.61	13,603
187,000	10.8	12.0	11.0	13.0	4369	1,414	1.39	21,206
500,000	9.8	10.3	9.9	12.1	4370	4,950	1.98	74,256
800,000	9.5	9.7	9.6	11.4	4371	7,093	1.39	106,401

Assumptions

A default value of 0.90 was assumed for the rated load factor.

The reference savings values were calculated for hypothetical units with capacities equal to the midpoint of each interval found in the IECC 2012 or 2015 standard, except for units ≥ 760 kBtu/hour (which used 800 kBtu/hour). Business savings uses 599 average full load hours from the table above.

The efficient condition cooling performance criteria were set using the "All Other" Heating Section Type (i.e., not "Electric Resistance (or None)" performance rating), as most DX cooling measures are assumed to be rooftop units with gas heating.

These measures are set up in SPECTRUM with a unit of measure question of "Enter Total Unit Incentive", which was done to facilitate the variable incentive that is based on the amount above the required minimum efficiency for the DX cooling unit. To convert the incremental cost per ton[2] to a per DX cooling unit incremental cost, the average tons per MMID from 2018 historical Focus on Energy data was used[8]. This results in the following incremental cost per DX Cooling unit:

Size Category	MMID	# of Applications	Average Capacity (tons)[8]	Incremental Cost ($/ton)[2]	Incremental Cost ($/DX Cooling Unit)
DX Cooling ≥ 5.42 to < 11.25 tons	4368	25	8.08	$126.84	$1,025.44
DX Cooling ≥ 11.25 to < 20.00 tons	4369	25	13.79	$126.84	$1,749.75
DX Cooling ≥ 20.00 to < 63.33 tons	4370	10	28.63	$37.83	$1,083.06
DX Cooling ≥ 63.33 tons	4371	1	72.50	$37.83	$2,742.68

Sources

1. PA Consulting Group Inc. *State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study.* Final Report. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
   Similar AC measures (MMIDs 123, 124, 821–879, and 2192–2194).
2. Northeast Energy Efficiency Partnerships and Navigant. *NEEP Incremental Cost Study Phase Three Final Report.* May 28, 2014. Table 10. http://www.neep.org/sites/default/files/resources/NEEP%20ICS3%20Report%20FINAL%202014%20June%2022_0.pdf
   Used CEE Tier 2 values.

3. International Code Council. *2012 International Energy Conservation Code*. Table C403.2.3(1). 2012. https://codes.iccsafe.org/public/document/IECC2012
4. International Code Council. *2006 International Energy Conservation Code*. Table 503.2.3(1). 2006. https://codes.iccsafe.org/public/chapter/content/4274/
5. Consortium for Energy Efficiency. *High Efficiency Commercial Air Conditioning and Heat Pump Initiative*. Appendix B, p. 40-41. May 30, 2018. https://library.cee1.org/system/files/library/13655/Final_2018_CEE_HECAC_Initiative_Description.pdf
   Values for "Heating Section Type" = "All Other."
6. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
7. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com/
   DEER model runs were weather normalized for statewide use by population density.
8. Historical Focus on Energy project data. SPECTRUM. January 1, 2018 to December 31, 2018. Business Incentive, Ag Schools and Government, and Large Energy User programs had 113 projects with 187 DX cooling units, of which 61 projects and 122 DX cooling units had capacity information entered in the Actual Capacity field in SPECTRUM.

Revision History

Version Number	Date	Description of Change
01	10/07/2015	Initial TRM entry
02	12/15/2015	Revised per evaluator comments
03	11/10/2017	Updated to standardize offer across business and multifamily programs
04	01/2019	Updated efficient EER requirements, measure unit, costs

A/C Split System, ≤ 65 MBh, SEER 15/16/17/18+

	Measure Details
Measure Master ID	A/C Split System, ≤ 65 MBh: SEER 15, 4736 SEER 16, 4737 SEER 17, 4738 SEER 18+, 4739 A/C Single Package, ≤ 65 MBh: SEER 15, 4740 SEER 16, 4741 SEER 17, 4742 SEER 18+, 4743
Measure Unit	Per ton
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Rooftop Unit / Split System AC
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by SEER level and application type
Peak Demand Reduction (kW)	Varies by SEER level and application type
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by SEER level and application type
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Varies by measure, see Incremental Costs by Measure table[2]

Measure Description

A split-system air conditioner has a compressor and condenser located outside the building, and has an evaporator mounted inside the building in an air handler or blower. The system is connected by pipes that cycle refrigerant between the two heat exchangers. Energy savings result from installing a more efficient unit than the market standard. Additional savings are incurred because the unit must be installed with proper refrigerant charge and airflow. Proper adjustment of the refrigerant charge and airflow results in more efficient operation. Installation by a qualified contractor and regular servicing are required to maintain proper refrigerant charge and airflow.

Description of Baseline Condition

For split system air conditioners, the baseline condition is a SEER 13 unit for new construction[3] and a SEER 13 unit for existing buildings.[3] For single package air conditioners, the baseline condition is a SEER 14 unit for new construction[3] and a SEER 13 unit for existing buildings.[4]

Description of Efficient Condition

The efficient condition for both a split system and single package units is an air conditioning split system ≤ 65 MBh (5.42 tons) with SEER 15 or greater. Split system air conditioners must have both the condenser and evaporator coils replaced.

The condenser model, evaporator model, and AHRI reference number are required for all installations.

All capacity and efficiency ratings will be verified using the AHRI database.[5]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (CAP * 12) * (1 / SEER_{BASE} – 1 / SEER_{EE}) * EFLH_{COOL}$

Where:

CAP = Rated cooling capacity of the energy-efficient unit (tons)

12 = Conversion factor from tons to MBh

$SEER_{BASE}$ = Seasonal energy efficiency rating of baseline unit (= 14 for single package new construction,[3] = 13 for single package retrofits and all split systems[4])

$SEER_{EE}$ = Seasonal energy efficiency rating of efficient unit (= 15, 16, 17, or 18)

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 410 for multifamily, = 599 for business; see tables below)

Multifamily Equivalent Full-Load Cooling Hours by Location

Location	$EFLH_{COOL}$[6]	Weighting by Participant
Green Bay	344	22%
La Crosse	323	3%
Madison	395	18%
Milwaukee	457	48%
Wisconsin Average	380	9%
Overall	**410**	

Commercial, Industrial, Agriculture, and Schools & Government
Equivalent Full-Load Cooling Hours by Building Type

Building Type	$EFLH_{COOL}$[7]
College	877
Food Sales	749
Food Service	578
Healthcare	803
Hotel/Motel	663
Industrial	519
Office	578
Other	589
Public Assembly	535
Public Services (non-food)	535
Retail	567
School	439
Warehouse	358
Average	**599**

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (CAP * 12) * (1 / EER_{BASE} – 1 / EER_{EE}) * CF$

Where:

EER_{BASE} = Energy efficiency rating of baseline unit (= 11.2 for SEER 13 unit, = 11.8 for 14 SEER unit)

EER_{EE} = Energy efficiency rating of efficient unit (= 12.3 for 15 SEER unit, = 12.8 for 16 SEER unit, = 13.1 for 17 SEER unit, = 13.7 for 18 SEER unit)

CF = Coincidence factor (= 0.80)[8]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Deemed Savings per Ton by MMID and Sector

Sector	Equipment Type	Retrofit or New Construction	SEER	MMID	Savings (kW)	Annual Savings (kWh)	Lifecycle Savings (kWh)
Multifamily	Split System	Both	15	4736	0.078	50	750
			16	4737	0.109	71	1,065
			17	4738	0.135	89	1,335
			18	4739	0.157	105	1,575
	Packaged System	Retrofit	15	4740	0.078	50	750
			16	4741	0.109	71	1,065
			17	4742	0.135	89	1,335
			18	4743	0.157	105	1,575
		New Construction	15	4740	0.036	23	345
			16	4741	0.066	44	660
			17	4742	0.092	62	930
			18	4743	0.115	78	1,170
Commercial, Industrial, Agriculture, Schools & Government	Split System	Both	15	4736	0.078	74	1,110
			16	4737	0.109	104	1,560
			17	4738	0.135	130	1,950
			18	4739	0.157	154	2,310
	Packaged System	Retrofit	15	4740	0.078	74	1,110
			16	4741	0.109	104	1,560
			17	4742	0.135	130	1,950
			18	4743	0.157	154	2,310
		New Construction	15	4740	0.036	34	510
			16	4741	0.066	64	960
			17	4742	0.092	91	1,365
			18	4743	0.115	114	1,710

Assumptions

The additional savings incurred from proper adjustment of the refrigerant charge and airflow is highly variable and was unaccounted for in the savings algorithm.

SEER values were converted to EER (for calculating kilowatt savings) based on EER = (-0.02 * SEER^2) + 1.12 * SEER.[9]

Incremental costs per ton for split systems was determined by using costs for 3-ton units in the Itron workbook, which shows installed costs for many SEER levels. Incremental costs per ton for packaged systems were determined by extrapolating cost increases for SEER levels from 12 to 14, and averaging between new construction and retrofit baselines.

The following table shows incremental costs for each measure.

Incremental Costs by Measure

Measure	MMID	Incremental Cost (per ton)[2]
A/C Split System, ≤ 65 MBh, SEER 15	4736	$184.25
A/C Split System, ≤ 65 MBh, SEER 16	4737	$276.38
A/C Split System, ≤ 65 MBh, SEER 17	4738	$368.51
A/C Split System, ≤ 65 MBh, SEER 18	4739	$460.63
A/C Single Package, ≤ 65 MBh, SEER 15	4740	$725.37
A/C Single Package, ≤ 65 MBh, SEER 16	4741	$1,257.35
A/C Single Package, ≤ 65 MBh, SEER 17	4742	$1,789.32
A/C Single Package, ≤ 65 MBh, SEER 18	4743	$2,321.29

Sources

1. PA Consulting Group Inc. *State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study*. Final Report. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Itron. *Ex Ante Measure Cost Study results Matrix, Volume I: Hedonic Model Estimates, Version 1.7*. Spreadsheet "NR HW Heater WA017 MCS Results Matrix Volume I August 2016." https://energy.mo.gov/about/trm/supporting-documents
   Equipment + Labor tab, rows 152 through 175 for split system costs and rows 224 through 235 for packaged system costs.
3. International Code Council. *2015 International Energy Conservation Code.* Table C403.2.3(1). 2015. https://codes.iccsafe.org/public/document/IECC2015/chapter-4-ce-commercial-energy-efficiency
4. International Code Council. *2012 International Energy Conservation Code*. Table C403.2.3(1). 2012. https://codes.iccsafe.org/public/document/IECC2012
5. Air-Conditioning, Heating, and Refrigeration Institute. "Directory of Certified Product Performance." www.ahridirectory.org
6. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

7. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com/
DEER model runs were weather normalized for statewide use by population density.
8. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
9. Wassmer, M. A. "Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations." Master's Thesis, University of Colorado at Boulder. 2003.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	11/2017	Updated common structure across business, small business, and multifamily sectors
03	12/2018	Added separate baselines for split system and single package equipment. Updated incremental costs.

A/C Split System, Condensing Unit Only, High Efficiency

	Measure Details
Measure Master ID	A/C Split System, Condensing Unit Only, High Efficiency, 3909
Measure Unit	Per ton
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Rooftop Unit / Split System AC
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by capacity
Peak Demand Reduction (kW)	Varies by capacity
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by capacity
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$82.34[7]

Measure Description

This measure is installing a high-efficiency condensing unit as part of a split system air conditioning system. This measure applies to replacing an existing unit at the end of its useful life or installing a new unit in a new or existing building. This measure covers "condensing unit only" replacements where the coil and air handling unit (AHU) are not replaced at the same time, and new installations of custom-built split system air conditioners that do have the AHU, coil, and condensing unit combination listed in AHRI. These types of systems are a better fit for IECC's condensing unit minimum efficiency requirements, as the manufacturer data is rated as "condensing unit only," and generally appears to be higher than a "complete system" or "matched air handler" rating that includes the condensing unit, AHU, and cooling coil together.

Description of Baseline Condition

The baseline equipment for existing buildings is a standard efficiency condensing unit that meets the 2006 IECC energy efficiency requirements. The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

Standard air-cooled condensing unit ≥ 135,000 Btu/hr = 10.1 EER[2]

The baseline equipment for new construction or where new equipment is required by code is a standard efficiency condensing unit that meets the 2009 IECC energy efficiency requirements. The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

Standard air-cooled condensing unit ≥ 135,000 Btu/hr = 10.1 EER[3]

Description of Efficient Condition

The efficient equipment is a high-efficiency condensing unit that exceeds energy efficiency requirements listed below. The efficient condition is set at CEE Tier 2 levels, which offer between 7.6% and 10.0% peak kW savings over current federal minimum EER requirements.[4] A value of 9% was used to determine the savings, so a baseline of 10.1 EER / (1 – 0.09) = 11.1 EER.

Efficient air-cooled condensing unit ≥ 135,000 Btu/hr = 11.1 EER

Annual Energy-Savings Algorithm

$kWh_{SAVED} = Capacity * 12{,}000 * RLF * EFLH_C * (1 / 1{,}000) * (1/EER_{BASE} – 1/EER_{EE})$

Where:

Capacity = Capacity (size) of the condensing unit in tons

12,000 = Btuh to tons conversion factor

RLF = Rated load factor; the peak cooling load/nameplate capacity. This factor compensates for oversizing of the air conditioning unit (= 0.90)

$EFLH_C$ = Equivalent full-load cooling hours (= varies by building type; see table below for default values)

1,000 = Kilowatt conversion factor

EER_{BASE} = Energy efficiency ratio of baseline condensing unit in Btu/watt-hour (= 10.1 EER)

EER_{EE} = Energy efficiency ratio of efficient condensing unit in Btu/watt-hour (= 11.1 EER or actual)

Cooling Equivalent Full Load Hours by Building Type

Building Type	$EFLH_C$[5]
College	877
Food Sales	749
Food Service	578
Healthcare	803
Hotel/Motel	663
Industrial	519
Office	578
Other	589
Public Assembly	535
Public Services (non-food)	535
Retail	567
School	439
Warehouse	358
Average	**599**

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = Capacity * (1 / 1,000) * CF * ($1/EER_{BASE} - 1/EER_{EE}$)

Where:

CF = Coincidence factor (= 0.8)[6]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED}$ * EUL

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Though the measure is hybrid, reference savings values for various capacities are listed in the table below. Actual savings will vary.

Reference Savings Values by Capacity

Capacity (Btuh)	EER_{BASE}	EER_{EE}	kWh_{BASE}	kWh_{EE}	kWh_{SAVED}	kW_{BASE}	kW_{EE}	kW_{SAVED}	$kWh_{LIFECYCLE}$
187,000	10.1	11.1	10,008	9,106	902	14.85	13.51	1.34	13,524
500,000	10.1	11.1	26,688	24,284	2,404	39.60	36.04	3.57	36,065
800,000	10.1	11.1	42,701	38,854	3,847	63.37	57.66	5.71	57,704

Assumptions

The average (mean) value for all building types was used to determine cooling EFLH.

A default value of 0.90 was assumed for the rated load factor.

The deemed savings values were calculated for hypothetical units with capacities equal to the midpoint of each interval found in the IECC 2009 standard, but the < 65,000 Btu/hr and 65,000 to 135,000 Btu/hr categories were excluded since the condensing unit only rating in the IECC only applies to ≥ 135,000 Btu/hr capacity.

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
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3. International Energy Conservation Code. Table 503.2.3(6). 2009. http://codes.iccsafe.org/app/book/toc/2009/I-Codes/2009%20IECC%20HTML/index.html
4. Consortium for Energy Efficiency. "High Efficiency Commercial Air-conditioning and Heat Pumps Initiative." Table 3, p. 26. January 12, 2016. https://library.cee1.org/sites/default/files/library/5347/CEE_2016_HECAC_Initiative_Description_and_Specification.pdf
5. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com/
   DEER model runs were weather normalized for statewide use by population density.
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7. Northeast Energy Efficiency Partnerships. "Incremental Cost Study Phase Three Final Report." Table 10. May 2014. http://www.neep.org/incremental-cost-study-phase-3
   Average of CEE Tier 2 values ($126.84 and $37.83)

Revision History

Version Number	Date	Description of Change
01	07/2016	Initial TRM entry

Air Source Heat Pump, ≤65 MBh

	Measure Details
Measure Master ID	Air-Source Heat Pump, ≤ 65 MBh: SEER 15 and 9.0 HSPF, 4744 SEER 16 and 9.0 HSPF, 4745 SEER 17 and 9.0 HSPF, 4746 SEER 18 and 9.0 HSPF, 4747
Measure Unit	Per ton
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Other
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therms Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therms Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/ton)	SEER 15 = $308.16 (MMID 4744); SEER 16 = $432.82 (MMID 4745); SEER 17 = $576.29 (MMID 4746); SEER 18 = $719.75 (MMID 4747)[2]

Measure Description

A split-system air-source heat pump has a compressor and condenser/evaporator located outside the building and has an evaporator/condenser mounted inside the building in an air handler or blower. The outside unit and inside unit are connected by pipes that carry refrigerant between the two heat exchangers. Packaged units contain compressors, the condenser, and the evaporator in the same equipment. Heat pumps use reversing valves to switch the roles of the evaporator and condenser. In cooling mode the outside condenser/evaporator operates as a condenser. In heating mode the outside condenser/evaporator operates as an evaporator. Energy savings result from installing a more efficient unit than the market standard.

Description of Baseline Condition

The baseline condition is an air cooled heat pump with a cooling capacity of 5.42 tons or less, a cooling efficiency of 14 SEER, and a heating efficiency of 8.2 HSPF for split systems and 8.0 HSPF for packaged systems[3] for both new construction and retrofits.

Description of Efficient Condition

The efficient condition is an air cooled heat pump with a cooling capacity of 5.42 tons or less, a cooling efficiency of 15, 16, 17, or 18 SEER, and a heating efficiency of at least 9.0 HSPF for both split systems and packaged systems.

All capacity and efficiency ratings should be verified using the AHRI database.[4] For split systems, the AHRI capacity and efficiency ratings must be with the matched evaporator. Condensing unit only applications are not eligible.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{COOL} + kWh_{HEAT}$

$kWh_{COOL} = (CAP * 12) * [(1 / SEER_{BASE}) – (1 / SEER_{EE})] * EFLH_{COOL}$

$kWh_{HEAT} = (CAP * 12) * [(1 / HSPF_{BASE}) – (1 / HSPF_{EE})] * EFLH_{HEAT}$

Where:

CAP = Rated cooling capacity of the energy-efficient unit (tons)

12 = Conversion factor from tons to MBh

$SEER_{BASE}$ = Cooling seasonal energy efficiency rating of baseline unit (= 14 MBh per kilowatt)[3]

$SEER_{EE}$ = Seasonal energy-efficiency rating of efficient unit (= 15 SEER for MMID 4744, = 16 SEER for MMID 4745, = 17 SEER for MMID 4746, = 18 SEER for MMID 4747)

$EFLH_{COOL}$ = Equivalent full-load hours in cooling mode (= 410 average for Wisconsin multifamily buildings, = 599 average for Wisconsin commercial buildings; see tables below)

$HSPF_{BASE}$ = Heating seasonal performance factor of baseline unit (= 8.2 MBh per kilowatt; see Assumptions)

$HSPF_{EE}$ = Heating seasonal performance factor of efficient unit (= 9.0 MBh per kilowatt)

$EFLH_{HEAT}$ = Equivalent full-load hours in heating mode (= 1,158 for multifamily,[5] = 1,890 average for Wisconsin commercial buildings; see table below)

Multifamily Equivalent Full-Load Cooling Hours by Location

Location	$EFLH_{COOL}$[5]	Weighting by Participant
Green Bay	344	22%
La Crosse	323	3%
Madison	395	18%
Milwaukee	457	48%
Wisconsin Average	380	9%
Overall	**410**	

Commercial, Industrial, Agriculture, and Schools & Government Cooling Equivalent Full-Load Cooling Hours by Building Type

Building Type	$EFLH_{COOL}$[6]
College	877
Food Sales	749
Food Service	578
Healthcare	803
Hotel/Motel	663
Industrial	519
Office	578
Other	589
Public Assembly	535
Public Services (non-food)	535
Retail	567
School	439
Warehouse	358
Average	**599**

Supporting Inputs for Equivalent Full-Load Heating Hours by City for Business

Location	$EFLH_{HEAT}$[7]	Weighting by Participant
Green Bay	1,852	22%
Lacrosse	1,966	3%
Madison	1,934	18%
Milwaukee	1,883	48%
Wisconsin Average	1,909	9%
Weighted Average	**1,890**	**100%**

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (CAP * 12) * [(1 / EER_{BASE}) – (1 / EER_{EE})] * CF$

Where:

EER_{BASE} = $-0.02 * SEER_{BASE}^2 + 1.12 * SEER_{BASE}$ in MBh per kilowatt[8]

EER_{EE} = $-0.02 * SEER_{EE}^2 + 1.12 * SEER_{EE}$ in MBh per kilowatt[8]

CF = Coincidence factor (= 0.80)[9]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Deemed Savings per Ton

Type	MMID	Savings (kW)	Annual Savings (kWh)	Lifecycle Savings (kWh)
Multifamily				
15 SEER	4744	0.0358	174	2,610
16 SEER	4745	0.0663	195	2,925
17 SEER	4746	0.0923	213	3,195
18 SEER	4747	0.1146	229	3,435
Business				
15 SEER	4744	0.0358	280	4,200
16 SEER	4745	0.0663	310	4,650
17 SEER	4746	0.0923	336	5,040
18 SEER	4747	0.1146	360	5,400

Assumptions

Incremental costs per ton were determined by averaging incremental costs per ton for both split systems and packaged systems, across sizes specified in the Itron workbook.[2] Cost data was available up to 16 SEER for split systems and up to 15 SEER for packaged systems. Costs for higher SEER units for each system type were determined by linear extrapolation.

The heating seasonal performance factor of the baseline unit is 8.2 for split systems and 8.0 for packaged systems.[3] Since this measure does not distinguish between the two system types, the more conservative value (8.2) was used.

Sources

1. PA Consulting Group Inc. *State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study*. Final Report. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Itron. *Ex Ante Measure Cost Study results Matrix, Volume I: Hedonic Model Estimates, Version 1.7*. Spreadsheet "NR HW Heater WA017 MCS Results Matrix Volume I August 2016." https://energy.mo.gov/about/trm/supporting-documents
   Equipment + Labor tab, rows 134–150 for split heat pump costs, and rows 291–303 for packaged heat pump costs.
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4. Air-Conditioning, Heating, and Refrigeration Institute. "Directory of Certified Product Performance." www.ahridirectory.org.
5. Cadmus. "Focus on Energy Evaluated Deemed Savings Changes." November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
6. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com/
DEER model runs that were weather-normalized for statewide use by population density.
7. Several Cadmus metering studies reveal that the ENERGY STAR EFLHs calculator is overestimated by 25%. The $EFLH_{HEAT}$ were adjusted by population-weighted heating degree days and TMY3 values.
8. Wassmer, M. "A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations." Masters Thesis, University of Colorado at Boulder. 2003.
9. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Updated March 22, 2010. www.focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	12/31/2018	Initial TRM entry

HVAC Chiller

	Measure Details
Measure Master ID	Chiller, Air Cooled: < 150 tons, Path A, 4712 ≥ 150 tons, Path A, 4713 < 150 tons, Path B, 4714 ≥ 150 tons, Path B, 4715 Chiller, Water Cooled, Positive Displacement: < 75 tons, Path A, 4716 ≥ 75 and < 150 tons, Path A, 4717 ≥ 150 and < 300 tons, Path A, 4718 ≥ 300 and < 600 tons, Path A, 4719 ≥ 600 tons, Path A, 4720 < 75 tons, Path B, 4721 ≥ 75 and < 150 tons, Path B, 4722 ≥ 150 and < 300 tons, Path B, 4723 ≥ 300 and < 600 tons, Path B, 4724 ≥ 600 tons, Path B, 4725 Chiller, Water Cooled, Centrifugal: < 150 tons, Path A, 4726 ≥ 150 and < 300 tons, Path A, 4727 ≥ 300 and < 400 tons, Path A, 4728 ≥ 400 and < 600 tons, Path A, 4729 ≥ 600 tons, Path A, 4730 < 150 tons, Path B, 4731 ≥ 150 and < 300 tons, Path B, 4732 ≥ 300 and < 400 tons, Path B, 4733 ≥ 400 and < 600 tons, Path B, 4734 ≥ 600 tons, Path B, 4735
Measure Unit	Per ton
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Chiller
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0

	Measure Details
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	Varies by measure,[2] see Chiller Incremental Cost table

Measure Description

Chillers are used for commercial and industrial space cooling applications in order to provide adequate temperature control via chilled water. The proposed measure applies to the replacement of less efficient chillers with more efficient chillers that supply the same amount of cooling.

Description of Baseline Condition

The baseline condition is a chiller that meets the minimum efficiencies described by 2015 IECC.[3] It is assumed that new chillers are installed when the existing unit has failed or is at the end of its useful life.

Baseline Chiller Efficiency[3]

Size	MMIDs	kW / ton			
		Path A		Path B	
		Full	Part (IPLV)	Full	Part (IPLV)
Air Cooled					
< 150 tons	4712, 4714	1.190	0.880	1.240	0.760
≥150 tons	4713, 4715	1.190	0.860	1.240	0.750
Water Cooled, Positive Displacement					
< 75 tons	4716, 4721	0.750	0.600	0.780	0.500
≥ 75 and < 150 tons	4717, 4722	0.720	0.560	0.750	0.490
≥ 150 and < 300 tons	4718, 4723	0.660	0.540	0.680	0.440
≥ 300 and < 600 tons	4719, 4724	0.610	0.520	0.625	0.410
≥ 600 tons	4720, 4725	0.560	0.500	0.585	0.380
Water Cooled, Centrifugal					
< 150 tons	4726, 4731	0.610	0.550	0.695	0.440
≥ 150 and < 300 tons	4727, 4732	0.610	0.550	0.635	0.400
≥ 300 and < 400 tons	4728, 4733	0.560	0.520	0.595	0.390
≥ 400 and < 600 tons	4729, 4734	0.560	0.500	0.585	0.380
≥ 600 tons	4730, 4735	0.560	0.500	0.585	0.380

Chillers designed for Path A are optimized at full load, so the full-load efficiency is lower while the part-load efficiency remains at code level. Chillers designed for Path B are optimized at part load, so the part-load efficiency is lower while the full-load efficiency remains at code level. An efficiency reduction of 0.03 kW/ton was selected as the “better than code” amount based on review of 2018 chiller projects to date. Focus on Energy has historically offered incentives for a reduction of about 0.05 kW/ton or 0.06 kW/ton better than full-load efficiency of the old code, but this amount was reduced due to the baseline efficiency improvements in IECC’s 2015 code update.

Chillers must be driven by an electric motor. Absorption chillers and engine or steam turbine driven chillers do not qualify.

Description of Efficient Condition

The efficient equipment is a chiller that meets or exceeds the full load efficiency and the part load efficiency listed in the table below.

Efficient Chiller Efficiency

Size	MMIDs	kW / ton			
		Path A		Path B	
		Full	Part (IPLV)	Full	Part (IPLV)
Air Cooled					
< 150 tons	4712, 4714	1.160	0.880	1.240	0.730
≥150 tons	4713, 4715	1.160	0.860	1.240	0.720
Water Cooled, Positive Displacement					
< 75 tons	4716, 4721	0.720	0.600	0.780	0.470
≥ 75 and < 150 tons	4717, 4722	0.690	0.560	0.750	0.460
≥ 150 and < 300 tons	4718, 4723	0.630	0.540	0.680	0.410
≥ 300 and < 600 tons	4719, 4724	0.580	0.520	0.625	0.380
≥ 600 tons	4720, 4725	0.530	0.500	0.585	0.350
Water Cooled, Centrifugal					
< 150 tons	4726, 4731	0.580	0.550	0.695	0.410
≥ 150 and < 300 tons	4727, 4732	0.580	0.550	0.635	0.370
≥ 300 and < 400 tons	4728, 4733	0.530	0.520	0.595	0.360
≥ 400 and < 600 tons	4729, 4734	0.530	0.500	0.585	0.350
≥ 600 tons	4730, 4735	0.530	0.500	0.585	0.350

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (IPLV_{BASE} - IPLV_{EE}) * LF * \text{Ton-hours}$

Where:

$IPLV_{BASE}$ = Integrated part-load value of baseline chiller in kW per ton (see Baseline Chiller Efficiency table above)

$IPLV_{EE}$ = Integrated part-load value of efficient chiller at AHRI conditions in kW per ton (= user input)

LF = Load factor (= 0.85)[4]

Ton-hours = Annual chiller load (= hours * efficient chiller capacity at AHRI conditions; see Assumptions)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (\text{Full Load kW/ton}_{BASE} - \text{Full Load kW/ton}_{EE}) * LF * Tons * CF$

Where:

$\text{Full Load kW/ton}_{BASE}$ = kW/ton full-load value of baseline chiller (see Baseline Chiller Efficiency table above)

$\text{Full Load kW/ton}_{EE}$ = kW/ton full-load value of efficient chiller at AHRI conditions (= user input)

Tons = Capacity in tons of the efficient chiller at AHRI conditions (= user input)

CF = Coincidence factor (= 0.8)[5]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 20 years)[1]

Assumptions

The incremental measure cost was calculated using a 2013 incremental cost study from Northeast Energy Efficiency Partnership.[2] The closest chiller efficiencies to the program baseline and efficient condition were selected, then the cost for sizes in the range for the MMID were used directly (or averaged if more than one size was available).

For Path B, the baseline and efficient condition full-load kW/ton are the same (the part-load kW/ton varies). The cost reference, however, only has cost by varying full-load kW/ton, so the incremental cost for Path B was assumed to be the same at that for Path A.

Chiller Incremental Cost

Measure	Path A MMID	Path B MMID	Closest IC Information					Incremental Cost $/ton
			Tonnage of Chiller from Cost Source	Baseline kW/ton	Baseline $/ton	Efficient kW/ton	Efficient $/Ton	
Air Cooled								
< 150	4712	4714	Avg 50, 100	1.212	$172	1.141	$526	$354
≥ 150	4713	4715	Avg 150, 200, 400	1.212	$49	1.141	$149	$101
Water Cooled, Positive Displacement								
< 75	4716	4721	Avg 50, 100	0.78	$0	0.720	$57	$57
≥ 75 to < 150	4717	4722	100	0.72	$38	0.680	$63	$25
≥ 150 to < 300	4718	4723	200	0.68	$61	0.640	$122	$61
≥ 300 to < 600	4719	4724	400	0.64	$61	0.600	$92	$31
≥ 600	4720	4725	400	0.64	$61	0.600	$92	$31
Water Cooled, Centrifugal								
< 150	4726	4731	100	0.60	$73	0.580	$110	$37
≥ 150 to < 300	4727	4732	Avg 150, 200	0.60	$43	0.580	$64	$21
≥ 300 to < 400	4728	4733	300	0.58	$91	0.540	$152	$61
≥ 400 to < 600	4729	4734	600	0.58	$46	0.540	$76	$30
≥ 600	4730	4735	600	0.58	$46	0.540	$76	$30

Ton-hours were calculated by first determining a linear load profile for the chiller, with 100% load occurring at 95°F, the design ambient temperature for chillers at their rated capacity, and with the low end point at 40% load occurring at an outside air temperature equal to the chiller lock-out temperature. Below this, it was assumed that the air-side economizer handles cooling load. Then, using Wisconsin population weighted bin weather data, the ton-hours for each weather bin were calculated by multiplying the calculated tons by the number of hours in that bin. For temperature bins over the 95°F design temperature, the tons were limited to the chiller maximum capacity.

Population Weighting Percentages

Location	Weighting by Location
Green Bay	22%
Lacrosse	3%
Madison	18%
Milwaukee	48%
Average	**9%**

Temperature bin hours, population weighted for the state of Wisconsin, are listed in the table below. The four cities account for 91% of the population. The hours used for the remaining 9% of the population are the average of the four cities.

Bin Hours[6]

Temperature Range	Green Bay	LaCrosse	Madison	Milwaukee	Average	Weighted Average
95°F to 100°F	0	7	0	5	3	**3**
90°F to 95°F	22	46	25	16	27	**21**
85°F to 90°F	62	121	86	59	82	**68**
80°F to 85°F	275	355	339	225	299	**267**
75°F to 80°F	398	445	486	400	432	**419**
70°F to 75°F	445	489	447	497	470	**474**
65°F to 70°F	675	762	723	692	713	**698**
60°F to 65°F	871	746	770	936	831	**877**
55°F to 60°F	647	583	605	545	595	**584**
50°F to 55°F	543	615	597	679	609	**626**
45°F to 50°F	404	444	491	471	453	**457**
40°F to 45°F	579	597	510	723	602	**638**
35°F to 40°F	777	826	905	883	848	**859**
30°F to 35°F	820	719	741	720	750	**748**
25°F to 30°F	507	425	396	423	438	**438**
20°F to 25°F	579	457	439	531	502	**520**
15°F to 20°F	443	319	353	390	376	**392**
10°F to 15°F	265	227	212	228	233	**234**
5°F to 10°F	178	208	164	125	169	**150**
0°F to 5°F	90	110	105	88	98	**93**
-5°F to 0°F	81	106	157	61	101	**88**
-10°F to -5°F	83	109	105	57	89	**76**
-15°F to -10°F	9	23	70	6	27	**21**

Temperature Range	Green Bay	LaCrosse	Madison	Milwaukee	Average	Weighted Average
-20°F to -15°F	7	9	21	0	9	**6**
-25°F to -20°F	0	6	9	0	4	**2**
-30°F to -25°F	0	6	4	0	3	**1**

Sources

1. California Energy Commission and California Public Utilities Commission. *Database for Efficient Resources (DEER)*. EUL/RUL Values. 2008. http://www.deeresources.com/files/deer2008exante/downloads/EUL_Summary_10-1-08.xls
2. Northeast Energy Efficiency Partnerships. *Incremental Cost Study Phase Two Final Report: A Report on 12 Energy Efficiency Measure Incremental Costs in Six Northeast and Mid-Atlantic Markets*. January 2013. http://www.neep.org/incremental-cost-study-phase-2
3. 2015 International Energy Conservation Code. Table C403.2.3(7). 2015. https://codes.iccsafe.org/public/document/IECC2015
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6. National Solar Radiation Data Base, 1991- 2005 Update: Typical Meteorological Year 3. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html

Revision History

Version Number	Date	Description of Change
01	10/31/2018	Initial TRM entry

Packaged Terminal Heat Pumps (PTHPs)

	Measure Details
Measure Master ID	PTHP <8,000 Btu/h, 2699 PTHP 8,000–9,999 Btu/h, 2702 PTHP 10,000–12,999 Btu/h, 2701 PTHP ≥13,000 Btu/h, 2700
Measure Unit	Per PTHP
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Packaged Terminal Unit (PTAC, PTHP)
Sector(s)	Commercial, Schools & Government, Industrial, Agriculture, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	<8,000 Btu/h = $58 (MMID 2699), 8,000–9,999 Btu/h = $69 (MMID 2702), 10,000–12,999 Btu/h = $77 (MMID 2701), ≥13,000 Btu/h = $49 (MMID 2700)[2]

Measure Description

Packaged terminal heat pumps (PTHPs) are self-contained heating and air conditioning units typically found in hotel rooms and multifamily dwellings. They have supplemental electric resistance heaters for when the heat pump cannot provide sufficient heat.

Description of Baseline Condition

The baseline condition is a packaged terminal air conditioner (PTAC) unit with electric resistance heat and a cooling EER meeting the minimum guidelines in the table below.

Minimum Cooling Efficiency Requirements for Packaged Terminal Air Conditioners[3]

New Construction / Retrofit	Minimum Efficiency
New Construction	$EER = 14.0 - (0.300 * Cap_{COOL} / 1{,}000)$
Retrofit	$EER = 10.9 - (0.213 * Cap_{COOL} / 1{,}000)$

Baseline EER requirements, using the equations from the table above and an assumed size for each measure, are shown in the table below.

Minimum PTAC Cooling Efficiencies (EER)[3]

Size Range	MMID	Size (Btu/h) for Minimum Efficiency	New Construction	Retrofit
< 8,000 Btu/h	2699	7,000	11.90	9.41
8,000–9,999 Btu/h	2702	9,000	11.30	8.98
10,000–12,999 Btu/h	2701	12,000	10.40	8.34
≥ 13,000 Btu/h	2700	15,000	9.50	7.71

Retrofit efficiencies only apply to units with existing sleeves that are less than 16-inches tall and less than 42-inches wide. Retrofit units are factory labeled as follows: "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS." (emphasis in original)

Description of Efficient Condition

The efficient condition is a PTHP meeting the Focus on Energy minimum efficiencies. See Assumptions for details.

Minimum Efficiencies for Qualifying Equipment

Cooling Capacity Range	MMID	New Construction		Retrofit	
		EER	COP	EER	COP
< 8,000 Btu/h	2699	12.7	3.1	10.7	3.1
8,000–9,999 Btu/h	2702	12.1	3.0	10.4	3.0
10,000–12,999 Btu/h	2701	10.9	2.9	9.9	2.9
≥ 13,000 Btu/h	2700	10.3	2.9	9.3	2.9

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{COOL} + kWh_{HEAT}$

$kWh_{COOL} = EFLH_{COOL} * (Cap_{COOL} / 1{,}000) * [(1 / EER_{BASE}) - (1 / EER_{EE})]$

$kWh_{HEAT} = EFLH_{HEAT} * Cap_{COOL} * [(1 / COP_{BASE}) - (1 / COP_{EE})] / 3{,}412$

Where:

$EFLH_{COOL}$ = Equivalent full-load hours during cooling mode (= 410[4] for multifamily, 599 for business; see Assumptions)

Cap_{COOL} = Nominal cooling capacity in Btu/h (= user input)

EER_{BASE} = Energy efficiency ratio of baseline unit (= see Assumptions)

EER_{EE} = Energy efficiency ratio of energy-efficient unit (= see Description of Efficient Condition)

$EFLH_{HEAT}$ = Equivalent full-load hours during heating mode (= 711 for multifamily, 1,161 for business; see Assumptions)

COP_{BASE} = Coefficient of performance of baseline equipment (= 1.0; see Assumptions)

COP_{EE} = Coefficient of performance of energy-efficient equipment (= see Description of Efficient Condition)

3,412 = Btu per kWh conversion factor

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Cap_{COOL} / 1{,}000) * [(1 / EER_{BASE}) - (1 / EER_{EE})] * CF$

Where:

CF = Coincidence factor (= 0.80)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

The energy savings are presented in the tables below.

Annual, Summer Coincident Peak, and Lifecycle Savings for Retrofits

Size Range	MMID	Multifamily			Business		
		kW	Annual kWh	Lifecycle kWh	kW	Annual kWh	Lifecycle kWh
< 8,000 Btu/h	2699	0.0718	1,025	15,375	0.0718	1,663	24,945
8,000–9,999 Btu/h	2702	0.1092	1,306	19,590	0.1092	2,117	31,755
10,000–12,999 Btu/h	2701	0.1808	1,731	25,965	0.1808	2,801	42,015
≥ 13,000 Btu/h	2700	0.2671	2,185	32,775	0.2671	3,530	52,950

Annual, Summer Coincident Peak, and Lifecycle Savings for New Construction

Size Range	MMID	Multifamily			Business		
		kW	Annual kWh	Lifecycle kWh	kW	Annual kWh	Lifecycle kWh
< 8,000 Btu/h	2699	0.0252	1,003	15,045	0.0296	1,634	24,510
8,000–9,999 Btu/h	2702	0.0358	1,272	19,080	0.0421	2,070	31,050
10,000–12,999 Btu/h	2701	0.0360	1,660	24,900	0.0423	2,704	40,560
≥ 13,000 Btu/h	2700	0.0834	2,098	31,470	0.0981	3,411	51,165

Assumptions

Minimum EER values for new construction for each size range were determined by finding an EER that at least three major manufacturers can meet based on data from AHRI.[5]

Minimum COP values for new construction were determined by rounding up from code minimum values for new construction. The formulas to determine the code minimum efficiencies are shown in the tables below for reference.

Code Minimum Heating Efficiency Requirements[3]

New Construction / Retrofit	Minimum Efficiency
New Construction	$COP = 3.2 – (0.026 * Cap_{COOL} / 1,000)$
Retrofit	$COP = 2.9 – (0.026 * Cap_{COOL} / 1,000)$

Minimum Heating Efficiency for Qualifying Equipment

Size Range	MMID	Size (Btu/h) for Minimum Efficiency	Retrofit		New Construction	
			Code	Program	Code	Program
< 8,000 Btu/h	2699	7,000	2.72	3.1	3.02	3.1
8,000–9,999 Btu/h	2702	9,000	2.67	3.0	2.97	3.0
10,000–12,999 Btu/h	2701	12,000	2.59	2.9	2.89	2.9
≥ 13,000 Btu/h	2700	15,000	2.51	2.9	2.81	2.9

Minimum EER values for retrofits for 2019 are equal to those in the 2018 Focus on Energy incentive catalog.

Minimum COP values for retrofits are equal to those for new construction.

Since the heat source for the baseline PTAC is an electric resistance heater, its COP = 1.0.Data for determining the equivalent full-load hours are presented in the tables below.

Supporting Inputs for Equivalent Full-Load Cooling Hours for Business Buildings

Building Type	$EFLH_{COOL}$[6]
College	877
Food Sales	749
Food Service	578
Healthcare	803
Hotel/Motel	663
Industrial	519
Office	578
Other	589
Public Assembly	535
Public Services (non-food)	535
Retail	567
School	439
Warehouse	358
Average	**599**

Supporting Inputs for Equivalent Full-Load Cooling Hours by City for Multifamily[7]

Location	$EFLH_{COOL}$	Weighting by Participant
Green Bay	344	22%
Lacrosse	323	3%
Madison	395	18%
Milwaukee	457	48%
Wisconsin Average	380	9%
Weighted Average	**410**	**100%**

Supporting Inputs for Equivalent Full-Load Heating Hours by City for Business[8]

Location	$EFLH_{HEAT}$	Weighting by Participant
Green Bay	1,852	22%
Lacrosse	1,966	3%
Madison	1,934	18%
Milwaukee	1,883	48%
Wisconsin Average	1,909	9%
Weighted Average	**1,890**	**100%**

$EFLH_{HEAT}$ values were adjusted to account for electric resistance heat when the outside temperature is below 40°F. The controls are assumed to run only the electric heater when the outside temperature is below 25°F, to run both the heat pump and electric heater between 25°F and 40°F, and to run only the heat pump above 40°F.[9] No heating is assumed above 65°F, the common base for heating degree days. Using average bin weather data for 20 Wisconsin locations, the heat pump is expected to operate 61.4% (= 4,245 / 6,914) of the hours when the temperature is below 65°F. The adjusted $EFLH_{HEAT}$ values are 1,158 hours[5] * 61.4% = 711 hours for multifamily and 1,890 hours * 61.4% = 1,161 hours for business.

Supporting Calculation for Electric Heat Adjustment

Temperature Range	Hours in Temperature Range	Heat Control	% Heat Pump Hours	Total Heat Pump Hours	% of Hours Below 65°F
40°F–65°F	3,274	Heat pump only	100%	3,274	47%
25°F–40°F	1,943	Heat pump + electric heater	50%	971	14%
<25°F	1,697	Electric heater only	0%	0	0%
Total	**6,914**	**-**	**-**	**4,245**	**61%**

Summary of Equivalent Full-Load Cooling and Heating Hours

Building Type	$EFLH_{COOL}$	$EFLH_{HEAT}$
Multifamily	410	711
Business	599	1,161

Average costs were determined by the following method:

1. Prices were collected for each size from four manufacturers (Amana, LG, Friedrich, and GE) from two sources (Grainger and Total Home Supply).
2. The lowest cost was determined for each size category and each manufacturer.
3. The lowest costs from the four manufacturers were averaged for each size.

This procedure was followed for PTHPs that meet the minimum efficiencies for the energy-efficient case, and again for PTACs for the baseline case. The incremental cost for each size is the average PTHP cost minus the average PTAC cost.

Sources

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   DEER model runs that were weather-normalized for statewide use by population density.
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8. Several Cadmus metering studies reveal that the ENERGY STAR EFLHs calculator are overestimated by 25%. The $EFLH_{HEAT}$ were adjusted by population-weighted heating degree days and TMY3 values.
9. "ENERGY STAR Multifamily High Rise Program Simulation Guidelines, Version 1.0, Revision 03." p. 19, Section 3.8.2.2. January 2015. https://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/mfhr/ENERGY%20STAR%20MFHR%20Simulation%20Guidelines_Version_1%200_Rev03.pdf?5c90-3dd6

Revision History

Version Number	Date	Description of Change
01	11/2018	Updated for 2019 – Changed baseline system from PTHP to PTAC with electric resistance heat. Updated efficiencies due to new energy code. Updated costs. Updated EFLHs.

Data Center and Telecom Cooling, ≤5.4 Tons

	Measure Details
Measure Master ID	Split System: SEER 15, <5.4 tons, Data Center/Telecom, 4768 SEER 16, <5.4 tons, Data Center/Telecom, 4769 SEER 17, <5.4 tons, Data Center/Telecom, 4770 SEER 18, <5.4 tons, Data Center/Telecom, 4771 Single Package: SEER 15, <5.4 tons, Data Center/Telecom, 4772 SEER 16, <5.4 tons, Data Center/Telecom, 4773 SEER 17, <5.4 tons, Data Center/Telecom, 4774 SEER 18, <5.4 tons, Data Center/Telecom, 4775
Measure Unit	Per ton
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Other
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therms Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therms Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/ton)	Varies by measure, see Incremental Costs section[2]

Measure Description

This measure is an efficient air conditioner serving a data center, telecom, or similar facility. A split-system air conditioner has a compressor and condenser located outside the building, and has an evaporator mounted inside the building in an air handler or blower. The system is connected by pipes that cycle refrigerant between the two heat exchangers. In single package systems, all refrigeration system components are in a single unit. Energy savings result from installing a more efficient unit than the market standard.

Description of Baseline Condition

The baseline condition for split systems is an air conditioner with a cooling capacity of 5.4 tons or less and a cooling efficiency of 13 SEER for new construction[3] or existing buildings.[4] The baseline condition for packaged systems is an air conditioner with a cooling capacity of 5.4 tons or less and a cooling efficiency of 14 SEER for new construction[3] and of 13 SEER for existing buildings.[4]

Description of Efficient Condition

The efficient condition for both split systems and packaged systems is an air conditioner with a cooling capacity of 5.4 tons or less and a cooling efficiency of at least 15 SEER.

The condenser model, evaporator model, and AHRI reference number are required for all installations. All capacity and efficiency ratings will be verified using the AHRI database.[5] For mini-split/ductless systems, the AHRI capacity and efficiency ratings must be with the matched evaporator. Condensing unit only mini-split/ductless applications are not eligible.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (CAP * 12) * LF * [(1 / SEER_{BASE}) – (1 / SEER_{EE})] * EFLH_{COOL}$

Where:

CAP = Rated cooling capacity of the energy-efficient unit, in tons (= user input)

12 = Conversion factor from tons to MBh

LF = Load factor (= 0.65)[6]

$SEER_{BASE}$ = Cooling seasonal energy efficiency rating of baseline unit, in MBh per kilowatt (= 14 for single package new construction,[3] = 13 for single package retrofits[4] and all split systems[3,4])

$SEER_{EE}$ = Seasonal energy efficiency rating of efficient unit, in MBh per kilowatt (= 15 SEER for MMIDs 4768 and 4772, = 16 SEER for MMIDs 4769 and 4773, = 17 SEER for MMIDs 4770 and 4774, = 18 SEER for MMIDs 4771 and 4775)

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 8760; see Assumptions)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (CAP * 12) * LF * [(1 / EER_{BASE}) – (1 / EER_{EE})] * CF$

Where:

EER_{BASE} = Energy efficiency rating of baseline unit (= 11.2 for SEER 13 unit, = 11.8 for 14 SEER; see Assumptions)

EER_{EE} = Energy efficiency rating of efficient unit (= 12.3 for 15 SEER, = 12.8 for 16 SEER, = 13.1 for 17 SEER, = 13.7 for 18 SEER; see Assumptions)

CF = Coincidence factor (= 1.0)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Deemed Savings per Ton

Type	MMID	Savings (kW)	Annual Savings (kWh)	Lifecycle Savings (kWh)
Split Systems				
15 SEER	4768	0.0635	701	10,515
16 SEER	4769	0.0883	986	14,790
17 SEER	4770	0.1094	1,237	18,555
18 SEER	4771	0.1275	1,460	21,900
Packaged Systems, Existing Buildings				
15 SEER	4772	0.0635	701	10,515
16 SEER	4773	0.0883	986	14,790
17 SEER	4774	0.1094	1,237	18,555
18 SEER	4775	0.1275	1,460	21,900
Packaged Systems, New Construction				
15 SEER	4772	0.0291	325	4,875
16 SEER	4773	0.0539	610	9,150
17 SEER	4774	0.0750	861	12,915
18 SEER	4775	0.0931	1,085	16,275

Assumptions

Data centers, telecom, and similar facilities require cooling year round. Systems smaller than 5.42 tons typically do not have any air-side or water-side economizers, so the equivalent full load cooling hours ($EFLH_{COOL}$) is 8,760 hours per year. The load factor accounts for equipment oversizing.

SEER values were converted to EER (for calculating kilowatt savings) based on EER = (-0.02 * SEER^2) + 1.12 * SEER.[7]

The baseline cooling efficiencies are the current code (2015 IECC) for new construction and the previous code (2009 IECC) for retrofits.

The coincidence factor is assumed to be 1.0 because the cooling load is constant year round, so it does not change any during the peak period. The load factor accounts for equipment cycling due to oversizing.

Incremental Costs

The incremental costs per ton for split systems were determined by using costs for 3-ton units in the Itron workbook, which shows installed costs for many SEER levels. Incremental costs per ton for packaged systems were determined for higher SEER levels by extrapolating cost increases for SEER 12 to SEER 14. Incremental costs were relative to 13 SEER for split systems and packaged systems in existing buildings, and relative to 14 SEER for packaged systems in new construction. For packaged systems, incremental costs per ton were averaged between new construction and retrofit baselines.

Incremental Costs by Measure and Delivery

Measure	MMID	Incremental Cost (per ton)[2]
A/C Split System, ≤ 65 MBh, SEER 15	4768	$184.25
A/C Split System, ≤ 65 MBh, SEER 16	4769	$276.38
A/C Split System, ≤ 65 MBh, SEER 17	4770	$368.51
A/C Split System, ≤ 65 MBh, SEER 18	4771	$460.63
A/C Single Package, ≤ 65 MBh, SEER 15	4772	$725.37
A/C Single Package, ≤ 65 MBh, SEER 16	4773	$1,257.35
A/C Single Package, ≤ 65 MBh, SEER 17	4774	$1,789.32
A/C Single Package, ≤ 65 MBh, SEER 18	4775	$2,321.29

Sources

1. Pacific Gas and Electric Company. *2016 PG&E Data Center Baseline and Measurement and Verification (M&V) Guidelines*. p. 19. February 2016. http://www.calmac.org/publications/2016_PG%26E_Data_Center_Baseline_and_M%26V_Guidelines.pdf
2. Itron. *Ex Ante Measure Cost Study results Matrix, Volume I: Hedonic Model Estimates, Version 1.7*. Spreadsheet "NR HW Heater WA017 MCS Results Matrix Volume I August 2016." Equipment + Labor tab, rows 152–175 for split system costs and rows 224–135 for packaged system costs. https://energy.mo.gov/about/trm/supporting-documents
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4. International Code Council. *2009 International Energy Conservation Code*. Table 503.2.3(1). https://codes.iccsafe.org/content/chapter/4718/

5. Air-Conditioning, Heating, and Refrigeration Institute. “Directory of Certified Product Performance.” www.ahridirectory.org.
6. Technical Support Document to Final Rule: Standards, Federal Register, 77 FR 28928:28994-5. Section V. Methodology and Discussion of Comments for Computer Room Air Conditioners, Subsection D., Energy Use Characterization. May 16, 2012. http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0029-0038
7. Wassmer, M. “A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations.” Masters Thesis, University of Colorado at Boulder. 2003.

Revision History

Version Number	Date	Description of Change
01	12/31/2018	Initial TRM entry

Energy-Efficient Drycooler for Data Center

	Measure Details
Measure Master ID	Energy-Efficient Drycooler for Data Center, 2305
Measure Unit	Per ton
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Economizer
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Electricity Savings (kWh)	Varies by ton
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by ton
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$4,882.57[2]

Measure Description

This measure is installing a water-side economizer system that is automatically controlled to enable economizer (free cooling) operation based on outside air temperature. When the outdoor temperature is below a certain value, air conditioning compressors can be turned off.

Description of Baseline Condition

The baseline condition is direct expansion (DX) computer room air conditioning (CRAC) units with no water-side economizer. The system—including CRAC fan, compressor, and condenser fans—operates continuously the entire year to meet the continuous data center cooling load. DX CRAC units with existing economizers or non-functioning economizers do not qualify.

Description of Efficient Condition

The efficient condition is adding a water-side economizer to the DX CRAC unit, which consists of a fluid (typically glycol) loop with a cooling coil in the CRAC unit, a dry cooler outside, and a fluid loop circulating pump. The CRAC unit fan continues to circulate air through the data center. The pressure drop through the added fluid loop cooling coil adds to the static pressure requirement for the CRAC unit fan. The compressor and condenser fans do not operate when the temperature outside is below its enable/disable setpoint temperature (such as 35°F).

Above the drycooler's enable/disable setpoint temperature (such as 65°F), the fluid loop does not operate and the DX system operates as in the baseline condition. Between these enable/disable setpoint temperatures, when both the drycooler and the compressor are allowed to operate, the fluid loop system provides as much cooling as it can, while the DX system makes up the difference. The fluid loop circulation pump and drycooler fans use less power than the DX system compressor, which saves energy.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{BASE} - kWh_{EE}$

$kWh_{BASE} = Cap * \Sigma[(LF * Eff_{COOL,BASE} + P_{CRAC,BASE}) * HOU]$ for each temperature bin

$kWh_{EE} = Cap * \Sigma[(LF * Eff_{COOL,EE} + P_{CRAC,EE} + P_{PUMP} + P_{DC}) * HOU]$ for each temperature bin

$P_{CRAC,BASE} = HP_{CRAC} * 0.746 * MLF_{CRAC,BASE} / Eff_{CRAC}$

$P_{CRAC,EE} = HP_{CRAC} * 0.746 * MLF_{CRAC,EE} / Eff_{CRAC}$

$P_{PUMP} = HP_{PUMP} * 0.746 * MLF_{PUMP} / Eff_{PUMP}$

$P_{DC} = HP_{DC} * 0.746 * MLF_{DC} / Eff_{DC}$

Where:

Cap = Installed cooling capacity of DX split system serving CRAC unit in tons (= user input)

LF = Average load factor on DX cooling system (= 0.65)[3]

$Eff_{COOL,BASE}$ = Air cooled condensing unit efficiency in kilowatts per ton (= user input; otherwise use 1.64 kW/ton per Assumptions)

$P_{CRAC,BASE}$ = CRAC unit fan power per ton without the glycol coil in kW/ton

HP_{CRAC} = CRAC fan horsepower per ton (= user input; otherwise use 0.42 hp/ton per Assumptions)

0.746 = Conversion from horsepower to kilowatts

$MLF_{CRAC,BASE}$ = Motor load factor for CRAC fan without glycol cooling coil (= 0.8; see Assumptions)

EFF_{CRAC} = CRAC fan motor efficiency (= 0.91; see Assumptions)

HOU = Number of hours in temperature bin (= varies with temperature; see Assumptions)

$P_{CRAC,EE}$ = CRAC unit fan power per ton with the glycol coil in kW/ton

$MLF_{CRAC,EE}$ = Motor load factor for CRAC fan with glycol cooling coil (= 0.85; see Assumptions)

P_{PUMP} = Glycol pump power per ton in kW/ton

HP_{PUMP} = Glycol pump horsepower per ton (= user input; otherwise use 0.09 hp/ton per Assumptions)

MLF_{PUMP} = Glycol pump motor load factor (= 0.8; see Assumptions)

Eff_{PUMP} = Glycol pump motor efficiency (= 0.85; see Assumptions)

P_{DC} = Dry cooler fan power per ton in kW/ton

HP_{DC} = Drycooler total fan horsepower per ton (= user input; otherwise use 0.24 hp/ton per Assumptions below)

MLF_{DC} = Motor load factor for drycooler fans (= 0.80; see Assumptions)

Eff_{DC} = Drycooler fan motor efficiency (= 0.65; see Assumptions)

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

At temperatures other than rated condition, down to a minimum condenser temperature of 65°F,[5] the DX cooling system efficiency is calculated using standardized energy modeling equations published by COMNET,[4] a program to standardize building energy modeling that is managed by New Buildings Institute. The cooling system efficiency remains constand below 65°F. Greater detail of savings algorithm inputs can be found in the workbook associated with this workpaper. Motor load factors are assumed to be 0.85 for the CRAC fan in the energy-efficient case and 0.80[6] for other motors. The load factor for the CRAC fan is higher in the energy-efficient case compared to the baseline case to account for the pressure drop from the glycol coil. The value of 0.85 is based on engineering judgement.

The minimum outside air for ventilation is 0 CFM.

Fan and pump powers per ton and motor efficiency were determined from manufacturer data[7,8] and are presented in the table below. These will be used if the actual horsepower of the components are not provided on the application.

Fan and Pump Power per Ton and Efficiency

Equipment	Power	Power Units	Motor Efficiency
CRAC Supply Fan	0.42	hp/ton	95%
Compressor	1.64	kW/ton	-
Condenser Fans	0.15	kW/ton	-
Drycooler Fans	0.24	kW/ton	-
Glycol Pump	0.09	hp/ton	85%

Between 35°F and 65°F, the fraction of the cooling load met by the DX cooling system varies linearly from 0 (off) at 35°F and 1.0 (always on) at 65°F.

Weather data was population weighted using the weighting factors shown in the following table.

Population Weighting Percentages

Location	Weighting by Location
Green Bay	22%
Lacrosse	3%
Madison	18%
Milwaukee	48%
Other (4-City Average)	9%

The four cities account for 91% of the state's population. The values used for the remaining 9% of the state are the averages of the four cities.

Temperature bin hours, population weighted for the state of Wisconsin, are listed in the table below.

Temperature Bin Hours[9]

Temperature Range	Green Bay	LaCrosse	Madison	Milwaukee	Four-City Average	Weighted Average
95°F to 100°F	0	7	0	5	3	3
90°F to 95°F	22	46	25	16	27	21
85°F to 90°F	62	121	86	59	82	68
80°F to 85°F	275	355	339	225	299	267
75°F to 80°F	398	445	486	400	432	419
70°F to 75°F	445	489	447	497	470	474
65°F to 70°F	675	762	723	692	713	698
60°F to 65°F	871	746	770	936	831	877
55°F to 60°F	647	583	605	545	595	584
50°F to 55°F	543	615	597	679	609	626

Temperature Range	Green Bay	LaCrosse	Madison	Milwaukee	Four-City Average	Weighted Average
45°F to 50°F	404	444	491	471	453	**457**
40°F to 45°F	579	597	510	723	602	**638**
35°F to 40°F	777	826	905	883	848	**859**
30°F to 35°F	820	719	741	720	750	**748**
25°F to 30°F	507	425	396	423	438	**438**
20°F to 25°F	579	457	439	531	502	**520**
15°F to 20°F	443	319	353	390	376	**392**
10°F to 15°F	265	227	212	228	233	**234**
5°F to 10°F	178	208	164	125	169	**150**
0°F to 5°F	90	110	105	88	98	**93**
-5°F to 0°F	81	106	157	61	101	**88**
-10°F to -5°F	83	109	105	57	89	**76**
-15°F to -10°F	9	23	70	6	27	**21**
-20°F to -15°F	7	9	21	0	9	**6**
-25°F to -20°F	0	6	9	0	4	**2**
-30°F to -25°F	0	6	4	0	3	**1**

Sources

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2. Wisconsin Focus on Energy. Historical Focus on Energy Project Data obtained from SPECTRUM. Business Incentive and Agriculture, Schools and Government Programs had six projects from 2012 to 2015 with an average cost of $4,882.57/ton.
3. Technical Support Document to Final Rule: Standards, Federal Register, 77 FR 28928:28994-5. Section V. Methodology and Discussion of Comments for Computer Room Air Conditioners, Subsection D., Energy Use Characterization. May 16, 2012. http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0029-0038
4. COMNET. Modelling Guidelines, Section 3.7.5 Cooling Systems. https://comnet.org/375-cooling-systems
5. Daikin. *Chiller Application Guide*. p. 18. 2014. https://www.daikinapplied.com/o365/api/graphapi/GetDocument/Doc100/Daikin_AG_31-003_Chiller_Application_Guide.pdf/

6. U.S. Department of Energy. *Determining Electric Motor Load and Efficiency.* https://www.energy.gov/sites/prod/files/2014/04/f15/10097517.pdf
Figure 1 shows an acceptable operating range of 55% to 100%. Selected 80% as typical.
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8. Vertiv. *Liebert DS Thermal Management Systems System, System Design Catalog, 35 to 105 kW (10 to 30 ton) Capacity, Upflow and Downflow, 50 and 60 Hz, Air-cooled, Water/Glycol-cooled, GLYCOOL Economizer Coil, Dual-Cool DX with Secondary Chilled-water Coil*. 2018. https://www.vertivco.com/globalassets/products/thermal-management/room-cooling/liebert-ds-28-105kw-8-30-tons-system-design-manual.pdf
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Revision History

Version Number	Date	Description of Change
01	02/28/2019	Initial TRM entry

Steam Trap Repair, < 10 psig, General Heating

	Measure Details
Measure Name and ID	Steam Trap Repair, <10 psig, General Heating, Prescriptive: 7/32" or Smaller, 4004, 4648 1/4", 4005, 4649 5/16", 4006, 4650 3/8" or Larger, 4007, 4651
Measure Unit	Per steam trap
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Steam Trap
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure, see table below
Lifecycle Electricity Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure, see table below
Water Savings (gal/year)	0
Effective Useful Life (years)	6[1]
Incremental Cost ($/unit)	$50.89[2]

Measure Description

Steam distribution systems contain steam traps, which are automatic valves that remove condensate, air, and other non-condensable gases while preventing or minimizing steam loss. This measure is the repair of failed open and leaking steam traps on steam systems supplying space heating only.

Steam traps that fail in the open position allow steam to escape into the condensate lines before the available heat energy can be used for space heating, wasting the energy used to make the steam. By replacing or repairing traps that have failed in the open position, the wasted heating energy can be conserved.

The measure specifications are as follows:

- Boiler must be used for space heating, not process applications
- Repaired traps must be leaking steam, not be failed in the closed position or plugged
- The incentive is available once per year per system
- Municipal steam systems do not qualify
- When mass replacing steam traps, 20% of traps replaced will qualify
- System pressure must be < 10 psig

A steam trap survey and repair log must be completed. The information required to determine savings includes a trap identification tag number, location description, nominal steam pressure, trap type, trap condition (functioning, failed open, or failed closed), and trap orifice diameter.

Description of Baseline Condition

The measure baseline is a steam trap that has failed in the open position and is leaking steam into the condensate line in a steam system. The steam from the boiler must be used for space heating and not for process applications. It is important to note that the trap must be failed in the open position and not be failed in the closed position or plugged.

Description of Efficient Condition

The efficient condition is replacing or repairing traps that have failed in the open position, providing the ability to use steam heat that was previously wasted.

Annual Energy-Savings Algorithm

$$\text{Therm}_{SAVED} = 1.9 * K * 60 * (\pi * D^2/4) * \sqrt{([P_{ABS} - \{P_1 - P_2\}] * [P_1 - P_2])} * h_{FG} * HOU * DF / (100{,}000 * eff)$$

Where:

1.9 = Constant based on units and fluid flow equation[3]

K = Discharge coefficient (= 0.55)[4]

60 = Conversion from minutes to hours

D = Steam trap orifice diameter (= 7/32-inches, 1/4-inches, 5/16-inches, or 3/8-inches)

P_{ABS} = System absolute pressure in pounds per square inch (= 20.7 psia; steam gage pressure at trap inlet (6 psig) + atmospheric pressure at sea level in pounds per square inch (14.7 psi))[5]

P_1 = Steam pressure at trap inlet (= 6 psig)[5]

P_2 = Steam pressure at trap outlet, condensate tank pressure (= 0 psig)

h_{FG} = Latent heat of steam at system absolute pressure (= 959 Btu/lb)[6]

HOU = Annual hours of operation the boiler is on and the system is at design pressure (= 5,510)[7]

DF = Derating factor to account for the average percentage of time the trap fails in the open position and actual versus theoretical energy loss (= 5.9%)[5]

100,000 = Conversion factor from Btu to therms

eff = Boiler efficiency (= 80%)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure, as it does not generate electric savings.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 6 years)[1]

Deemed Savings

Deemed Savings

Measure Name	MMID	Energy Savings (therms)	
		Annual	Lifecycle
Steam Trap Repair, < 10 psig, General Heating, 7/32-inches or Smaller	4004	86	517
Steam Trap Repair, < 10 psig, General Heating, 1/4-inches	4005	113	676
Steam Trap Repair, < 10 psig, General Heating, 5/16-inches	4006	176	1,056
Steam Trap Repair, < 10 psig, General Heating, 3/8-inches or Larger	4007	253	1,521

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Average measure cost of five projects (Radiator Measure MMID 2772) from 2012 to 2014 for low-pressure heating measures, with extrapolated industrial costs.
3. Hornaday, William T. "Steam: Its Generation and Use." Equation 50. Merchant Books, 2007. http://www.gutenberg.org/files/22657/22657-h/chapters/flow.html#page_321
   This formula applies for subsonic flow, which occurs when steam flows through an orifice where $P_2 \geq 58\%$ of P_1.
4. Manczyk Energy Consulting. "Estimating the Cost of Steam Loss Through the Orifice of a Steam Trap." http://invenoinc.com/file/Estimating-the-Steam-Loss-through-a-Orifice-of-a-Steam-Trap.pdf
   The discharge coefficient was determined by converging flow rates with the Napier equation at $P_2 = 0.58 * P_1$. The Napier equation is used to determine flow rate through an orifice when $P_2 \leq 0.58 * P_1$. The Napier equation is in fact Equation 49 in source 3, with an added discharge coefficient of 0.6. Matching Equation 50 in source 3 to the Napier formula in the link above, at

$P_2 = 0.58 * P_1$, produces this equality: $1.9 * (\pi/4 * D^2) * K * \surd([P_1 – 0.42 * P_1] * 0.42 * P_1) * 60 = 24.24 * P_1 * D^2$. Note that 60 is inserted to convert lb/min to lb/hr, and that P_1 and P_2 are treated as absolute pressures. Solving this produces K = 0.55.

5. Cadmus. “Focus on Energy Steam Trap Study.” 2016. Unpublished.
   The study determined realized savings from billing data for 35 sites that had applied for steam trap incentives during the 2012 to 2014 program years. This study revealed 6 psig as the weighted average pressure of < 10 psig steam traps surveyed.
   These sites had an overall realization rate of billing data results to calculated savings (using algorithms in this workpaper with site-specific values and the previous derating factor of 50%) of 11.8%, suggesting that a derating factor of 5.9% would be more appropriate. Note: the 50% derating factor came from: Enbridge Steam Saver Program. 2005.
6. The Engineering Toolbox. “Properties of Saturated Steam - Imperial Units.”
   http://www.engineeringtoolbox.com/saturated-steam-properties-d_273.html
7. Appendix B. Outside Air Temperature Bin Analysis table.
   PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Updated March 22, 2010.
   https://focusonenergy.com/sites/default/files/
   bpdeemedsavingsmanuav10_evaluationreport.pdf
   Since HOU is dependent on trap type, a weighted average HOU was calculated for this measure. Approximately 10% of traps are float-and-thermostatic type traps (Wisconsin TRM v1.0). These are under pressure whenever the boiler is operating, an estimated nine months or 6,570 hours per year. The remaining 90% of traps are thermostatic and are under pressure only when the building is in heating, approximately 5,392 hours per year according to the Outside Air Temperature Bin Analysis table in Appendix B. These values produce a weighted average of 5,510 hours per year.

Revision History

Version Number	Date	Description of Change
01	1/2017	Initial workpaper
02	5/2018	Adjusted derating factor to 5.9%

Steam Trap Repair, > 10 psig, General Heating

	Measure Details
Measure Master ID	Steam Trap Repair, 10-49 psig, General Heating, Prescriptive: 7/32" or Smaller, 4008 1/4", 4009 5/16", 4010 3/8" or Larger, 4011 Steam Trap Repair, 50-124 psig, General Heating, Prescriptive: 7/32" or Smaller, 4012 1/4", 4013 5/16", 4014 3/8" or Larger, 4015 Steam Trap Repair, 125-225 psig, General Heating, Prescriptive: 7/32" or Smaller, 4016 1/4", 4017 5/16", 4018 3/8" or Larger, 4019 Steam Trap Repair, > 225 psig, General Heating, Prescriptive: 7/32" or Smaller, 4020 1/4", 4021 5/16", 4022 3/8" or Larger, 4023
Measure Unit	Per system psi, absolute
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Steam Trap
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure, see algorithm below
Lifecycle Electricity Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure, see algorithm below
Water Savings (gal/year)	0
Effective Useful Life (years)	6[1]
Incremental Cost ($/unit)	Varies by measure, see table below

Measure Description

Steam distribution systems contain steam traps, which are automatic valves that remove condensate, air, and other non-condensable gases while preventing or minimizing steam loss. This measure is the repair of failed open and leaking steam traps on steam systems supplying space heating only.

Steam traps that fail in the open position allow steam to escape into the condensate lines before the available heat energy can be used for space heating, wasting the energy used to make the steam. By replacing or repairing traps that have failed in the open position, the wasted heating energy can be conserved.

The measure specifications are as follows:

- Boiler must be used for space heating, not process applications
- Repaired traps must be leaking steam, not be failed in the closed position or plugged
- Incentive is available once per year per system
- Municipal steam systems do not qualify
- When mass replacing steam traps, 20% of traps replaced will qualify
- System pressure must be ≥ 10 psig

A steam trap survey and repair log must be completed. The information required to determine savings includes a trap identification tag number, location description, nominal steam pressure, trap type, trap condition (functioning, failed open, or failed closed), and trap orifice diameter. The implementer should record the absolute system steam pressure at trap inlet (psia = psig + 14.7) as a savings input.

Description of Baseline Condition

The measure baseline is a steam trap that has failed in the open position and is leaking steam into the condensate line in a high pressure (≥ 10 psig) steam system. The steam from the boiler must be used for space heating and not for process applications. The boiler is assumed to operate with 80% efficiency. It is important to note that the trap must be failed in the open position and not be failed in the closed position or plugged.

Description of Efficient Condition

The efficient condition is replacing or repairing traps that have failed in the open position, providing the ability to use steam heat that was previously wasted.

Annual Energy-Savings Algorithm

The steam leakage rate was determined following the Napier equation.[2]

$\text{Therm}_{\text{SAVED}} = 24.24 * P_{\text{ABS}} * D^2 * h_{\text{FG}} * \text{HOU} * \text{DF} \ / \ (100{,}000 * \text{eff})$

Where:

24.24 = Constant from Napier equation when units for absolute system pressure are in psia and units of diameter are in inches

P_{ABS} = System absolute pressure in pounds per square inch (= steam gauge pressure at trap inlet plus atmospheric pressure at sea level in pounds per square inch [= psig + 14.7]; system absolute pressure at steam trap inlet to be input by implementers)

D = Steam trap orifice diameter in inches (= 7/32-inches, 1/4-inches, 5/16-inches, or 3/8-inches)

h_{FG} = Latent heat of vaporization for water at P_{ABS} (= varies by measure; see table below)

HOU = Annual hours of operation when the boiler is on and the system is at design pressure (= 5,510)[4]

DF = Derating factor to account for the average percentage a trap fails in the open position, and to account for actual versus theoretical energy loss (= 5.9%)[3]

100,000 = Conversion factor from Btu to therms

eff = Boiler efficiency (= 80%)

The amount of therms saved varies based on system pressure (the system absolute pressure at trap inlet is to be recorded by implementers) and orifice diameter.

The latent heat of vaporization value (h_{FG}) corresponds to the assumed system absolute pressures (P_{ABS}), as shown in the table below. The latent heat of vaporization values for each measure's pressure range was determined using assumed mid-range pressures. The implementers are to input the absolute system pressure at trap inlet when calculating savings. The following is a simplified algorithm to calculate annual savings:

$\text{Therm}_{\text{SAVED}}$ = System Absolute Pressure * Annual Savings Multiplier

= [System Gauge Pressure + 14.7] * Annual Savings Multiplier

Pressure, Latent Heat, and Savings Multipliers

Measure Name	MMID	Assumed P_{ABS} for h_{FG}[3]	Deemed h_{FG} Latent Heat of Steam (Btu/lb)[5]	Annual Savings Multiplier (therms/psia)	Lifetime Savings Multiplier (therms/psia)
Steam Trap Repair, 10-49 psig, General Heating					
7/32" or Smaller	4008	44.7	929	4.4	26.3
1/4"	4009		929	5.7	34.3
5/16"	4010		929	8.9	53.6
3/8" or Larger	4011		929	12.9	77.2
Steam Trap Repair, 50-124 psig, General Heating					
7/32" or Smaller	4012	102.2	887.5	4.2	25.1
1/4"	4013		887.5	5.5	32.8
5/16"	4014		887.5	8.5	51.2
3/8" or Larger	4015		887.5	12.3	73.8
Steam Trap Repair, 125-225 psig, General Heating					
7/32" or Smaller	4016	190.2	846.8	4.0	23.9
1/4"	4017		846.8	5.2	31.3
5/16"	4018		846.8	8.1	48.9
3/8" or Larger	4019		846.8	11.7	70.4
Steam Trap Repair, > 225 psig, General Heating					
7/32" or Smaller	4020	240.7	827.8	3.9	23.4
1/4"	4021		827.8	5.1	30.6
5/16"	4022		827.8	8.0	47.8
3/8" or Larger	4023		827.8	11.5	68.8

For example, for MMID 4008 (Steam Trap Repair, 10-49 psig, General Heating, 7/32-inches or Smaller), a steam trap repaired on a 11 psig system with an orifice diameter of 7/32-inches has an annual savings multiplier of 4.4 and would result in an annual savings of 113.1 therms:

$$\text{Therm}_{\text{SAVED}} = 24.24 * (11 + 14.7) * 0.21875^2 * 929 * 5{,}510 * 5.9\% / (100{,}000 * 80\%)$$

or

$$\text{Therm}_{\text{SAVED}} = (11 + 14.7) * 4.4 = 113.1$$

Summer Coincident Peak Savings Algorithm

There are no peak coincident savings for this measure, which does not generate electric savings.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 6 years)[1]

Incremental Cost

Incremental Cost and Source

Measure Name	MMID	Incremental Cost	Source
Steam Trap Repair, 10-49 psig, General Heating			
7/32" or Smaller	4008	$100.81	Average of 15 projects for MMID 3269 in 2014
1/4"	4009	$79.84	Average of 22 projects for MMID 3270 in 2014. One project with outlier cost excluded.
5/16"	4010	$70.60	Average of 11 projects for MMID 3271 in 2014
3/8" or Larger	4011	$231.67	Average of nine projects for MMID 3272 in 2014. One project with outlier cost excluded.
Steam Trap Repair, 50-124 psig, General Heating			
7/32" or Smaller	4012	$391.02	Average of four projects for MMID 2547 (Repair leaking steam trap, 50-125 psig), 2013 and 2014
1/4"	4013		
5/16"	4014		
3/8" or Larger	4015		
Steam Trap Repair, 125-225 psig, General Heating			
7/32" or Smaller	4016	$633.83	One project for MMID 2545 in 2013
1/4"	4017		
5/16"	4018		
3/8" or Larger	4019		
Steam Trap Repair, >225 psig, General Heating			
7/32" or Smaller	4020	$1,127.66	Pressure-based extrapolation of costs for MMIDs 2547 and 2545 and average costs for MMIDs 3269, 3270, 3271, and 3272
1/4"	4021		
5/16"	4022		
3/8" or Larger	4023		

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. “Steam Pressure Reduction: Opportunities and Issues.” November 2005. https://energy.gov/eere/amo/downloads/steam-pressure-reduction-opportunities-and-issues
3. Cadmus. “Focus on Energy Steam Trap Study.” 2016.
   The study determined realized savings from billing data for 35 steam trap sites during the 2012 to 2014 program years. These sites had an overall realization rate of billing data results to calculated savings of 11.8% (using algorithms in this workpaper with site-specific values and the previous derating factor of 50%), suggesting that a derating factor of 5.9% would be more appropriate. The 50% derating factor came from the Enbridge Steam Saver Program, 2005.
4. Appendix B. Outside Air Temperature Bin Analysis table.
   PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
   Since HOU is dependent on trap type, a weighted average HOU was calculated for this measure. Approximately 10% of traps are float-and-thermostatic type traps (Wisconsin TRM v1.0). These are under pressure when the boiler is operating, an estimated nine months or 6,570 hours per year. The remaining 90% of traps are thermostatic and are under pressure only when the building is heating, approximately 5,392 hours per year according to the Outside Air Temperature Bin Analysis table in Appendix B. These values produce a weighted average of 5,510 hours per year.
5. The Engineering Toolbox. “Properties of Saturated Steam - Imperial Units.” http://www.engineeringtoolbox.com/saturated-steam-properties-d_273.html
   User must take the ‘Assumed P_{ABS} for h_{FG}’ value from the table above and subtract 14.7 psi to correspond to the correct gauge pressure listed in this source’s table when looking up corresponding h_{FG} value.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry; system pressure < 50 psig
02	01/2015	Initial TRM entry; system pressure > 50 psig
03	07/2016	Included all MMIDs for pressure ≥ 15psi, corrected algorithm
04	02/2017	Changed assumptions for all measures
05	05/2018	Adjusted DF to 5.9%

Steam Trap Repair, < 10 psig, Radiator

	Measure Details
Measure Name	Steam Trap Repair, < 10 psig, Radiator, 2772
Measure Unit	Per steam trap
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Steam Trap
Sector(s)	Commercial, Agriculture, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	113
Lifecycle Electricity Savings (kWh)	0
Lifecycle Therm Savings (Therms)	676
Water Savings (gal/year)	0
Effective Useful Life (years)	6[1]
Incremental Cost ($/unit)	$58.31[2]

Measure Description

Steam distribution systems contain steam traps, which are automatic valves that remove condensate, air, and other non-condensable gases while preventing or minimizing steam loss. This measure is the repair of failed open and leaking steam traps on steam systems supplying space heating only.

Steam traps that fail in the open position allow steam to escape into the condensate lines before the available heat energy can be used for space heating, wasting the energy used to make the steam. By replacing or repairing traps that have failed in the open position, the wasted heating energy can be conserved.

The measure specifications are as follows:

- Steam trap must be for a space heating radiator
- Repaired traps must be leaking steam, not be failed in the closed position or plugged
- Incentive is available once per year per system
- Municipal steam systems do not qualify
- When mass replacing steam traps, 20% of traps replaced will qualify
- System pressure must be < 10 psig with a 1/4-inch diameter orifice

A steam trap survey and repair log must be completed. The information required to determine savings includes a trap identification tag number, location description, nominal steam pressure, trap type, trap condition (functioning, failed open, or failed closed), and trap orifice diameter.

Description of Baseline Condition

The measure baseline is a steam trap that has failed in the open position and is leaking steam into the condensate line in a steam system. The steam from the boiler must be used for space heating and not for process applications. It is important to note that the trap must be failed in the open position and not be failed in the closed position or plugged.

Description of Efficient Condition

The efficient condition is replacing or repairing traps that have failed in the open position, providing the ability to use steam heat that was previously wasted.

Annual Energy-Savings Algorithm

The steam trap is assumed to be failed in the open position in an HVAC steam distribution system operating with a boiler efficiency of 80%. The savings are calculated from the steam leakage rate according to the following formula:[3]

$$\text{Therm}_{\text{SAVED}} = 1.9 * K * 60 * (\pi * D^2/4) * \sqrt{([P_{\text{ABS}} – \{P_1 – P_2\}] * [P_1 – P_2])} * h_{\text{FG}} * \text{HOU} * \text{DF} / (100{,}000 * \text{eff})$$

Where:

1.9 = Constant based on units and fluid flow equation[3]

K = Discharge coefficient (= 0.55)[4]

60 = Unit conversion for minutes per hour

D = Steam trap orifice diameter (= 1/4-inches)

P_{ABS} = System absolute pressure in pounds per square inch (= 20.7 psia; steam gage pressure at trap inlet (6 psig) plus atmospheric pressure at sea level (14.7 psi)[5]

P_1 = Steam pressure at trap inlet (= 6 psig)[5]

P_2 = Steam pressure at trap outlet, condensate tank pressure (= 0 psig)

h_{FG} = Latent heat of steam at P_{ABS} (= 959 Btu/lb)[6]

HOU = Annual hours of operation the boiler is on and the system is at design pressure (= 5,510)[8]

DF = Derating factor to account for the average percentage of time a trap fails in the open position, and to account for actual versus theoretical energy loss (= 5.9%)[5]

100,000 = Conversion factor from Btu to therms

eff = Boiler efficiency (= 80%)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure, as it does not generate electric savings.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}} = \text{Therm}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (= 6 years)[1]

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 1,018 units over 21 projects from 2013 to 2018.
3. Hornaday, William T. "Steam: Its Generation and Use." Equation 50. Merchant Books, 2007. July 13, 2016. http://www.gutenberg.org/files/22657/22657-h/chapters/flow.html#page_321
   The equation applies to subsonic flow, which occurs when steam flows through an orifice where $P_2 \geq 58\%$ of P_1
4. Manczyk Energy Consulting. "Estimating the Cost of Steam Loss Through the Orifice of a Steam Trap." http://invenoinc.com/file/Estimating-the-Steam-Loss-through-a-Orifice-of-a-Steam-Trap.pdf
   The discharge coefficient was determined by converging flow rates with the Napier equation at $P_2 = 0.58 * P_1$. The Napier equation is used to determine flow rate through an orifice when $P_2 \leq 0.58 * P_1$. This is equation 49 from source 3, with an added discharge coefficient of 0.6. Matching equation 50 in source 3 to the Napier formula at $P_2 = 0.58 * P_1$ produces this equality: $1.9 * (\pi/4 * D^2) * K * \sqrt{}([P_1 – 0.42 * P_1] * 0.42 * P_1) * 60 = 24.24 * P_1 * D^2$. Note that 60 is inserted to convert lb/min to lb/hr, and that P_1 and P_2 are treated as absolute pressures. Solving this equation produces $K = 0.55$.
5. Cadmus. "Focus on Energy Steam Trap Study." 2016. Unpublished.
   The study determined realized savings from billing data for 35 sites that had applied for steam trap incentives during the 2012 to 2014 program years. This study revealed 6 psig as the weighted average pressure of < 10 psig steam traps surveyed.
   These sites had an overall realization rate of billing data results to calculated savings of 11.8%

(using algorithms in this workpaper with site-specific values and the previous derating factor of 50%), suggesting that a derating factor of 5.9% would be more appropriate. The 50% derating factor came from the Enbridge Steam Saver Program, 2005.

6. “The Engineering Toolbox.” http://www.engineeringtoolbox.com/saturated-steam-properties-d_273.html
7. Enbridge Steam Saver Program. 2005.
8. Appendix B. Outside Air Temperature Bin Analysis table.
   https://focusonenergy.com/sites/default/files/TRM_Fall_2015__10-22-15.compressed2.pdf
   PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Updated March 22, 2010.
   https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
   Since HOU is dependent on trap type, a weighted average HOU was calculated for this measure. Approximately 10% of traps are float-and-thermostatic type traps (Wisconsin TRM v1.0). These are under pressure whenever the boiler is operating, an estimated nine months or 6,570 hours per year. The remaining 90% of traps are thermostatic and are under pressure only when the building is in heating, approximately 5,392 hours per year according to the Outside Air Temperature Bin Analysis table in Appendix B. These values produce a weighted average of 5,510 hours per year.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry; system pressure < 50 psig
02	01/2015	Initial TRM entry; system pressure > 50 psig
03	07/2016	Corrected algorithm for subsonic flow (when P2 ≥ 0.58 * P1) and adjusted derating factor to match savings calculations to billing analysis results
04	05/2018	Adjusted derating factor to 5.9%

Chiller Plant Setpoint Adjustment

	Measure Details
Measure Master ID	EBTU Chiller Plant: Chilled Water Setpoint Adjustment, 3659 Condenser Water Setpoint Adjustment, 3660
Measure Unit	Per ton
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$108.00[2]

Measure Description

The intent of this measure is to capture savings associated with adjusting the chilled water setpoint to a higher temperature that is determined to still meet the building cooling load requirement. This involves re-programming the chiller plant controls to optimize chilled water setpoint temperatures for the building based on usage. This measure includes condenser water temperature setpoint adjustments as well.

This measure is not applicable to DX cooling systems. This measure is not applicable to buildings that already use a chilled water reset control strategy or that normally change their chilled water setpoint temperature on a regular basis for control.

The measure can be applied only once per building during the EUL. This measure is meant to be a part of the Express Building Tune-Up Program to help optimize building HVAC systems to operate more efficiently at existing building load conditions. It does not apply to newly constructed facilities that have not been commissioned.

Description of Baseline Condition

The baseline measure is a chiller plant with an opportunity for energy savings from adjusting either the chilled and/or condenser water supply setpoint temperature values of a chiller system up or down a few degrees, respectively. The existing chiller cannot already use a chiller control that varies the chiller and condenser temperatures on a regular basis.

Description of Efficient Condition

This efficient measure is a chiller plant that has undergone a setpoint increase in the chilled water and/or a setpoint decrease in the condenser water loop supply temperatures. The HVAC professional implementing these changes must also verify that any change in setpoint temperature values must still be determined to adequately meet building cooling loads to avoid undoing the setpoint changes later.

Annual Energy-Savings Algorithm

Savings are determined by summing the baseline and proposed energy consumption formulas below across the bin data temperature ranges and corresponding bin temperature hours found in the EBTU workbook.[3,4]

$$kWh_{SAVED} = kWh_{BASE} – kWh_{PROPOSED}$$

$$\begin{aligned} kWh_{BASE} = \Sigma\ [(&\Delta T_{EXISTING\ CHILLED\ H2O} * 500 * \text{Chiller GPM} * \text{bin hrs} * \text{Chiller\_Eff} * \text{Area Load} / 12{,}000)\ - \\ &(\Delta T_{BASELINE\ LMTD} * 500 * \text{Condenser GPM} * \text{bin hrs} * \text{Chiller\_Eff} * \text{Area Load} / 12{,}000)] \end{aligned}$$

$$\begin{aligned} kWh_{PROPOSED} = \Sigma\ [(&\Delta T_{PROPOSED\ CHILLED\ H2O} * 500 * \text{Chiller GPM} * \text{bin hrs} * \text{Chiller\_Eff} * \text{Area Load} / 12{,}000)\ - \\ &(\Delta T_{PROPOSED\ LMTD} * 500 * \text{Condenser GPM} * \text{bin hrs} * \text{Chiller\_Eff} * \text{Area Load} / 12{,}000)] \end{aligned}$$

Where:

$\Delta T_{EXISTING\ CHILLED\ H2O}$ = Estimated chilled water return temperature - existing chilled water supply temperature

$\Delta T_{PROPOSED\ CHILLED\ H2O}$ = Estimated chilled water return temperature - proposed chilled water supply temperature

500 = Water sensible heat equation constant

Chiller GPM = (= 2 GPM/ton)[5]

bin hours = Bin hours used in workbook for each respective city[4]

Chiller_Eff = kW/ton partial load rating (= based on chiller type; see table below)

Area Load = Percentage based on linear interpolation of a 60°F dry bulb OAT balance point, bin data dry bulb OAT, and 2.5% dry bulb design summer/winter conditions for different Wisconsin cities[6] (see Assumptions for more explanation of 2.5% dry bulb design conditions)

12,000 = Btu to ton conversion factor

$\Delta T_{\text{BASLINE LMTD}}$ = Logarithmic mean (see equation below)

LMTD = $(\Delta T_A - \Delta T_B) / [\ln(\Delta T_A / \Delta T_B)] = (\Delta T_A - \Delta T_B) / [\ln \Delta T_A - \ln \Delta T_B)]$

Where:

ΔT_A = Existing condenser water supply temperature (= 95°F)[7]

ΔT_B = Existing chilled water return temperature – existing chilled water supply temperature

Condenser GPM = (= 3 GPM/ton for electric chillers)[5]

$\Delta T_{\text{PROPOSED LMTD}}$ = Logarithmic mean (see equation below)

LMTD = $(\Delta T_A - \Delta T_B) / [\ln(\Delta T_A / \Delta T_B)] = (\Delta T_A - \Delta T_B) / [\ln \Delta T_A - \ln \Delta T_B)]$

Where:

ΔT_A = Proposed condenser water supply temperature (=95°F)[7]

ΔT_B = Proposed chilled water return temperature – proposed chilled water supply temperature

Cooling Efficiency Factor by System Type[8]

Cooling System Type	Cooling System Efficiency Factor at Partial Load (kW/ton)
Air-Cooled Chiller	0.95
Water-Cooled Chiller	0.64

The workbook calculator requires the following measure-specific inputs to be provided from the trained professional performing the tune-up/optimization measure:

- Chiller capacity (tons) = AHRI rated capacity (if possible), otherwise = general rated capacity
- Existing and proposed chilled water setpoints
- Existing and proposed condenser water setpoints
- Cooling system type (air-cooled chiller or water-cooled chiller)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / Hours_{COOL} * CF$

Where:

$Hours_{COOL}$ = Annual cooling hours of operation (= varies by city; see table below)

Annual Cooling Hours by City

City	BIN Annual Cooling Hours (Outside Air Temperature > 60°F)[9]
Green Bay	2,748
La Crosse	2,971
Madison	2,876
Milwaukee	2,830

CF = Coincidence factor (= 1)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)[1]

Assumptions

- Chilled and condenser water flow rates are assumed to be 2 GPM and 3 GPM per ton, respectively, of cooling system refrigeration capacity.[5]
- 2.5% dry bulb design conditions mean that for cooling/heating seasons, the HVAC system is designed to adequately handle the cooling/heating of a given building for all outdoor air temperatures that do not exceed the hottest/coldest 2.5% of hours in the respective season. Explained another way, this is the point where the cooling/heating system can adequately handle the cooling/heating load of a given building for 97.5% of the total anticipated peak cooling/heating hours for the year.

Sources

1. Cadmus. EUL Response Memo. April 26, 2013. (Used Retrocommissioning Program EUL standard and direction from CB&I to keep 5 year EUL standard).
2. RSMeans 2013 Facilities Construction Cost Data, 29th Edition
3. Wisconsin Focus on Energy. EBTU Measures Workbook Calculator.

4. National Renewable Energy Laboratory. Bin temperature data from respective Wisconsin city TMY3 weather data. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#W
5. Edison Electric Institute. Technical Information Handbook. p. 23. 2000.
6. ASHRAE Handbook, Fundamentals Volume for Wisconsin Cities. 1985. http://publicecodes.cyberregs.com/icod/ipc/2012/icod_ipc_2012_appd.htm
7. Edison Electric Institute. Technical Information Handbook. p. 12. 2000.
8. ASHRAE 90.1-2007. Table 6.8.1C. Simple average of minimum efficiency for chillers with capacity between 0 tons and 300 tons.

Revision History

Version Number	Date	Description of Change
01	09/2013	Initial TRM entry

Cooling System Tune-Up

	Measure Details
Measure Master ID	Chiller System Tune Up: Air Cooled, ≤ 500 Tons, 2666 Air Cooled, > 500 Tons, 2667 Water Cooled, ≤ 500 Tons, 2668 Water Cooled, > 500 Tons, 2669
Measure Unit	Per ton
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by cooling mechanism
Peak Demand Reduction (kW)	Varies by cooling mechanism
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by cooling mechanism
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$35.00[4]

Measure Description

This measure is a chiller system tune-up for air and water-cooled chillers completed in accordance with the chiller system tune-up checklist.

Tune-up requirements:

- Clean condenser coil/tubes
- Check cooling tower for scale or buildup
- Check contactors condition
- Check evaporator condition
- Check low-pressure controls
- Check high-pressure controls
- Check filter, replace as needed
- Check belt, replace as needed
- Check crankcase heater operation
- Check economizer operation

Measurement requirements:

- Record system pressure psig
- Record compressor amp draw
- Record liquid line temperature in °F
- Record subcooling and superheat temperatures in °F
- Record suction pressure psig and temperature in °F
- Record condenser fan amp draw
- Record supply motor amp draw

Description of Baseline Condition

The baseline is air-cooled and water-cooled chillers that operate at a diminished efficiency from design specifications.

Description of Efficient Condition

The efficient condition is a chiller system tune-up conducted to ensure that equipment is operating at its best and as preventative maintenance to extend the life of the equipment. Tune-ups improve the chiller's efficiency and performance and are useful system checks, as regular maintenance keeps the equipment operating as specified.

Annual Energy-Savings Algorithm

Because the existing chiller efficiency cannot be determined without extensive testing, the ASHRAE 90.1-2007[3] minimum efficiency for chillers is used for the baseline efficiency.

Minimum Efficiencies from ASHRAE 90.1-2007

Equipment Type	Size Category	Minimum Efficiency
Air Cooled, with Condenser	All capacities	2.80 COP; 3.05 IPLV
Air Cooled, without Condenser	All capacities	3.10 COP; 3.45 IPLV
Water Cooled, Electrically Operated, Positive Displacement (Reciprocating)	All capacities	4.2 COP; 5.05 IPLV
Water Cooled, Electrically Operated, Positive Displacement (Rotary Screw and Scroll)	< 150 tons	4.45 COP; 5.20 IPLV
	≥ 150 tons and < 300 tons	4.90 COP; 5.60 IPLV
Water Cooled, Electrically Operated, Positive Displacement (Rotary Screw and Scroll)	≥ 300 tons	5.50 COP; 6.15 IPLV
Water Cooled, Electrically Operated, Centrifugal	< 150 tons	5.00 COP; 5.25 IPLV
	≥ 150 tons and < 300 tons	5.55 COP; 5.90 IPLV
	≥ 300 tons	6.10 COP; 6.40 IPLV

The annual energy savings and demand reduction are calculated by applying a percentage savings to the baseline consumption. Parametric runs were applied to estimate deemed savings for this measure.

Existing Equipment as a Baseline:

$kWh_{SAVED} = (IPLV_{BASLINE\ EXISTING}) * ton * HOU * \%\ savings$

Where:

$IPLV_{BASLINE\ EXISTING}$ = Integrated part load value of baseline chiller (= 3.05 for air cooled; = 5.85 for water cooled)[3]

ton = Equipment size (= 50, 100, 150 for air cooled; = 100, 200, 300 for water cooled)

HOU = Determined from weather bin hours and building design cooling load (~ 1,440)

% savings = Percentage savings associated with a chiller tune-up (= 5%)[2]

Summer Coincident Peak Savings Algorithm

Existing Equipment as a Baseline:

$kW_{SAVED} = (Full\ Load\ kW/Ton_{BASELINE\ EXISTING} * \%\ savings) * CF * Tons$

Where:

$Full\ Load\ kW/ton_{BASELINE\ EXISTING}$ = Full load power draw of baseline chiller[3]

CF = Coincidence factor (= 0.80)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)[1]

Deemed Savings

Deemed Savings by Measure Type

	Air Cooled (MMID 2666 if ≤ 500 Tons; MMID 2667 if > 500 Tons)	Water Cooled (MMID 2668 if ≤ 500 Tons; MMID 2669 if > 500 Tons)
Average Annual Deemed Savings (kWh/year/ton)	83	44
Peak Demand Reduction (kW/ton)	0.0461	0.0242
Average Lifecycle Deemed Savings (kWh/year/ton)	415	218

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. United States Department of Energy. *Building Technologies Program: Hospitals Benefit by Improving Inefficient Chiller Systems.* White paper. August 2011. The paper found that coil cleaning, the primary savings associated with this cooling tune-up measure, reduces annual cooling energy consumption by 5% to 7%.
3. ASHRAE 90.1-2007 air cooled and water-cooled chiller efficiencies. Simple averages were taken from the following sizes (in tons): air cooled 50, 100, 150; water cooled 100, 200, 300. The respective IPLVs were applied: air cooled 3.05, 3.05, 3.05; water cooled 5.25, 5.9, 6.4.
4. Illinois Technical Reference Manual. p. 154. 2013. Incremental Cost source listed as: Act on Energy Commercial Technical Reference Manual No. 2010-4. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry

Guest Room Energy Management

	Measure Details
Measure Master ID	Guest Room Energy Management Controls: Electric Heat PTAC Systems, 2373 PTHP Systems, 4748 Not Otherwise Specified, 2374
Measure Unit	Per room
Measure Type	Prescriptive (MMIDs 2373 and 4748); Hybrid (MMID 2374)
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Agriculture, Commercial, Industrial, Schools & Government
Annual Energy Savings (kWh)	Varies by system type
Peak Demand Reduction (kW)	Varies by system type
Annual Therm Savings (Therms)	0 (MMIDs 2373 and 4748); Varies for MMID 2374
Lifecycle Energy Savings (kWh)	Varies by system type
Lifecycle Therm Savings (Therms)	0 (MMIDs 2373 and 4748); Varies for MMID 2374
Water Savings (gal/year)	0
Effective Useful Life (years)	8[1]
Incremental Cost ($/unit)	$260[2]

Measure Description

A guest room energy management system controls HVAC systems in hotel rooms by setting back thermostat setpoints when the room is unoccupied. Guest room energy management controls reduce the energy wasted by reducing over-heating and over-cooling unoccupied rooms. Lighting controls are not part of this measure.

Description of Baseline Condition

The baseline condition is standard thermostats with no automatic temperature setbacks controlling the HVAC systems serving hotel guest rooms or similar rooms. The HVAC equipment has code minimum heating and cooling efficiencies. The HVAC system for MMID 2373 is a packaged terminal air conditioner (PTAC) with electric resistance heat and code minimum cooling efficiencies shown in the table below.

Minimum Cooling Efficiency Requirements for Packaged Terminal Air Conditioners

New Construction or Retrofit	EER[3]
New Construction	$14.0 - (0.300 * Cap_{COOL} / 1,000)$
Retrofit	$10.9 - (0.213 * Cap_{COOL} / 1,000)$

The HVAC system for 4748 is a packaged terminal heat pump (PTHP) with supplemental electric resistance heat and code minimum efficiencies shown in the table below.

Minimum Cooling Efficiency Requirements for Packaged Terminal Heat Pumps

New Construction or Retrofit	EER[3]	COP[3]
New Construction	$14.0 - (0.300 * Cap_{COOL} / 1{,}000)$	$3.2 - (0.026 * Cap_{COOL} / 1{,}000)$
Retrofit	$10.8 - (0.213 * Cap_{COOL} / 1{,}000)$	$2.9 - (0.026 * Cap_{COOL} / 1{,}000)$

The HVAC system for 2374 matches the system for the project.

Description of Efficient Condition

The efficient condition is an occupancy-based guest room energy management system controlling the baseline HVAC system. Occupancy control may be key-activated or sensed due to motion or body heat. “Front Desk Only” controls do not qualify. When the room is occupied, the room temperature setpoint is controlled by the occupants. When the room is unoccupied, the guest room energy management system sets back the temperature setpoint to an unoccupied heating or cooling setpoint.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{SAVED,COOL} + kWh_{SAVED,HEAT}$

$kWh_{SAVED,COOL} = EFLH_{COOL} * Cap_{COOL} * \%\ Savings / (1{,}000 * EER)$

$kWh_{SAVED,HEAT} = \{[EFLH_{HEAT,EL} * (Cap_{HEAT,EL} + Cap_{BOILER,EL})] + [EFLH_{HEAT,HP} * Cap_{HEAT,HP} / (3{,}412 * COP)]\} * \%\ Savings$

Where:

$EFLH_{COOL}$ = Equivalent full-load hours during cooling mode (= 663 for hotel/motel)[4]

Cap_{COOL} = Nominal cooling capacity (= 9,000 Btu/h for MMIDs 2373 and 4748, = user input for MMID 2374; see Assumptions)

% Savings = Percentage of savings (= 18.4%)[5]

1,000 = Watts to kilowatt conversion factor

EER = Energy efficiency ratio in Btu/h per watt (= varies for MMIDs 2373 and 4748, = user input for MMID 2374; see Assumptions)

$EFLH_{HEAT,EL}$ = Equivalent full-load hours during heating mode (= 1,890 for MMIDs 2373 and 2374, = 729 for MMID 4748; see Assumptions)

$Cap_{HEAT,EL}$ = Heating capacity of electric heater (= 2.36 kW for MMIDs 2373 and 4748, = user input for MMID 2374; see Assumptions)

$Cap_{BOILER,EL}$ = Heating capacity of electric boiler (= 0 kW for MMIDs 2373 and 4748, = user input for MMID 2374; see Assumptions)

$EFLH_{HEAT,HP}$ = Equivalent full-load hours during heating mode of heat pump (= 0 for MMIDs 2373 and 2374, = 1,161 for 4748; see Assumptions)

$Cap_{HEAT,HP}$ = Nominal heating capacity of heat pump (= 0 Btu/h for MMIDs 2373 and 2374; = 0.893 * Cap_{COOL} for MMID 4748; see Assumptions)

3,412 = Btu/h to kilowatt conversion factor

COP = Coefficient of performance (= 1.0 for MMID 2373, = varies for MMID 4748, = user input for MMID 2374; see Assumptions)

$Therm_{SAVED} = EFLH_{HEAT} * Cap_{HEAT} * \% Savings / (100{,}000 * Eff)$

Where:

$EFLH_{HEAT}$ = Equivalent full-load hours during heating mode (= 1,890; see Assumptions)

Cap_{HEAT} = Heating capacity of natural gas equipment (= 0 Btu/h for MMIDs 2373 and 4748, = user input for MMID 2374)

% Savings = Percentage of savings (= 18.4%)[5]

100,000 = Btu to therms conversion factor

Eff = Thermal efficiency of the natural gas–fired equipment as a fraction (= 0 for MMIDs 2373 and 4748, = user input for MMID 2374)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = Cap_{COOL} * \% Savings * CF / (1{,}000 * EER)$

Where:

CF = Coincidence factor (= 0.8)[6]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 8 years)[1]

Deemed Savings

The energy savings are presented in the table below.

Annual and Lifecycle Savings by Measure

MMID	System	New Construction			Retrofit		
		kW	Annual kWh	Lifecycle kWh	kW	Annual kWh	Lifecycle kWh
2373	PTAC	0.1172	918	7,344	0.1475	943	7,544
4748	PTHP	0.1172	584	4,672	0.1491	629	5,032

Assumptions

For MMID 2373, the EER is based on a PTAC unit with 9,000 Btu/h capacity.

Cooling Efficiency of Packaged Terminal Air Conditioners

New Construction or Retrofit	EER
New Construction	11.30
Retrofit	8.98

For MMID 4748, the EER and COP are based on a PTHP with a 9,000 Btu/h cooling capacity. The weighted average capacity of PTHPs incented by Focus on Energy from January 1, 2016 through May 31, 2018 was 9,175 Btu/h.[7]

Efficiencies of Packaged Terminal Heat Pumps

New Construction or Retrofit	EER	COP
New Construction	11.30	3.0
Retrofit	8.88	2.7

For MMID 2374, the EER is the electrical efficiency of the overall system, which might include auxiliary equipment like cooling tower fans and pumps, if applicable.

The heating capacity of the heat pump as a percentage of cooling capacity is the average of data from the Air-Conditioning, Heating & Refrigeration Institute for listed PTHPs.[8] For a cooling capacity of 9,000 Btu/h, the heating capacity is 8,038 Btu/h (= 0.893 * 9,000 Btu/h). The equivalent electric heater capacity is 2.36 kW (= 8,038 Btu/h / 3,412 kW per Btu/h).

No savings are claimed for evaporator fans, condenser fans, cooling tower fans, or pumps. No water savings are claimed for any cooling towers on water source heat pump systems.

Cooling equivalent full-load hours are for hotel/motel and are not the average of multiple commercial building types.

Data for determining the heating equivalent full-load hours are presented in the table below.

Supporting Inputs for Equivalent Full-Load Heating Hours by City for Business[9]

Location	$EFLH_{HEAT}$	Weighting by Participant
Green Bay	1,852	22%
Lacrosse	1,966	3%
Madison	1,934	18%
Milwaukee	1,883	48%
Wisconsin Average	1,909	9%
Weighted Average	**1,890**	**100%**

$EFLH_{HEAT,HP}$ values were adjusted to account for electric resistance heat when the outside temperature is below 40°F. The controls are assumed to run only the electric heater when the outside temperature is below 25°F, run both the heat pump and electric heater between 25°F and 40°F, and run only the heat pump above 40°F.[10] No heating is assumed above 65°F, the common base for heating degree days. Using average bin weather data for 20 Wisconsin locations, the heat pump is expected to operate 61.41% of the hours when the temperature is below 65°F (= 4,245/6,914, but with unrounded values). The adjusted $EFLH_{HEAT}$ value is 1,890 hours * 61.41% = 1,161 hours for hotel/motel. The electric heater operates during the remaining heating hours (= 1,890 – 1,161 = 729 hours).

Supporting Calculation for Electric Heat Adjustment for Heat Pumps

Temperature Range	Hours in Temperature Range	Heat Control	Percentage of Heat Pump Hours	Total Heat Pump Hours
40°F to 65°F	3,274	Heat pump only	100%	3,274
25°F to 40°F	1,943	Heat pump + electric heater	50%	971
Less than 25°F	1,697	Electric heater only	0%	0
Total	**6,914**	**-**	**-**	**4,245**

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. *Illinois Statewide Technical Reference Manual for Energy Efficiency.* Version 6.0. p. 158. February 8, 2017. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Version_6.0_dated_February_8_2017_Final_Volumes_1-4_Compiled.pdf

3. *2015 International Energy Conservation Code.* Table C403.2.3(3). 2015. Accessed October 2018. https://codes.iccsafe.org/public/document/IECC2015
4. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” June 2, 2008. http://www.deeresources.com
   DEER model runs were weather normalized for Wisconsin statewide use by population density.
5. Pacific Northwest National Laboratory (Sullivan, G.P., and J. Blanchard). *Guest Room HVAC Occupancy-Based Control Technology Demonstration*. p. 1. September 2012. http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/creea_guest_room_occupancy-based_controls_report.pdf
6. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Section 4.5.7 Rooftop A/C. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
7. Historical Focus on Energy project data, MMIDs 2699 to 2702 for January 2016 to May 2018, which shows 1,717 PTHPs installed and an average of 9,175 Btu capacity.
8. Air-Conditioning, Heating & Refrigeration Institute. Accessed May 2018. www.ahridirectory.org
9. Several Cadmus metering studies reveal that the ENERGY STAR EFLHs calculators are overestimated by 25%. The $EFLH_{HEAT}$ was adjusted by population-weighted heating degree days and TMY3 values.
10. *ENERGY STAR Multifamily High Rise Program Simulation Guidelines*. Version 1.0, Revision 03. Section 3.8.2.2, p. 19. January 2015. https://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/mfhr/ENERGY%20STAR%20MFHR%20Simulation%20Guidelines_Version_1%200_Rev03.pdf?5c90-3dd6

Revision History

Version Number	Date	Description of Change
01	10/10/2018	Initial TRM entry

Economizer Optimization

	Measure Details
Measure Master ID	Economizer Optimization, 3661
Measure Unit	Per ton of refrigeration
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$108.00[2]

Measure Description

The intent of this measure is to determine economizer health and capture savings associated with correcting improper operation or damage of outside air economizer units. This measure can be applied only once per building address during the EUL lifecycle, and is meant to be a part of the Express Building Tune-Up Program to help optimize building HVAC systems to operate more efficiently at existing building load conditions. It does not apply to newly constructed facilities that have not already been commissioned.

Description of Baseline Condition

The baseline condition is an air handling unit with an economizer that is either not in operation at all or that is in operation but has a limited OAT range of operation and has the potential to expand.

Description of Efficient Condition

The efficient condition is bringing a nonoperational economizer back to at least a baseline value, or increasing the economizer OAT operating range above baseline. The efficient condition OAT economizer range should not exceed 55°F to 75°F.

Annual Energy-Savings Algorithm

The following algorithms are based off measure workpaper3066 (Economizer, RTU Optimization) as found in the 2015 Focus on Energy TRM.[3] The algorithms were iterated for and summed over bin data of every hour of the year with an outside air dry-bulb temperature greater than or equal to 55°F (April 1 to September 30), or the estimated average balance point of the buildings addressed. Bin data is found in the EBTU workbook.[4,5]

$kWh_{SAVED} = kWh/year_{BASELINE} - kWh/year_{PROPOSED}$

$kWh/year_{BASELINE} = kW_{HOUR\text{-}INTERVAL\text{-}BASELINE} * 1\ hour)$

$kW_{HOUR\text{-}INTERVAL\text{-}BASELINE} = CAP * R_{CAP} * (12 / EER) * Econ_{BASE}$

$kWh/year_{PROPOSED} = kW_{HOUR\text{-}INTERVAL\text{-}PROPOSED} * 1\ hour)$

$kW_{HOUR\text{-}INTERVAL\text{-}PROPOSED} = CAP * R_{CAP} * (12 / EER) * Econ_{PROP}$

Where:

CAP = Cooling capacity of equipment in tons (= varies by equipment; actual equipment values should be used)

R_{CAP} = Cooling load at which the air conditioning compressor is operating, as a percentage of the full load capacity CAP; interpolated for every hour between (55°F, 0%) and (95°F, 90%)

12 = Conversion factor from EER to kW/ton

EER = Energy efficiency ratio of the rooftop air handling unit, in Btu/(W*hr) (= varies by equipment; see table below)

Energy Efficiency Ratio by System Type

Cooling System Type	Cooling System Efficiency Factors (EER)
Direct Expansion	10.43[6]
Air-Cooled Chiller	12.63[7]
Water-Cooled Chiller	18.75[7]

$Econ_{BASE}$ = Binary variable (0 or 1) that indicates whether the economizer is in operation; baseline economizer operation occurs when the OAT range (dry-bulb) is operating between of 55°F and 65°F

1 hour = Duration of each hour-long interval

$Econ_{PROP}$ = Binary variable (0 or 1) that indicates whether the economizer is in operation; proposed economizer operation when the OAT range (dry-bulb) is greater than baseline of 55°F to 65°F

The following information is required to be supplied by the customer or trade ally applying for this measure:

- Type of facility chiller unit and capacity (tons)
- Efficiency of facility chiller unit (EER) when possible, otherwise a default value based on chiller unit type will be used
- Existing economizer OAT range (°F); when different than 55°F to 65°F, 'none' is also a possibility
- Proposed economizer OAT range (°F)

Summer Coincident Peak Savings Algorithm

There is no peak demand reduction from economizers because they are not expected to operate during peak demand hours based on typical economizer temperature ranges.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=5 years)[1]

Assumptions

Economizer modulation (mixing of outside air and inside air to match the setpoint temperature) is not accounted for in the savings analysis.

The fraction of full capacity of air conditioning compressor operation is assumed to be a linear function of outside air dry-bulb temperature (0% at 55°F and 90% at 95°F). This assumes correct sizing of the air conditioning unit installation, including some extra capacity for cooling beyond 95°F.

The savings are based on facility sizes within the EBTU scope requiring less than 300 tons of cooling.

The economizer operating time is assumed to be between April and September. This includes the peak summer months and some of the shoulder months when facility cooling needs are most expected. Temperature data for these months was pulled from the general TMY3 bin temperature data used for all EBTU measures.[5]

Sources

1. Cadmus. *EUL Response Memo*. April 26, 2013.
   Used the Retrocommissioning Program EUL standard and direction from CB&I to keep 5 year EUL standard).
2. RSMeans Facilities Construction Cost Data, 29th Edition. 2013. (54.00 per hour labor rate for work performed on air cooling equipment). Estimated two hours for completion of this measure based on historical project experience. Estimate will be re-evaluated after first year of EBTU program and trade ally pricing feedback.
3. *Focus on Energy Technical Reference Manual.* 2015. Pgs. 69-71, measure 3066.
4. Focus on Energy EBTU Measures Workbook Calculator. Internal Implementer Spreadsheet. 2015.
5. Natural Renewable Energy Laboratory. Bin temperature data comes from respective Wisconsin cities TMY3 weather data. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#W
6. IECC 2009. Table 503.2.3(1)
   Direct expansion cooling efficiency values determined from simple minimum efficiencies averages for system capacities of ≥ 5.5 tons.
7. ASHRAE 90.1-2007. Table 6.8.1C.
   Chiller unit part load efficiency values determined from simple minimum efficiencies averages for chiller capacities of 0 tons to 300 tons.

Revision History

Version Number	Date	Description of Change
01	01/2016	Initial TRM entry

Data Center Airside Economizer

	Measure Details
Measure Master ID	Air-Side Economizer, Data Center/Telecom, 4776
Measure Unit	Per ton
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Economizer
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by location
Peak Demand Reduction (kW)	Varies by location
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by location
Lifecycle Therm Savings (Therms)	Varies by location
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$108.00[2]

Measure Description

This measure is installing an air-side economizer that offsets or reduces the need for mechanical cooling in data centers or similar computer facilities that operate continuously. When the outside air is below the economizer high limit temperature, the air conditioning compressors can be turned off or run for fewer hours. For water-cooled systems, there are also savings associated with turning off cooling tower pumps and fans.

Description of Baseline Condition

The baseline condition is an air handler with a fixed ventilation rate (fixed damper, no air- or water-side economizer), where the minimum ventilation rate for data centers is typically zero. The cooling system operates continuously the entire year to meet the continuous data center cooling load.

Description of Efficient Condition

The efficient condition is an air handler that includes an air-side economizer controller, actuator, and sensor, controlled by either the dry bulb temperature or enthalpy.

Annual Energy-Savings Algorithm

The electrical energy saved is equal to the energy used by the cooling system in the baseline during hours that the economizer system provides full or partial cooling. Greater detail of savings algorithm inputs can be found in the workbook associated with this workpaper.

$kWh_{SAVED} = \Sigma\ [(LF * CAP * Eff_{COOL} + 0.746 * HP_{CT\_FAN} * ML_{CT\_FAN} / Eff_{CT\_FAN} + 0.746 * HP_{CT\_PUMP} * ML_{CT\_PUMP} / Eff_{CT\_PUMP}) * Econ_{OPERATING}]$ for each hour

Where:

LF = Average load factor on cooling system (= 0.65)[3]

CAP = Installed (non-backup/redundant) cooling capacity in tons (= user input)

Eff_{COOL} = Cooling system efficiency in kilowatts per ton (= user input)

0.746 = Conversion from horsepower to kilowatts

HP_{CT_FAN} = Horsepower of cooling tower fan motor, if any (= 0 if no cooling tower, = user input otherwise)

ML_{CT_FAN} = Motor loading of cooling tower fan motor, if any (= 0 if no cooling tower, = user input otherwise; if not known assume 0.8)

Eff_{CT_FAN} = Motor efficiency of cooling tower fan motor, if any (= 0 if no cooling tower, = user input otherwise; if not known assume code minimum based on horsepower)

HP_{CT_PUMP} = Horsepower of cooling tower water pump motor, if any (= 0 if no cooling tower, = user input otherwise)

ML_{CT_PUMP} = Motor loading of cooling tower water pump motor, if any (= 0 if no cooling tower, = user input otherwise; if not known assume 0.8)

Eff_{CT_PUMP} = Motor efficiency of cooling tower water pump motor, if any (= 0 if no cooling tower, = user input otherwise; if not known assume code minimum based on horsepower)

$Econ_{OPERATING}$ = Fraction that indicates the degree of economizer operation (= 1 when the outside air (dry bulb) temperature is below the design mixed air temperature, = 0 when the outside air temperature is above the economizer high limit temperature setpoint, = linear interpolation in between these values)

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = average of $[(LF * CAP * Eff_{COOL} + 0.746 * HP_{CT\_FAN} * ML_{CT\_FAN} / Eff_{CT\_FAN} + 0.746 * HP_{CT\_PUMP} * ML_{CT\_PUMP} / Eff_{CT\_PUMP}) * Econ_{OPERATING}]$ across all hours during the peak period of 1 p.m. to 4 p.m. weekdays in June, July, and August.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Assumptions

Savings calculations are based on several assumptions:

- The cooling load is constant throughout the year
- The cooling system efficiency is constant at all outside temperatures
- The minimum ventilation airflow during non-economizer hours is 0 CFM

The hourly interval weather data were obtained from TMY3 data.[4]

Motor efficiencies, if not available, are assumed to be the code minimum for a totally enclosed fan cooled at 1,800 rpm.

The following table shows the default motor efficiencies based on horsepower.

Default Motor Efficiency

hp	Efficiency[5]
1	82.5%
1.5	84.0%
2	84.0%
3	87.5%
5	87.5%
7.5	89.5%
10	89.5%
15	91.0%
20	91.0%
25	92.4%
30	92.4%
40	93.0%
50	93.0%
60	93.6%
75	94.1%
100	94.5%
125	94.5%
150	95.0%
200	95.0%

Sources

1. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." EUL Table. 2014. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx
2. RS Means. Facilities Construction Cost Data. 29th Edition. 2013.
   Assumed $54.00 per hour labor rate for work performed on air cooling equipment. Estimated 2 hours for completion based on project experience.
3. Technical Support Document to Final Rule: Standards, Federal Register, 77 FR 28928:28994-5. Section V. Methodology and Discussion of Comments for Computer Room Air Conditioners, Subsection D., Energy Use Characterization. May 16, 2012. http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0029-0038
4. National Renewable Energy Laboratory. "TMY3 Weather Data: National Solar Radiation Data Base." http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html.
5. ASHRAE 90.1-2013. Table 10.8-2. Accessed December 2018. https://ashrae.iwrapper.com/ViewOnline/Standard_90.1-2013_I-P

Revision History

Version Number	Date	Description of Change
01	10/04/2018	Initial TRM entry

Hot Water Supply Reset

	Measure Details
Measure Master ID	Hot Water Supply Reset, 3662
Measure Unit	Per MBh
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by temperature setpoint
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by temperature setpoint
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$108.00[2]

Measure Description

The intent of this measure is to capture savings by lowering the boiler hot water supply setpoint temperature for the primary heating loop based on actual building load and outdoor air temperature. This measure applies to non-condensing natural gas boilers only. This measure is meant to help optimize HVAC systems to operate more efficiently at existing building load conditions. It does not apply to newly constructed facilities that have not been commissioned.

Description of Baseline Condition

The baseline measure is an eligible building with a boiler hot water heating system that has working controls in place but does not use a hot water reset supply strategy, or has a reset strategy that an HVAC service professional determines can be optimized further.

Description of Efficient Condition

The efficient measure is a trained HVAC service professional determining if a new/change in the hot water supply reset strategy is possible to implement while still safely meeting buildings heating load requirements. The reset strategy should incorporate maximum and minimum water temperatures to correspond with the minimum and maximum outdoor air temperature range, respectively. Savings are calculated based on the particular existing and proposed reset strategy, accounting for boiler capacity. Hot water supply reset control incentives are for existing space heating boilers only. The controls should be set so that the boiler return water is not more than 10°F above the manufacturer’s recommended minimum return temperature. The system must have an outdoor air temperature sensor in a shaded location, preferably on the north side of the building.

Annual Energy-Savings Algorithm

Savings are determined by summing the baseline and proposed energy consumption formulas below across the bin data temperature ranges and corresponding bin temperature hours found in the EBTU workbook.[3,4]

$\text{Therm}_{\text{SAVED}} = \text{Therm}_{\text{BASELINE}} - \text{Therm}_{\text{PROPOSED}}$

$\text{Therm}_{\text{BASELINE}} = \Sigma\ [500 * \text{GPM} * (\text{HW Supply Temp}_{\text{BASE}} - \text{HW Return Temp}) * \text{Area Load} / 100{,}000 / \text{boiler eff} * \text{Bin Hours}]$

$\text{Therm}_{\text{PROPOSED}} = \Sigma\ [500 * \text{GPM} * (\text{HW Supply Temp}_{\text{PROP}} - \text{HW Return Temp}) * \text{Area Load} / 100{,}000 / \text{boiler eff} * \text{Bin Hours}]$

Where:

500 = Water sensible heat formula constant[5]

GPM = Average gallons per minute of heating water during heating season (= user defined)

$\text{HW Supply Temp}_{\text{BASE}}$ = Existing hot water maximum supply temperature in °F (= user defined)

$\text{HW Supply Temp}_{\text{PROP}}$ = Proposed hot water reset curve temperature in °F (= user defined)

HW Return Temp = Hot water return temperature (= estimated based on OAT and hottest water supply temperature in the system; return temperature schedule is a constant between baseline and proposed used to model heat loss reduction

Area Load = Percentage of area load based on linear interpolation of a 60°F dry bulb OAT balance point, bin data dry bulb OAT, and 2.5% dry bulb design summer/winter conditions for different Wisconsin cities;[6] see Assumptions for more explanation of 2.5% dry bulb design conditions

100,000 = Conversion from Btu to therm

boiler eff = Efficiency of natural gas to heat conversion for heating purposes (= 80%)

Bin Hours = Dry-bulb temperature and time of day (also known as temperature bin data) (= based on statewide BIN weather data)[4]

The workbook calculator requires the following measure-specific inputs provided from the trained professional performing the tune-up/optimization measure:

- Actual average heating water supply loop flow rate (GPM) if known, or at ΔT=20°F conditions (can be listed or calculated based on boiler output rating)
- Boiler input MBh and efficiency rating (used for incentive calculation purposes)
- Existing constant hot water setpoint temperature
- Existing OAT hot water reset range along with corresponding maximum and minimum setpoints (°F; if prior reset strategy was in place)
- New OAT hot water reset range along with corresponding maximum and minimum setpoints (°F)

Summer Coincident Peak Savings Algorithm

There is no peak demand reduction for this measure.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}} = \text{Therm}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (=5 years)[1]

Assumptions

- Return water temperature schedule is assumed to be at ΔT=30°F for the coldest OAT and at ΔT=10°F for the warmest OAT compared to the existing hot water heating setpoint.[5]
- Assumed that the return water temperature schedule across the OAT range will stay the same between existing and hot water reset schedule to model the reduction of heat losses and subsequent energy savings.
- Assumed a constant GPM flow rate (should be based on the heating season average GPM if possible, or the rated boiler flow rate when boiler is at ΔT=20°F operation).
- Assumed that the hot water setpoint at minimum OAT range will be greater than or equal to the existing hot water setpoint constant.

- If hot water reset temperatures at higher OAT dip below the constant estimated for return water scheduled temperatures, then the hot water reset supply temperature will equal the calculated return temperature (since it effectively shuts off the boiler).
- Assumed that boiler operation occurs only during periods when OAT < 60°F.
- Assumed that the HVAC service professional making adjustment ensures that boiler return water will stay above the boiler minimum.
- 2.5% dry bulb design conditions means that for cooling/heating seasons, the HVAC system is designed to adequately handle the building cooling/heating for all outdoor air temperatures that do not exceed the hottest/coldest 2.5% of hours of the respective season. Explained another way, this means that the cooling/heating system can adequately handle the cooling/heating load of a given building for 97.5% of the total anticipated peak cooling/heating hours for the year.

Sources

1. Cadmus. *EUL Response Memo.* April 26, 2013. Used the Retrocommissioning Program EUL standard and direction from CB&I to keep 5 year EUL standard).
2. RSMeans 2013 Facilities Construction Cost Data, 29th Edition
3. Wisconsin Focus on Energy. EBTU Measures Workbook Calculator.
4. Natural Renewable Energy Laboratory. Bin temperature data comes from respective Wisconsin cities TMY3 weather data. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#W
5. Edison Electric Institute. *Technical Information Handbook*. p. 24. 2000.
6. ASHRAE. *Handbook, Fundamentals Volume for Wisconsin Cities*. 1985. http://publicecodes.cyberregs.com/icod/ipc/2012/icod_ipc_2012_appd.htm

Revision History

Version Number	Date	Description of Change
01	08/10/2015	Initial TRM entry

Natural Gas Furnace Tune-Up, Small Business

	Measure Details
Measure Master ID	Natural Gas Furnace Tune-Up, Small Business, 3916
Measure Unit	Per MBtu per hour of furnace capacity
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by furnace capacity
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by furnace capacity
Lifecycle Energy Savings (kWh)	Varies by furnace capacity
Lifecycle Therm Savings (Therms)	Varies by furnace capacity
Water Savings (gal/yr)	0
Effective Useful Life (years)	2[1]
Measure Incremental Cost ($/unit)	$1.53 per MBtu/hr[2]

Measure Description

This measure is for a natural gas furnace that provides space heating at a small business. Inspecting, cleaning, and adjusting the furnace will improve the performance for correct and efficient operation.

Description of Baseline Condition

The baseline condition is a natural gas furnace for a small business customer that has not had a tune-up in the previous two years.

Description of Efficient Condition

To qualify for a small business furnace tune-up, a trained HVAC technician must complete the following:

- Measure before and after combustion efficiency using an electronic flue natural gas analyzer
- Check and clean blower assembly and components per manufacturer’s recommendations
- Lubricate motor, where applicable, and inspect and replace fan belt, if required
- Inspect for natural gas leaks
- Clean burner per manufacturer’s recommendations and adjust as needed
- Check ignition system and safety systems and clean and adjust as needed
- Check and clean heat exchanger per manufacturer’s recommendations
- Inspect exhaust/flue for proper attachment and operation
- Inspect control box, wiring, and controls for proper connections and performance

- Check air filter and clean or replace as needed
- Inspect duct work connected to furnace for leaks or blockages
- Measure temperature rise and adjust flow as needed
- Check for correct line and load volts/amps
- Perform carbon monoxide test and adjust heating system until results are within acceptable limits

Annual Energy-Savings Algorithm

Natural Gas Savings

$Therm_{SAVED} = CAP * EFLH_{HEAT} * [1/Eff_{BASE} – 1/(Eff_{BASE} + Eff_{INCREASE})] / 100$

Electric Savings

$kWh_{SAVED} = Therm_{SAVED} * FanEnergy\% * 29.31$

Where:

CAP = Furnace capacity (input), MBtu/hr

$EFLH_{HEAT}$ = Equivalent full-load hours of heating (= 1,890)[3]

Eff_{BASE} = Furnace efficiency before the tune-up (= user-defined input)

$Eff_{INCREASE}$ = Furnace efficiency improvement due to tune-up (= user-defined input)

100 = Conversion factor from MBtu/hr to therms

FanEnergy%= Furnace fan energy use as a percentage of annual fuel consumption (= 3.14%)[1]

29.31 = Conversion factor from therms to kWh

Summer Coincident Peak Savings Algorithm

There are no summer peak coincident savigns for this measure since electric use only occurs during the heating season.

Lifecycle Energy-Savings Algorithm

$Therms_{LIFECYCLE} = Therms_{SAVED} * EUL$

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 2 years)[1]

Assumptions

The Illinois TRM entry for small business furnace tune-ups[1] assumes a tune-up efficiency improvement of approximately 2%. Based on engineering judgment, average furnace efficiency may be approximately 80%. Using those assumed inputs, the reference savings for this measure are shown in the following table.

Savings per MBh of Furnace Capcity

Peak Demand Reduction (kW)	Annual Savings		Lifecycle Savings	
	Electric (kWh per MBtu/hr)	Natural Gas (therms per MBtu/hr)	Electric (kWh per MBtu/hr)	Natural Gas (therms per MBtu/hr)
0.0	0.530	0.576	1.061	1.152

Assumptions

The average of the furnace tune-up costs[2] identified online were averaged, resulting in $127.50 per furnace tune up. Using average furnace size for MMID 3491 and 3492 found an average size of 83.3 MBh for 188 measures from January 1, 2016 to October 31, 2017, which results in a cost of $1.53/MBh.

Sources

1. Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 5.0, Volume 2*. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Almost_Final_PDF/IL_TRM_Effective_060116_Version_5.0_Vol_2_C_and_I_012216_Clean.pdf
2. Capital Heating & Cooling. Website. Accessed November 2017. https://www.capitalhvac.com/TipsArticles/furnace-tune-up-cost
   Cost Helper. Website. Accessed November 2017. http://home.costhelper.com/furnace-tune-up.html
   Home Improvement Educator. Website. Accessed November 2017. http://www.homeimprovementeducator.com/seasonal/fall-furnace-tuneups.html
   Engineering judgement based on local pricing and typical furnace size.
3. Several Cadmus metering studies reveal that the ENERGY STAR calculator EFLHs are overestimated by 25%. The $EFLH_{HEAT}$ was adjusted by population-weighted HDD and TMY3 values.

Revision History

Version Number	Date	Description of Change
01	09/2016	Initial TRM entry
02	01/2019	Removed MMID 4098

Gas Furnaces with ECM

	Measure Details
Measure Master ID	Furnace with ECM, ≥95%+ AFUE, NG, 3491 Furnace with ECM, ≥90%+ AFUE, NG, 3492
Measure Unit	Per MBh input capacity (for savings) Per furnace (for incentive and incremental cost)
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Furnace
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	Varies
Annual Therm Savings (Therms)	Varies
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	Varies
Water Savings (gal/year)	0
Effective Useful Life (years)	18[1]
Incremental Cost ($/unit)	≥95%+ AFUE = $723 (MMID 3491); ≥90%+ AFUE = $575 (MMID 3492)[2]

Measure Description

Residential-style natural gas furnaces are available with higher thermal efficiencies than the baseline code-minimum efficiency, which saves energy by consuming less natural gas. The efficient furnace also has an electronically commutated motor (EMC). These measures are specific to business and multifamily properties.

Description of Baseline Condition

Current code requirements are that furnaces must have an annual fuel utilization efficiency (AFUE) of 80%.[3] The furnace must also have a constant speed non–ECM.

Description of Efficient Condition

The efficient condition is a furnace with an ECM (constant speed, multi-speed, or variable speed) and a minimum AFUE of at least 95% for MMID 3491 or at least 90% for MMID 3492 as listed by the Air-conditioning, Heating and Refrigeration Institute.

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}} = \text{Cap} * (\text{AFUE}_{\text{EE}} / \text{AFUE}_{\text{BASE}} – 1) * \text{EFLH}_{\text{HEAT}} / 100$

$\text{kWh}_{\text{SAVED}} = (\text{kWh}_{\text{COOL}} + \text{kWh}_{\text{HEAT}} + \text{kWh}_{\text{CIRC}}) / \text{AvgSize}$

$\text{kWh}_{\text{COOL}} = \text{EFLH}_{\text{COOL}} * 12 * (1/\text{SEER}_{\text{BASE}} – 1/ \text{SEER}_{\text{ECM}}) * \%\text{AC}$

$\text{kWh}_{\text{HEAT}} = \text{EFLH}_{\text{HEAT}} * \Delta\text{kW}_{\text{HEAT}}$

$\text{kWh}_{\text{CIRC}} = \text{Hours}_{\text{CIRC}} * \Delta\text{kW}_{\text{CIRC}}$

Where:

Cap = Input capacity of the efficient furnace in MBh (= user input)

AFUE_{EE} = Thermal efficiency of efficient equipment (= 0.95 for MMID 3491; = 0.90 for MMID 3492)

$\text{AFUE}_{\text{BASE}}$ = Thermal efficiency of baseline equipment (= 0.80)[3]

$\text{EFLH}_{\text{HEAT}}$ = Equivalent full load heating hours (= 1,158 for multifamily,[4] = 1,890 for business;[5] see Assumptions)

100 = Conversion factor, MBh per therm

$\text{EFLH}_{\text{COOL}}$ = Equivalent full load cooling hours (= 410 for multifamily,[4] = 599 for business[6])

12 = Conversion factor, MBh per ton

$\text{SEER}_{\text{BASE}}$ = Baseline cooling efficiency (= 12 SEER)[4]

SEER_{ECM} = Cooling efficiency of furnace with an ECM (= 13 SEER)[4]

%AC = Percentage of furnaces that have air conditioning (= 84% for multifamily,[7] = 92.5% for business;[4] see Assumptions)

$\Delta\text{kW}_{\text{HEAT}}$ = Supply fan demand during heating mode (= 0.116 kW)[4]

$\text{Hours}_{\text{CIRC}}$ = Annual hours supply fan is on circulate setting (= 1,020)[4]

$\Delta\text{kW}_{\text{CIRC}}$ = Supply fan demand during circulate setting (= 0.207 kW)[4]

AvgSize = Average furnace size in MBh to convert ECM per furnace savings to per MBh savings (= 72 MBh for multifamily,[8] = 84.3 MBh for business[9])

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = Tons * 12 * (1 / EER_{BASE} – 1 / EER_{ECM}) * \%AC / AvgSize * CF$

Where:

Tons = Average cooling capacity (= 1.374 for multifamily,[10] = 3.327 for business)[11]

EER_{BASE} = Baseline full load cooling efficiency (= 10.5)[4]

EER_{ECM} = Baseline full load cooling efficiency of furnace with an ECM (= 11)[4]

CF = Coincidence factor (= 0.80)[12]

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 18 years)[1]

Deemed Savings

The savings are presented in the table below.

Savings by Measure, per MBh Input

MMID	Sector	Eff_{EE}	kW	Annual		Lifecycle	
				kWh	Therms	kWh	Therms
3491	Multifamily	95%	0.0007	5.2	2.2	93.6	39.6
	Commercial, Industrial, Agriculture, Schools & Government		0.0015	5.6	3.5	100.8	63.0
3492	Multifamily	90%	0.0007	5.2	1.4	93.6	25.2
	Commercial, Industrial, Agriculture, Schools & Government		0.0015	5.6	2.4	100.8	43.2

Assumptions

Multifamily in-unit furnaces are assumed to be sized similary to single-family furnaces, and use the single-family value for EFLH. While it is likely that residential-style furnaces in commercial settings are also sized similarly, at this time they are deemed to use standard commercial EFLH values. Data for determining the heating equivalent full-load hours for business are presented in the table below.

Supporting Inputs for Equivalent Full-Load Heating Hours by City for Business[4]

Location	$EFLH_{HEAT}$	Weighting by Participant
Green Bay	1,852	22%
Lacrosse	1,966	3%
Madison	1,934	18%
Milwaukee	1,883	48%
Wisconsin Average	1,909	9%
Weighted Average	**1,890**	**100%**

An unknown fraction of businesses with furnaces also have air conditioning. It is deemed that this fraction follows that of single family homes receiving furnaces.[4]

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces." Table 8.5.1. February 10, 2015. https://www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0027
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5. Several Cadmus metering studies reveal that the ENERGY STAR EFLHs calculator is overestimated by 25%. The $EFLH_{HEAT}$ were adjusted by population-weighted heating degree days and TMY3 values.
6. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com
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8. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average furnace size of 13,000 furnaces. 2012.

9. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average furnace size of 719 furnaces in 517 business projects for MMID 3491. September 2014 through November 2018.
10. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average air conditioner size of 450 units in 36 multifamily projects for MMIDs 4364–4367. March 2018 through September 2018.
11. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average air conditioner size of 260 units in 114 business projects for MMIDs 4364–4367. January 2018 through November 2018.
12. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Updated March 22, 2010. www.focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	10/11/2018	Initial TRM entry

Outside Air Intake Control Optimization

	Measure Details
Measure Master ID	Outside Air Intake Control Optimization, 3663
Measure Unit	Per CFM reduced
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Schools & Government
Annual Energy Savings (kWh)	Varies by baseline and proposed energy consumption
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by baseline and proposed energy consumption
Lifecycle Energy Savings (kWh)	Varies by baseline and proposed energy consumption
Lifecycle Therm Savings (Therms)	Varies by baseline and proposed energy consumption
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$212.00[2]

Measure Description

The intent of this measure is to capture savings associated with reducing outside air (OA) supply CFM to a minimum. The outside air intake levels should always conform to local codes and ASHRAE 62.1 standards. This measure applies to buildings that currently do not use a variable outside air intake control strategy. Measure can be applied only once per building during the EUL. This measure is meant to be a part of the Express Building Tune-Up Program to help optimize building HVAC systems to operate more efficiently at existing building load conditions. It does not apply to newly constructed facilities that have not been commissioned.

Description of Baseline Condition

The baseline measure is an eligible building that a qualified HVAC control professional has verified can save energy by reducing the outside air intake CFM compared to existing levels. The building must currently exceed the minimum outside air intake levels for standard occupancy as defined by local or state requirements.

Description of Efficient Condition

The efficient measure is having a trained HVAC professional determine an appropriate adjustment to the outside air intake levels that conforms to all applicable building codes but is reduced and will still meet the buildings requirements for proper ventilation. Measure rebates do not apply if the outside air CFM needs to increase.

Annual Energy-Savings Algorithm

Savings are determined by summing the baseline and proposed energy consumption formulas below across the bin data temperature ranges and corresponding bin temperature hours found in the EBTU workbook.[3,4]

$$kWh_{SAVED} = (Btu_{BASELINE} - Btu_{PROPOSED}) / 12{,}000 * Chiller\_Eff + (Fan\ Energy_{BASE} - Fan\ Energy_{PROP})$$

$$Therm_{SAVED} = (Btu_{BASELINE} - Btu_{PROPOSED}) / 100{,}000 / Gas\ Eff$$

$$Btu_{BASELINE} = \Sigma\ (1.08 * OA\ existing\ supply\ CFM * |ST - OAT| * Bin\ Hours)$$

$$Btu_{PROPOSED} = \Sigma\ (1.08 * OA\ proposed\ supply\ CFM * |ST - OAT| * Bin\ Hours)$$

$$Fan\ Energy_{BASE} = Supply\ Fan\ hp * 0.7465 * Load\ Factor / Fan\ motor\ Efficiency * annual\ hours\ of\ fan\ operation$$

$$Fan\ Energy_{PROP} = Supply\ Fan\ hp * (OA\ proposed\ supply\ CFM / OA\ existing\ supply\ CFM)^{2.5} * 0.7465 * Load\ Factor / Fan\ motor\ Efficiency * annual\ hours\ of\ fan\ operation$$

Where:

1.08 = Constant for air sensible heat equation[5]

OA existing supply CFM = Actual outside air supply airflow (= based on user input)

ST = Building setpoint temperature (= 70°F for OAT > 60°F = 75°F for OAT < 60°F)

OAT = Outside air temperature (= determined by Wisconsin BIN data in EBTU workbook)[4]

Bin Hours = Dry-bulb temperature and time of day (also known as temperature bin data)

OA proposed supply CFM = Proposed air supply airflow (= based on user input) (= based on user input)

12,000 = Conversion factor from Btu to tons

Chiller_Eff = Kilowatts per ton (= varies by chiller type based on 80% of full load rating, see table below)

Cooling Efficiency by System Type

Cooling System Type	Cooling System Efficiency Factor at Partial Load (kW/ton)
Direct Expansion	1.15[6]
Air-Cooled Chiller	0.95[7]
Water-Cooled Chiller	0.64[7]

Supply Fan hp = Horsepower of supply fan (= based on user input)

0.7465 = Conversion from horsepower to kW

Load Factor = Ratio of average demand to maximum demand (= 80%)

Fan motor efficiency = Ratio between power transferred to the airflow and the power used by the fan (= actual motor nameplate rating)

Annual hours of fan operation = Hours in use (= based on user input)

2.5 = Fan affinity law

100,000 = Conversion from Btu to therm

Gas Eff = Efficiency of gas unit (= 80%)

The workbook calculator requires the following measure-specific inputs to be provided from the trained professional performing the tune-up/optimization measure:

- Existing outside air intake volume in CFM
- Modified outside air intake volume in CFM (must still meet code minimum for carbon dioxide level control)
- Air supply fan size (horsepower)
- Number of hours outside air supply fan runs annually

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / Hours_{COOL} * CF$

Where:

$Hours_{COOL}$ = Annual cooling hours of operation (= varies by city; see table below)

Annual Cooling Hours by City[8]

City	BIN Annual Cooling Hours (OAT > 60°F)
Green Bay	2,748
La Crosse	2,971
Madison	2,876
Milwaukee	2,830

CF = Coincidence factor (= 1 assuming that the reduction of outside air intake CFM will be constant over entire summer peak period)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (=5 years)[1]

Assumptions

- Partial load kW/ton rating for DX, air cooled, and water-cooled chillers is the average of the IEER and IPLV minimum efficiency values.[6,7]
- Assumed use of 1 CFM of total supply air per square foot of conditioned building space.
- Assumed heating and cooling balance temperature of 60°F

Sources

1. Cadmus. EUL Response Memo. April 26, 2013.
   Used the Retrocommissioning Program EUL standard and direction from CB&I to keep 5 year EUL standard.
2. RSMeans 2013 Facilities Construction Cost Data, 29th Edition
3. Wisconsin Focus on Energy. EBTU Measures Workbook Calculator.
4. Natural Renewable Energy Laboratory. Bin temperature data comes from respective Wisconsin cities TMY3 weather data. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#W
5. Edison Electric Institute. Technical Information Handbook. p. 24. 2000.
6. International Energy Conservation Code. Table 503.2.3(1). 2009. DX cooling efficiency values determined from simple average of minimum efficiencies for systems with ≥ 5.5-ton capacity.
7. ASHRAE 90.1-2007, Table 6.8.1C. Chiller unit part load efficiency values determined from simple average of minimum efficiencies for chillers with capacity 0 tons to 300 tons.
8. Wisconsin Focus on Energy. Technical Reference Manual. p. 389, Outside Air Temperature Bin Analysis. January 2015.

Revision History

Version Number	Date	Description of Change
01	11/2014	Initial TRM entry

Schedule Optimization

	Measure Details
Measure Master ID	Schedule Optimization: Weekday Heating, 4407 Weekday Cooling, 4408 Weekend Heating, 4409 Weekend Cooling, 4410
Measure Unit	Average setback hour
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Schools & Government
Annual Energy Savings (kWh)	Varies by type of schedule optimization
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by type of schedule optimization
Lifecycle Energy Savings (kWh)	Varies by type of schedule optimization
Lifecycle Therm Savings (Therms)	Varies by type of schedule optimization
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$300.00[2]

Measure Description

This measure captures savings associated with resetting the scheduled weekly building nighttime (or unoccupied) supply air setpoint temperatures via programmable thermostats or direct digital control (DDC) systems. This is a simple temperature setback measure and not a temperature reset control strategy.

For this measures’ savings to apply, the heating supply fuel must be natural gas, and cooling must be supplied by an electrically powered system. The measure can be applied only once per building during the EUL. This measure is meant to be a part of the Express Building Tune-Up Program to help optimize buildings HVAC systems to operate more efficiently at existing building load conditions. It does not apply to newly constructed facilities that have not been commissioned.

Description of Baseline Condition

The baseline measure is a building that already has an HVAC system not using its hourly setback scheduling or a building that can increase its scheduled setback hours. An eligible building must have a consistent weekly operation schedule throughout the year. The average setback hours will be used when schedules vary day-to-day during the week or over the weekend. A buildings standard heating and cooling schedule are both eligible for adjustment.

Description of Efficient Condition

This efficient measure is an increased number of average scheduled setback hours controlled through a building programmable HVAC system. A buildings' standard daily scheduled setback time must be increased by at least one hour during the weekdays or weekends to be eligible for an incentive.

Annual Energy-Savings Algorithm

Savings are the sum of the baseline and proposed energy consumption formulas below across the bin data temperature ranges and corresponding bin temperature hours.[3,4]

Energy savings are effectively summed over every hour of the year, effectively assuming that the same hour of the day (e.g., 1:00 a.m. to 2:00 a.m.) for each day in a given month will yield the same Btu/hour of energy use.

$kWh_{SAVED} = kWh_{BASE} - kWh_{PROPOSED}$

$Therm_{SAVED} = Therm_{BASE} - Therm_{PROPOSED}$

$kWh_{BASE} = \Sigma_{EXISTING}$ (1.08 * Hourly CFM * |SAT – MAT| * # of days per month / 12,000 * chiller_eff)

$Therm_{BASE} = \Sigma_{EXISTING}$ (1.08 * Hourly CFM * |SAT - MAT| * # of days per month / 100,000 / boiler_eff)

Baseline data is based on the user-defined existing building schedule.

$kWh_{PROPOSED} = \Sigma_{PROPOSED}$ (1.08 * Hourly CFM * |SAT - MAT| * # of days per month / 12,000 * chiller_eff)

$Therm_{PROPOSED} = \Sigma_{PROPOSED}$ (1.08 * Hourly CFM * |SAT - MAT| * # of days per month / 100,000 / boiler_eff)

Proposed data is based on the user-defined proposed building schedule, and should reflect a reduction of HVAC running during occupied hours compared to the baseline.

Where:

1.08 = Constant for air sensible heat equation[5]

Hourly CFM = Total building airflow in CFM multiplied by hourly area load (where the area load is a percentage value based on a linear interpolation of a 60°F dry bulb OAT balance point, bin data dry bulb OAT, and 2% dry bulb design summer (see Assumptions), 1% dry bulb design winter conditions for different Wisconsin cities)[6]

SAT = Supply air temperature for occupied hours (= 60°F for OAT > 60°F; = 75°F for OAT ≤ 60°F); for scheduled unoccupied temperature setback hours, SAT is the standard occupied hour temperature setting, plus or minus the user-defined setback temperature for cooling and heating periods, respectively

MAT = (RAT * Return Air CFM + Weighted Average Hourly Temperature * Outside Air CFM) / Total Airflow CFM

Where:

RAT = Return air temperature (= 75°F for OAT > 60°F; 68°F for OAT ≤ 60°F)

Return Air CFM = Total Airflow CFM - Outside Air CFM

Weighted Average Hourly Temperature = Calculated based on the maximum and minimum temperatures over every given hour of the day and number of occurrences per month based on bin data[3]

Outside Air CFM = Amount of outside air expected based on facility type and square footage as determined through CBECS statistical data inserted in the EBTU workbook[7,3]

Total Airflow CFM = 1 CFM per square foot of facility space

# of days per month = Varies by month (= 31 in January; = 28 in February; etc.)

12,000 = Btu to ton conversion factor

chiller_eff = Cooling efficiency of chiller (= varies by chiller type; see table below)

Cooling Efficiency by System Type

Cooling System Type	Cooling System Efficiency Factor at Partial Load Rating (kW/ton)
Direct Expansion[8]	1.15
Air-Cooled Chiller[9]	0.95
Water-Cooled Chiller[9]	0.60

100,000 = Btu to therm conversion factor

boiler_eff = Efficiency of natural gas to heat conversion for heating purposes (= 80%)

The workbook calculator requires the following inputs to be provided from the trained professional performing the tune-up/optimization measure:

- Majority facility space type (e.g., offices, classroom, lobby, health club)
- Square footage of facility’s conditioned space affected by schedule change
- Baseline (pre) and efficient (post) heating and cooling schedule hours, indicating when the system turns on and off during a typical weekday and weekend in 24-hour time format
- Amount of planned temperature setback degrees during scheduled unoccupied times
- Type of facility cooling system (direct expansion, air cooled, or water cooled)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure, as the temperature setback scheduling is not expected to occur during Wisconsin Focus on Energy peak demand hours of 1:00 p.m. to 4:00 p.m. from June through August.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (=5 years)[1]

Assumptions

- RAT fixed values (75°F for OAT > 60°F and 68°F for OAT < 60°F) are for calculation purposes
- SAT setpoints are increased or decreased by 5°F during weekly scheduled unoccupied hours during cooling and heating periods, respectively
- Heating and cooling balance temperature of 60°F
- Therm savings are calculated when daily weighted hourly temperatures are less than 60°F
- kWh savings are calculated when daily weighted hourly temperatures are greater than 60°F
- Same average weekly hours schedule is repeated throughout the year
- Total supply is 1 CFM per building square foot
- 2% and 1% dry bulb design conditions for cooling/heating seasons means that the HVAC system is designed to adequately handle the cooling/heating of a given building for all outdoor air temperatures that do not exceed the hottest/coldest 2% and 1% of hours of the respective season. Explained another way, it means the cooling/heating system can adequately handle the

cooling/heating load of a given building for 98% and 99% of the total anticipated peak cooling/heating hours for the year.

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Focus on Energy. Engineering Judgement.
   While RSMeans 2016 shows $59 per hour under 23 09 33.10 – Electronic Control System for HVAC, engineer stakeholders for Focus on Energy believe that $100 per hour is a more realistic rate, and that three hours is a realistic average time to complete.
3. Wisconsin Focus on Energy. EBTU Measures Workbook Calculator.
4. National Renewable Energy Laboratory. Bin temperature data comes from respective Wisconsin cities TMY3 weather data. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#W
5. Edison Electric Institute. Technical Information Handbook. Pg. 24. 2000.
6. American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc. ASHRAE Handbook: Fundamentals. Chapter 14 – Climatic Design Information. "Appendix: Design Conditions for Selected Locations." 2017.
7. U.S. Energy Information Administration. "2003 CBECS Survey Data." http://www.eia.gov/consumption/commercial/data/2003/
8. International Energy Conservation Code. Table 403.2.3(1). 2012. CHAPTER 4 [CE] COMMERCIAL ENERGY EFFICIENCY | 2012 International Energy Conservation Code | ICC publicACCESS
   Direct expansion cooling efficiency values (air conditioners, air cooled) determined as simple averages of minimum efficiencies for system capacities of ≥ 5.5 tons.
9. ASHRAE 90.1-2010, Table 6.8.1-3.
   Chiller unit part-load efficiency values were determined as simple averages of minimum efficiencies for air cooled chillers with capacity of < 150 tons and ≥ 150 tons, and for water cooled chillers <150 tons and between 150 and 300 tons, Path A.

Revision History

Version Number	Date	Description of Change
01	11/2014	Initial TRM entry
02	12/2017	Renamed measures to remove square footage bins and change measure unit to average setback hour

Supply Air Temperature Reset

	Measure Details
Measure Master ID	Supply Air Temperature Reset, Heating, 3672 Supply Air Temperature Reset, Cooling, 3673
Measure Unit	Per degree Fahrenheit
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Schools & Government
Annual Energy Savings (kWh)	Varies by type of reset
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by type of reset
Lifecycle Energy Savings (kWh)	Varies by type of reset
Lifecycle Therm Savings (Therms)	Varies by type of reset
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$96.00[2]

Measure Description

This measure captures savings associated with implementing a new supply air temperature (SAT), cooling or heating, reset strategy or optimizing a programmed SAT reset strategy based on OAT ranges. To claim the measure savings, the heating must be supplied by a natural gas boiler, and the cooling system must be electrically powered. The savings apply specifically to constant air volume (CAV) systems.

This measure is meant to be a part of the Express Building Tune-Up Program to help optimize building HVAC systems to operate more efficiently at existing building load conditions. It does not apply to newly constructed facilities that have not been commissioned.

Description of Baseline Condition

This baseline measure is an HVAC system with preset SAT setpoints that are not based on OAT.

Description of Efficient Condition

This efficient measure is implementing or optimizing an SAT reset strategy based on OAT. The reset strategy should incorporate a maximum and minimum supply air temperature for both heating and cooling modes to correspond with a minimum and maximum outdoor air temperature range, respectively.

Annual Energy-Savings Algorithm

Savings are the sum of the baseline and proposed energy consumption formulas below across the bin data temperature ranges and corresponding bin temperature hours.[3,4]

kWh_{SAVED} = Σ (SAT Btu Baseline – SAT Btu Proposed) / 12,000 * chiller_eff * % building affected

$Therm_{SAVED}$ = Σ (SAT Btu Baseline – SAT Btu Proposed) / 100,000 / boiler_eff * % building affected

SAT Btu Baseline = [(1.08 * Area_Load * |SAT_{BASE} - OAT| * Outside Air CFM + 1.08 * Area_Load * |SAT_{BASE} - RAT| * Return Air CFM] * bin hours

SAT Btu Proposed = [(1.08 * Area_Load * |SAT_{RESET} - OAT| * Outside Air CFM + 1.08 * Area_Load * |SAT_{RESET} - RAT| * Return Air CFM] * bin hours

Where:

1.08 = Constant for air sensible heat equation[5]

Area Load = Percentage value based on linear interpolation of a 60°F dry bulb OAT balance point, bin data dry bulb OAT, and 2.5% dry bulb design summer/winter conditions for different Wisconsin cities[6] (see Assumptions for more explanation about the 2.5% dry bulb design conditions)

SAT_{BASE} = Supply air temperature baseline (= user defined input; constant)

OAT = Outside Air Temperature (= determined from workbook bin data)

Outside Air CFM = Amount of outside air expected based on facility type and square footage as determined through CBECS statistical data inserted in the EBTU workbook[7,3]

RAT = Return air temperature (= 75°F for OAT > 60°F; = 68°F for OAT < 60°F)

Return Air CFM = Total building airflow – Outside Air CFM

bin hours = Heating and cooling hours for each city based on OAT[4]

SAT_{RESET} = OAT reset range (= user input)

12,000 = Btu to ton conversion factor

chiller_eff = Cooling efficiency of chiller (= varies by chiller type; see table below)

Cooling Efficiency by System Type

Cooling System Type	Cooling System Efficiency Factor at Partial Load (kW/ton)
Direct Expansion	1.15[8]
Air-Cooled Chiller	0.95[9]
Water-Cooled Chiller	0.64[9]

% building affected = Amount of total building conditioned square footage affected by implementing the SAT reset control (= user defined input)

100,000 = Btu to therm conversion factor

boiler_eff = Efficiency of natural gas to heat conversion for heating purposes (= 80%)

The workbook calculator requires the following measure-specific inputs to be provided from the trained professional performing the tune-up/optimization measure:

- OAT Reset Range – Heating and Cooling (°F)
- Existing Facility Supply Air Heating and Cooling Temperature Setpoints (°F)
- SA Reset Temperature Range – Heating and Cooling (°F)
- Facility Type (e.g., office, library, retail)
- Useable Facility Square Footage
- Percentage of Total Facility Area Cooled
- Percentage of Total Facility Area Heated
- Number of Building Zones Affected
- Type of Chiller System
- Percentage of Building Square Footage Affected

Summer Coincident Peak Savings Algorithm

There is no peak demand reduction associated with this measure because during peak demand times, the cooling system will be operating above the bounds of the SAT reset curve.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)[1]

Assumptions

- Partial load kW/ton rating for air-cooled and water-cooled chillers is average IPLV minimum efficiency value found in Focus on Energy HVAC catalog[9]
- Total supply of 1 CFM per building conditioned square foot

- Heating and cooling balance temperature = 60°F
- 2.5% dry bulb design conditions means that for cooling/heating seasons, the HVAC system is designed to adequately handle the cooling/heating of a given building for all outdoor air temperatures that do not exceed the hottest/coldest 2.5% of hours of the respective season. Explained another way, this means the cooling/heating system can adequately handle the cooling/heating load of a given building for 97.5% of the total anticipated peak cooling/heating hours for the year.

Sources

1. Cadmus. EUL Response Memo. April 26, 2013.
   Used Retrocommissioning Program EUL standard and direction from CB&I to keep five year EUL standard.
2. RSMeans 2013 Facilities Construction Cost Data, 29th Edition
3. Wisconsin Focus on Energy. EBTU Measures Workbook Calculator.
4. Natural Renewable Energy Laboratory. Bin temperature data comes from respective Wisconsin cities TMY3 weather data. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#W
5. Edison Electric Institute. Technical Information Handbook. p. 24. 2000.
6. ASHRAE. Handbook, Fundamentals Volume for Wisconsin Cities. 1985.
   http://publicecodes.cyberregs.com/icod/ipc/2012/icod_ipc_2012_appd.htm
7. U.S. Energy Information Administration. National CBECS Statistical Data. 2003.
   http://www.eia.gov/consumption/commercial/data/2003/
8. International Energy Conservation Code. Table 503.2.3(1). 2009. DX cooling efficiency values determined as simple average minimum efficiencies for systems with capacity ≥ 5.5 tons.
9. ASHRAE 90.1-2007. Table 6.8.1C. Chiller unit part load efficiency values are simple average minimum efficiencies for chillers with capacity of 0 tons to 300 tons.

Revision History

Version Number	Date	Description of Change
01	11/2014	Initial TRM entry

Temperature Sensor Calibration

	Measure Details
Measure Master ID	Temperature Sensor Calibration, 3674
Measure Unit	Per degree of calibration
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Schools & Government
Annual Energy Savings (kWh)	Varies by temperature ranges and hours
Peak Demand Reduction (kW)	Varies by temperature ranges and hours
Annual Therm Savings (Therms)	Varies by temperature ranges and hours
Lifecycle Energy Savings (kWh)	Varies by temperature ranges and hours
Lifecycle Therm Savings (Therms)	Varies by temperature ranges and hours
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$108.00[2]

Measure Description

This measure captures savings by calibrating temperature sensors in an air handling unit feeding a particular building zone. The measure savings are specific to air distribution systems, but are otherwise flexible. This measure does not include the cost to replace sensors that have completely failed.

To apply measure savings, the heating supply must be produced by a natural gas boiler, while the cooling system must be electrically powered. The measure can be applied only once per building during the EUL. This measure is meant to be a part of the Express Building Tune-Up Program to help optimize building HVAC systems to operate more efficiently at existing building load conditions. It does not apply to newly constructed facilities that have not been commissioned.

This measure is applicable for supply air temperature (SAT) and indoor air room temperature (IAT) sensors that are measuring and providing control feedback to the building HVAC systems.

Description of Baseline Condition

The baseline measure is a facility’s SAT and IAT sensors not having been calibrated and no Wisconsin Focus on Energy rebate applied for at least five years.

Description of Efficient Condition

The efficient measure is to re-calibrate SAT and IAT sensors by averaging three separate temperature readings with a secondary calibrated temperature device within close proximity of the sensor to be calibrated. This will determine the amount the facility temperature sensors are off from actual in order to make the necessary calibrations. The recalibrated sensors will help ensure that excess energy is not being wasted to heat or cool a space. Broken sensors that need total replacement are not eligible. Calibrated sensors should be adjusted to within two decimal places.

Annual Energy-Savings Algorithm

Savings are the sum of the baseline and proposed energy consumption formulas below across the bin data temperature ranges and corresponding bin temperature hours found in the EBTU workbook.[3,4]

kWh_{SAVED} = Σ (Temp Sensor cooling Btu Baseline – Temp Sensor cooling Btu Proposed) / 12,000 * chiller_eff * % building affected * bin hours

$Therm_{SAVED}$ = Σ (Temp Sensor heating Btu Baseline – Temp Sensor heating Btu Proposed) / 80% / 100,000 * % building affected * bin hours

Temp Sensor cooling/heating Btu Baseline = 1.08 * $Area\_Load_{BASE}$ * |SAT - OAT| * Outside Air CFM + 1.08 * $Area\_Load_{BASE}$ * Δ (SAT - RAT) * Return Air CFM

Temp Sensor cooling/heating Btu Proposed = 1.08 * $Area\_Load_{PROP}$ * |SAT - OAT| * Outside Air CFM + 1.08 * $Area\_Load_{PROP}$ * Δ (SAT - RAT) * Return Air CFM

Where:

1.08 = Constant for air sensible heat equation[5]

$Area\_Load_{BASE}$ = Percentage value based on linear interpolation of a 60°F dry bulb OAT balance point, bin data dry bulb OAT, and 2.5% dry bulb design summer/winter conditions for different Wisconsin cities[6] (see Assumptions for more explanation about the 2.5% dry bulb design conditions)

SAT = Supply air temperature (= 60°F for OAT > 60°F; = 75°F for OAT < 60°F)

OAT = Outside air temperature

Outside Air CFM = Amount of outside air expected based on facility type and square footage as determined through CBECS statistical data inserted in the EBTU workbook[7,3]

RAT = Return air temperature (= 75°F for OAT > 60°F; = 68°F for OAT < 60°F)

Return Air CFM = Total building airflow – Outside Air CFM (per zone)

$Area\_Load_{PROP}$ = Percentage value based on linear interpolation of a 60°F dry bulb OAT balance point, bin data dry bulb OAT ± calibrated values, and 2.5%

dry bulb design maximum/minimum temperatures for different Wisconsin cities[6]

12,000 = Btu to ton conversion factor

chiller_eff = kW/ton based on 80% of full load rating of chiller units (= based on type of chiller; see table below)

Cooling Efficiency by System Type

Cooling System Type	Cooling System Efficiency Factor at Partial Load (kW/ton)
Direct Expansion	1.15[8]
Air-Cooled Chiller	0.95[9]
Water-Cooled Chiller	0.64[9]

% building affected = Amount of total building square footage affected by sensor calibration (= user defined)

bin hours = Heating and cooling hours for each city based on OAT[4]

80% = Efficiency of natural gas to heat conversion for heating purposes

100,000 = Btu to therm conversion factor

The workbook calculator requires the following measure-specific inputs to be provided from the trained professional performing the tune-up/optimization measure:

- An average of three separate measurement reading of the un-calibrated air handling unit temperature sensor to determine the current baseline reading (measurements should be out two decimal places)
- An average of three separate temperature readings of the calibrated air flowing near the un-calibrated temperature sensor, used to read and calibrate the un-calibrated sensor (measurements should be out two decimal places)
- Majority facility space type (e.g., offices, classroom, lobby, health club)
- Percentage of facility being heated
- Percentage of facility being cooled
- Square footage of usable facility space
- Chiller system type (direct expansion, air cooled, or water cooled)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / Hours_{COOL} * CF$

Where:

$Hours_{COOL}$ = Annual cooling hours of operation (= based on city; see table below)

Annual Cooling Hours by City

City	BIN Annual Cooling Hours (OAT > 60°F)[10]
Green Bay	2,745
La Crosse	2,971
Madison	2,874
Milwaukee	2,830

CF = Coincidence factor (= 1)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (=5 years)[1]

Assumptions

- Therm savings are calculated only when the calibrated reading is greater than the original sensors reading
- kWh savings are calculated only when the calibrated reading is less than the original sensor reading
- Heating and cooling balance temperature = 60°F
- Total supply of 1 CFM per building square foot
- 2.5% dry bulb design conditions means that for cooling/heating seasons, the HVAC system is designed to adequately handle the cooling/heating of a given building for all outdoor air temperatures that do not exceed the hottest/coldest 2.5% of hours of the respective season. Explained another way, this means the cooling/heating system can adequately handle the cooling/heating load of a given building for 97.5% of the total anticipated peak cooling/heating hours for the year.

Sources

1. Cadmus. EUL Response Memo. April 26, 2013.
   Used Retrocommissioning Program EUL standard and direction from CB&I to keep 5 year EUL standard)
2. RSMeans 2013 Facilities Construction Cost Data, 29th Edition
3. Wisconsin Focus on Energy. EBTU Measures Workbook Calculator.
4. Natural Renewable Energy Laboratory. Bin temperature data comes from respective Wisconsin cities TMY3 weather data. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#W
5. Edison Electric Institute. Technical Information Handbook. p. 24. 2000.
6. ASHRAE. Handbook, Fundamentals Volume for Wisconsin Cities. 1985. http://publicecodes.cyberregs.com/icod/ipc/2012/icod_ipc_2012_appd.htm
7. U.S. Energy Information Administration. National CBECS Statistical Data. 2003. http://www.eia.gov/consumption/commercial/data/2003/
8. International Energy Conservation Code. Table 503.2.3(1). 2009. DX cooling efficiency values determined as simple average minimum efficiencies for systems with capacity ≥ 5.5 tons.
9. ASHRAE 90.1-2007. Table 6.8.1C. Chiller unit part load efficiency values are simple average minimum efficiencies for chillers with capacity of 0 tons to 300 tons.
10. Wisconsin Focus on Energy Technical Reference Manual. Outside Air Temperature Bin Analysis, p. 389. January 2015.

Revision History

Version Number	Date	Description of Change
01	11/2014	Initial TRM entry

Valve Repair

	Measure Details
Measure Master ID	Valve Repair, Chilled Water, 3675 Valve Repair, Hot Water, 3676
Measure Unit	Per MBh
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by type of repair
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by type of repair
Lifecycle Energy Savings (kWh)	Varies by type of repair
Lifecycle Therm Savings (Therms)	Varies by type of repair
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$112.00[2]

Measure Description

This measure captures savings associated with repairing a chilled or hot water valve serving a cooling/heating coil in a central air handling unit. This measure is for addressing a valve that has a 70% failure rate at open or higher.

The incremental cost does not account for the potential replacement of unrepairable/broken valves. The heating supply must be produced by a natural gas boiler, and the cooling system must be electrically powered. The measure can be applied only once per building during the EUL. This measure is meant to be a part of the Express Building Tune-Up Program to help optimize building HVAC systems to operate more efficiently at existing building load conditions. It does not apply to newly constructed facilities that have not been commissioned.

Description of Baseline Condition

The baseline measure is a chilled or hot water valve in need of repair due to being stuck open at 70% or greater. If the valve is stuck at some point less than 70% open, this measure does not apply.

Description of Efficient Condition

The efficient measure is replacing or repairing a failed valve back to its optimal working state.

Annual Energy-Savings Algorithm

Savings are the sum of the baseline and proposed energy consumption formulas below across the bin data temperature ranges and corresponding bin temperature hours found in the EBTU workbook.[3,4]

kWh_{SAVED} = Σ [(Valve cooling Btu Baseline – Valve cooling Btu Proposed) / 12,000 * chiller_eff * Adjusted Hours]

$Therm_{SAVED}$ = Σ [(Valve heating Btu Baseline – Valve heating Btu Proposed) / 80% / 100,000 * Adjusted Hours]

Valve heating/cooling Btu Baseline = Capacity of heat_cool coil being served * 1,000 * stuck valve position % * Area Load

Valve heating/cooling Btu Proposed = Capacity of heat_cool coil being served * 1,000 * working valve position % * Area Load

Where:

Capacity of heat_cool coil being served = Expressed in MBh or Tons (= user defined; MBh for chilled water = # tons * 12)

1,000 = Kilowatt conversion factor

Stuck valve position % = Percentage open (= user defined)

Area Load = Percentage value based on linear interpolation of a 60°F dry bulb OAT balance point, bin data dry bulb OAT, and 2.5% dry bulb design summer/winter conditions for different Wisconsin cities[5] (see Assumptions for more explanation about the 2.5% dry bulb design conditions)

Working valve position % = Workbook-calculated value based on bin data OAT

12,000 = Btu to ton conversion factor

chiller_eff = Efficiency of cooling system in kilowatts per ton (= based on type of chiller; see table below)

Cooling Efficiency by System Type

Chiller Type	Cooling System Efficiency Factor at Partial Load (kW/ton)
Air-Cooled	0.95[6]
Water-Cooled	0.64[6]

Adjusted Hours = Bin hours * EFLH (see table below) / 8,760 total annual hours[4]

EFLH = Equivalent Full Load Hours

8,760 = Total hours in a year

Bin Hours = The number of average hours of occurrence during a month or year of a particular range of weather condition

Equivalent Full-Load Heating and Cooling Hours by City

City	$EFLH_{COOL}$[7]	$EFLH_{HEAT}$[7]
Green Bay	344	1,852
La Crosse	323	1,966
Madison	395	1,934
Milwaukee	457	1,883

80% = Efficiency of natural gas to heat conversion for heating purposes

100,000 = Btu to therm conversion factor

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (=5 years)[1]

Assumptions

- Heating and cooling balance temperature = 60°F
- 2.5% dry bulb design conditions means that for cooling/heating seasons, the HVAC system is designed to adequately handle the cooling/heating of a given building for all outdoor air temperatures that do not exceed the hottest/coldest 2.5% of hours of the respective season. Explained another way, this means the cooling/heating system can adequately handle the cooling/heating load of a given building for 97.5% of the total anticipated peak cooling/heating hours for the year.

Sources

1. Cadmus. EUL Response Memo. April 26, 2013.
   Used Retrocommissioning Program EUL standard and direction from CB&I to keep five year EUL standard.
2. RSMeans 2013 Facilities Construction Cost Data, 29th Edition
3. Wisconsin Focus on Energy. EBTU Measures Workbook Calculator.
4. Natural Renewable Energy Laboratory. Bin temperature data comes from respective Wisconsin cities TMY3 weather data. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#W
5. ASHRAE. Handbook, Fundamentals Volume for Wisconsin Cities. 1985. http://publicecodes.cyberregs.com/icod/ipc/2012/icod_ipc_2012_appd.htm
6. ASHRAE 90.1-2007. Table 6.8.1C. Chiller unit part load efficiency values are simple average minimum efficiencies for chillers with capacity of 0 tons to 300 tons.
7. Several Cadmus metering studies reveal that the ENERGY STAR calculator EFLH are over-estimated by 25%. The EFLHHEAT were adjusted by population-weighted HDD and TMY-3 values.

Revision History

Version Number	Date	Description of Change
01	11/2014	Initial TRM entry

VFD Fan Motor Control Restoration

	Measure Details
Measure Master ID	VFD Fan Motor Control Restoration, 3677
Measure Unit	Per horsepower
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by temperature ranges and hours
Peak Demand Reduction (kW)	Varies by temperature ranges and hours
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by temperature ranges and hours
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$56.00[2]

Measure Description

This measure captures savings associated with correcting the operating setting on a variable frequency drive (VFD) controlling an HVAC system-related fan motor that is stuck in ‘hand’ mode or is in bypass mode. Measure rebate does not apply if the original VFD was incented by Wisconsin Focus on Energy. Measure rebate applies to all other VFDs only once per building during the EUL. This measure is meant to be a part of the Express Building Tune-Up Program to help optimize building HVAC systems to operate more efficiently at existing building load conditions. It does not apply to newly constructed facilities that have not been commissioned.

Description of Baseline Condition

The baseline measure is a fan motor in a facility using a VFD for motor control, but not using the ‘automatic’ VFD control features.

Description of Efficient Condition

The efficient measure is restoring the automatic control features of a VFD controlling a fan motor load. The VFD should not be manually altered in its control operation after being set to automatic mode.

Annual Energy-Savings Algorithm

Savings are the sum of the baseline and proposed energy consumption formulas below across the bin data temperature ranges and corresponding bin temperature hours found in the EBTU workbook.[3,4]

kWh_{SAVED} = VFD Motor Baseline - VFD Motor Proposed

VFD Motor Baseline = Σ [Motor hp * 0.7465 / Motor eff * (Motor loading $\%_{BASE}$)^2.5 * Adjusted Run Hours]

VFD Motor Proposed = Σ [Motor hp * 0.7465 / Motor eff * (Motor loading $\%_{PROP}$)^2.5 * Adjusted Run Hours]

Where:

Motor hp = VFD controlled motor nameplate horsepower rating

0.7465 = Horsepower to kW conversion factor

Motor eff = Specific VFD controlled motor nameplate efficiency; otherwise use default of 90%

Motor Loading $\%_{BASE}$ = Percent capacity (Load Factor) of motor at baseline (= user defined)

Adjusted Run Hours = Bin hours * (annual VFD operational hours / 8,760 annual hours)

Motor Loading $\%_{PROP}$ = Percent capacity (Load Factor) of motor proposed; assumes the VFD is set back to 'automatic' control based on user-defined loading minimum and maximum percentages and on area load (area load is a percentage based on a linear interpolation of a 60°F dry bulb OAT balance point, bin data dry bulb OAT, and 2.5% dry bulb design summer/winter conditions for different Wisconsin cities;[5] see Assumptions for more explanation about the 2.5% dry bulb design conditions)

The workbook calculator requires the following measure-specific inputs to be provided from the trained professional performing the tune-up/optimization measure:

- Annual hours of VFD/fan operation
- Fan VFD application (cooling tower fan, chiller system fan, boiler/heating fan)
- Existing VFD control state (auto, manual, bypassed/off)
- Fan motor nameplate capacity controlled by VFD (horsepower)
- Fan motor nameplate efficiency percentage
- Measured speed at setpoint if VFD is stuck in 'hand' mode (Hz)
- VFD fan control loading minimum and maximum percentages

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / Hours_{FAN} * CF$

Where:

$Hours_{FAN}$ = Annual hours of operation for the fan controlled by the VFD

CF = Coincidence factor (= based on VFD fan use; see table below)

Coincidence Factor by VFD Fan Use[6]

VFD Use	CF	Details
Cooling Tower Fan	0.9	DEER model runs were weather-normalized for statewide use by population density
Boiler Draft/Heating Fan	0.0	Assumed that heating fan not operating at peak summer period

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=5 years)[1]

Assumptions

- Assumes 100% load factor for all motors running in a VFD bypassed state.
- 2.5% dry bulb design conditions means that for cooling/heating seasons, the HVAC system is designed to adequately handle the cooling/heating of a given building for all outdoor air temperatures that do not exceed the hottest/coldest 2.5% of hours of the respective season. Explained another way, this means the cooling/heating system can adequately handle the cooling/heating load of a given building for 97.5% of the total anticipated peak cooling/heating hours for the year.

Sources

1. Cadmus. EUL Response Memo. April 26, 2013. Used the Retrocommissioning Program EUL standard and direction from CB&I to keep 5 year EUL standard.
2. RSMeans 2013 Facilities Construction Cost Data, 29th Edition
3. Wisconsin Focus on Energy. EBTU Measures Workbook Calculator.
4. Natural Renewable Energy Laboratory. Bin temperature data comes from respective Wisconsin cities TMY3 weather data. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#W

5. ASHRAE. Handbook, Fundamentals Volume for Wisconsin Cities. 1985. http://publicecodes.cyberregs.com/icod/ipc/2012/icod_ipc_2012_appd.htm
6. Wisconsin Focus on Energy Technical Reference Manual. p. 225, Variable Frequency Drive, summer coincident peak savings algorithm VFD coincidence factor chart. 2015.

Revision History

Version Number	Date	Description of Change
01	10/2014	Initial TRM entry

VFD Pump Control Restoration

	Measure Details
Measure Master ID	VFD Pump Control Restoration, 3678
Measure Unit	Per horsepower
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by temperature ranges and hours
Peak Demand Reduction (kW)	Varies by temperature ranges and hours
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by temperature ranges and hours
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$56.00[2]

Measure Description

This measure captures savings associated with correcting the operating setting on a variable frequency drive (VFD) controlling an HVAC system-related pump motor that is stuck in 'hand' mode or is in bypass mode. Measure rebate does not apply if the original VFD was incented by Wisconsin Focus on Energy. Measure rebate applies to all other VFDs only once per building during the EUL. This measure is meant to be a part of the Express Building Tune-Up Program to help optimize building HVAC systems to operate more efficiently at existing building load conditions. It does not apply to newly constructed facilities that have not been commissioned.

Description of Baseline Condition

The baseline measure is a pump motor in a facility using a VFD for pump control, but not using the 'automatic' VFD control features.

Description of Efficient Condition

The efficient measure is restoring the automatic control features of a VFD controlling a pump load. The VFD should not be manually altered in its control operation after being set to automatic mode.

Annual Energy-Savings Algorithm

Savings are the sum of the baseline and proposed energy consumption formulas below across the bin data temperature ranges and corresponding bin temperature hours found in the EBTU workbook.[3,4]

kWh_{SAVED} = VFD Pump Baseline - VFD Pump Proposed

VFD Pump Baseline = Σ [Motor hp * 0.7465 / Motor eff * (Motor loading $\%_{BASE}$)^2.5 * Adjusted Run Hours]

VFD Pump Proposed = Σ [Motor hp * 0.7465 / Motor eff * (Motor loading $\%_{PROP}$)^2.5 * Adjusted Run Hours]

Where:

Motor hp = VFD controlled motor nameplate horsepower rating

0.7465 = Horsepower to kW conversion factor

Motor eff = Specific VFD controlled pump motor nameplate efficiency; otherwise use default of 90%

Motor Loading $\%_{BASE}$ = Percent capacity (Load Factor) of motor at baseline (= user defined)

Adjusted Run Hours = Bin hours * (annual VFD operational hours / 8,760 annual hours)

Motor Loading $\%_{PROP}$ = Percent capacity (Load Factor) of motor proposed; assumes the VFD is set back to 'automatic' control based on user-defined loading minimum and maximum percentages and on area load (area load is a percentage based on a linear interpolation of a 60°F dry bulb OAT balance point, bin data dry bulb OAT, and 2.5% dry bulb design summer/winter conditions for different Wisconsin cities;[5] see Assumptions for more explanation about the 2.5% dry bulb design conditions)

The workbook calculator requires the following measure-specific inputs to be provided from the trained professional performing the tune-up/optimization measure:

- Annual hours of VFD/fan operation
- Fan VFD application (cooling tower fan, chiller system fan, boiler/heating fan)
- Existing VFD control state (auto, manual, bypassed/off)
- Fan motor nameplate capacity controlled by VFD (horsepower)
- Fan motor nameplate efficiency percentage
- Measured speed at setpoint if VFD is stuck in 'hand' mode (Hz)
- VFD fan control loading minimum and maximum percentages

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / Hours_{PUMP} * CF$

Where:

$Hours_{PUMP}$ = Annual hours of operation for the pump controlled by the VFD

CF = Coincidence factor (= based on VFD pump use; see table below)

Coincidence Factor by VFD Pump Use[6]

VFD Use	CF	Source
Chilled Water Pump	0.9	DEER model runs were weather-normalized for statewide use by population density
Hot Water Pump	0.0	Assumed that heating/hot water pump not operating at peak times

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=5 years)[1]

Assumptions

- Assumes 100% load factor for all motors running in a VFD bypassed state.
- 2.5% dry bulb design conditions means that for cooling/heating seasons, the HVAC system is designed to adequately handle the cooling/heating of a given building for all outdoor air temperatures that do not exceed the hottest/coldest 2.5% of hours of the respective season. Explained another way, this means the cooling/heating system can adequately handle the cooling/heating load of a given building for 97.5% of the total anticipated peak cooling/heating hours for the year.

Sources

1. Cadmus. EUL Response Memo. April 26, 2013. Used the Retrocommissioning Program EUL standard and direction from CB&I to keep 5 year EUL standard.
2. RSMeans 2013 Facilities Construction Cost Data, 29th Edition
3. Wisconsin Focus on Energy. *EBTU Measures Workbook Calculator.* January 2015.
4. Natural Renewable Energy Laboratory. Bin temperature data from respective Wisconsin City TMY3 weather data. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#W

5. ASHRAE. *Handbook, Fundamentals Volume for Wisconsin Cities*. 1985. http://publicecodes.cyberregs.com/icod/ipc/2012/icod_ipc_2012_appd.htm
6. *Wisconsin Focus on Energy Technical Reference Manual.* p. 225, Variable Frequency Drive, summer coincident peak savings algorithm VFD coincidence factor chart. 2015.

Revision History

Version Number	Date	Description of Change
01	10/2014	Initial TRM entry

Variable Speed ECM Pump, Domestic Hot Water Recirculation, Heating Water Circulation, and Cooling Water Circulation

	Measure Details
Measure Master ID	Variable Speed ECM Pump: Domestic Hot Water Recirculation: < 100 Watts Max Input, 3494, 4602 100 - 500 Watts Max Input, 3495, 4603 > 500 Watts Max Input, 4604 Heating Water Circulation: < 100 Watts Max Input, 3497, 4605 100 - 500 Watts Max Input, 3498, 4606 > 500 Watts Max Input, 3499, 4607 Cooling Water Circulation: < 100 Watts Max Input, 4608 100 - 500 Watts Max Input, 4609 > 500 Watts Max Input, 3502, 4610 Water Loop Heat Pump Circulation: < 100 Watts Max Input, 4611 100 - 500 Watts Max Input, 3504, 4612 > 500 Watts Max Input, 3505, 4613
Measure Unit	Per pump
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Variable Speed Drive
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by wattage
Peak Demand Reduction (kW)	Varies by wattage
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by wattage
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Varies by measure and wattage, see Appendix D

Measure Description

ECMs are high-efficiency brushless DC motors. They are typically fractional horsepower motors that have several benefits over the more common PSC fractional horsepower motor. One of these advantages is higher overall efficiency. PSC motors are generally 20% to 60% efficient, depending on their loading, while ECM motor efficiencies range from 70% to 80%. Other advantages include a reduction in the pump motor size, the variable speed capability of the pump, the ability to provide constant flow with varying pressures, a wider range of rpm, and the ability to be controlled by direct digital controls.

DHW recirculating pumps are commonly used in multifamily and commercial buildings to shorten the amount of time it would otherwise take for hot water to reach the occupants on upper floors and that have long piping runs. These recirculation pumps can be operated continuously or be controlled by a timer or an aquastat. An aquastat turns on the pump only when the temperature of the return line falls below a certain setpoint. Many of the ECM recirculating pumps currently on the market have integrated aquastat controls and the ability to be controlled and monitored wirelessly.

Heating and cooling water circulation pumps are commonly used in baseboard and radiant floor heating systems, as well as in coils in forced air systems in multifamily and commercial buildings. Cooling loops are often part of heat pump circulation systems. Often the primary and secondary loops run constantly throughout the heating or cooling season. ECM circulator pumps can modulate their speed to match the load.

Description of Baseline Condition

The baseline condition is a standard efficiency, constant volume PSC pump for domestic heating or cooling circulation without variable speed capabilities.

Description of Efficient Condition

The efficient condition is a properly sized, high-efficiency ECM pump for domestic heating or cooling circulation with variable speed capabilities to match demand.

Savings for this measure are from the reduction in the pump motor size, the variable speed capability of the pump, and the increased efficiency of the ECMs versus the fraction horsepower PSC motors.

Annual Energy-Savings Algorithm

Heating and Cooling Circulation Pumps:

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * HOU$

$Watts_{BASE} = Watts_{EE} * R$

$HOU_{HEATING} = HDD * 24 * \Delta T$

$HOU_{COOLING} = CDD * 24 * \Delta T$

Water Loop Heat Pump Circulation Pumps:

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * (HOU_{HEATING} + HOU_{COOLING})$

$Watts_{BASE} = Watts_{EE} * R$

$HOU_{HEATING} = HDD * 24 * \Delta T$

$HOU_{COOLING} = CDD * 24 * \Delta T$

DHW Recirculation Pumps:

$kWh_{SAVED} = (Watts_{BASE} / 1{,}000 * HOU_{DHW\text{-}BASE}) – (Watts_{EE} / 1{,}000 * HOU_{DHW\text{-}EE})$

$HOU_{DHW\text{-}BASE} = HOU_{UNCONTROLLED} * 44.5\% + HOU_{CONTROLLED} * 55.5\%$

$HOU_{DHW\text{-}EE} = HOU_{CONTROLLED}$

Where:

$Watts_{BASE}$ = Power consumption of constant speed PSC pump (= 278 watts for < 100 watt VSD ECM pumps; = 1,389 watts for 100 watt to 500 watt VSD ECM pumps; = 5,556 watts for > 500 watt VSD ECM pumps)

$Watts_{EE}$ = Power consumption of variable speed ECM pump (= 50 watts for < 100 watt VSD ECM pumps; = 250 watts for 100 watt to 500 watt VSD ECM pumps; = 1,000 watts for > 500 watt VSD ECM pumps)

1,000 = Kilowatt conversion factor

HOU = Average annual pump run hours

R = Ratio of ECM watts to baseline watts based on measured data of comparable efficient and nonefficient pumps (18%)[2]

$HOU_{HEATING}$= Average annual pump run hours for heating (= 2,285)[3]

HDD = Heating degree days (= 7,616; see table below)[5]

24 = Conversion factor, hours per day

ΔT = Design temperature difference (= 80°F for heating; = 20°F for cooling as 95°F outdoor design - 75°F indoor design)[6]

$HOU_{COOLING}$= Average annual pump run hours for cooling (= 678)[3]

CDD = Cooling degree days (= 565; see table below)[5]

Heating and Cooling Degree Days by Location

Location	HDD[5]	CDD[5]
Milwaukee	7,276	548
Green Bay	7,725	516
Wausau	7,805	654
Madison	7,599	630
La Cross	7,397	729
Minocqua	8,616	423
Rice Lake	8,552	438
Statewide Weighted	**7,616**	**565**

$HOU_{DHW\text{-}BASE}$= Average annual pump run hours for DHW recirculating (= 5,114)[3]

$HOU_{DHW\text{-}EE}$= Average annual pump run hours for DHW recirculating (= 2,190)[3]

$HOU_{UNCONTROLLED}$= Average annual pump run hours for DHW recirculating continuously running (= 8,760)

44.5% = Constant[4]

$HOU_{CONTROLLED}$ = Average annual pump run hours for DHW recirculating controlled by a timer or aquastat (= 2,190)[3]

55.5% = Constant[4]

Summer Coincident Peak Savings Algorithm

The summer coincident peak savings algorithm only applies to cooling circulation pumps and DHW recirculation pumps.

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= 0.299 for chilled water pumps,[5] = 1.0 for DHW pumps)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Energy Savings for DHW Recirculation

Savings	< 100 Watt VSD ECM Pump MMID 3494	100 - 500 Watt VSD ECM Pump MMID 3495
Energy Savings (kWh)	1,311	6,555
Lifecycle Savings (kWh)	19,666	98,329
Demand Reduction (kW)	0.228	1.139

Energy Savings for Heating Circulation

Savings	< 100 Watt VSD ECM Pump MMID 3497	100 - 500 Watt VSD ECM Pump MMID 3498	> 500 Watt VSD ECM Pump MMID 3499
Energy Savings (kWh)	520	2,602	10,409
Lifecycle Savings (kWh)	7,807	39,035	156,142
Demand Reduction (kW)	0.000	0.000	0.000

Energy Savings for Cooling Circulation

Savings	> 500 Watt VSD ECM Pump MMID 3502
Energy Savings (kWh)	3,089
Lifecycle Savings (kWh)	46,330
Demand Reduction (kW)	1.362

Energy Savings for Water Loop Heat Pump Circulation

Savings	100 - 500 Watt VSD ECM Pump MMID 3504	> 500 Watt VSD ECM Pump MMID 3505
Energy Savings (kWh)	3,375	13,498
Lifecycle Savings (kWh)	50,618	202,472
Demand Reduction (kW)	0.341	1.362

Assumptions

Variable Speed ECM Pump, < 100 Watts Max Input

- Wattage inputs for qualifying pumps under 100 watts range from 3 watts to 93 watts. 50 watts was used as a conservative midpoint.

Variable Speed ECM Pump, 100 - 500 Watts Max Input

- Wattage inputs for qualifying pumps between 100 watts and 500 watts range from 130 watts to 500 watts. 250 watts was used as a conservative midpoint.

Variable Speed ECM Pump, > 500 Watts Max Input

- Wattage inputs for qualifying pumps greater than 500 watts range from 587 watts to 2,500 watts. 1,000 watts was used as a conservative midpoint.

Sources

1. U.S. Department of Energy. *Pump Life Cycle Costs: A Guide to LCC Analysis for Pumping Systems*. p. 4. January 2001. https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/pumplcc_1001.pdf.
2. Cadmus. Impact Evaluation of the 2011–2012 ECM Circulator Pump Pilot Program. Table 2. Pump Spot Measurements. October 18, 2012.
3. DHW Recirculation System Control Strategies. Final Report 99-1. p. 3-30. January 1999. Hours of use for pumps with an aquastat control in multifamily applications.
4. Lawrence Berkeley National Laboratory. Water Heaters and Hot Water Distribution Systems. Prepared for California Energy Commission Public Interest Energy Research Program. p. 16, Figure 10: Control Types Installed or Maintained by Contractors. May 2008.
5. Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 2.0. p. 235. June 7, 2013.
6. Used to match other measures: example: Natural Gas Furnace with ECM, 95%+ AFUE (Existing), 1981.

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	01/2019	Removed MMIDs 3496, 3500, 3501, and 3503

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Informaton Technology

Efficient UPS and Efficient Rectifier

	Measure Details
Measure Master ID	Efficient UPS, 4777 Efficient Rectifier, 4778
Measure Unit	Per kilowatt of IT load
Measure Type	Hybrid
Measure Group	Information Technology
Measure Category	Other
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	Varies
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$59.00[1]

Measure Description

This measure is replacing an inefficient uninterruptable power supply (UPS) or rectifier with an efficient UPS or rectifier in a data center, telecom, or similar facility that operates 24 hours per day, seven days per week. UPS units provide backup power in data centers and draw power constantly to keep their batteries charged. A federal standard specifying minimum efficiencies goes into effect in 2019, so this measure is not applicable to new construction. A rectifier converts alternating current (AC) to direct current (DC).

Description of Baseline Condition

The baseline condition is an existing UPS or rectifier whose efficiency in normal mode (not in energy saver mode) is less than 90%.

Description of Efficient Condition

The efficient condition is a new UPS or rectifier whose efficiency in normal mode (not in energy saver mode) is at least 94%.

Annual Energy-Savings Algorithm

$\text{KWh}_{\text{SAVED}} = \text{kWh}_{\text{BASE}} - \text{kWh}_{\text{EE}}$

$\text{kWh}_{\text{BASE}} = \text{Load} * \text{HOU}_{\text{EQUIP}} / \text{Eff}_{\text{BASE}} + \text{Load} * (1 – \text{Eff}_{\text{BASE}}) * \text{HOU}_{\text{COOL}} * \text{kW/ton}_{\text{COOL}} * 3.413 / 12$

$\text{kWh}_{\text{EE}} = \text{Load} * \text{HOU}_{\text{EQUIP}} / \text{Eff}_{\text{EE}} + \text{Load} * (1 – \text{Eff}_{\text{EE}}) * \text{HOU}_{\text{COOL}} * \text{kW/ton}_{\text{COOL}} * 3.413 / 12$

Where:

Load = Average IT load in kilowatts (= user input; see Assumptions)
$\text{HOU}_{\text{EQUIP}}$ = Hours of operation per year for UPS or rectifier (= 8,760)
Eff_{BASE} = Efficiency of existing UPS, fraction (= user input)
HOU_{COOL} = Hours of operation per year for the cooling system (= varies; see Assumptions)
$\text{kW/ton}_{\text{COOL}}$ = Efficiency of cooling system in kilowatts per ton (= user input; see Assumptions)
3.413 / 12 = Factor to convert kilowatts of heat to tons of cooling
Eff_{EE} = Efficiency of new UPS or rectifier, fraction (= user input)

Summer Coincident Peak Savings Algorithm

$\text{kW}_{\text{SAVED}} = \text{kW}_{\text{BASE}} - \text{kW}_{\text{EE}}$

$\text{kW}_{\text{BASE}} = \text{Load} * \text{CF}_{\text{EQ}} / \text{Eff}_{\text{BASE}} + \text{Load} * \text{CF}_{\text{COOL}} * (1 – \text{Eff}_{\text{BASE}}) * \text{kW/ton}_{\text{COOL}} * 3{,}413 / 12{,}000$

$\text{kW}_{\text{EE}} = \text{Load} * \text{CF}_{\text{EQ}} / \text{Eff}_{\text{EE}} + \text{Load} * \text{CF}_{\text{COOL}} * (1 – \text{Eff}_{\text{EE}}) * \text{kW/ton}_{\text{COOL}} * 3{,}413 / 12{,}000$

Where:

CF_{EQ} = Coincidence factor for UPS or rectifier (= 1.0)
CF_{COOL} = Coincidence factor for cooling system (= 0.82)

Lifecycle Energy-Savings Algorithm

$\text{kWh}_{\text{LIFECYCLE}} = \text{kWh}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (= 10 years)[1]

Assumptions

Small IT systems (those smaller than or equal to 50 kW) are assumed to have no air-side economizer and to operate continuously throughout the year, so HOU_{COOL} = 8,760 hours. Larger systems are assumed to have an air-side economizer that allows the cooling system to be turned off for half the year, so HOU_{COOL} = 4,380 hours. This corresponds to approximately a 45°F changeover temperature, which is a conservative assumption.

Normal mode efficiencies are to be used, rather than eco mode efficiencies, which can be disabled; using the value for normal mode is more conservative. The efficiency of the new UPS or rectifier comes from the manufacturer's published data. The efficiency of the existing UPS or rectifier can come from the manufacturer's data, by directly measuring input and output power, or from a display on the UPS.

Cooling system efficiency accounts for the power for any auxiliary equipment such as pumps and cooling towers. For an air-cooled chiller, $kW/ton_{COOL} = kW/ton_{CHILLER} + (kW_{CHILLED\_WATER\_PUMP}) / tons$. For a water-cooled chiller, $kW/ton_{COOL} = kW/ton_{COMPRESSOR} + (kW_{CHILLED\_WATER\_PUMP} + kW_{CONDENSER\_WATER\_PUMP} + kW_{COOLING\_TOWER\_FANS}) / tons$. For a direct expansion system, which has no auxiliary equipment, $kW/ton_{COOL} = 12 / EER$. The pump and fan power for any water-side economizers are neglected.

A more efficient UPS or rectifier gives off less waste heat than a less efficient UPS or rectifier, so in addition to lower cooling energy, heating energy may increase. However, due to the heat generation by equipment in typical data centers, any heaters seldom run, if at all. Any increase in heating energy is assumed to be negligible.

The coincidence factor for the UPS or rectifier is assumed to be 1.0 because the equipment operates all hours of the peak period.

Sources

1. California Municipal Utilities Association. *Savings Estimation Technical Reference Manual 2017, Third Edition.* Section 8.12, p. 8–15. https://www.cmua.org/files/CMUA-POU-TRM_2017_FINAL_12-5-2017%20-%20Copy.pdf
2. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

Revision History

Version Number	Date	Description of Change
01	12/31/2018	Initial TRM entry

Lighting

Lighting Fixture, Agricultural Daylighting

	Measure Details
Measure Master ID	Lighting Fixture, Agricultural Daylighting: ≤ 155 Watts, 3019 156–250 Watts, 3020 251–365 Watts, 3021
Measure Unit	Per luminaire or complete retrofit kit
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Controls
Sector(s)	Agriculture
Annual Energy Savings (kWh)	Varies by wattage
Peak Demand Reduction (kW)	Varies by wattage
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by wattage
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	≤ 155–250 watts = $325.87 (MMIDs 3019 and 3020)[2] 251–365 watts = $535.04 (MMID 3021)[5]

Measure Description

Various lighting technologies—such as LED, induction, ceramic metal halide, pulse start metal halide, and linear fluorescent high bay products—are energy-efficient alternatives to 320-watt pulse start metal halide fixtures. These options have become a popular for dairy facilities upgrades to long day lighting, a process used to help increase cows' milk production by simulating longer days and therefore increasing the animal food intake and thus milk production. Long day lighting requires a minimum of 15 foot-candles of photopic light being present at cow eye level for 16 hours to18 hours each day.

Energy savings are achieved when installing energy-efficient LED, induction, ceramic metal halide, pulse start metal halide, and/or linear fluorescent options instead of 250-watt and 320-watt pulse start metal halide fixtures. When the design is optimized to the technology, a considerable amount of energy can be saved.

Description of Baseline Condition

The baseline condition is 250-watt and 320-watt pulse start metal halide options in new construction buildings and upon retrofit upgrades to long day lighting.

Description of Efficient Condition

The efficient condition is qualifying LED, induction, ceramic metal halide, pulse start metal halide, and/or linear fluorescent high bay options. Pulse start metal halides are not acceptable for new construction applications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{320\ WATT\ PSMH} – kWh_{EE\ HIGH\ BAY} * Hours$

Where:

$kWh_{320\ WATT\ PSMH}$ = Annual electricity consumption of pulse start metal halide

$KWh_{EE\ HIGH\ BAY}$ = Annual electricity consumption of an eligible high/low bay option using LED, induction, ceramic metal halide, pulse start metal halide, or linear fluorescent technology

Hours = 6,205 hours; see Assumptions

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = Qty * (kWh_{SAVED})/1,000 * CF$

Where:

Qty = Quantity

1,000 = Kilowatt conversion factor

CF = Coincidence factor (= 1.0)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Annual Deemed Savings for Agricultural Long Day Lighting

Measure	MMID	Existing Building	New Construction
Long Daylighting High Bay Fixtures, ≤ 155 Watts	3019	834 kWh, 0.1344 kW	874 kWh, 0.1409 kW
Long Daylighting High Bay Fixtures, 156 - 250 Watts	3020	908 kWh, 0.1463 kW	956 kWh, 0.1541 kW
Long Daylighting High Bay Fixtures, 251 - 365 Watts	3021	847 kWh, 0.1365 kW	892 kWh, 0.1438 kW

Lifecycle Deemed Savings for Agricultural Long Day Lighting

Measure	MMID	Existing Building	New Construction
Long Daylighting High Bay Fixtures, ≤ 155 Watts	3019	12510 kWh	13110 kWh
Long Daylighting High Bay Fixtures, 156 - 250 Watts	3020	13620 kWh	14340 kWh
Long Daylighting High Bay Fixtures, 251 - 365 Watts	3021	12705 kWh	13380 kWh

Assumptions

A 320-watt pulse start metal halide was used as the baseline (it is the industry standard for lighting in several high bay applications including agricultural facilities), but 250-watt pulse start metal halides are also used in lower wattage applications.

The design of the long day lighting system should be based on the energy-efficient technology used.

Hours was based on long day lighting studies, which reveal that in order for long day lighting to work, the lights must deliver a minimum of 15 foot-candles at cow eye level for 16 hours to 18 hours a day (17 * 365 = 6,205 hours).

The coincidence factor of 1 was based on the system being on for 16 hours to 18 hours each day.[3,4]

The energy-efficient high bay option is based on the following:

- An average of the following replacements was used to generate the deemed savings values in place of 320-watt PSMH:
  - Eligible Replacements = 5.8% 200-watt induction, 5.8% 225-watt induction, 5.8% 165-watt induction, 5.8% 200-watt PSMH or CMH, 5.8% 210-watt PSMH or CMH, 5.8% 220-watt PSMH or CMH, 5.8% 4-foot 6-lamp T8, 5.8% 4-foot 4-lamp T5HO, 5.8% LED < 250 watts, 5.8% 250-watt induction, 5.8% 300-watt induction, 5.8% 250-watt PSMH or CMH, 5.8% 270-watt PSMH or CMH, 5.8% 315-watt PSMH or CMH, 5.8% 4-foot 8-lamp T8, 5.8% 4-foot 6-lamp T5HO, and 5.8% LED < 365 watts

- An average of the following replacements was used to generate the deemed savings values in place of 250-watt metal halide:
    - Eligible Replacements = 10% 120-watt to 125-watt induction,10% 150-watt induction,10% 165-watt induction,10% 125-watt PSMH or CMH, 10% 140-watt PSMH or CMH, 10% 150-watt PSMH or CMH, 10% 4-foot 4-lampT8, 10% 4-foot 3-lamp T5HO, 10% 4-foot 2-lamp T5HO, and 10% LED < 155 watts

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Focus on Energy Evaluation Business Programs: Incremental Cost Study Final Report. October 28, 2009.
3. Photoperiod Manipulation of Lactation in Dairy Cattle. (2001-2004). Accessed April 30, 2012. http://www.livestocktrail.illinois.edu/photoperiod
4. University of Wisconsin–Madison. Long Day Lighting in Dairy Barns (August 2000). Healthy Farmers, Healthy Profits Project. Second Edition.
5. WESCO Distribution Pricing, 2013 + Labor * 10% add for barn install location = $535.04

Revision History

Version Number	Date	Description of Change
01	01/01/2013	Initial TRM entry
02	04/23/2013	Updated proposed fixture wattage for new construction, removed PSMH as option for new construction, and updated savings values

Daylighting Control

	Measure Details
Measure Master ID	Daylighting Control, 3406
Measure Unit	Per watt controlled
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	8[1]
Incremental Cost ($/unit)	$0.73[2]

Measure Description

Daylighting controls save energy by reducing the total wattage input of the connected lighting load by matching the light output of the connected electric lighting system to the amount of natural light supplied by the sun that enters the space being lit. This is accomplished using dimming light sources or a system that steps the light of the connected fixtures based on controlling the lamps inside each connected fixture to produce different levels of illumination. This measure will provide reinforcement that integrating daylighting controls is an effective method to further reduce energy consumption.

Description of Baseline Condition

The baseline condition is any lighting equipment that is not connected to a daylighting controls system.

Description of Efficient Condition

The efficient condition is any lighting equipment that is connected to a daylighting controls system.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{UNCONTROLLED} * \text{Savings Factor}$

$kWh_{UNCONTROLLED} = Wattage_{UNCONTROLLED} / 1{,}000 * CF * HOU$

Where:

$KWh_{UNCONTROLLED}$ = Annual electricity consumption per watt of lighting load that is not controlled by daylighting controls

Savings Factor = Savings percentage achieved per watt of lighting load that is controlled by daylighting controls[6]

$Wattage_{UNCONTROLLED}$ = Instantaneous electric consumption of lamp or fixture

1,000 = Kilowatt conversion factor

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF[3,5]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64
Multifamily	0.77

HOU = Average annual run hours (= varies by sector; see table below)

Average Annual Run Hours by Sector

Sector	HOU[3,4]
Commercial	3,730
Industrial	3,299
Agriculture	4,745
Schools & Government	4,698
Multifamily	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = Wattage_{UNCONTROLLED} / 1{,}000 * CF$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (8 years)[1]

Deemed Savings

Annual Savings per Watt of Lighting Load Controlled by Daylighting Controls

Measure	Commercial 3,730 (0.77)		Industrial 4,745 (0.77)		Agriculture 4,698 (0.67)		Schools & Gov 3,239 (0.64)		Multifamily 5,950 (0.77)	
	kWh	kW	kWh	kWh	kW	kW	kWh	kW	kWh	kW
Daylighting Control	1.12	0.0	1.43	0.97	0.0	0.0	1.41	0.0	1.78	0.0

Lifecycle Savings per Watt of Lighting Load Controlled by Daylighting Controls

Measure	Commercial 3,730 (0.77)	Industrial 4,745 (0.77)	Agriculture 4,698 (0.67)	Schools & Gov 3,239 (0.64)	Multifamily 5,950 (0.77)
	kWh	kWh	kWh	kWh	kWh
Daylighting Control	8.96	11.44	11.28	7.76	14.24

Sources

1. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com/
2. Actual cost from 2015-16 program data, 21 applications
3. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3-2 Lighting Hours of Use in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. Tetra Tech. "ACES Deemed Savings Desk Review." November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
5. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf Coincidence factor is within range of similar programs; see Table 4-1 showing multifamily housing (in unit) CF of 65% to 83%.
6. Williams, Allison, B. Atkinson P.E., K. Garbesi Ph.D., E. Page P.E., and F. Rubenstein, FIES. "Lighting Controls in Commercial Buildings." Luekos Vol. 8, No. 3 (January 2012).

Revision History

Version Number	Date	Description of Change
01	04/2014	Initial TRM entry

Bi-Level Controls, High Bay Fixtures

	Measure Details
Measure Master ID	Bi Level Controls, High Bay Fixtures, General: 3979
Measure Unit	Per controlled fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by sector; see Deemed Savings tables
Peak Demand Reduction (kW)	Varies by sector; see Deemed Savings tables
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector; see Deemed Savings tables
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	8[1]
Incremental Cost ($/unit)	$81.06[2]

Measure Description

This measure is bi-level controls for high bay fixtures. Numerous new and existing installations use LED, induction, linear fluorescent, ceramic metal halide, and pulse start metal halide fixtures to light their high bay interiors, commonly in full light output 24 hours a day. Bi-level controls and replacement products use ultrasonic and passive infrared sensors to adjust the light output to a safe but energy conserving low level when these spaces become unoccupied. These products save energy by more efficiently lighting the spaces based on occupancy.

Description of Baseline Condition

The baseline condition is LED, induction, fluorescent, ceramic metal halide, and/or pulse start metal halide fixture input wattages with no lighting controls at building interior.

Description of Efficient Condition

The efficient condition is individually controlled light fixtures that may include dimming, stepped dimming, and hi-lo ballast controls. The control must include a passive infrared and/or ultrasonic occupancy sensor with a feature to stay “on” in case of failure.

Fixtures must operate in a low standby light level during vacancy and switch to full light output upon occupancy. A conservative estimate of 50% of full wattage during unoccupied periods is assumed.

Annual Energy-Savings Algorithm

All the savings algorithms and methodology for this measure are from the Focus on Energy Business Programs Deemed Savings Manual V1.0.[3]

The kWh savings shown below were initially determined for each space type and sector using the percentage of time the lights are "off" and the deemed hours of use for each sector (see tables below). Using several years of historical data,[4] the weighted average, based on program implementation across space and sector types, was used to calculate a single kWh savings value for each sector.

kWh_{SAVED} = LtgWatts / 1,000 * % Off * HOU * 50%

1. Where:

LtgWatts = Lighting wattage controlled, deemed (= 310 watts; see table below)

1,000 = Kilowatt conversion factor

% Off = Percentage of time lights are controlled (= varies by space type; see table below)

HOU = Baseline hours per year (= varies by sector; see table below)

50% = Bi-level factor for fixtures that include dimming, stepped dimming, or hi-lo ballast controls (at least 50% of light source or lamps must be reduced to qualify for incentive)

Percentage of Hours Lights are "Off" by Space Type[3]

Space Type	Cal. SPC	RLW Schools	LRC	Maine	Average
Gymnasiums	35%	48%	-	35%	**39%**
Industrial	45%	-	-	-	**45%**
Retail	15%	-	-	-	**15%**
Warehouses	45%	-	65%	50%	**53%**
Public Assembly	35%	59%	-	-	**47%**
Other	-	-	-	-	**40%**

Hours of Use by Sector

Sector	HOU[3]
Commercial	3,730
Schools & Government	3,239
Industrial	4,745
Agriculture	4,698

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = LtgWatts / 1,000 * CF

Where:

CF = Coincidence factor (= varies by space type; see table below)

Coincidence Factors by Space Type (Various Sources)[3]

Space Type	Cal. SPC	RLW Schools	Average
Gymnasiums	14%	15%	**15%**
Industrial	18%	-	**18%**
Retail	6%	-	**6%**
Warehouses	18%	-	**18%**
Public	14%	10%	**12%**
Other	-	-	**14%**

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 8 years)[1]

Deemed Savings

Annual and Lifecycle Deemed Savings for Agriculture and Commercial Sectors

Space Type	Agriculture				Commercial			
	kW	1y kWh	LC kWh	Wgt[4]	kW	1y kWh	LC kWh	Wgt[4]
Gymnasium	0.0465	284	2,272	0.167	0.0465	226	1,808	0.155
Industrial	0.0559	328	2,624	0.167	0.0559	260	2,080	0.062
Retail	0.0186	109	872	0.167	0.0186	87	696	0.541
Warehouse	0.0559	386	3,088	0.167	0.0559	307	2,456	0.046
Public Assembly	0.0372	343	2,744	0.167	0.0372	272	2,176	0.000
Other	0.0434	292	2,336	0.167	0.0434	231	1,848	0.196
Bi Level Controls, High Bay Fixtures, General	**0.0429**	**290**	**2,323**	**--**	**0.0318**	**158**	**1,261**	**--**

Annual and Lifecycle Deemed Savings for Industrial and Schools & Government Sectors

Measure	Industrial				Schools & Government			
	kW	1y kWh	LC kWh	Wgt[4]	kW	1y kWh	LC kWh	Wgt[4]
Gymnasium	0.0465	287	2,296	0.000	0.0465	196	1,568	0.839
Industrial	0.0559	331	2,648	0.551	0.0559	226	1,808	0.020
Retail	0.0186	110	880	0.000	0.0186	75	600	0.000
Warehouse	0.0559	390	3,120	0.449	0.0559	266	2,128	0.000
Public Assembly	0.0372	346	2,768	0.000	0.0372	236	1,888	0.000
Other	0.0434	294	2,352	0.000	0.0434	201	1,608	0.141
Bi Level Controls, High Bay Fixtures, General	**0.0559**	**357**	**2,860**	**--**	**0.0462**	**197**	**1,578**	**--**

Assumptions

Bi-level controls are able to and must achieve at least a 50% reduction in power requirements.

Historical data from 28 projects from May 2014 through October 2016[4] was used to calculate a single weighted savings for each sector based on space types. The weighted values are provided in the tables above.

For wattages, product weightings were based on historical project information (gathered on October 3, 2013) with a projected increase and prevalence of LED fixtures based on market knowledge. The higher weighting of LED fixtures leads to a more conservative wattage estimate (see table below).

Weighted Average High Bay Lighting Replacement Wattage[3]

Measure	Watts	Agriculture	Commercial	Industrial	Schools & Government	Total
250-399 Watt Replacements	185	13.90%	5.10%	9.70%	18.50%	9.00%
400-699 Watt Replacements	316	73.50%	61.40%	74.90%	70.40%	70.70%
400-999 Watt Replacements	335	12.60%	30.40%	10.30%	9.20%	16.00%
≤ 500 Watts, Replacing ≥ 1,000 Watts	355	0.00%	2.50%	4.40%	1.10%	3.60%
≤ 800 Watts, Replacing ≥ 1,000 Watts	591	0.00%	0.60%	0.70%	0.70%	0.70%
Total		**100%**	**100%**	**100%**	**100%**	**100%**
Average Watts		**300**	**318**	**309**	**295**	**310**

Wattages for LED, induction, fluorescent, ceramic metal halide, and pulse start metal halide fixtures were grouped into five replacement categories based on the existing high bay fluorescent replacement option groups from the Deemed Savings Manual V1.0 (Table 4-204).[3] A weighted average of the wattages per lighting technology was then taken for the four groups based on historical project information (gathered on October 3, 2013), with a projected increase in the prevalence of LED fixtures. Refer to the following table for the technology weightings.

Lighting Technology Weightings[5]

Technology	Weighting
Linear Fluorescent	65%
LED	20%
PSMH/CMH	10%
Induction	5%

Wattage by Fixture Type

Replacing 250-399 Watt HID		Replacing 400 HID < 365 Watt		Replacing 1,000 HID < 800 Watt	
Measure Name	**Wattage**	**Measure Name**	**Wattage**	**Measure Name**	**Wattage**
Induction 120 watt	132	Induction 250 watt	275	Induction 750 watt	825
Induction 125 watt	138	Induction 300 watt	330	PSMH or CMH 575 watt	640
Induction 150 watt	161	PSMH or CMH 250 watt	281	LED	690
Induction 165 watt	174	PSMH or CMH 270 watt	290	T8 or T5HO ≤ 800 watt	535
PSMH or CMH 125 watts	146	PSMH or CMH 315 watt	343		
PSMH or CMH 140 watts	154	PSMH or CMH 320 watt	640		
PSMH or CMH 150 watts	185	LED	296		
LED	119	T8 6 lamp or T5HO 4 lamp	212		
T8 4 lamp or T5HO 2 lamp	144	T8 8 lamp or T5HO 6 lamp	359		
T8 6 lamp or T5HO 4 lamp	212	T8 or T5HO ≤ 500 watt	363		

Wattage by Fixture Type

Replacing 400 HID < 250 Watt		Replacing 1,000 HID < 500 Watt	
Measure Name	**Wattage**	**Measure Name**	**Wattage**
Induction 200 watt	220	LED	338
PSMH or CMH 200 watt	225	T8 8 lamp or T5HO 6 lamp	359
PSMH or CMH 210 watt	229	T8 or T5HO ≤ 500 watt	363
PSMH or CMH 220 watt	242		
LED	169		
T8 6 lamp or T5HO 4 lamp	212		

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf For lighting measures, add occupancy sensors or multilevel switching to a retrofit project where high bay fluorescent replaces HID.
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 1,732 units over 28 projects from 2016 to 2018.
3. Materials: WESCO Distribution Pricing, 2013.
4. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. "Bi Level Controls for High Bay Supplemental Data."
Adjustment Calcs Tab showing historical data from 28 projects from May 2014 – October 2016 used to weight savings for the sensor measures.
6. Based on a rounded average of historical project information (gathered October 3, 2013).

Revision History

Version Number	Date	Description of Change
01	12/2012	Initial TRM entry
02	10/2013	Changed entry from hybrid to prescriptive (MMID 3115)
03	11/2016	Used historical data to simplify deemed savings into one measure and updated EUL
04	12/2018	Updated incremental cost

Occupancy Sensors for High Bay Fixtures

	Measure Details
Measure Master ID	Occupancy Sensor, On/Off, High Bay, General, 3978
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	8[1]
Incremental Cost ($/unit)	$95.00[2]

Measure Description

This measure is occupancy sensors for high bay fixtures. Numerous new and existing installations use LED, induction, fluorescent, ceramic metal halide, and pulse start metal halide fixtures to light their high bay interiors, commonly in full light output for 24 hours a day. Occupancy controls and replacement products use ultrasonic and passive infrared sensors to turn the fixture off when these spaces become unoccupied. These products save energy by more efficiently lighting the spaces based on occupancy.

Description of Baseline Condition

The baseline condition is LED, induction, fluorescent, ceramic metal halide, and/or pulse start metal halide fixture input wattages with no lighting controls at the building interior.

Description of Efficient Condition

The efficient condition is an indoor wall, ceiling, or fixture mounted occupancy sensor being used to control a high bay fixture. The control must include a passive infrared and/or ultrasonic occupancy sensor with a feature stay “on” in case of failure.

Annual Energy-Savings Algorithm

All algorithms and methodology are from the Focus on Energy Business Programs Deemed Savings Manual V1.0.[3]

The kWh savings were initially determined for each space type and sector using the percentage of time the lights are off in addition to the deemed hours of use for each sector (see tables below). Using several years of historical data,[4] the weighted average, based on the frequency of program implementation across space and sector types, was used to calculate a single kWh savings value for each sector.

$kWh_{SAVED} = LtgWatts / 1{,}000 * \% Off * HOU$

Where:

LtgWatts = Lighting wattage controlled, deemed (= 310 watts)

1,000 = Kilowatt conversion factor

% Off = Percentage of time lights are controlled (= varies by space type; see table below)

HOU = Baseline hours per year (= varies by sector; see table below)

Percentage of Time Lights are Controlled by Space Type[3]

Space Type	Cal. SPC	RLW Schools	LRC	Maine	Average
Gymnasiums	35%	48%	-	35%	**39%**
Industrial	45%	-	-	-	**45%**
Retail	15%	-	-	-	**15%**
Warehouses	45%	-	65%	50%	**53%**
Public Assembly	35%	59%	-	-	**47%**
Other	-	-	-	-	**40%**

Hours of Use by Sector

Sector	HOU[3]
Commercial	3,730
Schools & Government	3,239
Industrial	4,745
Agriculture	4,698

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = LtgWatts / 1{,}000 * CF$

Where:

CF = Coincidence factor (=varies by space type; see table below)

Coincidence Factors by Space Type[3]

Space Type	Cal. SPC	RLW Schools	Average
Gymnasiums	14%	15%	**15%**
Industrial	18%	-	**18%**
Retail	6%	-	**6%**
Warehouses	18%	-	**18%**
Public	14%	10%	**12%**
Other	-	-	**14%**

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 8 years)[1]

Deemed Savings

Annual and Lifecycle Deemed Savings for Agriculture and Commercial Sectors

Measure	Agriculture				Commercial			
	kW	1y kWh	LC kWh	Wgt[4]	kW	1y kWh	LC kWh	Wgt[4]
Gymnasium	0.0465	569	4,552	0.000	0.0465	451	3,608	0.006
Industrial	0.0559	656	5,248	0.438	0.0559	521	4,168	0.191
Retail	0.0186	219	1,752	0.000	0.0186	174	1,392	0.064
Warehouse	0.0559	773	6,184	0.076	0.0559	613	4,904	0.589
Public Assembly	0.0372	685	5,480	0.000	0.0372	544	4,352	0.000
Other	0.0434	583	4,664	0.486	0.0434	463	3,704	0.150
Occupancy Sensor, High Bay Fixtures, General	**0.0498**	**629**	**5,036**	**--**	**0.0516**	**544**	**4,352**	**--**

Annual and Lifecycle Deemed Savings for Industrial and Schools & Government Sectors

Measure	Industrial				Schools & Government			
	kW	1y kWh	LC kWh	Wgt[4]	kW	1y kWh	LC kWh	Wgt[4]
Gymnasium	0.0465	574	4,592	0.000	0.0465	392	3,136	0.420
Industrial	0.0559	663	5,304	0.780	0.0559	452	3,616	0.036
Retail	0.0186	221	1,768	0.000	0.0186	151	1,208	0.000
Warehouse	0.0559	780	6,240	0.209	0.0559	533	4,264	0.163
Public Assembly	0.0372	692	5,536	0.000	0.0372	472	3,776	0.031
Other	0.0434	589	4,712	0.011	0.0434	402	3,216	0.351
Occupancy Sensor, High Bay Fixtures, General	**0.0558**	**687**	**5,494**	**--**	**0.0470**	**423**	**3,384**	**--**

Assumptions

Historical data from 28 projects from May 2014 through October 2016[4] was used to calculate a single weighted savings for each sector based on space types. The weighted values are provided in the tables above.

For wattages, product weightings were based on historical project information (gathered October 3, 2013) with a projected increase and prevalence of LED fixtures based on market knowledge. The higher weighting of LED fixtures leads to a more conservative wattage estimate (see table below).

Weighted Average High Bay Lighting Replacement Wattage[5]

Measure	Watts	Agriculture	Commercial	Industrial	Schools & Government	Total
250-399 Watt Replacements	185	13.90%	5.10%	9.70%	18.50%	9.00%
400-699 Watt Replacements	316	73.50%	61.40%	74.90%	70.40%	70.70%
400-999 Watt Replacements	335	12.60%	30.40%	10.30%	9.20%	16.00%
≤ 500 Watts, Replacing ≥ 1,000 Watts	355	0.00%	2.50%	4.40%	1.10%	3.60%
≤ 800 Watts, Replacing ≥ 1,000 Watts	591	0.00%	0.60%	0.70%	0.70%	0.70%
Total		**100%**	**100%**	**100%**	**100%**	**100%**
Average Watts		**300**	**318**	**309**	**295**	**310**

Wattages for LED, induction, fluorescent, ceramic metal halide, and pulse start metal halide fixtures were grouped into five replacement categories based on the existing high bay fluorescent replacement option groups from Table 4-204 in the Focus on Energy Business Programs Deemed Savings Manual V1.0.[3] A weighted average of the wattages per lighting technology was then taken for the four groups based on historical project information (gathered October 3, 2013), with a projected increase and prevalence of LED fixture. Refer to the following table for the technology weightings.

Lighting Technology Weightings

Technology	Weighting[5]
Linear Fluorescent	65%
LED	20%
PSMH/CMH	10%
Induction	5%

Wattage by Fixture Type

Replacing 250-399 Watt HID		Replacing 400 HID < 365 Watt		Replacing 1,000 HID < 800 Watt	
Measure Name	**Wattage**	**Measure Name**	**Wattage**	**Measure Name**	**Wattage**
Induction 120 watt	132	Induction 250 watt	275	Induction 750 watt	825
Induction 125 watt	138	Induction 300 watt	330	PSMH or CMH 575 watt	640
Induction 150 watt	161	PSMH or CMH 250 watt	281	LED	690
Induction 165 watt	174	PSMH or CMH 270 watt	290	T8 or T5HO ≤ 800 watt	535
PSMH or CMH 125 watts	146	PSMH or CMH 315 watt	343		
PSMH or CMH 140 watts	154	PSMH or CMH 320 watt	640		
PSMH or CMH 150 watts	185	LED	296		
LED	119	T8 6 lamp or T5HO 4 lamp	212		
T8 4 lamp or T5HO 2 lamp	144	T8 8 lamp or T5HO 6 lamp	359		
T8 6 lamp or T5HO 4 lamp	212	T8 or T5HO ≤ 500 watt	363		

Wattage by Fixture Type

Replacing 400 HID < 250 Watt		Replacing 1,000 HID < 500 Watt	
Measure Name	**Wattage**	**Measure Name**	**Wattage**
Induction 200 watt	220	LED	338
PSMH or CMH 200 watt	225	T8 8 lamp or T5HO 6 lamp	359
PSMH or CMH 210 watt	229	T8 or T5HO ≤ 500 watt	363
PSMH or CMH 220 watt	242		
LED	169		
T8 6 lamp or T5HO 4 lamp	212		

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
   For lighting measure, add occupancy sensors or multi-level switching to a retrofit project where high bay fluorescent replaces HID.
2. WESCO Distribution Pricing, 2013.
   ($70.00) + Labor ($25.00) = $95.00
3. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Section 4.9.17, p. 4-234. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. “Occupancy Sensors for High Bay Supplemental Data.”
   Adjustment Calcs Tab showing historical data from 431 projects from January 2014 – October 2016 used to weight savings for the sensor measures.
5. Based on a rounded average of historical project information (gathered October 3, 2013).

Revision History

Version Number	Date	Description of Change
01	10/07/2013	Updated deemed savings and all fixture options and wattages
02	11/01/2016	Used historical data to simplify deemed savings into one measure and updated EUL

Non-High Bay Occupancy/Vacancy Sensor

	Measure Details
Measure Master ID	Non-High Bay Occupancy/Vacancy Sensor, 4812
Measure Unit	Per watt controlled
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gallons)	0
Effective Useful Life (years)	8[1]
Incremental Cost ($/unit)	$0.73[2]

Measure Description

Non-high bay occupancy/vacancy sensors reduce energy consumption by reducing the operating hours for lighting equipment in low occupancy areas, such as hallways, storage rooms, and restrooms. Occupancy sensors automatically turn lights off a preset time after people leave a space and turn lights on automatically when movement is detected. Occupancy sensors feature a delay adjustment that determines the time that lights are on after no occupancy is detected, as well as a sensitivity adjustment that determines the magnitude of the signal required to trigger the occupied status.

The two primary technologies used for occupancy sensors are passive infrared (PIR) and ultrasonic. PIR sensors determine occupancy by detecting the difference in heat between a body and the background. Ultrasonic sensors detect people using volumetric detectors and broadcast sounds above the range of human hearing, then measure the time it takes the waves to return. Other sensing technologies, like microwaves or tools that incorporate dual methodologies, are also eligible.

Description of Baseline Condition

The baseline condition is no occupancy sensor, with lighting fixtures controlled by manual wall switches.

Description of Efficient Condition

The efficient condition is a hard-wired, fixture-, wall-, or ceiling-mounted occupancy sensor, where lighting fixtures are controlled by the sensors based on detected occupancy.

Annual Energy-Savings Algorithm

kWh_{SAVED} = Watts / 1,000 * SF * HOU

Where:

Watts = Controlled lighting wattage

1,000 = Kilowatt conversion factor

SF = Savings factor, deemed (= 41%)[3]

HOU = Average annual run hours (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950

Summer Coincident Peak Savings Algorithm

There are no deemed summer peak savings for these measures. Although occupancy sensors may reduce load during the peak period, most savings occur during non-peak hours.

kW_{SAVED} = Watts * CF / 1,000

Where:

CF = Coincidence factor (= 0)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 8 years)[1]

Deemed Savings

Annual Savings (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
Non-High Bay Occupancy/Vacancy Sensor	4812	1.53	1.95	1.93	1.33	2.44

Lifecycle Savings (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
Non-High Bay Occupancy/Vacancy Sensor	4812	12.24	15.60	15.44	10.64	19.52

Assumptions

The deemed summer peak savings is set to zero. Although occupancy sensors may reduce load during the peak period, no savings are assumed because the measure uses are widely variable and most savings will occur during non-peak hours.

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." Appendix B. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Incremental cost based on similar MMID 3406. Actual cost from 2015 and 2016 program data, 21 applications.
3. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 4-161. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3-2. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluation323report.pdf
5. Tetra Tech. "ACES Deemed Savings Desk Review." Table 1. November 3, 2010. https://focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf 16.3 hours per day for multifamily housing.

Revision History

Version Number	Date	Description of Change
01	01/01/2019	Initial TRM entry

Occupancy Sensor, LED Refrigerated Case Lights

	Measure Details
Measure Master ID	Occupancy Sensor, LED Refrigerated Case Lights, 2482
Measure Unit	Per fixture controlled
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	112
Peak Demand Reduction (kW)	0.013
Annual Therm Savings (Therms)	0
Life-cycle Energy Savings (kWh)	894.4
Life-cycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	8[1]
Incremental Cost ($/unit)	$37.92[2]

Measure Description

Controls for LED case lights effectively save energy by turning off lights when unnecessary. These motion controls may involve one sensor that controls a bank of cases, or one sensor per door. The sensors reduce the runtime of the case lighting, effectively reducing the lighting energy usage, and they also produce less waste heat in the cases, which decreases the cooling load on the refrigeration system and energy needed by the refrigeration compressors.

Description of Baseline Condition

The baseline condition is DLC-qualified vertical LED lighting in refrigerated display cases.

Description of Efficient Condition

The efficient condition is DLC-qualified vertical LED lighting in refrigerated display cases with case light occupancy sensors.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = [(Watts_{BASE}) + (Watts_{BASE}) / COP] * SF / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Wattage of the LED case lighting (= 17.73)[3]

COP = Coefficient of performance (= 1.52 weighted average; 2.3 for non-self-contained coolers,[4] 1.4 for non-self-contained freezers,[4] 0.5 for self-contained coolers,[5] and 0.6 for self-contained freezers)[5]

SF = Savings factor (= 41%)[5]

1,000 = Kilowatt conversion factor

HOU = Average annual run hours (= 8,760)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = [(Watts_{BASE}) + (Watts_{BASE}) / COP] * SF / 1{,}000$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=8 years)[1]

Assumptions

It is assumed that the fixtures are upgraded to LEDs in self-contained cases 10% of the time and in non-self-contained cases 90% of the time, based on historical Wisconsin program installations. It is also assumed that the fixtures are upgraded to LEDs in coolers 25% of the time and in freezers 75% of the time, as the majority of cases with doors are for freezer applications; however, more and more customers are beginning to install cases with doors for cooler applications.

Self-contained coefficient of performance was converted from the kW per horsepower of each size tier in tables 4-71 and 4-72 of the Business Programs: Deemed Savings Manual V1.0[5] to kW per ton, where 1 ton of refrigeration is equal to 4.7143 hp, then is converted to COP, where COP is equal to 12 kW per ton divided by 3.412. The average COP for self-contained coolers and freezers was calculated based on the weighting from these same tables.

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf. Value for general occupancy sensors used.
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 3,450 units over 22 projects from 2015 to 2018.
3. Design Lights Consortium. *Product List.* Vertical Refrigerated Case Luminaires primary use category. Accessed March 30, 2016. https://www.designlights.org/
4. United States Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Office. “Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration.” DOE Publication ID 6180. Table 3-7. September 2009. http://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf
   The capacity and power values were calculated to yield the EER, then converted to COP based on COP being equal to EER divided by 3.412.
5. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	03/11/2016	Updated based on Focus on Energy Deemed Savings Manual
02	10/2017	Updated EUL
03	12/2018	Updated incremental cost

Occupancy Sensors – Prescriptive

	Measure Details
Measure Master ID	Occupancy Sensor, Ceiling Mount: ≤ 500 Watts, 2471 ≥ 1,001 Watts, 2472 501-Watts to 1,000 Watts, 2473 Occupancy Sensor, ≤ 200 Watts: Wall Mount, 2483 Fixture Mount, 2474 Wall or Ceiling Mount, CALP, 3201 Fixture Mount, CALP, 3605 Occupancy Sensor > 200 Watts: Wall Mount, 2484 Fixture Mount, 2475 Fixture Mount, CALP, 3606 Occupancy Sensor, Fixture Mount: ≤ 60 Watts, SBP Package, 3619 ≤ 60 Watts, SBP After A La Carte, 3621
Measure Unit	Per sensor
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by connected wattage
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by connected wattage
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	8[1]
Incremental Cost ($/unit)	Varies by measure, see Appendix D

Measure Description

Occupancy sensors reduce energy consumption by reducing the operating hours for lighting equipment in low occupancy areas, such as hallways, storage rooms, and restrooms. Occupancy sensors automatically turn lights off a preset time after people leave a space, and turn lights on automatically when movement is detected. Occupancy sensors feature a delay adjustment that determines the time that lights are on after no occupancy is detected, as well as a sensitivity adjustment that determines the magnitude of the signal required to trigger the occupied status.

The two primary technologies used for occupancy sensors are passive infrared (PIR) and ultrasonic. PIR sensors determine occupancy by detecting the difference in heat between a body and the background. Ultrasonic sensors detect people using volumetric detectors and broadcast sounds above the range of human hearing, then measure the time it takes the waves to return.

Description of Baseline Condition

The baseline condition is no occupancy sensor, with lighting fixtures being controlled by manual wall switches.

Description of Efficient Condition

The efficient condition is a hard-wired, fixture-, wall-, or ceiling-mounted occupancy sensor, where lighting fixtures are controlled by the sensors based on detected occupancy.

Annual Energy-Savings Algorithm

kWh_{SAVED} = Watts / 1,000 * SF* HOU

Where:

Watts = Controlled lighting wattage (= varies by measure; see table below)

Controlled Lighting Wattage for Occupancy Sensors by Measure

Measure Name	MMID	Average Connected Wattage
Ceiling Mount, ≤ 500 Watts	2471	350[2]
Ceiling Mount, ≥ 1,001 Watts	2472	1,200[2]
Ceiling Mount, 501-1,000 Watts	2473	750[2]
Wall Mount, ≤ 200 Watts	2483, 2474, 3201, 3605	150[2]
Wall Mount, > 200 Watts	2484, 2475, 3606	350[2]
Fixture Mount, ≤ 60 Watts	3619, 3621	35[3]

1,000 = Kilowatt conversion factor

SF = Savings factor, deemed (= 41%)[3]

HOU = Annual operating hours (= varies by sector; see table below)

Annual Operating Hours by Sector [3]

Sector	HOU
Multifamily	5,950
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239

Summer Coincident Peak Savings Algorithm

There are no deemed summer peak savings for this measure. Although occupancy sensors may reduce load during the peak period, most savings will occur during non-peak hours.

kW_{SAVED} = Watts / 1,000 * CF

Where:

CF = Coincidence factor (= 0)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

Where:

EUL = Effective useful life (= 8 years)[1]

Deemed Savings

Deemed Annual Energy Savings (kWh) for Occupancy Sensors

Measure Name	MMID	Multifamily	Commercial	Industrial	Agriculture	Schools & Government
Ceiling Mount, ≤ 500 Watts	2471	854	535	681	674	465
Ceiling Mount, ≥ 1,001 Watts	2472	2,927	1,835	2,335	2,311	1,594
Ceiling Mount, 501-1,000 Watts	2473	1,830	1,147	1,459	1,445	996
Wall Mount, ≤ 200 Watts	2483, 2474, 3201, 3605	366	229	292	289	199
Wall Mount, > 200 Watts	2484, 2475, 3606	854	535	681	674	465
Fixture Mount, ≤ 60 Watts	3619, 3621	86	52	67	66	46

Deemed Lifecycle Electricity Savings (kWh) for Occupancy Sensors

Measure Name	MMID	Multifamily	Commercial	Industrial	Agriculture	Schools & Government
Ceiling Mount, ≤ 500 Watts	2471	6,831	4,282	5,447	5,393	3,718
Ceiling Mount, ≥ 1,001 Watts	2472	23,419	14,681	18,676	18,491	12,749
Ceiling Mount, 501-1,000 Watts	2473	14,637	9,176	11,673	11,557	7,968
Wall Mount, ≤ 200 Watts	2483, 2474, 3201, 3605	2,927	1,835	2,335	2,311	1,594
Wall Mount, > 200 Watts	2484, 2475, 3606	6,831	4,282	5,447	5,393	3,718
Fixture Mount, ≤ 60 Watts	3619, 3621	686	419	534	528	364

Assumptions

Occupancy controls at small commercial facilities can be expected achieve a 41% savings[3], based on an average derived from sources that specify the different savings factors in different spaces such as offices, corridors, restrooms, and storage areas.

The deemed summer peak savings is set to zero. Although occupancy sensors may reduce load during the peak period, no savings are assumed because uses are widely variable and most savings will occur during non-peak hours.

Occupancy controls at small commercial facilities can be expected achieve a 50% reduction in power requirements, so a 40% reduction is used as a conservative estimate. No kilowatt savings are estimated because of the variable nature of the uses.

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Average wattage taken from common pin-based CFL fixtures and 4-foot linear fluorescent fixtures ≤ 60 watts and > 60 watts.
3. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Updated March 22, 2010. Table 3.2 and Table 4-163. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. WESCO Distribution Pricing, 2013 ($95.00) + Labor ($25.00) = $120.00

5. WESCO Distribution Pricing ($70.00) + Labor ($25.00) = $95.00
6. WESCO Distribution Pricing, 2013 ($18.75) + Labor ($16.25) = $35.00f

Revision History

Version Number	Date	Description of Change
01	04/06/2015	Initial TRM entry
02	04/12/2015	Combined workpapers, added comments
03	04/2017	Replaced MMID 3561 with MMIDs 3619 and 3621

Networked Lighting Controls (NLC)

	Measure Details
Measure Master ID	NLC Low Lumen Tier, 3965 NLC High Lumen Tier, 3966
Measure Unit	Per square foot controlled
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agricultural, Schools & Government
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	16[1]
Incremental Cost ($/unit)	$1.68[2]

Measure Description

These measures are for Design Lights Consortium-listed advanced/networked lighting control systems. Many new and existing lighting installations use LED or fluorescent fixtures to light their interior spaces. In order for an advanced/networked lighting control system to be DLC listed, it must be capable of networking luminaires and devices, occupancy sensing, daylight harvesting, high-end trim, zoning, addressability of luminaires and devices, and continuous dimming. These networked lighting controls save energy by more efficiently controlling the spaces through simplified commissioning, potential real-time usage information and analytics for end users, interoperatability with other building systems, and flexible reconfiguration if space or task uses were to change. Two separate measures have been created to establish incentive tiers that separate low lumen output/high fixture density applications from high lumen output/low fixture density applications due to variations in space type footprints.

Description of Baseline Condition

The baseline condition is an LED or fluorescent lighting systems with no existing controls or basic lighting control systems.

Description of Efficient Condition

The efficient condition is a control system that meets the DLC Networked Lighting Control specifications.[3]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (LPD_{CONTROLLED} / 1{,}000) * SF) * HOU$

Where:

$LPD_{CONTROLLED}$ = Lighting wattage controlled per square foot (= 0.61 watts per square foot)[4]

1,000 = Watt to kilowatt conversion factor

SF = Savings factor for advanced lighting controls (= 47%)[5]

HOU = Average annual run hours (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU[6]
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (LPD_{CONTROLLED}) / 1{,}000 * SF) * CF$

Where:

CF = Coincidence factor (= varies by space type; see table below)

Coincidence Factors by Sector

Sector	CF[6]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 16 years)[1]

Deemed Savings

Average Annual Deemed Savings per Square Foot

Measure	Commercial		Industrial		Agriculture		Schools & Gov	
	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Advanced Lighting Controls	1.07	0.0002	1.36	0.0002	1.35	0.0002	0.93	0.0002

Average Lifecycle Deemed Savings per Square Foot (kWh)

Measure	Commercial	Industrial	Agriculture	Schools & Gov
Advanced Lighting Controls	17.11	21.77	21.55	14.86

Sources

1. Cadmus review of manufacturers' measure life (referenced interior fixture measures 3111, 3400, 3401, and 3393).
2. Manufacturer's representative quotations for office lighting controls, July 2016. Average of quotations from Lutron and Douglas Lighting Controls.
3. DesignLights Consortium. "Networked Lighting Control Systems Technical Requirements." https://www.designlights.org/default/assets/File/DLC_Networked-Lighting-Controls-Technical-Requirements_V1_01.pdf
4. Focus on Energy Design Assistance Program building completion data. September 9, 2016 through April 30, 2017, with eight total LED projects that exclude manufacturing and warehousing spaces.
5. Lighting Research Center. "Literature Review of Energy Savings from Luminaire-Integrated Controls." Last revised November 19, 2015.
6. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3-2. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	11/14/2016	Initial TRM entry

PhotoLighting Controls, Photocell with Internal Timer or Wireless Schedule, Exterior

	Measure Details
Measure Master ID	Lighting Controls, Photocell with Internal Timer or Wireless Schedule, Exterior, 3253
Measure Unit	Per control
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	262
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	2,096
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	8[1]
Measure Incremental Cost ($/unit)	$65.52[2]

Measure Description

Numerous new and existing installations use LED, induction, fluorescent, and HID technology to light exterior spaces. These fixtures commonly operate in full light output from dusk until dawn each night and are controlled by either a basic photocell or simple basic timer. By installing a photocell control with integrated timers or wireless remote location scheduling technology, the amount of annual run hours for the connected fixtures can be reduced. This is accomplished by setting the timers to turn off the connected fixtures for a minimum of four hours per night during periods of minimal activity or after business hours. These products save energy by reducing the annual run hours of the connected lighting fixtures via scheduling.

Description of Baseline Condition

The baseline condition is LED, induction, fluorescent, and HID fixture input wattages controlled by simple timers or basic photocells installed in exterior spaces.

Description of Efficient Condition

The efficient condition is LED, induction, fluorescent, and HID fixtures with photocell controls that include integrated timers or the ability to wirelessly schedule the run hour times of the connected fixtures.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kW_{FIXTURES} * (HOU_{PRE} - HOU_{POST})$

Where:

$kW_{FIXTURES}$ = Input of the fixture(s) being controlled (= 0.1496 kW)[3]

HOU_{PRE} = Average annual run hours of pre-existing system (= 4,380)[4]

HOU_{POST} = Average annual run hours of post-installation system (= 2,628, see the Assumptions section)

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for exterior lighting applications.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 8 years)[1]

Deemed Savings

Annual and Lifecycle Deemed Savings

Measure	MMID	Annual Savings	Lifecycle Savings
Lighting Controls, Photocell with Internal Timer or Wireless Schedule, Exterior	3253	262 kW	2,096 kWh

Assumptions

A typical baseline is 4,380 annual hours of operation for nighttime hours an exterior lamp is on. This is based on an annual average of 12 hours per day from NOAA data.[4] This also includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.

Run hours reduction is based on an estimated 40% schedule reduction per night. Typical scheduled and controlled systems are on for four to eight hours per night. This reduction is less than the reduction assumed for networked lighting control (NLC) measures (MMIDs 4340, 4342, 4344, and 4346) because only a single scheduling strategy is being employed, whereas NLC systems may incorporate scheduling, occupancy sensing, high-end trim, and/or continuous dimming strategies.

The input fixture wattage is derived from a U.S. Department of Energy market characterization report.[3] Table 4.29 in this report shows average market wattage for building exterior (97 watts) and parking (216 watts) applications. Table 4.27 shows an inventory of outdoor lamps, with 107,914 building exterior lamps and 83,519 parking lamps. The population weighted average wattage is therefore 149.6 watts.

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 643 units over 31 projects from 2014 to 2018.
3. U.S. Department of Energy. "2015 U.S. Lighting Market Characterization." Table 4.29 and Table 4.27. November 2017. https://energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf Population-weighted average wattage taken from "Building Ext.: C&I" and "Parking" applications.
4. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/

Revision History

Version Number	Date	Description of Change
01	09/08/2017	Initial TRM entry
02	12/2018	Updated incremental cost

8-Foot Linear Fluorescent T8 Replacement System

	Measure Details
Measure Master ID	T8, 2-Lamp, 4-Foot, HPT8 or RWT8: Replacing T12, 1-Lamp, 8-Foot, 0.78 < BF < 1.00, 3122 Replacing T12, 1-Lamp, 8-Foot, BF ≤ 0.78, 3123 Replacing T12HO, 1-Lamp, 8-Foot, 0.78 < BF < 1.00, 3124, 3801 Replacing T12HO, 1-Lamp, 8-Foot, BF ≤ 0.78, 3125 Replacing T12HO, 1-Lamp, 8-Foot, BF > 1.00, 3126, 3802 T8, 4-Lamp, 4-Foot, HPT8 or RWT8: Replacing T12, 2-Lamp, 8-Foot, 0.78 < BF < 1.00, 3127, 3803 Replacing T12, 2-Lamp, 8-Foot, BF ≤ 0.78, 3128 Replacing T12HO, 2-Lamp, 8-Foot, 0.78 < BF < 1.00, 3129, 3804 Replacing T12HO, 2-Lamp, 8-Foot, BF ≤ 0.78, 3130 Replacing T12HO, 2-Lamp, 8-Foot, BF > 1.00, 3131, 3805 Replacing T12VHO, 2-Lamp, 8-Foot, 0.78 < BF < 1.00, 3132 Replacing T12VHO, 2-Lamp, 8-Foot, BF ≤ 0.78, 3133 Replacing T12VHO, 2-Lamp, 8-Foot, BF > 1.00, 3134
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Fluorescent, Linear
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Varies by measure, see Appendix D[2]

Measure Description

This measure is high performance and reduced wattage 4-foot linear fluorescent lighting fixtures that use low ballast factors, high wattage lamps, or reduced wattage lamps are an energy-efficient alternative to 8-foot, standard wattage T12, T12HO, and T12VHO linear fluorescent fixtures. These products can be installed on a two-to-one basis to replace 1-lamp or 2-lamp T12 luminaires without sacrificing lighting quality.

Description of Baseline Condition

For existing buildings, the baseline measure is 8-foot, 1-lamp or 2-lamp standard T12, T12HO, and T12VHO linear fluorescent fixtures. High output (HO) 8-foot T12 baseline lamps range from 95 watts to 110 watts, while for very high output (VHO) lamps the range is 185 watts to 215 watts.

Description of Efficient Condition

The efficient measure is 2-lamp or 4-lamp, 4-foot, high performance T8 fixtures with normal and low ballast factor, and reduced wattage, 25-watt and 28-watt T8s with high, normal, and low ballast factors.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{8' \, T12} - kWh_{HP/RW}$

Where:

$kWh_{8' \, T12}$ = Annual electricity consumption of an 8-foot T12, T12HO, or T12VHO linear fluorescent lamp fixture

$kWh_{HP/RW}$ = Annual electricity consumption of a 4-foot, linear fluorescent, high performance or reduced wattage fixture

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = Wattage/1{,}000 * CF$

Where:

Wattage = Wattage of installed fixture

1,000 = Kilowatt conversion factor

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF[5]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Annual Deemed Savings for 8-FootLinear Fluorescent T8 Replacement System

Measure	MMID	Commercial 3,730 (0.77)		Schools & Gov 3,239 (0.64)		Industrial 4,745 (0.77)		Agriculture 4,698 (0.67)	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 1-Lamp, 8-Foot, 0.78 < BF < 1.00	3122	112	0.0231	97	0.0192	142	0.0231	141	0.0201
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 1-Lamp, 8-Foot, BF ≤ 0.78	3123	137	0.0283	119	0.0235	174	0.0283	173	0.0246
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 2-Lamp, 8-Foot, 0.78 < BF < 1.00	3127, 3803	129	0.0266	112	0.0221	164	0.0266	162	0.0231
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 2-Lamp, 8-Foot, BF ≤ 0.78	3128	175	0.0362	152	0.0301	223	0.0362	220	0.0315
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 1-Lamp, 8-Foot, BF > 1.00	3126, 3802	202	0.0416	175	0.0346	257	0.0416	254	0.0362
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 1-Lamp, 8-Foot, 0.78 < BF < 1.00	3124, 3801	269	0.0555	234	0.0461	342	0.0555	339	0.0483
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 1-Lamp, 8-Foot, BF ≤ 0.78	3125	294	0.0606	255	0.0504	374	0.0606	370	0.0527
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 2-Lamp, 8-Foot, BF > 1.00	3131, 3805	322	0.0665	280	0.0553	410	0.0665	406	0.0579
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 2-Lamp, 8-Foot, BF ≤ 0.78	3130	507	0.1047	440	0.0870	645	0.1047	639	0.0911

Measure	MMID	Commercial 3,730 (0.77)		Schools & Gov 3,239 (0.64)		Industrial 4,745 (0.77)		Agriculture 4,698 (0.67)	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12VHO, 2-Lamp, 8-Foot, BF > 1.00	3134	967	0.1997	840	0.1660	1,230	0.1997	1,218	0.1738
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12VHO, 2-Lamp, 8-Foot, 0.78 < BF < 1.00	3132	1,106	0.2284	960	0.1898	1,407	0.2284	1,393	0.1987
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12VHO, 2-Lamp, 8-Foot, BF ≤ 0.78	3133	1,153	0.2379	1,001	0.1977	1,467	0.2379	1,452	0.2070

Lifecycle Deemed Savings for 8-Foot Linear Fluorescent T8 Replacement System

Measure	MMID	Commercial 3,730 (0.77)	Schools & Gov 3,239 (0.64)	Industrial 4,745 (0.77)	Agriculture 4,698 (0.67)
		kWh	kWh	kWh	kWh
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 1-Lamp, 8-Foot, 0.78 < BF < 1.00	3122	1,680	1,455	2,130	2,115
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 1-Lamp, 8-Foot, BF ≤ 0.78	3123	2,055	1,785	2,610	2,595
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 2-Lamp, 8-Foot, 0.78 < BF < 1.00	3127, 3803	1,935	1,680	2,460	2,430
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 2-Lamp, 8-Foot, BF ≤ 0.78	3128	2,625	2,280	3,345	3,300
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 1-Lamp, 8-Foot, BF > 1.00	3126, 3802	3,030	2,625	3,855	3,810
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 1-Lamp, 8-Foot, 0.78 < BF < 1.00	3124, 3801	4,035	3,510	5,130	5,085
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 1-Lamp, 8-Foot, BF ≤ 0.78	3125	4,410	3,825	5,610	5,550

Measure	MMID	Commercial 3,730 (0.77)	Schools & Gov 3,239 (0.64)	Industrial 4,745 (0.77)	Agriculture 4,698 (0.67)
		kWh	kWh	kWh	kWh
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 2-Lamp, 8-Foot, BF > 1.00	3131, 3805	4,830	4,200	6,150	6,090
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 2-Lamp, 8-Foot, BF ≤ 0.78	3130	7,605	6,600	9,675	9,585
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12VHO, 2-Lamp, 8-Foot, BF > 1.00	3134	14,505	12,600	18,450	18,270
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12VHO, 2-Lamp, 8-Foot, 0.78 < BF < 1.00	3132	16,590	14,400	21,105	20,895
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12VHO, 2-Lamp, 8-Foot, BF ≤ 0.78	3133	17,295	15,015	22,005	21,780

Measure Costs for 8-Foot Linear Fluorescent T8 Replacement System[2]

Measure	MMID	Cost ($)
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 1-Lamp, 8-Foot, 0.78 < BF < 1.00	3122	$41.00
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 1-Lamp, 8-Foot, BF ≤ 0.78	3123	$41.00
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 2-Lamp, 8-Foot, 0.78 < BF < 1.00	3127, 3803	$66.00
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 2-Lamp, 8-Foot, BF ≤ 0.78	3128	$66.00
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 1-Lamp, 8-Foot, BF > 1.00	3126, 3802	$41.00
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 1-Lamp, 8-Foot, 0.78 < BF < 1.00	3124, 3801	$41.00
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 1-Lamp, 8-Foot, BF ≤ 0.78	3125	$41.00
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 2-Lamp, 8-Foot, BF > 1.00	3131	$66.00
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 2-Lamp, 8-Foot, BF ≤ 0.78	3130	$66.00
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12VHO, 2-Lamp, 8-Foot, BF > 1.00	3134	$66.00
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12VHO, 2-Lamp, 8-Foot, 0.78 < BF < 1.00	3132	$66.00
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12VHO, 2-Lamp, 8-Foot, BF ≤ 0.78	3133	$66.00

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." EUL Table. 2014. http://www.deeresources.com/
Rated ballast life of 70,000 hours, not rated on bulb life. As such the value is capped at 15 years.
2. 2014 Focus on Energy Program Data; verified with average price of lamps on 1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013. Assumes T8 and CEE ballast as baseline.
3. Michigan Master Measure Database. 2011 baselines. Updated May 26, 2011.
4. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3.2 Lighting Hours of Use in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs Deemed Savings Manual V1.0." Table 3.2 Coincidence Factor for Lighting in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	12/2012	Initial TRM entry
02	10/2016	Removed MMID 3314
03	01/2019	Removed MMIDs 3307, 3309, and 3312

Interior New Construction Lighting, Lighting Power Density (LPD)

	Measure Details
Measure Master ID	Interior New Construction Lighting: LPD ≥20% below code requirements, 4336 LPD ≥30% below code requirements, 4337 LPD ≥40% below code requirements, 4338
Measure Unit	Per square foot
Measure Type	Hybrid
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agricultural, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	N/A
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	N/A
Water Savings (gal/yr)	N/A
Effective Useful Life (years)	15[1]
Measure Incremental Cost ($/unit)	$0.35 per square foot (for MMID 4336); $0.49 per square foot (MMID 4337); $0.62 per square foot (for MMID 4338)[1]

Measure Description

Newly constructed or repurposed buildings must follow Lighting Power Density (LPD) limits defined by IECC 2009 with Wisconsin Amendments found in SPS Chapter 363. This measure is intended to encourage building owners and lighting designers to exceed code minimums in an easy-to-use format, taking advantage of code definitions.

Description of Baseline Condition

The baseline condition is any newly constructed or repurposed building subject to IECC 2009 with Wisconsin Amendments Watts/ft^2 building type definitions.

Description of Efficient Condition

The efficient condition is a lighting fixture design that meets a minimum 20% reduction in code defined LPD values without controls.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (LPD_{CODE} - LPD_{DESIGN}) * sq\ ft * HOU / 1{,}000$

Where:

LPD_{CODE} = Code allowed watts per square foot (= defined by building type; see table below)[2]

LPD_{DESIGN} = Proposed watts per square foot in lighting design

sq ft = Building square footage (= defined by user)

HOU = Average annual run hours (= defined by user or program-defined based on sector; see table below)[3]

1,000 = Kilowatt conversion factor

Code Lighting Power Density by Building Type

Building Area Type	LPD (Watts/sq ft)[2]
Penitentiary	1.0
Performing Arts Theater	1.6
Police/Fire Station	1.0
Post Office	1.1
Religious Building	1.3
Retail	1.5
School/University	1.2
Sports Arena	1.1
Town Hall	1.1
Transportation	1.0
Warehouse	0.8
Workshop	1.4

Hours-of-Use by Sector

Sector	HOU[3]
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (LPD_{CODE} – LPD_{DESIGN}) * sq\ ft / 1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)[4]

Coincidence Factor by Sector

Sector	CF[4]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

Incremental cost in the Efficiency Vermont TRM[1] is defined as watts per square foot reduction. To arrive at an incremental cost per square foot, the average LPD of IECC 2009 defined building types (1.11)[3] was multiplied by 25%, 35%, or 45% LPD reduction for each tier, then multiplied by the $1.25 defined by Efficiency Vermont's TRM.[1]

Sources

1. Efficiency Vermont. *Technical Reference User Manual*. Lighting Power Density Measure. p. 89. March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf
2. International Energy Conservation Code. Table 505.5.2. 2009. https://codes.iccsafe.org/public/chapter/content/4718/
3. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3.2. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	11/01/2017	Initial TRM entry

4-Foot Linear LED, Replacing 8-Foot T12 or T8, 1 or 2 Lamp

	Measure Details
Measure Master ID	4FT Linear LED 2L: Replacing 8FT 1L T8 or T12, 4314, 4445 Replacing 8FT 1L T8 or T12, Exterior, 4315, 4446 Replacing 8FT 1L T8 or T12, Exterior 24/7, 4316, 4447 Replacing 8FT 1L T8HO or T12HO, 4317, 4448 Replacing 8FT 1L T8HO or T12HO, Exterior, 4318, 4449 Replacing 8FT 1L T8HO or T12HO, Exterior 24/7, 4319, 4450 4FT Linear LED 4L: Replacing 8FT 2L T8 or T12, 4320, 4451 Replacing 8FT 2L T8 or T12, Exterior, 4321, 4452 Replacing 8FT 2L T8 or T12, Exterior 24/7, 4322, 4453 Replacing 8FT 2L T8HO or T12HO, 4323, 4454 Replacing 8FT 2L T8HO or T12HO, Exterior, 4324, 4455 Replacing 8FT 2L T8HO or T12HO, Exterior 24/7, 4325, 4456 4FT Linear LED 2L: Replacing 8FT 2L T8 or T12, 4326, 4457 Replacing 8FT 2L T8 or T12, Exterior, 4327, 4458 Replacing 8FT 2L T8 or T12, Exterior 24/7, 4328, 4459 Replacing 8FT 2L T8HO or T12HO, 4329, 4460 Replacing 8FT 2L T8HO or T12HO, Exterior, 4330, 4461 Replacing 8FT 2L T8HO or T12HO, Exterior 24/7, 4331, 4462
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Non-exterior and exterior 12-hour = 12 (MMIDs 4314, 4315, 4317, 4318, 4320, 4321, 4323, 4324, 4326, 4327, 4329, and 4330)

	Measure Details
	Exterior 24-hour = 6 (MMIDs 4316, 4319, 4321, 4325, 4328, and 4331)[1]
Incremental Cost	1-lamp upgrades = \$52.00 (MMIDs 4314–4320);[2] 2-lamp upgrades = \$103.00 (MMIDs 4321–4325);[2] 2-lamp 8-foot to 2-lamp 4-foot upgrades = \$125.58 (MMIDs 4326–4331)[2]

Measure Description

Four-foot T8 LEDs are an energy-efficient alternative to standard 8-foot T8 or T12 fluorescent lamps commonly found throughout commercial, industrial, agriculture, school, government, and multifamily spaces. These products can replace 8-foot T8 or T12 lamps two-for-one, in tandem, and this measure incorporates several common retrofit scenarios.

Description of Baseline Condition

The baseline condition is 1- and 2-lamp standard output and high output 8-foot T8 or T12 fluorescent lamps.

Description of Efficient Condition

The efficient condition equipment must be DesignLights Consortium-listed in the T8 Four-Foot Linear Replacement Lamps General Application, and have a tested or reported wattage of 24 or less. This measure is not intended to be used in refrigerated case lighting applications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{FLUORESCENT} - Watts_{LED}) / 1{,}000 * HOU$

Where:

$Watts_{FLUORESCENT}$ = Average wattage of T8 and T12 systems (1 lamp = 65 watts, 2 lamp = 108 watts, 1 lamp HO = 104 watts, 2 lamp HO = 184 watts)

$Watts_{LED}$ = Average wattage consumption of DLC-listed 4-foot linear LED < 24 watts (= 16.5 watts)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector, see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950
Exterior[6]	4,380
Exterior 24/7	8,760

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{FLUORESCENT} - Watts_{LED}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector, see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily	0.77
Exterior	0.00
Exterior 24/7	1.00

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 16 years)[1]

Deemed Savings

Annual Energy Savings (kWh)

Measure	MMID	Com-mercial	Indus-trial	Agri-culture	Schools & Gov	Multi-family
4FT Linear LED 2L						
Replacing 8FT 1L T8 or T12	4314	119	152	150	104	190
Replacing 8FT 1L T8 or T12, Exterior	4315	140	140	140	140	140
Replacing 8FT 1L T8 or T12, Exterior 24/7	4316	280	280	280	280	280
Replacing 8FT 1L T8HO or T12HO	4317	263	335	331	228	419
Replacing 8FT 1L T8HO or T12HO	4318	309	309	309	309	309
Replacing 8FT 1L T8HO or T12HO	4319	618	618	618	618	618
4FT Linear LED 4L						
Replacing 8FT 2L T8 or T12	4320	157	199	197	136	250
Replacing 8FT 2L T8 or T12, Exterior	4321	184	184	184	184	184
Replacing 8FT 2L T8 or T12, Exterior 24/7	4322	368	368	368	368	368
Replacing 8FT 2L T8HO or T12HO	4323	440	560	554	382	702
Replacing 8FT 2L T8HO or T12HO, Exterior	4324	517	517	517	517	517
Replacing 8FT 2L T8HO or T12HO, Exterior 24/7	4325	1,034	1,034	1,034	1,034	1,034
4FT Linear LED 2L						
Replacing 8FT 2L T8 or T12	4326	280	356	352	243	446
Replacing 8FT 2L T8 or T12, Exterior	4327	329	329	329	329	329
Replacing 8FT 2L T8 or T12, Exterior 24/7	4328	657	657	657	657	657
Replacing 8FT 2L T8HO or T12HO	4329	563	716	709	489	898
Replacing 8FT 2L T8HO or T12HO, Exterior	4330	661	661	661	661	661
Replacing 8FT 2L T8HO or T12HO, Exterior 24/7	4331	1,323	1,323	1,323	1,323	1,323

Demand Reduction (kW)

Measure	MMID	Com-mercial	Indus-trial	Agri-culture	Schools & Gov	Multi-family
4FT Linear LED 2L						
Replacing 8FT 1L T8 or T12	4314	0.0246	0.0246	0.0214	0.0205	0.0246
Replacing 8FT 1L T8 or T12, Exterior	4315	N/A	N/A	N/A	N/A	N/A
Replacing 8FT 1L T8 or T12, Exterior 24/7	4316	0.032	0.032	0.032	0.032	0.032
Replacing 8FT 1L T8HO or T12HO	4317	0.0543	0.0543	0.0472	0.0451	0.0543
Replacing 8FT 1L T8HO or T12HO	4318	N/A	N/A	N/A	N/A	N/A
Replacing 8FT 1L T8HO or T12HO	4319	0.0705	0.0705	0.0705	0.0705	0.0705

Measure	MMID	Com-mercial	Indus-trial	Agri-culture	Schools & Gov	Multi-family
4FT Linear LED 4L						
Replacing 8FT 2L T8 or T12	4320	0.0323	0.0323	0.0281	0.0269	0.0323
Replacing 8FT 2L T8 or T12, Exterior	4321	N/A	N/A	N/A	N/A	N/A
Replacing 8FT 2L T8 or T12, Exterior 24/7	4322	0.042	0.042	0.042	0.042	0.042
Replacing 8FT 2L T8HO or T12HO	4323	0.0909	0.0909	0.0791	0.0755	0.0909
Replacing 8FT 2L T8HO or T12HO, Exterior	4324	N/A	N/A	N/A	N/A	N/A
Replacing 8FT 2L T8HO or T12HO, Exterior 24/7	4325	0.118	0.118	0.118	0.118	0.118
4FT Linear LED 2L						
Replacing 8FT 2L T8 or T12	4326	0.0578	0.0578	0.0503	0.048	0.0578
Replacing 8FT 2L T8 or T12, Exterior	4327	N/A	N/A	N/A	N/A	N/A
Replacing 8FT 2L T8 or T12, Exterior 24/7	4328	0.075	0.075	0.075	0.075	0.075
Replacing 8FT 2L T8HO or T12HO	4329	0.1163	0.1163	0.1012	0.0966	0.1163
Replacing 8FT 2L T8HO or T12HO, Exterior	4330	N/A	N/A	N/A	N/A	N/A
Replacing 8FT 2L T8HO or T12HO, Exterior 24/7	4331	0.151	0.151	0.151	0.151	0.151

Lifecycle Savings (kWh)

Measure	MMID	Com-mercial	Indus-trial	Agri-culture	Schools & Gov	Multi-family
4FT Linear LED 2L						
Replacing 8FT 1L T8 or T12	4314	1,428	1,824	1,800	1,248	2,280
Replacing 8FT 1L T8 or T12, Exterior	4315	1,680	1,680	1,680	1,680	1,680
Replacing 8FT 1L T8 or T12, Exterior 24/7	4316	1,680	1,680	1,680	1,680	1,680
Replacing 8FT 1L T8HO or T12HO	4317	3,156	4,020	3,972	2,736	5,028
Replacing 8FT 1L T8HO or T12HO	4318	3,708	3,708	3,708	3,708	3,708
Replacing 8FT 1L T8HO or T12HO	4319	3,708	3,708	3,708	3,708	3,708
4FT Linear LED 4L						
Replacing 8FT 2L T8 or T12	4320	1,884	2,388	2,364	1,632	3,000
Replacing 8FT 2L T8 or T12, Exterior	4321	2,208	2,208	2,208	2,208	2,208
Replacing 8FT 2L T8 or T12, Exterior 24/7	4322	2,208	2,208	2,208	2,208	2,208
Replacing 8FT 2L T8HO or T12HO	4323	5,280	6,720	6,648	4,584	8,424
Replacing 8FT 2L T8HO or T12HO, Exterior	4324	6,204	6,204	6,204	6,204	6,204
Replacing 8FT 2L T8HO or T12HO, Exterior 24/7	4325	6,204	6,204	6,204	6,204	6,204

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
4FT Linear LED 2L						
Replacing 8FT 2L T8 or T12	4326	3,360	4,272	4,224	2,916	5,352
Replacing 8FT 2L T8 or T12, Exterior	4327	3,948	3,948	3,948	3,948	3,948
Replacing 8FT 2L T8 or T12, Exterior 24/7	4328	3,942	3,942	3,942	3,942	3,942
Replacing 8FT 2L T8HO or T12HO	4329	6,756	8,592	8,508	5,868	10,776
Replacing 8FT 2L T8HO or T12HO, Exterior	4330	7,932	7,932	7,932	7,932	7,932
Replacing 8FT 2L T8HO or T12HO, Exterior 24/7	4331	7,938	7,938	7,938	7,938	7,938

Sources

1. DesignLights Consortium. *Qualified Product List.* Accessed August 2017. https://www.designlights.org/lighting-controls/download-the-qpl/
   The average rated life of models participating in linear LED measures is 51,160 hours. Non-exterior measures (with a sector-average HOU of 4,103) and 12-hour measures (with an HOU of 4,380) have an EUL of 12 years. Exterior 24/7 measures (with an HOU of 8,760) have an EUL of six years.
2. Pricing was collected from online sources and distributors for lamps, ballasts, drivers, and 8-foot conversion kits used in MMIDs 3616 and 3617. Labor was estimated. Incremental costs were determined between a baseline conversion of 8-foot T12 lamps to T8 lamps with a new ballast and an improved conversion of 8-foot T12 lamps to 4-foot T8 LED lamps with a new ballast. Eight-foot, 2-lamp conversions to 4-foot, 2-lamp removes the incremental material cost of two 4-foot T8 LED lamps ($11.29 each from MMID 3512) and is added to the incremental cost of the 8-foot 2-lamp conversion.
3. DesignLights Consortium. *Product List.* Accessed October 13, 2017. https://www.designlights.org/search/
4. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3.2 Lighting Hours of Use and Coincidence Factor by Sector. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. "ACES Deemed Savings Desk Review." November 3, 2010. Common Area Lighting section, p. 9–11. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf

6. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/
   This report includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
7. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs; see Table 4-1 showing multifamily housing (in unit) CF of 65% to 83%.

Revision History

Version Number	Date	Description of Change
01	10/13/2017	Initial TRM entry

DLC HB ≤ 180W Replacing or Instead of 6L T8 or 4L T5HO

	Measure Details
Measure Master ID	LED Fixture, ≤ 180 Watts, Replacing 4 Lamp T5 or 6 Lamp T8, High Bay, DLC Listed, 3393, 4467
Measure Unit	Per luminaire
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	$202.23[2]

Measure Description

LED high bay fixtures save energy when replacing 4-lamp T5HO or 6-lamp T8 high bay products by providing a similar lumen output with lower input wattage. These products can be installed on a one-for-one basis to replace 4-lamp T5HO or 6-lamp T8 high bay luminaires.

Description of Baseline Condition

The baseline condition is a combination of 4-foot 4-lamp T5HO and 6-lamp T8 high/low bay fixtures for existing buildings and new construction buildings. An average of 25% 4-foot 4-lamp T5HO (234 watts) and 75% 6-lamp T8 (224 watts) high/low bay luminaires was used to generate the baseline wattage (see Assumptions).

Description of Efficient Condition

The efficient condition is a DesignLights Consortium LED fixture listed in the High-Bay General Application, consuming less than or equal to 180 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000$

Where:

$Watts_{BASE}$ = Average power consumption of current 4-lamp T5HO and 6-lamp T8 high/low bay luminaires (= 227 watts, see Assumptions)

$Watts_{EE}$ = Average power consumption of DLC-listed LED high/low bay luminaire (= 109 watts)[3]

HOU = Hours of use (= varies by sector; see table below)

1,000 = Kilowatt conversion factor

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1,000$

Where:

CF = Coincidence factor (= varies by sector, see table below)

Coincidence Factor by Sector

Sector	HOU
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[6]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 20 years)[1]

Deemed Savings

Annual Savings

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
DLC HB ≤ 180W Replacing or Instead of 6L T8 or 4L T5HO	3393	438	0.0905	558	0.0905	552	0.0787	381	0.0752	699	0.0905

Lifecycle Savings

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
DLC HB ≤ 180W Replacing or Instead of 6L T8 or 4L T5HO	3393	8,760	11,160	11,040	7,620	13,980

Assumptions

Fixture weightings are based on a combination of feedback from energy audit experience, Lighting Certified (LC) individuals through the National Council on Qualifications for the Lighting Professions (NCQLP), and individuals with lighting sales experience. Each fixture wattage is sourced from the Focus on Energy Default Wattage Guide.

In discussions with the DLC, it was determined that the rated lifetime hours reported in the *DLC Qualified Product List*[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer spec sheets often do list actual L70 test data, so these data were used to obtain an average rated lifetime for participating models.[1]

Sources

1. SPECTRUM. Online lookups from January 2018 and MMID 3901 participation data from January through December 2017 show that 15 participating models, comprising 4,120 units and 51% of total measure participation, have an average spec sheet rated life of 111,333 hours. With an average HOU of 4,472, the EUL is 25 years. Lighting EULs are capped at 20 years.
2. August 2018 online lookups of four base and efficient models on www.1000bulbs.com, www.bulbs.com, www.lightbulbsupply.com, www.topbulb.com, and www.prolighting.com show an average efficient fixture price of $214.99 and base bulb price of $12.76, for an incremental cost of $202.23.
3. DesignLights Consortium. *Product List*. January 12, 2018.
4. PA Consulting Group Inc. "State of Wisconsin Public Service Commissin of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3-2. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. "ACES Deemed Savings Desk Review." Table 1. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
6. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. Table 4-1. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs: table shows multifamily housing (in unit) CF of 65% to 83%.

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	03/2017	Removed from TRM
03	09/2017	Reactivated measure from 2016 program offerings with updated wattages, deemed savings, and EUL

DLC HB ≤ 250W Replacing or Instead of 8L T8 or 6L T5HO

	Measure Details
Measure Master ID	LED Fixture, ≤ 250 Watts, Replacing 8 Lamp T8 or 6 Lamp T5HO, High Bay, 4347, 4468
Measure Unit	Per luminaire
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	$77.83[2]

Measure Description

LED high bay fixtures save energy when replacing 6-lamp T5HO or 8-lamp T8 high bay products by providing a similar lumen output with lower input wattage. These products can be installed on a one-for-one basis to replace 6-lamp T5HO or 8-lamp T8 high bay luminaires.

Description of Baseline Condition

The baseline condition is a combination of 4-foot 6-lamp T5HO and 8-lamp T8 high/low bay fixtures for existing buildings and new construction buildings. An average of 50% 4-foot 6-lamp T5HO (355 watt) and 50% 8-lamp T8 (291 watt) high/low bay luminaires was used to generate the baseline wattage (see Assumptions).

Description of Efficient Condition

The efficient condition is a DesignLights Consortium LED fixture listed in the High-Bay General Application, consuming less than or equal to 250 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000$

Where:

$Watts_{BASE}$ = Average power consumption of current 6-lamp T5HO and 8-lamp T8 high/low bay luminaires (= 323 watts, see Assumptions)

$Watts_{EE}$ = Average power consumption of DLC-listed LED high/low bay luminaire (= 132 watts)[3]

HOU = Hours of use (= varies by sector; see table below)

1,000 = Kilowatt conversion factor

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1,000$

Where:

CF = Coincidence factor (= varies by sector, see table below)

Coincidence Factor by Sector

Sector	HOU
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[6]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 20 years)[1]

Deemed Savings

Annual Savings

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
DLC HB ≤ 250W Replacing or Instead of 8L T8 or 6L T5HO	4347	712	0.1471	906	0.1471	897	0.1280	619	0.1222	1,136	0.1471

Lifecycle Savings

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
DLC HB ≤ 250W Replacing or Instead of 8L T8 or 6L T5HO	4347	14,240	18,120	17,940	12,380	22,720

Assumptions

Fixture weightings are based on a combination of feedback from energy audit experience, Lighting Certified (LC) individuals through the National Council on Qualifications for the Lighting Professions (NCQLP), and individuals with lighting sales experience. Each fixture wattage is sourced from the Focus on Energy Default Wattage Guide.

In discussions with the Design Lights Consortium, it was determined that the rated lifetime hours reported in the *DLC Qualified Product List*[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer spec sheets often do list actual L70 test data, so these data were used to obtain an average rated lifetime for participating models.[1]

Sources

1. SPECTRUM. Online lookups from January 2018 and MMID 3902 participation data from January through December 2017 show that six participating models, comprising 2,778 units and 51% of total measure participation, have an average spec sheet rated life of 98,667 hours. With an average HOU of 4,472, the EUL is 22 years. Lighting EULs are capped at 20 years.
2. Full fixture cost of $90.58 is derived from August 2018 online lookups at www.warehouselighting.com, www.prolighting.com, www.amazon.com, and www.greenelectricalsupply.com. Base lamp cost of $12.75 derived from online lookups at www.1000bulbs.com, www.bulbs.com, and www.lightbulbs.com. Incremental cost is $77.83.
3. DesignLights Consortium. *Product List.* January 17, 2018.
   Average measured wattage for products listed in the luminaire High Bay General Application is ≤ 250 watts.
4. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Table 3-2. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. “ACES Deemed Savings Desk Review.” Table 1. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
6. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review.” Final Report. Table 4-1. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs: table shows multifamily housing (in unit) CF of 65% to 83%.

Revision History

Version Number	Date	Description of Change
01	09/20/2017	Initial TRM entry
02	12/2018	Updated incremental cost

DLC Listed 2x2 LED Fixtures

	Measure Details
Measure Master ID	LED Fixture, 2x2, DLC Listed: Low Output, 3400 High Output, 3401 Low Output w/LLLC, 4332, 4463 High Output w/LLLC, 4333, 4464
Measure Unit	Per luminaire
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agricultural, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$38.71 for MMIDs 3400, 4332, and 4463;[2] $111.04 for MMIDs 3401, 4333, and 4464[3]

Measure Description

LED 2x2 troffers save energy when replacing two- to four-lamp T8 products and two- to four-lamp 2G11 base lamps by providing a similar lumen output with lower input wattage. These products can be installed on a one-for-one basis to replace 2x2 two- to four-lamp T8, T12, or 2G11 lamp base luminaires and may incorporate Luminaire Level Lighting Controls (LLLC). LLLCs are sensors and controls integrated into luminaires that provide occupancy, daylight, high-end trim, and potential other sensory functions such as air temperature and space utilization. This granular control can yield additional savings, easier control commissioning, and occupant comfort.

Description of Baseline Condition

The baseline condition is two-foot, two-, three-, and 4-lamp T8 or 2G11 lamp base troffers for existing buildings and new construction buildings.

Description of Efficient Condition

For low output 2x2 measures, the efficient condition is DesignLights Consortium products listed in the “2x2 Luminaires for Ambient Lighting of Interior Commercial Spaces” and “Integrated Retrofit Kits for 2x2 Luminaires” primary use categories, which consume less than or equal to 36 watts and may contain LLLC.

For high output 2x2 measures, the efficient condition is DesignLights Consortium products listed in the “2x2 Luminaires for Ambient Lighting of Interior Commercial Spaces” and “Integrated Retrofit Kits for 2x2 Luminaires” primary use categories, which consume less than or equal to 85 watts and may contain LLLC.

Annual Energy-Savings Algorithm

Low Output 2x2

$kWh_{SAVED} = [Watts_{BASE} – Watts_{EE} * (1 – SF)] / 1,000 * HOU$

Where:

$Watts_{BASE}$ = Baseline wattage, the average power consumption of 2-, 3-, or 4-lamp 17-watt T8 or 2-lamp T8 U-bend fixtures, weighted at 2%/38%/20%/40% (= 56 watts, see Assumptions section)

$Watts_{EE}$ = Energy efficient wattage, the average power consumption of DLC-listed LED fixtures less than or equal to 36 watts (= 30.1 watts)[4]

SF = LLLC savings factor, deemed (= 0% for MMIDs 3400 and 3401; = 41% for MMIDs 4332 and 4333)[5]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU[5,6]
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239
Multifamily	5,950

High Output 2x2

$kWh_{SAVED} = [Watts_{BASE} - Watts_{EE} * (1 - SF)] / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Baseline wattage, the average power consumption of 2-, 3-, or 4-lamp 2G11 base fixtures, weighted between 40-watt, 50-watt, and 55-watt lamps (= 146 watts, see Assumptions section)

$Watts_{EE}$ = Energy efficient wattage, the average power consumption of DLC-listed LED fixtures less than or equal to 85 watts (= 34.6 watts)[4]

SF = LLLC savings factor, deemed (= 0% for MMIDs 3400 and 3401; = 41% for MMIDs 4332 and 4333)[5]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table above)[5]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) * CF_{WATTAGE} / 1{,}000 + Watts_{EE} * CF_{WATTAGE} * CF_{CONTROLS} / 1{,}000$

Where:

$CF_{WATTAGE}$ = Coincidence factor for wattage reduction (= varies by sector; see table below)

$CF_{CONTROLS}$ = Coincidence factor for controls (= 0 for MMIDs 3400 and 3401; varies by sector for MMIDs 4332 and 4333, see table below)

Coincidence Factor

Sector	$CF_{WATTAGE}$[5,7]	$CF_{CONTROLS}$[5]
Commercial	0.77	0.14
Industrial	0.77	0.18
Agriculture	0.67	0.14
Schools & Government	0.64	0.14
Multifamily	0.77	0.14

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Annual Savings for DLC-Listed 2X2 LEDs

Measure	MMID	Savings	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
Low Output	3400	kWh	95	121	120	83	152
		kW	0.0197	0.0197	0.0171	0.0164	0.0197
High Output	3401	kWh	414	526	521	359	660
		kW	0.0854	0.0854	0.0743	0.0710	0.0854
Low Output w/LLLC	4332	kWh	141	180	178	123	226
		kW	0.0229	0.0239	0.0200	0.0191	0.0229
High Output w/LLLC	4333	kWh	467	594	588	405	744
		kW	0.0891	0.0902	0.0775	0.0741	0.0891

Lifecycle Savings for DLC-Listed 2X2 LEDs (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
Low Output	3400	1,045	1,331	1,320	913	1,672
High Output	3401	4,554	5,786	5,731	3,949	7,260
Low Output w/LLLC	4332	1,551	1,980	1,958	1,353	2,486
High Output w/LLLC	4333	5,137	6,534	6,468	4,455	8,184

Assumptions

Fixture lamp weightings used in baseline calculation are listed in the table below. The assumptions are based on a combination of feedback from energy audit experience, Lighting Certified individuals through the National Council on Qualifications for the Lighting Professions, and individuals with lighting sales experience.

Fixture Lamp Weightings Used in Baseline Calculation

<table>
<tr><th colspan="3">2 Lamp T8 Wattage</th><th colspan="3">2 Lamp T8 U Bend Wattage</th><th colspan="3">3 Lamp T8 Wattage</th><th colspan="3">4 Lamp T8 Wattage</th></tr>
<tr><td colspan="3">36</td><td colspan="3">55</td><td colspan="3">52</td><td colspan="3">66</td></tr>
<tr><td colspan="3">2%</td><td colspan="3">40%</td><td colspan="3">38%</td><td colspan="3">20%</td></tr>
<tr><th colspan="4">2-Lamp 40W 2G11 2x2</th><th colspan="4">3-Lamp 40W 2G11 2x2</th><th colspan="4">4-Lamp 40W 2G11 2x2</th></tr>
<tr><td colspan="4">5%</td><td colspan="4">25%</td><td colspan="4">5%</td></tr>
<tr><th colspan="4">2-Lamp 50W 2G11 2x2</th><th colspan="4">3-Lamp 50W 2G11 2x2</th><th colspan="4">4-Lamp 50W 2G11 2x2</th></tr>
<tr><td colspan="4">5%</td><td colspan="4">25%</td><td colspan="4">5%</td></tr>
<tr><th colspan="4">2-Lamp 55W 2G11 2x2</th><th colspan="4">3-Lamp 55W 2G11 2x2</th><th colspan="4">4-Lamp 55W 2G11 2x2</th></tr>
<tr><td colspan="4">5%</td><td colspan="4">20%</td><td colspan="4">5%</td></tr>
</table>

Sources

1. DesignLights Consortium. *Qualified Product List*. Accessed August 2017. https://www.designlights.org/search
   Average rated life of models participating in linear LED measures is 51,160 hours. With an average HOU of 4,472, the EUL is 11 years.
2. August 2018 online lookups of four base and efficient models show an average efficient fixture price of $55.60 and base bulb price of $16.89, for an incremental cost of $38.71.
3. August 2018 online lookups of four base and efficient models on www.1000bulbs.com, www.batteriesplus.com, www.lightbulbs.com, and www.prolighting.com show an average efficient fixture price of $127.93 and base bulb price of $16.89, for an incremental cost of $111.04.
4. SPECTRUM. January 2017 through December 2017.
   Measure participation data shows that the average efficient wattages for participating models are 30.1 watts and 34.6 watts for MMIDs 3400 and 3401, respectively.
5. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Updated March 22, 2010. Table 3.2 for nonresidential HOU and CF. Table 4-161 for lighting control savings factor. Table 4-206 for lighting control coincidence factor. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. Tetra Tech. “ACES Deemed Savings Desk Review.” November 3, 2010. Table 1. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
7. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review.” Final Report. Table 4-1. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs; table shows multifamily housing (in unit) CF of 65% to 83%.

Revision History

Version Number	Date	Description of Change
01	04/01/2014	Initial TRM entry
02	10/07/2015	Updated savings and definitions
03	10/09/2017	Included 2x2 measures with LLLC
04	12/2018	Updated incremental cost

DLC HB ≤ 300W Replacing or Instead of 10L T8 or 8L T5HO

	Measure Details
Measure Master ID	LED Fixture, ≤ 300 Watts, Replacing 10 Lamp T8 or 8 Lamp T5HO, High Bay, 4795
Measure Unit	Per luminaire
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	$90.58[2]

Measure Description

LED high bay fixtures save energy when replacing 8-lamp T5HO or 10-lamp T8 high bay products by providing a similar lumen output with lower input wattage. These products can be installed on a one-for-one basis to replace 8-lamp T5HO or 10-lamp T8 high bay luminaires.

Description of Baseline Condition

The baseline condition is a combination of 4-foot 8-lamp T5HO and 10-lamp T8 high/low bay fixtures for existing buildings and new construction buildings. An average of 50% 4-foot 8-lamp T5HO (468 watt) and 50% 10-lamp T8 (368 watt) high/low bay luminaires was used to generate the baseline wattage (see Assumptions).

Description of Efficient Condition

The efficient condition is a DLC LED fixture listed in the High-Bay General Application, consuming less than or equal to 300 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1{,}000$

Where:

$Watts_{BASE}$ = Average power consumption of current 8-lamp T5HO and 10-lamp T8 high/low bay luminaires (= 418 watts; see Assumptions)

$Watts_{EE}$ = Average power consumption of DLC-listed LED high/low bay luminaire (= 140.8 watts)[3]

HOU = Hours of use (= varies by sector; see table below)

1,000 = Kilowatt conversion factor

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1{,}000$

Where:

CF = Coincidence factor (= varies by sector, see table below)

Coincidence Factor by Sector

Sector	HOU
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 20 years)[1]

Deemed Savings

Annual Savings

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
DLC HB ≤ 300W Replacing or Instead of 10L T8 or 8L T5HO	4795	1,034	0.2135	1,315	0.2135	1,302	0.1857	898	0.1774

Lifecycle Savings (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov
DLC HB ≤ 300W Replacing or Instead of 10L T8 or 8L T5HO	4795	20,680	26,300	26,040	17,960

Assumptions

Fixture weightings are based on a combination of feedback from energy audit experience, Lighting Certified individuals through the NCQLP, and individuals with lighting sales experience. Each fixture wattage is sourced from the Focus on Energy *Default Wattage Guide*.

In discussions with the DLC, it was determined that the rated lifetime hours reported in the DLC *Qualified Product List*[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer specification sheets often list actual L70 test data, so these data were used to obtain an average rated lifetime for participating models.[1]

Sources

1. EUL based on MMID 3092 SPECTRUM data. Online lookups from January 2018 and MMID 3092 participation data from January through December 2017 show that six participating models, comprising 2,778 units and 51% of total measure participation, have an average specification sheet rated life of 98,667 hours. With an average HOU of 4,472, the EUL is 22 years. Lighting EULs are capped at 20 years.
2. Incremental cost based on MMID 4347.
3. Warehouse Lighting. Website. Accessed September 2017. www.warehouse-lighting.com
   ProLighting. Website. Accessed September 2017. www.prolighting.com
   Green Electrical Supply. Website. Accessed September 2017. www.greenelectricalsupply.com
   Amazon. Website. Accessed September 2017. www.amazon.com
4. DesignLights Consortium. *Product List*. October 4, 2018.
   Average measured wattage for products listed in the luminaire High Bay General Application ≤ 300 watts.
5. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Table 3-2. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	01/01/2019	Initial TRM entry

DLC HB ≤ 350W Replacing or Instead of 12L T8 or 10L T5HO

	Measure Details
Measure Master ID	LED Fixture, ≤ 350 Watts, Replacing 12 Lamp T8 or 10 Lamp T5HO, High Bay, 4796
Measure Unit	Per luminaire
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	$90.58[2]

Measure Description

LED high-bay fixtures save energy when replacing 10-lamp T5HO or 12-lamp T8 high-bay products by providing a similar lumen output with lower input wattage. These products can be installed on a one-for-one basis to replace 10-lamp T5HO or 12-lamp T8 high bay luminaires.

Description of Baseline Condition

The baseline condition is a combination of 4-foot 10-lamp T5HO and 12-lamp T8 high/low bay fixtures for existing buildings and new construction buildings. An average of 50% 4-foot 10-lamp T5HO (585 watt) and 50% 12-lamp T8 (442 watt) high/low bay luminaires was used to generate the baseline wattage (see Assumptions).

Description of Efficient Condition

The efficient condition is a DLC LED fixture listed in the High-Bay General Application, consuming less than or equal to 350 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1{,}000$

Where:

$Watts_{BASE}$ = Average power consumption of current 10-lamp T5HO and 12-lamp T8 high/low bay luminaires (= 513.5 watts, see Assumptions)

$Watts_{EE}$ = Average power consumption of DLC-listed LED high/low bay luminaire (= 147.1 watts)[3]

HOU = Hours of use (= varies by sector; see table below)

1,000 = Kilowatt conversion factor

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1{,}000$

Where:

CF = Coincidence factor (= varies by sector, see table below)

Coincidence Factor by Sector

Sector	HOU
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 20 years)[1]

Deemed Savings

Annual Savings

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
DLC HB ≤ 350W Replacing or Instead of 12L T8 or 10L T5HO	4796	1,367	0.2271	1,739	0.2821	1,721	0.2455	1,187	0.2345

Lifecycle Savings (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov
DLC HB ≤ 350W Replacing or Instead of 12L T8 or 10L T5HO	4796	27,340	34,780	34,420	23,740

Assumptions

Fixture weightings are based on a combination of feedback from energy audit experience, Lighting Certified individuals through the NCQLP, and individuals with lighting sales experience. Each fixture wattage is sourced from the Focus on Energy *Default Wattage Guide*.

In discussions with the Design Lights Consortium, it was determined that the rated lifetime hours reported in the DLC *Qualified Product List*[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer specification sheets often list actual L70 test data, so these data were used to obtain an average rated lifetime for participating models.[1]

Sources

1. EUL based on MMID 3092 SPECTRUM data. Online lookups from January 2018 and MMID 3092 participation data from January through December 2017 show that six participating models, comprising 2,778 units and 51% of total measure participation, have an average specification sheet rated life of 98,667 hours. With an average HOU of 4,472, the EUL is 22 years. Lighting EULs are capped at 20 years.
2. Incremental cost based on MMID 4347.
3. Warehouse Lighting. Website. Accessed September 2017. www.warehouse-lighting.com
   ProLighting. Website. Accessed September 2017. www.prolighting.com
   Green Electrical Supply. Website. Accessed September 2017. www.greenelectricalsupply.com
   Amazon. Website. Accessed September 2017. www.amazon.com
4. DesignLights Consortium. *Product List*. October 4, 2018.
   Average measured wattage for products listed in the luminaire High Bay General Application is less than or equal to 350 watts.
5. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3-2. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	01/01/2019	Initial TRM entry

Four Pin-Base LED Lamp

	Measure Details
Measure Master ID	DLC Listed, Four Pin-Base Lamp Replacing CFL, Interior, 4779 DLC Listed, Four Pin-Base Lamp Replacing CFL, Exterior, 4780
Measure Unit	Per watt reduced
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	11 (see Assumptions)[1]
Incremental Cost ($/unit)	$0.84[2]

Measure Description

This measure is replacing four pin-base CFL lamps, interior or exterior, with four pin-base LED lamps.

Description of Baseline Condition

The baseline equipment is interior or exterior four pin-base CFL lighting.

Description of Efficient Condition

The efficient condition is an interior or exterior DLC-listed (Technical Requirements v4.4 minimum) four pin-base LED lamp, in the Four Pin-Base Replacement Lamps for CFLs category in one of the following primary use categories:

- Vertically / Horizontally-Mounted Lamps
    - Replacement Lamps (“Plug and Play”) (UL Type A)
- 2G11 Base Replacement Lamps
    - Internal Driver / Line Voltage Lamp-Style Retrofit Kits (UL Type B)
    - 2-Lamp External Drive Lamp-Style Retrofit Kits (UL Type C)
    - 3-Lamp External Drive Lamp-Style Retrofit Kits (UL Type C)
    - Dual Mode Internal Drive (UL Type A or B)

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) * HOU / 1{,}000 = Watts_{REDUCED} * HOU / 1{,}000$

Where:

$Watts_{BASE}$ = Power consumption of baseline lamp

$Watts_{EE}$ = Power consumption of DLC-listed LED product

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

$Watts_{REDUCED}$ = Watt reduction

Hours of Use by Sector

Sector	HOU
Commercial[3]	3,730
Industrial[3]	4,745
Agriculture[3]	4,698
Schools & Government[3]	3,239
Multifamily[4]	5,950
Exterior[5]	4,380
Average (non-exterior)	**4,472**

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) * CF / 1{,}000$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[3]	0.77
Industrial[3]	0.77
Agriculture[3]	0.67
Schools & Government[3]	0.64
Multifamily[6]	0.77
Exterior	0

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years; see Assumptions)

Deemed Savings

Here, deemed savings are calculated on a per–watt reduction basis. The values in the table indicate the savings from defining $Watts_{REDUCED}$ as 1.0 in the algorithm above for each sector.

Annual Savings (per watt reduced)

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Interior	4779	3.73	0.0008	4.75	0.0008	4.7	0.0007	3.24	0.0006	5.95	0.0008
Exterior	4780	4.38	N/A	4.38	N/A	4.38	N/A	4.38	N/A	4.38	N/A

Lifecycle Savings (kWh per watt reduced)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
Interior	4779	41	52	52	36	65
Exterior	4780	48	48	48	48	48

Assumptions

Effective useful life was determined by dividing minimum rated life of DLC-listed products in the Four Pin-Base Replacement Lamps for CFLs category (50,000 hours)[1] by the average sector HOU of 4,472 hours.

The incremental cost per watt is the average of the differences between CFL lamps (13 watt, 26 watt, 32 watt, and 42 watt) and equivalent LED lamps (6 watt, 12 watt, 16 watt, and 22 watt, respectively). Prices were obtained from supplier websites.[2]

Sources

1. DesignLights Consortium. Website. Accessed October 2018. https://www.designlights.org/solid-state-lighting/testing-reporting-requirements/four-pin-base-replacement-lamps-for-cfls/
2. 1000 Bulbs. Accessed October 2018. www.1000bulbs.com
   Amazon. Accessed October 2018. www.amazon.com
   Bulbs. Accessed October 2018. www.bulbs.com

Home Depot. Accessed October 2018. www.homedepot.com
Grainger. Accessed October 2018. www.grainger.com

3. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. Tetra Tech. "ACES Deemed Savings Desk Review." Table 1. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
5. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/
This report includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
6. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
Coincidence factor is within range of similar programs; see Table 4-1 showing multifamily housing (in unit) CF of 65% to 83%.

Revision History

Version Number	Date	Description of Change
01	10/19/2018	Initial TRM entry

ENERGY STAR LED Lamp Replacing < 23 Watt CFL

	Measure Details
Measure Master ID	LED Lamp, ENERGY STAR: Replacing < 23 Watt CFL, 3745, 3838 Replacing < 23 Watt CFL, In Unit, 3747
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by hours of use
Peak Demand Reduction (kW)	Varies by hours of use
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by hours of use
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Varies by sector
Incremental Cost ($/unit)	$0.99[4]

Measure Description

LED lamps save energy and increase rated life when replacing CFL products by providing a similar lumen output with lower input wattage.

Description of Baseline Condition

The baseline condition is the average wattage of ENERGY STAR-listed CFLs consuming < 23 watts.

Description of Efficient Condition

The efficient condition is the average wattage of ENERGY STAR-listed LEDs equivalent to ≤ 75 watt incandescent.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{LEDEE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Average wattage of ENERGY STAR-listed CFLs consuming < 23 watts (= 14 watts)[5]

$Watts_{LEDEE}$ = Energy efficient wattage; average wattage of ENERGY STAR-listed LEDs equivalent to ≤ 75 watt incandescent (= 8.9 watts)[6]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239
Multifamily - Common Area	5,950
Multifamily - In Unit	840

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{LED}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64
Multifamily - Common Area	0.77
Multifamily - In Unit	0.11

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= varies by sector; see table below)

Effective Useful Life by Sector

Sector	EUL
Commercial[1]	5 years
Industrial[1]	5 years
Agriculture[1]	5 years
Schools & Government[1]	5 years
Multifamily - Common Area[2]	4 years
Multifamily - In Unit[3]	15 years

Deemed Savings

Annual Savings - ENERGY STAR LED Lamp Replacing < 23 Watt CFL

Commercial		Industrial		Agriculture		Schools & Gov		Multifamily- Common Area		Multifamily – In Unit	
kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
19	0.0039	24	0.0039	24	0.0034	16	0.0033	30	0.0039	4	0.0006

Lifecycle Savings (kWh) - ENERGY STAR LED Lamp Replacing < 23 Watt CFL

Commercial	Industrial	Agriculture	Schools & Gov	Multifamily- Common Area	Multifamily – In Unit
95	120	120	80	120	60

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 3,453 omnidirectional and decorative LEDs is 21,787 hours. With a sector-averaged HOU of 4,103, the EUL is 5 years.
2. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 3,453 omnidirectional and decorative LEDs is 21,787 hours. With an HOU of 5,950, the EUL is 4 years.
3. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 3,453 omnidirectional and decorative LEDs is 21,787 hours. With an HOU of 840, the EUL is 26 years. However, a 15-year EUL cap has been deemed for most residential screw-base LED measures. This comes as a result of measure persistence concerns (http://www.neep.org/sites/default/files/resources/ResLightingDeeperDiveFINAL1.pdf) and LED lifetime cap practices of other programs (in Connecticut, Illinois, Massachusetts, Minnesota, Rhode Island, Vermont, and Washington DC).
4. August 2018 online lookups of four base and efficient models on www.1000bulbs.com, www.bulbs.com, www.lightbulbsupply.com, www.superiorlighting.com, www.ilighting.com, and www.topbulb.com show an average efficient lamp price of $2.88 and base lamp price of $1.89, for an incremental cost of $0.99.
5. ENERGY STAR product list. October 20, 2015.
6. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Table 3.2 Lighting Hours of Use in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
7. Tetra Tech. “ACES Deemed Savings Desk Review.” November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
   Multifamily Applications for Common Areas (5,949.5 annual operating hours based on 16.3 hours/day * 365 days/year).
8. Cadmus. Field Study Research of Residential Lighting. October 18, 2013. Results published in the 2014 Focus on Energy Deemed Savings Report: https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

9. Cadmus. Field Study Research: Residential Lighting (CFL and incandescent bulbs). October 25, 2013.
10. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
    Average rated life of 3,453 omnidirectional and decorative LEDs is 21787 hours. With a sector-averaged HOU of 4,103, the EUL is 5 years.

Revision History

Version Number	Date	Description of Change
01	10/20/2015	Initial TRM entry
02	10/2017	Updated EUL except 3747
03	12/2018	Updated incremental cost, removed MMID 3746

ENERGY STAR LED Lamp Replacing ≥ 23 Watt CFL

	Measure Details
Measure Master ID	LED Lamp, ENERGY STAR: Replacing ≥ 23 Watt CFL, 3742, 3837 Replacing ≥ 23 Watt CFL, Common Area, 3743 Replacing ≥ 23 Watt CFL, In Unit, 3744
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by hours of use
Peak Demand Reduction (kW)	Varies by hours of use
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by hours of use
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Varies by sector
Incremental Cost ($/unit)	$4.92[4]

Measure Description

LED lamps save energy and increase rated life when replacing CFL products by providing a similar lumen output with lower input wattage.

Description of Baseline Condition

The baseline condition is the average wattage of ENERGY STAR-listed CFLs consuming ≥ 23 watts.

Description of Efficient Condition

The efficient condition is the average wattage of ENERGY STAR-listed LEDs equivalent to > 75 watt incandescent.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{LEDEE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Average wattage of ENERGY STAR-listed CFLs consuming ≥ 23 watts (= 26 watts)[5]
$Watts_{LEDEE}$ = Energy efficient wattage; average wattage of ENERGY STAR-listed LEDs equivalent to > 75 watt incandescent (= 16.7 watts)[5]
1,000 = Kilowatt conversion factor
HOU = Hours of use (= varies by sector; see table below)

Hours of use by Sector

Sector	HOU[7]
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239
Multifamily - Common Area	5,950
Multifamily - In Unit	840

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{LEDEE}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF[6]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64
Multifamily - Common Area	0.77
Multifamily - In Unit	0.11

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= varies by sector; see table below)

Effective Useful Life by Sector

Sector	EUL
Commercial[1]	5 years
Industrial[1]	5 years
Agriculture[1]	5 years
Schools & Government[1]	5 years
Multifamily - Common Area[2]	4 years
Multifamily - In Unit[3]	15 years

Deemed Savings

Annual Savings - ENERGY STAR LED Lamp Replacing ≥ 23 Watt CFL

Commercial MMID 3742, 3837		Industrial MMID 3742, 3837		Agriculture MMID 3742, 3837		Schools & Gov MMID 3742, 3837		Multifamily – Common Area MMID 3743		Multifamily – In Unit MMID 3744	
kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
33	0.0069	42	0.0069	42	0.0060	29	0.0057	53	0.0069	7	0.0010

Lifecycle Savings (kWh) - ENERGY STAR LED Lamp Replacing ≥ 23 Watt CFL

Commercial MMID 3742, 3837	Industrial MMID 3742, 3837	Agriculture MMID 3742, 3837	Schools & Gov MMID 3742, 3837	Multifamily – Common Area MMID 3743	Multifamily – In Unit MMID 3744
165	210	210	145	212	105

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 3,453 omnidirectional and decorative LEDs is 21,787 hours. With a sector-averaged HOU of 4,103, the EUL is 5 years.

2. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 3,453 omnidirectional and decorative LEDs is 21,787 hours. With an HOU of 5,950, the EUL is four years.
3. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 3,453 omnidirectional and decorative LEDs is 21,787 hours. With an HOU of 840, the EUL is 26 years. However, a 15-year EUL cap has been deemed for most residential screw-base LED measures. This comes as a result of measure persistence concerns (http://www.neep.org/sites/default/files/resources/ResLightingDeeperDiveFINAL1.pdf) and LED lifetime cap practices of other programs (in Connecticut, Illinois, Massachusetts, Minnesota, Rhode Island, Vermont, and Washington DC).
4. August 2018 online lookups of four base and efficient models on www.1000bulbs.com, www.bulbs.com, www.lightbulbsupply.com, www.superiorlighting.com, www.ilighting.com, and www.topbulb.com show an average efficient lamp price of $8.18 and base lamp price of $3.26, for an incremental cost of $4.92.
5. ENERGY STAR product list. October 20, 2015.
6. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3.2 Lighting Hours of Use in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
7. Cadmus. Field Study Research of Residential Lighting. October 18, 2013. Results published in the 2014 Focus on Energy Deemed Savings Report: https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
8. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 3,453 omnidirectional and decorative LEDs is 21787 hours. With a sector-averaged HOU of 4,103, the EUL is 5 years.

Revision History

Version Number	Date	Description of Change
01	10/20/2015	Initial TRM entry
02	10/2017	Updated EULs

ENERGY STAR LED Replacing Exterior Directional CFL

	Measure Details
Measure Master ID	LED, ENERGY STAR, Replacing Exterior Directional CFL: ≥ 23 Watt CFL, 3929, 4630 14–22 Watt CFL, 3930, 4631 ≤ 13 Watt CFL, 3931, 4632
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	6[1]
Incremental Cost ($/unit)	≥ 23 watt CFL = $3.83 (MMID 3929); 14–22 watt CFL = $9.49 (MMID 3930); ≤ 13 watt CFL = $2.14 (MMID 3931)[2]

Measure Description

ENERGY STAR-listed LED replacement lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with compact fluorescent lamps (CFLs). This measure will provide an energy-efficient alternative to using CFLs in several applications.

Description of Baseline Condition

The baseline condition is ENERGY STAR-listed CFLs and their incandescent equivalencies based on certified products dated September 19, 2016.

Description of Efficient Condition

The efficient condition is an ENERGY STAR-listed LED lamp in the Directional lamp category, with incandescent and CFL equivalency determined by ENERGY STAR's product specification for lamps v2.0.[3]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000$

Where:

$Watts_{BASE}$ = Power consumption of CFL lamps (= varies by wattage equivalence; see table below)

Power Consumption of CFL Directional by Wattage Equivalence

Wattage Equivalence	Average Power Consumption of CFL Directional[4]
≥ 23 Watt CFL	23 Watts
14 Watt – 22 Watt CFL	16 Watts
≤ 13 Watt CFL	11 Watts

$Watts_{EE}$ = Power consumption of efficient LED lamp (= varies by wattage equivalence; see table below and Assumptions)

Power Consumption of LED Lamp by Wattage Equivalence

Wattage Equivalence	Average Power Consumption of LED Lamp[4]
≥ 23 Watt CFL	13.8 Watts
14 Watt – 22 Watt CFL	10.1 Watts
≤ 13 Watt CFL	6.9 Watts

HOU = Average annual run hours (= 4,380)[5]

1,000 = Kilowatt conversion factor

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1,000$

Where:

CF = Coincidence factor (= 0)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 6 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED Lamp Replacing CFL

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
		kWh	kWh	kWh	kWh	kWh
≥ 23 Watt CFL	3929	40	40	40	40	40
14 Watt – 22 Watt CFL	3930	24	24	24	24	24
≤ 13 Watt CFL	3931	18	18	18	18	18

Average Lifecycle Deemed Savings for LED Lamp Replacing CFL

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
		kWh	kWh	kWh	kWh	kWh
≥ 23 Watt CFL	3929	240	240	240	240	240
14 Watt – 22 Watt CFL	3930	144	144	144	144	144
≤ 13 Watt CFL	3931	108	108	108	108	108

Assumptions

LED equivalent wattages are an average of ENERGY STAR-listed products. ENERGY STAR provides equivalent wattages for LEDs and CFLs based on incandescent lamps. For these calculations, ENERGY STAR-listed CFLs in the directional lamp category were accessed by their reported incandescent equivalents, then those incandescent equivalents were converted to reported LED equivalents and averaged within each specified CFL range.

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 4,225 directional LEDs is 25,351 hours. With an HOU of 4,380, the EUL is six years.
2. Cost data obtained in November 2016 through various online lighting retailers. A full list can be provided upon request.
3. ENERGY STAR. “ENERGY STAR Program Requirements Product Specification for Lamps (Light Bulbs) Eligibility Criteria Version 2.0.” https://www.energystar.gov/sites/default/files/Lamps%20Version%202.0%20Updated%20Spec.pdf

4. "ENERGY STAR Light Bulbs Certified Product List." Accessed September 19, 2016. https://www.energystar.gov/productfinder/product/certified-light-bulbs/results
5. U.S. Department of Commerce National Oceanic and Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/

Revision History

Version Number	Date	Description of Change
01	11/10/2016	Initial TRM entry
02	10/2017	Updated EUL Source

ENERGY STAR LED Replacing Exterior Directional Incandescent

	Measure Details
Measure Master ID	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent: 120W – 250W Incandescent, 3935, 4633 100W – 119W Incandescent, 3936, 4634 75W – 99W Incandescent, 3937, 4635 55W – 74W Incandescent, 3938, 4636 36W – 54W Incandescent, 3939, 4637 ≤ 35W Incandescent, 3940, 4638
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	6[1]
Incremental Cost ($/unit)	$0.37 (MMID 3035); $2.85 (MMID 3036); $3.56 (MMID 3037); $4.57 (MMID 3038); $3.34 (MMID 3039); $4.93 (MMID 3040)[2]

Measure Description

ENERGY STAR-listed LED replacement lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with standard wattage incandescent lamps. This measure will provide an energy-efficient alternative to using incandescent lamps in several applications.

Description of Baseline Condition

The baseline condition is ENERGY STAR-listed incandescent equivalencies based on certified LED products dated September 19, 2016. Weighted averages were taken based on the number of equivalent products certified in each wattage bin to reflect the range of products available in the market. Full incandescent wattages are used based on reflector/directional lamps being exempt from EISA legislation.[3]

Description of Efficient Condition

The efficient condition is an ENERGY STAR-listed LED lamp in Directional lamp category, with incandescent equivalency determined by ENERGY STAR's product specification for lamps v2.0.[4] Weighted averages were taken based on the number of LED products certified in each wattage bin to reflect the range of products available in the market.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1{,}000$

Where:

$Watts_{BASE}$ = Power consumption of incandescent lamps (= varies by wattage equivalence; see table below)

Baseline Wattage by Wattage Equivalence

Wattage Equivalence	Weighted Average Power Consumption of Incandescent Directional[1]
120 Watts – 250 Watts	132 Watts
100 Watts – 119 Watts	100 Watts
75 Watts – 99 Watts	79 Watts
55 Watts – 74 Watts	64 Watts
36 Watts – 54 Watts	49 Watts
≤ 35 Watts	33 Watts

$Watts_{EE}$ = Power consumption of efficient LED lamp (= varies by wattage equivalence; see table below)

Efficient Wattage by Wattage Equivalence

Wattage Equivalence	Weighted Average Power Consumption of LED Lamp[1]
120 Watts – 250 Watts	18.3 Watts
100 Watts – 119 Watts	17.1 Watts
75 Watts – 99 Watts	13.8 Watts
55 Watts – 74 Watts	9.7 Watts
36 Watts – 54 Watts	7.6 Watts
≤ 35 Watts	6.5 Watts

HOU = Average annual run hours (= 4,380)[5]

1,000 = Kilowatt conversion factor

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1{,}000$

Where:

CF = Coincidence factor (= 0)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 6 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED Lamp Replacing Incandescent

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
		kWh	kWh	kWh	kWh	kWh
120 Watts – 250 Watts	3935	499	499	499	499	499
100 Watts – 119 Watts	3936	364	364	364	364	364
75 Watts – 99 Watts	3937	284	284	284	284	284
55 Watts – 74 Watts	3938	237	237	237	237	237
36 Watts – 54 Watts	3939	182	182	182	182	182
≤ 35 Watts	3940	114	114	114	114	114

Average Lifecycle Deemed Savings for LED Lamp Replacing Incandescent

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
		kWh	kWh	kWh	kWh	kWh
120 Watts – 250 Watts	3935	2,994	2,994	2,994	2,994	2,994
100 Watts – 119 Watts	3936	2,184	2,184	2,184	2,184	2,184
75 Watts – 99 Watts	3937	1,704	1,704	1,704	1,704	1,704
55 Watts – 74 Watts	3938	1,422	1,422	1,422	1,422	1,422
36 Watts – 54 Watts	3939	1,092	1,092	1,092	1,092	1,092
≤ 35 Watts	3940	684	684	684	684	684

Assumptions

Calculations are based on exterior lighting that operates 4,380 hours annually, 12 hours per day (dusk to dawn).

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 4,225 directional LEDs is 25,351 hours. With an HOU of 4,380, the EUL is 6 years.
2. 1000 Bulbs. Website. Accessed November 2016. www.1000bulbs.com
   Home Depot. Website. Accessed November 2016. www.homedepot.com
   Lowes. Website. Accessed November 2016. www.lowes.com
   Lightology. Website. Accessed November 2016. www.lightology.com
3. Lighting Facts. “The Energy Independence and Security Act (EISA) of 2007.” http://www.lightingfacts.com/Library/Content/EISA
4. ENERGY STAR. “ENERGY STAR® Program Requirements Product Specification for Lamps (Light Bulbs) Eligibility Criteria Version 2.0.” https://www.energystar.gov/sites/default/files/Lamps%20Version%202.0%20Updated%20Spec.pdf
5. U.S. Department of Commerce National Oceanic & Atmospheric Administration. “NOAA Solar Calculator.” http://www.esrl.noaa.gov/gmd/grad/solcalc/

Revision History

Version Number	Date	Description of Change
01	11/08/2017	Initial TRM Entry
02	10/2017	Updated EUL Source

ENERGY STAR LED Replacing Exterior Omnidirectional and Decorative Incandescent or CFL

	Measure Details
Measure Master ID	LED Lamp, ENERGY STAR, Exterior: 1,600 – 1,999 Lumens, 3947, 4639 1,100 – 1,599 Lumens, 3948, 4640 800 – 1,099 Lumens, 3949, 4641 450 – 799 Lumens, 3950, 4642 250 – 449 Lumens, 3951, 4643
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$11.40 (MMID 3947); $8.66 (MMID 3948); $3.61 (MMID 3949); $3.73 (MMID 3950); $5.87 (MMID 3951)[2]

Measure Description

ENERGY STAR-listed LED replacement lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with standard wattage incandescent and CFLs. This measure provides an energy-efficient alternative to using incandescents and CFLs in several applications.

Description of Baseline Condition

The baseline condition is a weighted average by number of incandescent lamps and CFLs installed in 2016.[3,4] EISA compliant 72-watt, 53-watt, 43-watt, 29-watt, and 25-watt incandescent lamps and 23.6-watt, 19-watt, 13.4-watt, 9.7-watt, and 7-watt CFLs were used in this calculation with respect to lumens.

Description of Efficient Condition

The efficient condition is an ENERGY STAR-listed LED lamp in either the Omnidirectional or Decorative lamp category, with incandescent and CFL equivalency determined by the ENERGY STAR product specification for lamps v2.0.[5]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000$

Where:

$Watts_{BASE}$ = Average power consumption of incandescent lamps and CFLs (= varies by lumens and sector; see table below)

Power Consumption of Incandescent Lamps and CFLs (Watts)

Lumens	Business[1]	Residential[1]
1,600 – 1,999	70.8	69.9
1,100 – 1,599	52.2	51.6
800 – 1,099	42.3	41.7
450 – 799	28.5	28.2
250 – 449	24.6	24.2

$Watts_{EE}$ = Average power consumption of efficient LED lamp (= varies by lumens; see table below)

Power Consumption of Efficient LED Lamp (Watts)

Lumens	Watts[1]
1,600 – 1,999	16.3
1,100 – 1,599	12.4
800 – 1,099	9.6
450 – 799	6.5
250 – 449	4.6

1,000 = Kilowatt conversion factor

HOU = Average annual run hours (= 4,380)[6]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1,000$

Where:

CF = Coincidence factor (= 0)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED Lamp Replacing Incandescent or CFL

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov.	Multifamily
		kWh	kWh	kWh	kWh	kWh
1,600 – 1,999 Lumens	3947	239	239	239	239	235
1,100 – 1,599 Lumens	3948	174	174	174	174	172
800 – 1,099 Lumens	3949	143	143	143	143	141
450 – 799 Lumens	3950	96	96	96	96	95
250 – 449 Lumens	3951	87	87	87	87	86

Average Lifecycle Deemed Savings for LED Lamp Replacing Incandescent or CFL

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov.	Multifamily
		kWh	kWh	kWh	kWh	kWh
1,600 – 1,999 Lumens	3947	1,195	1,195	1,195	1,195	1,175
1,100 – 1,599 Lumens	3948	870	870	870	870	860
800 – 1,099 Lumens	3949	715	715	715	715	705
450 – 799 Lumens	3950	480	480	480	480	475
250 – 449 Lumens	3951	435	435	435	435	430

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017.
   https://www.energystar.gov/productfinder/
   Average rated life of 3,453 omnidirectional and decorative LEDs is 21,787 hours. With an HOU of 4,380, the EUL is 5 years.
2. 1000 Bulbs. Website. Accessed November 2016. www.1000bulbs.com
   Home Depot. Website. Accessed November 2016. www.homedepot.com
   LightBulbs.com. Website. Accessed November 2016. www.lightbulbs.com
   Wal-Mart. Website. Accessed November 2016. www.walmart.com
   Amazon. Website. Accessed November 2016. www.amazon.com

3. Historical Focus on Energy project data for Business Incentive and Chain Stores and Franchise programs. January 1, 2016 through October 24, 2016.
   Analyzed actual units installed for 2,294 projects, consisting of MMIDs 3112, 3113, 3742, and 3745. Determined percentage of lighting technology by total units installed as 2.5% CFL and 97.5% incandescent.
4. Historical Focus on Energy project data for Multifamily Energy Savings Program. January 1, 2016 through November 3, 2016.
   225 projects, consisting of MMIDs 3160, 3162, 3743, and 3746. Analyzed actual units installed and determined percentage of lighting technology by total units installed as 4.24% CFL and 95.76% incandescent.
5. ENERGY STAR. "ENERGY STAR® Program Requirements Product Specification for Lamps (Light Bulbs) Eligibility Criteria Version 2.0." https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Lamps%20V2%20Revised%20Spec.pdf
6. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/

Revision History

Version Number	Date	Description of Change
01	11/15/2016	Initial TRM entry
02	10/2017	Updated EUL

ENERGY STAR LED Replacing Interior Directional CFL

	Measure Details
Measure Master ID	LED Lamp, ENERGY STAR, Replacing Interior Directional CFL: ≥ 23 Watt CFL, 3932 14–22 Watt CFL, 3933 ≤ 13 Watt CFL, 3934 ≥ 23 Watt CFL in-unit, 4024 14–22 Watt CFL in-unit, 4025 ≤ 13 Watt CFL in-unit, 4026
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	business sectors and multifamily common areas = 6 (MMIDs 3932, 3933, and 3934);[1] multifamily in-unit = 15 (MMIDs 4024, 4025, and 4026)[8]
Incremental Cost ($/unit)	≥ 23 watt CFL = $3.83 (MMIDs 3932 and 4024) 14–22 watt CFL = $9.49 (MMIDs 3933 and 4025) ≤ 13 watt CFL = $2.14 (MMIDs 3934 and 4026)[2]

Measure Description

ENERGY STAR-listed LED replacement lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with compact fluorescent lamps (CFLs). This measure will provide an energy-efficient alternative to using CFL lamps in several applications.

Description of Baseline Condition

The baseline condition is ENERGY STAR-listed directional CFLs and their incandescent equivalencies based on certified products dated September 19, 2016.

Description of Efficient Condition

The efficient condition is an ENERGY STAR-listed LED lamp in the Directional lamp category, with incandescent and CFL equivalency determined by ENERGY STAR's product specification for lamps v2.0.[3]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) * HOU / 1{,}000$

Where:

$Watts_{BASE}$ = Power consumption of CFLs (= varies by wattage equivalence; see table below)

Power Consumption of CFL Directional by Wattage Equivalence

Wattage Equivalence	Average Power Consumption of CFL Directional[1]
≥ 23 Watt CFL	23 Watts
14 Watt – 22 Watt CFL	16 Watts
≤ 13 Watt CFL	11 Watts

$Watts_{EE}$ = Power consumption of efficient LED lamp (= varies by wattage equivalence; see table below)

Power Consumption of LED Directional by Wattage Equivalence

Wattage Equivalence	Average Power Consumption of LED Directional Lamp[1]
≥ 23 Watt CFL	13.8 Watts
14 Watt – 22 Watt CFL	10.1 Watts
≤ 13 Watt CFL	6.9 Watts

HOU = Average annual hours of use (= varies by sector; see table below)

Annual Hours of Use by Sector

Sector	HOU
Commercial[5]	3,730
Industrial[5]	4,745
Agriculture[5]	4,698
Schools & Government[5]	3,239
Multifamily – Common Area[6]	5,950
Multifamily – In Unit[7]	734

1,000 = Kilowatt conversion factor

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1,000$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[5]	0.77
Industrial[5]	0.77
Agriculture[5]	0.67
Schools & Government[5]	0.64
Multifamily[8]	0.77
Multifamily – In Unit[9]	0.055

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 6 years for business sectors and multifamily common area;[1] = 15 years for multifamily in-unit)[8]

Deemed Savings

Average Annual Deemed Savings for LED Lamp Replacing CFL

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
≥ 23 Watt CFL	3932	34	0.0071	44	0.0071	43	0.0062	30	0.0059
14 Watt – 22 Watt CFL	**3933**	**21**	**0.0042**	**26**	**0.0042**	**26**	**0.0037**	**18**	**0.0035**
≤ 13 Watt CFL	3934	15	0.0032	19	0.0032	19	0.0027	13	0.0026

Measure	MMID	Multifamily – Common Area		Multifamily – In Unit	
		kWh	kW	kWh	kW
≥ 23 Watt CFL	3932	55	0.0071	-	-
	4024	-	-	7	0.0005
14 Watt – 22 Watt CFL	**3933**	**33**	**0.0042**	**-**	**-**
	4025	**-**	**-**	**4**	**0.0003**
≤ 13 Watt CFL	3934	24	0.0032	-	-
	4026	-	-	3	0.0002

Average Lifecycle Deemed Savings for LED Lamp Replacing CFL

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily – Common Area	Multifamily – In Unit
		kWh	kWh	kWh	kWh	kWh	kWh
≥ 23 Watt CFL	3932	204	264	258	180	330	-
	4024	-	-	-	-	-	105
14 Watt – 22 Watt CFL	**3933**	**126**	**156**	**156**	**108**	**198**	**-**
	4025	**-**	**-**	**-**	**-**	**-**	**60**
≤ 13 Watt CFL	3934	90	114	114	78	144	-
	4026	-	-	-	-	-	45

Assumptions

LED equivalent wattages are an average of ENERGY STAR-listed products. ENERGY STAR provides equivalent wattages for LEDs and CFLs based on incandescent lamps. For these calculations, ENERGY STAR-listed CFLs in the directional lamp category were accessed by their reported incandescent equivalents, then those incandescent equivalents were converted to reported LED equivalents, averaging within each specified CFL range.

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 4,225 directional LEDs is 25,351 hours. With a sector-averaged HOU of 4,472, the EUL is 6 years.
2. 1000 Bulbs. Website. Accessed November 2016. www.1000bulbs.com
   Home Depot. Website. Accessed November 2016. www.homedepot.com
   Wal-Mart. Website. Accessed November 2016. www.walmart.com

3. ENERGY STAR. "ENERGY STAR® Program Requirements Product Specification for Lamps (Light Bulbs) Eligibility Criteria Version 2.0." https://www.energystar.gov/sites/default/files/Lamps%20Version%202.0%20Updated%20Spec.pdf
4. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Updated March 22, 2010. Table 3.2 Lighting Hours of Use in Commercial Applications. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. "ACES Deemed Savings Desk Review." November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
   Table 1 lists 16.3 hours per day for multifamily common areas.
6. Cadmus. "Focus on Energy Evaluated Deemed Savings Changes." November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
   2.01 hours per day for multifamily housing.
   Coincidence factor of 5.5% found for multifamily housing.
7. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs; see Table 4-1 showing multifamily housing (in unit) CF of 65% to 83%.
8. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 4,225 directional LEDs is 25,351 hours. With an HOU of 734, the EUL is 35 years. However, a 15-year EUL cap has been deemed for most residential screw-base LED measures. This comes as a result of measure persistence concerns (http://www.neep.org/sites/default/files/resources/ResLightingDeeperDiveFINAL1.pdf) and LED lifetime cap practices of other programs (in Connecticut, Illinois, Massachusetts, Minnesota, Rhode Island, Vermont, and Washington DC).

Revision History

Version Number	Date	Description of Change
01	11/10/2016	Initial TRM entry
02	04/2017	Added MMIDs 4078, 4079, and 4080
03	10/2017	Updated EUL Source
04	01/2019	Removed MMIDs 4078, 4079, and 4080

ENERGY STAR LED Replacing Interior Directional Incandescent

	Measure Details
Measure Master ID	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent: 120W – 250W Incandescent, 3941 100W – 119W Incandescent, 3942 75W – 99W Incandescent, 3943 55W – 74W Incandescent, 3944 36W – 54W Incandescent, 3945 ≤ 35W Incandescent, 3946 120W – 250W Incandescent, In Unit, 4027 100W – 119W Incandescent, In Unit, 4028 75W – 99W Incandescent, In Unit, 4029 55W – 74W Incandescent, In Unit, 4030 36W – 54W Incandescent, In Unit, 4031 ≤ 35W Incandescent, In Unit, 4032 BR30, Pack-Based, 4685
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Business sectors and multifamily common area = 6 (MMIDs 3941, 3942, 3943, 3944, 3945, and 3946)[1] Multifamily in-unit = 15 (MMIDs 4027, 4028, 4029, 4030, 4031, and 4032)[9] Pack-based = 4685
Incremental Cost ($/unit)	120W – 250W = $0.10 (MMIDs 3941 and 4027); 100W – 119W = $2.45 (MMIDs 3942 and 4028); 75W – 99W = $2.99 (MMIDs 3493 and 4029); 55W – 74W = $3.44 (MMIDs 3944 and 4030); 36W – 54W = $2.42 (MMIDs 3945 and 4031); ≤ 35W = $3.59 (MMIDs 3496 and 4032);[2] Pack-based = $4.15 (MMID 4685)[10]

Measure Description

ENERGY STAR-listed LED replacement lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with standard wattage incandescent lamps. This measure will provide an energy-efficient alternative to using incandescent lamps in several applications.

Description of Baseline Condition

The baseline condition is ENERGY STAR-listed incandescent equivalencies based on certified LED products dated September 19, 2016. Weighted averages were taken based on the number of equivalent products certified in each wattage bin to reflect the range of products available in the market. Full incandescent wattages are used based on reflector/directional lamps being exempt from EISA legislation.[3]

Description of Efficient Condition

The efficient condition is an ENERGY STAR-listed LED lamp in the Directional lamp category, with incandescent equivalency determined by ENERGY STAR’s product specification for lamps v2.0.[4] Weighted averages were taken based on the number of LED products certified in each wattage bin to reflect the range of products available in the market.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU * ISR / 1,000$

Where:

$Watts_{BASE}$ = Power consumption of incandescent lamps (= varies for prescriptive measures, see table below; = 49.2 watts for MMID 4685)

Baseline Wattage by Wattage Equivalence

Wattage Equivalence	Weighted Average Power Consumption of Incandescent Directional[1]
120 Watts – 250 Watts	132.2 Watts
100 Watts – 119 Watts	100.2 Watts
75 Watts – 99 Watts	78.6 Watts
55 Watts – 74 Watts	63.9 Watts
36 Watts – 54 Watts	49.2 Watts
≤ 35 Watts	32.5 Watts

$Watts_{EE}$ = Power consumption of efficient LED lamp (= varies for prescriptive measures, see table below; = 8 watts for MMID 4685[11])

Efficient Wattage by Wattage Equivalence

Wattage Equivalence	Weighted Average Power Consumption of LED Lamp[1]
120 Watts – 250 Watts	18.3 Watts
100 Watts – 119 Watts	17.1 Watts
75 Watts – 99 Watts	13.8 Watts
55 Watts – 74 Watts	9.7 Watts
36 Watts – 54 Watts	7.6 Watts
≤ 35 Watts	6.5 Watts

HOU = Average annual hours of use (= varies by sector, see table below)

Hours of Use by Sector

Sector	HOU
Commercial[6]	3,730
Industrial[6]	4,745
Agriculture[6]	4,698
Schools & Government[6]	3,239
Multifamily[7]	5,950
Multifamily – In Unit[8]	734

ISR = In-service rate (= 1 for non-pack-based measures, = 0.83 for MMID 4685[12])

1,000 = Kilowatt conversion factor

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1{,}000 * ISR$

Where:

CF = Coincidence factor (= varies by sector, see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[6]	0.77
Industrial[6]	0.77
Agriculture[6]	0.67
Schools & Government[6]	0.64
Multifamily[7]	0.77
Multifamily – In Unit[10]	0.055

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 6 years for business sectors and multifamily common area,[1] = 15 years for multifamily in-unit)[9]

Deemed Savings

Average Annual Deemed Savings for LED Lamp Replacing Incandescent, Non-Res

Measure	MMIDs	Commercial		Industrial		Agriculture		Schools & Gov	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
120 – 250 Watts	3941	425	0.0877	540	0.0877	535	0.0763	369	0.0729
100 – 119 Watts	3942	310	0.0640	394	0.0640	390	0.0557	269	0.0532
75 – 99 Watts	3943	242	0.0499	308	0.0499	305	0.0434	210	0.0415
55 – 74 Watts	3944	202	0.0417	257	0.0417	254	0.0363	175	0.0347
36– 54 Watts	3945	155	0.0320	197	0.0320	195	0.0279	135	0.0266
≤ 35 Watts	3946	97	0.0201	124	0.0201	122	0.0174	84	0.0167
BR30, Pack-Based	4685	128	0.0263	162	0.0263	--	--	--	--

Average Annual Deemed Savings for LED Lamp Replacing Incandescent, Multifamily

Measure	MMID	Multifamily – Common Area		Multifamily – In Unit	
		kWh	kW	kWh	kW
120 Watts – 250 Watts	3941	677	0.0877	--	--
	4027	--	--	84	0.0063
100 Watts – 119 Watts	3942	494	0.0640	--	--
	4028	--	--	61	0.0046
75 Watts – 99 Watts	3943	386	0.0499	--	--
	4029	--	--	48	0.0036
55 Watts – 74 Watts	3944	322	0.0417	--	--
	4030	--	--	40	0.0030
36 Watts – 54 Watts	3945	247	0.0320	--	--
	4031	--	--	31	0.0023
≤ 35 Watts	3946	155	0.0201	--	--
	4032	--	--	19	0.0014
BR30, Pack-Based	4685	--	--	--	--

Average Lifecycle Deemed Savings for LED Lamp Replacing Incandescent (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily – Common Area	Multifamily – In Unit
120 – 250 Watts	3941	2,550	3,240	3,210	2,214	4,062	--
	4027	--	--	--	--	--	1,260
100 – 119 Watts	3942	1,860	2,364	2,340	1,614	2,964	--
	4028	--	--	--	--	--	915
75 – 99 Watts	3943	1,452	1,848	1,830	1,260	2,316	--
	4029	--	--	--	--	--	720
55 – 74 Watts	3944	1,212	1,542	1,524	1,050	1,932	--
	4030	--	--	--	--	--	600
36 – 54 Watts	3945	930	1,182	1,170	810	1,482	--
	4031	--	--	--	--	--	465
≤ 35 Watts	3946	582	744	732	504	930	--
	4032	--	--	--	--	--	285
BR30, Pack-Based	4685	768	972	--	--	--	--

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 4,225 directional LEDs is 25,351 hours. With a sector-averaged HOU of 4,472, the EUL is six years.
2. 1000 Bulbs. Website. Accessed July 2018. www.1000bulbs.com
   Home Depot. Website. Accessed July 2018. www.homedepot.com
   Wal-Mart. Website. Accessed July 2018. www.walmart.com
3. Lighting Facts. “The Energy Independence and Security Act (EISA) of 2007.” http://www.lightingfacts.com/Library/Content/EISA
4. ENERGY STAR. “ENERGY STAR® Program Requirements Product Specification for Lamps (Light Bulbs) Eligibility Criteria Version 2.0.” Last modified February 2016. https://www.energystar.gov/sites/default/files/Lamps%20Version%202.0%20Updated%20Spec.pdf
5. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Updated March 22, 2010. Table 3.2 Lighting Hours of Use in Commercial Applications. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. Tetra Tech. “ACES Deemed Savings Desk Review.” November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
   Table 1 lists 16.3 hours per day for multifamily common areas.
7. Cadmus. “Focus on Energy Evaluated Deemed Savings Changes.” November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
   2.01 hours per day for multifamily housing.
   Coincidence factor of 5.5% found for multifamily housing.
8. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review.” Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs; see Table 4-1 showing multifamily housing (in unit) CF of 65% to 83%.
9. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 4,225 directional LEDs is 25,351 hours. With an HOU of 734, the calculated

life is 35 years. However, a 15-year EUL cap has been deemed for most residential screw-base LED measures. This comes as a result of measure persistence concerns (http://www.neep.org/sites/default/files/resources/ResLightingDeeperDiveFINAL1.pdf) and LED lifetime cap practices of other programs (in Connecticut, Illinois, Massachusetts, Minnesota, Rhode Island, Vermont, and Washington DC).

10. AM Conservation Group. Price quote for Focus on Energy program. March 2018.
11. AM Conservation. Website. Accessed March 19, 2018. http://www.amconservationgroup.com/products/energy-efficient-lighting/led-br30d-lamp/?variation_id=10231
    Lamp to be used is same model, but 4,000 K color temperature instead of 2,700 K as shown on specification sheet.
12. Navigant. *ComEd Rural Small Business Energy Efficiency Kits IPA Program Impact Evaluation Report*. August 1, 2018. Table 7-1. http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY9_Evaluation_Reports_Final/ComEd_PY9_Rural_SB_EE_Kits_IPA_Program_Impact_Evaluation_Report_2018-08-01.pdf
    Average of ISR values for office (0.75), restaurant (0.86), and retail (0.87) sites used.

Revision History

Version Number	Date	Description of Change
01	11/08/2016	Initial TRM entry
02	04/2017	Added MMIDs 4082–4086
03	10/2017	Updated EUL
04	3/19/2018	Added MMID 4685
05	12/2018	Updated costs, removed MMIDs 4081 – 4086, added MMID 4685

ENERGY STAR LED Replacing Omnidirectional and Decorative Incandescent or CFL

	Measure Details
Measure Master ID	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incandescent or CFL: 1,600 – 1,999 Lumens, 3952 1,100 – 1,599 Lumens, 3953 800 – 1,099 Lumens, 3954 450 – 799 Lumens, 3955 250 – 449 Lumens, 3956 1,600 – 1,999 Lumens In-Unit, 3957 1,100 – 1,599 Lumens In-Unit, 3958 800 – 1,099 Lumens In-Unit, 3959 450 – 799 Lumens In-Unit, 3960 250 – 449 Lumens In-Unit, 3961 800 Lumens, Pack-Based, 4686
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Business and multifamily common areas = 5;[1] Multifamily in-unit = 15[11]
Measure Incremental Cost ($/unit)	1,600 – 1,999 Lumens = $11.40 (MMIDs 3952, 3957);[2] 1,100 – 1,599 Lumens = $8.66 (MMIDs 3953, 3958);[2] 800 – 1,099 Lumens = $3.61 (MMIDs 3954, 3959);[2] 450 – 799 Lumens = $3.73 (MMIDs 3955, 3960);[2] 250 – 449 Lumens = $5.87 (MMIDs 3956, 3961);[2] 800 Lumens, Pack-Based = $2.75 (MMID 4686)[3]

Measure Description

ENERGY STAR-listed LED replacement lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with standard wattage incandescents and CFLs. This measure provides an energy-efficient alternative to using incandescents and CFLs in several applications.

Description of Baseline Condition

The baseline condition is a weighted average by number of incandescent lamps and CFLs installed for 2016 and 2017.[2] EISA-compliant 72-watt, 53-watt, 43-watt, 29-watt, and 25-watt incandescent lamps and 23.6-watt, 19-watt, 13.4-watt, 9.7-watt, and 7-watt CFLs were used in calculation with respect to lumens.

Description of Efficient Condition

The efficient condition is an ENERGY STAR-listed LED lamp in either the Omnidirectional or Decorative lamp category, with incandescent and CFL equivalency determined by ENERGY STAR's product specification for lamps v2.0.[4] Pack-based LED lamps have specific lumens and wattages; therefore, they exist as a separate measure.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000 * ISR$

Where:

$Watts_{BASE}$ = Power consumption of incandescent lamps and CFLs (= varies by number of lumens; see table below)

Baseline Wattage by Lumens

Lumens	Power Consumption of Incandescent Lamps and CFLs (watts)[1]	
	Business	Residential
1,600 – 1,999	67.5	66.8
1,100 – 1,599	49.9	49.4
800 – 1,099	40.3	39.8
450 – 799	27.2	26.9
250 – 449	23.3	23.1

$Watts_{EE}$ = Power consumption of efficient LED lamp (= varies by number of lumens; see table below)

Efficient Wattage by Lumens

Lumens	MMID	Power Consumption of Efficient LED Lamp
1,600 – 1,999[1]	3952, 3957	16.3 watts
1,100 – 1,599[1]	3953, 3958	12.4 watts
800 – 1,099[1]	3954, 3959	9.6 watts
800, Pack-Based[5]	4686	9.0 watts
450 – 799[1]	3955, 3960	6.5 watts
250 – 449[1]	3956, 3961	4.6 watts

HOU = Average annual hours of use (= varies by sector; see table below)

Hour of Use by Sector

Sector	HOU
Commercial[6]	3,730
Industrial[6]	4,745
Agriculture[6]	4,698
Schools & Government[6]	3,239
Multifamily[7]	5,950
Multifamily – In Unit[8]	734

1,000 = Kilowatt conversion factor

ISR = In-service rate (= 1 for prescriptive measures; = 0.83 for pack-based measures)[9]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1{,}000 * ISR$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[6]	0.77
Industrial[6]	0.77
Agriculture[6]	0.67
Schools & Government[6]	0.64
Multifamily[8]	0.77
Multifamily – In Unit[10]	0.055

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years for business sectors and multifamily common area;[1] = 15 years for multifamily in-unit[11])

Deemed Savings

Average Annual Deemed Savings for LED Lamp Replacing Incandescent or CFL, Non-Res

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
1,600 – 1,999 Lumens	3952	191	0.0395	243	0.0395	241	0.0343	166	0.0328
1,100 – 1,599 Lumens	3953	140	0.0289	178	0.0289	176	0.0251	121	0.0240
800 – 1,099 Lumens	3954	114	0.0236	146	0.0236	144	0.0206	99	0.0196
800 Lumens, Pack Based	4686	97	0.0200	123	0.0200	N/A	N/A	N/A	N/A
450 – 799 Lumens	3955	77	0.0160	98	0.0160	97	0.0139	67	0.0133
250 – 449 Lumens	3956	70	0.0144	89	0.0144	88	0.0126	61	0.0120

Average Annual Deemed Savings for LED Lamp Replacing Incandescent or CFL, Multifamily

Measure	MMID	Multifamily Common Area		Multifamily In Unit	
		kWh	kW	kWh	kW
1,600 – 1,999 Lumens	3952	301	0.0389	N/A	N/A
	3957	N/A	N/A	37	0.0028
1,100 – 1,599 Lumens	3953	220	0.0285	N/A	N/A
	3958	N/A	N/A	27	0.0020
800 – 1,099 Lumens	3954	180	0.0233	N/A	N/A
	3959	N/A	N/A	22	0.0017
450 – 799 Lumens	3955	122	0.0157	N/A	N/A
	3960	N/A	N/A	15	0.0011
250 – 449 Lumens	3956	110	0.0142	N/A	N/A
	3961	N/A	N/A	14	0.0010

Average Lifecycle Deemed Savings for LED Lamp Replacing Incandescent or CFL (kWh)

Measure	MMID	Comm.	Indust.	Agricul.	Schools & Gov	Multifamily Common Area	Multifamily In Unit
1,600 – 1,999 Lumens	3952	955	1,215	1,205	830	1,505	N/A
	3957	N/A	N/A	N/A	N/A	N/A	555
1,100 – 1,599 Lumens	3953	700	890	880	605	1,100	N/A
	3958	N/A	N/A	N/A	N/A	N/A	405
800 – 1,099 Lumens	3954	570	730	720	495	900	N/A
	3959	N/A	N/A	N/A	N/A	N/A	330
800 Lumens, Pack Based	4686	485	615	N/A	N/A	N/A	N/A
450 – 799 Lumens	395	385	490	485	335	610	N/A
	3960	N/A	N/A	N/A	N/A	N/A	225
250 – 449 Lumens	3956	350	445	440	305	550	N/A
	3961	N/A	N/A	N/A	N/A	N/A	210

Assumptions

The pack-based measure uses a commercial value of 3,730 HOU and an industrial value of 4,745 HOU.

Sources

1. ENERGY STAR Qualified Product List. Accessed March 2018. https://www.energystar.gov/productfinder/
   Average rated life of 3,400 omnidirectional and decorative LEDs is 20,572 hours. With an average HOU of 3,849, the EUL is five years.
2. Historical Focus on Energy project data. SPECTRUM. January 1, 2016 to December 31, 2017. Business Incentive, Chain Stores and Franchise, Ag School and Government, and Large Energy User programs had 1,234 projects, consisting of MMIDs 3112, 3113, 3742, and 3745. Data analysis of actual units installed revealed percentage of lighting technology by total units installed of 9.2% for CFLs and 90.8% for incandescents.
   Multifamily Energy Savings Program had 279 projects, consisting of MMIDs 3160, 3162, 3743, and 3746. Data analysis of actual units installed revealed percentage of lighting technology by total units installed of 10.7% for CFLs and 89.3% for incandescents.
3. Quote from Resource Action Programs.
4. ENERGY STAR. "ENERGY STAR® Program Requirements Product Specification for Lamps (Light Bulbs) Eligibility Criteria Version 2.0." Last modified February 2016. https://www.energystar.gov/sites/default/files/Lamps%20Version%202.0%20Updated%20Spec.pdf
5. AM Conservation. "LED A19 Lamp - 9 Watts." Accessed March 16, 2018. http://www.amconservationgroup.com/products/energy-efficient-lighting/led-dimmable-a19-2700k-lamps-enclosed-fixtures/?variation_id=10304
6. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Updated March 22, 2010. Table 3-2 Lighting Hours of Use in Commercial Applications. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
7. Tetra Tech. "ACES Deemed Savings Desk Review." November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
   Table 1 lists 16.3 hours per day for multifamily common areas.
8. Cadmus. "Focus on Energy Evaluated Deemed Savings Changes." November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
   2.01 hours per day for multifamily housing.
   Coincidence factor of 5.5% found for multifamily housing.
9. Navigant. *ComEd Rural Small Business Energy Efficiency Kits IPA Program Impact Evaluation Report*. August 1, 2018. http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY9_Evaluation_Reports

_Final/ComEd_PY9_Rural_SB_EE_Kits_IPA_Program_Impact_Evaluation_Report_2018-08-01.pdf
Table 7-1. Average of ISR values for office (0.75), restaurant (0.86), and retail (0.87) sites used.

10. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review.” Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
Coincidence factor is within range of similar programs; see Table 4-1 showing multifamily housing CF of 65% to 83%.
11. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
Average rated life of 3,453 omnidirectional and decorative LEDs is 21,787 hours. With an HOU of 734, the calculated EUL is 30 years. However, a 15-year EUL cap has been deemed for most residential screw-base LED measures. This comes as a result of measure persistence concerns (http://www.neep.org/sites/default/files/resources/ResLightingDeeperDiveFINAL1.pdf) and LED lifetime cap practices of other programs (in Connecticut, Illinois, Massachusetts, Minnesota, Rhode Island, Vermont, and Washington DC).

Revision History

Version Number	Date	Description of Change
01		Initial TRM entry
02	04/2017	Added MMIDs 4087–4091
03	10/2017	Updated EUL
04	03/2018	Added MMID 4686

Exterior Lighting Optimization (ELO)

	Measure Details
Measure Master ID	ELO, LED: DLC Outdoor – Low Output ≤ 4,999 lumens, 4339 With Networked Lighting Control, 4340 DLC Outdoor – Mid Output 5,000 – 9,999 lumens, 4341 With Networked Lighting Control, 4342 DLC Outdoor – High Output 10,000 – 29,999 lumens, 4343 With Networked Lighting Control, 4344 DLC Outdoor – Very High Output ≥ 30,000 lumens, 4345 With Networked Lighting Control, 4346
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Schools & Government, Agricultural, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	N/A
Annual Therm Savings (Therms)	N/A
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	N/A
Water Savings (gal/yr)	N/A
Effective Useful Life (years)	Without networked lighting control = 12 (MMIDs 4339, 4341, 4343, and 4345); with networked lighting control = 20 (MMIDs 4340, 4342, 4344, and 4346)[1]
Measure Incremental Cost ($/unit)	Varies by measure, see table below

Measure Description

Exterior Lighting Optimization (ELO) measures offer energy-efficient LED upgrade choices for replacing or retrofitting qualifying exterior luminaires. The ELO measures are structured in a format that supplies annual savings and set measure cost information for end users.

Description of Baseline Condition

ELO measures target the replacement or retrofit of the baseline condition, which is 100-watt to 1,000-watt HID systems that currently operate 4,380 hours per year. Fixtures must be exterior pole mount, wall mount, or fuel pump canopy mount where the head of the fixture is a minimum of 15-feet above finished grade.

Description of Efficient Condition

The efficient condition is DLC-listed LED fixtures or retrofit. When applicable, facilities may also choose to incorporate a DLC-listed networked lighting control (NLC) system capturing additional control savings.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = [(Watts_{HID} * HOU_{HID}) – (Watts_{ELO} * HOU_{ELO})] / 1{,}000$

Where:

$Watts_{HID}$ = Average power consumption of baseline measure (= 1,079 watts, 546 watts, 227 watts, and 116 watts)[3]

HOU_{HID} = Average annual run hours of baseline measure (= 4,380)[5]

$Watts_{ELO}$ = Average power consumption of efficient LED upgrade (354 watts, 150 watts, 72 watts, and 35 watts)[4]

HOU_{ELO} = Average annual run hours of efficient LED upgrade (= 4,380 for fixtures without controls; = 2,190 for fixture upgrade with controls; see the Assumptions section)

1,000 = Kilowatt conversion factor

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for ELO measures.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 12 years for standard measures; =20 years for measures with NLC)[1]

Annual and Lifecycle Energy Savings

Measure Description	MMID	Annual kWh Savings	Lifecycle kWh Savings
DLC Outdoor – Low Output ≤ 4,999 lumens	4339	355	4,260
DLC Outdoor – Low Output ≤ 4,999 lumens w/NLC	4340	416	8,320
DLC Outdoor – Mid Output 5,000 – 9,999 lumens	4341	679	8,148
DLC Outdoor – Mid Output 5,000 – 9,999 lumens w/NLC	4342	807	16,140
DLC Outdoor – High Output 10,000 – 29,999 lumens	4343	1,733	20,796
DLC Outdoor – High Output 10,000 – 29,999 lumens w/NLC	4344	1,996	39,920
DLC Outdoor – Very High Output ≥ 30,000 lumens	4345	3,176	38,112
DLC Outdoor – Very High Output ≥ 30,000 lumens w/NLC	4346	3,796	75,920

Assumptions

Options that include NLCs can have up to 75% in energy savings when coupled with a luminaire.[6] An estimate of 50% in burn hour reduction is used. This is more than the 40% savings assumed for integrated timer or wirelessly scheduled controls (MMID 3253) because NLC systems may incorporate additional strategies like occupancy sensing, high-end trim, and continuous dimming.

All labor data gathered to build the table below of Installed Measure Cost for LED systems is based on 2012 and 2013 data gathered from installation contractors from all four geographical quadrants of the Focus on Energy program territory. Of 40 installation parties contacted, 12 respondents completed the questionnaire in time to be included in the dataset used. Internet pricing data, accessed in August 2015 from a variety of sources, was used for LED materials, some HID ballasts, controls sockets, and photocell and timer controls. Products selected were randomly chosen based on meeting the measure definitions.

Installed Measure Cost

LED Fixture of Retrofit Measures	Incremental Cost[2]	Estimated Labor[2]
DLC Outdoor – Low Output ≤ 4,999 lumens	$129.76	$99
DLC Outdoor – Low Output ≤ 4,999 lumens w/NLC	$370.76	$99
DLC Outdoor – Mid Output 5,000 – 9,999 lumens	$354.90	$99
DLC Outdoor – Mid Output 5,000 – 9,999 lumens w/NLC	$595.90	$99
DLC Outdoor – High Output 10,000 – 29,999 lumens	$589.43	$99
DLC Outdoor – High Output 10,000 – 29,999 lumens w/NLC	$830.43	$99
DLC Outdoor – Very High Output ≥ 30,000 lumens	$720.89	$99
DLC Outdoor – Very High Output ≥ 30,000 lumens w/NLC	$961.89	$99

Sources

1. DesignLights Consortium. *Qualified Product List*. Accessed August 2017. https://www.designlights.org/search
   Average rated life of models participating in linear LED measures is 54,123 hours. With an HOU of 4,380 for standard fixtures, the EUL is 12 years. With an HOU of 2,190 for fixtures with NLC, calculated lifetime is 24 years. Lighting EULs are capped at 20 years.
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 207 units in 2018 for MMID 4339. Average cost of 207 units over 17 projects in 2018 for MMID 4340. Average cost of 95 units over 20 projects in 2018 for MMID 4341. Average cost of 95 units over 20 projects in 2018 for MMID 4342. Average cost of 238 units over 16 projects in 2018 for MMID 4343. Average cost of 238 units over 16 projects in 2018 for MMID 4344. Average cost of 133 units over seven projects in 2018 for MMID 4345. Average cost of 133 units over seven projects in 2018 for MMID 4346. Labor data gathered from 12 installation contractors in 2012 and 2013.
3. *Focus on Energy Default Wattage Guide*. Version 1.0. 2013.
4. SPECTRUM. Measure participation data from January 2017 through Novemer 2017 shows that the average participating models are 35 watts, 72 watts, 150 watts, and 354 watts for MMIDs 3099, 3110, and 3407, with respect to lumen output.
5. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. *NOAA Solar Calculator.* http://www.esrl.noaa.gov/gmd/grad/solcalc/
   This also includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
6. U.S. Department of Energy. *Exterior Lighting Control Guidance.* August 2013. https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/exterior-lighting-control-guidance.pdf

Revision History

Version Number	Date	Description of Change
01	10/11/2017	Initial TRM entry
02	12/2018	Updated incremental cost

LED Downlights Replacing CFL Downlight

	Measure Details
Measure Master ID	LED Fixture, Downlights: ≤ 18 Watts, Replacing 1-Lamp Pin-Based CFL Downlight, 3394
Measure Unit	Per luminaire
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	≤ 18 watts = $4.880 (MMID 3394)[2]

Measure Description

LED downlights can be used to replace existing 1- and 2-lamp pin-based CFL downlights used for the same application without sacrificing performance. LED downlights save energy because they consume less wattage than the 1- and 2-lamp pin-based CFL downlights products they replace.

Description of Baseline Condition

Low Wattage Downlights

The baseline condition is pin-based CFL downlights containing 1-lamp of 26 watts, 32 watts, or 42 watts in existing buildings and new construction or any 1-lamp pin-based CFL downlight between 26 watts and 45 watts. An average of 33.3% each for 1-lamp 26-watt pin-based CFL downlights, 1-lamp 32-watt pin-based CFL downlights, and 1-lamp 42-watt pin-based CFL downlights was used to generate the baseline usage (see Assumptions).

High Wattage Downlights

The baseline condition is pin-based CFL downlights containing 2-lamps of 26 watts, 32 watts, or 42 watts each in existing buildings and new construction or any 2-lamp pin-based CFL downlight with 26 watts to 45 watts. An average of 33.3% each for 2-lamp 26-watt pin-based CFL downlights, 2-lamp 32-watt pin-based CFL downlights, and 2-lamp 42-watt pin-based CFL downlights was used to generate the baseline usage (see Assumptions).

Description of Efficient Condition

Low Wattage Downlights

The efficient condition is low-wattage downlights that are ENERGY STAR-rated and/or Wisconsin Focus on Energy QPL-listed LED downlights that consume ≤ 18 watts.

High Wattage Downlights

The efficient condition is high-wattage downlights that are ENERGY STAR-rated and/or Wisconsin Focus on Energy QPL-listed LED downlights that consume > 18 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{CFL} – Watts_{LEDEE}) / 1,000 * HOU$

Where:

$Watts_{CFL}$ = Wattage of 1-lamp or 2-lamp pin-based CFL downlights with 26-watt, 32-watt, or 42-watt lamps (= 37 as average for low wattage system; = 75 as average for high wattage systems)

$Watts_{LEDEE}$ = Average power consumption of ENERGY STAR-rated and/or Wisconsin Focus on Energy QPL-listed LED fixture (= 13 for systems ≤ 18 watts; = 32 for systems > 18 watts)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{CFL} - Watts_{LEDEE}) / 1,000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor

Sector	CF[6]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64
Multifamily	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED Downlights Replacing 1 Lamp or 2 Lamp Pin-Based CFL

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED downlights > 18 watts	3395	160	0.0330	203	0.0330	201	0.0287	139	0.0274	255	0.0330

Average Lifecycle Deemed Savings for LED Downlights Replacing 1 Lamp or 2 Lamp Pin-Based CFL (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED downlights > 18 watts	3395	1,760	2,233	2,211	1,529	2,805

Assumptions

Fixture lamp weightings are based on a combination of energy audit experience and feedback from Lighting Certified individuals through the National Council on Qualifications for the Lighting Professions and individuals with lighting sales experience.

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 8,139 LED downlight fixtures is 46,550 hours. With a sector-averaged HOU of 4,472, the EUL is 10 years
2. August 2018 online lookups of 4 base and efficient models show an average efficient lamp price of $9.28 and base lamp price of $4.40, for an incremental cost of $4.88.
3. ENERGY STAR product list. August 28, 2015. (Average measured wattage taken from listed products in the Downlight Recessed, Downlight Solid State Retrofit, and Downlight Surface Mount fixture types, filtered by wattage limits).
4. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Table 3.2 Lighting Hours of Use in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. “ACES Deemed Savings Desk Review.” November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
   Multifamily Applications for Common Areas (5,949.5 annual operating hours based on 16.3 hours/day * 365 days/year).
6. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Table 3.2 Coincidence Factor for Lighting in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	04/01/2014	Initial TRM entry
02	08/28/2015	Updated savings information
03	10/2017	Updated EUL
04	12/2018	Updated incremental cost, removed MMID 3394

LED Downlight Fixtures ≤ 18 Watts

	Measure Details
Measure Master ID	LED Fixture, Downlight, ≤ 18 Watts, 3819
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost	$3.45[2]

Measure Description

LED downlight fixtures can replace existing incandescent fixtures without sacrificing performance, and save energy because they consume less wattage than the incandescent products they replace.

Description of Baseline Condition

The baseline condition is 50-watt to 99-watt incandescent fixtures using reflector lamps typically found in downlight retrofit applications. Reflector lamps are exempt from EISA lumen per watt standards.[7]

Description of Efficient Condition

The efficient equipment is an ENERGY STAR-rated downlight fixture that consumes ≤ 18 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1{,}000$

Where:

$Watts_{BASE}$ = Wattage of baseline incandescent fixtures; a weighted average of 10% for 50-watt, 40% for 65-watt, 25% for 75-watt and 25% for 90-watt sources was used (= 72.3 watts; see Assumptions)

$Watts_{EE}$ = Power consumption of efficient LED products (= 13 watts)[3]

HOU = Hours of use (= varies by sector; see table below)
1,000 = Kilowatt conversion factor

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{LED}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF[6]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64
Multifamily	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Assumptions

Lamp weightings are based on a combination of energy audit experience, direct install experience, and feedback from Lighting Certified individuals through the National Council on Qualifications for the Lighting Professions and individuals with lighting sales experience of fixtures categorized as downlights. Full incandescent baselines are used as customers are likely to replace failed equipment with the same technology as replacements are still available on the market with no changes to fixture performance.

Deemed Savings

Average Annual Deemed Savings for LED Downlights ≤ 18 Watts

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED Downlights ≤ 18 Watts Replacing 60 Watt to 100 Watt Incandescent	3819	222	0.0458	282	0.0458	280	0.0399	193	0.0381	354	0.0458

Average Lifecycle Deemed Savings for LED Downlights ≤ 18 Watts

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Downlights ≤ 18 Watts Replacing 60 Watt to 100 Watt Incandescent	3819	2,220	2,820	2,800	1,930	3,540

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/ Average rated life of 8,139 LED downlight fixtures is 46,550 hours. With a sector-averaged HOU of 4,472, the EUL is 10 years.
2. August 2018 online lookups of four base and efficient models on www.1000bulbs.com, www.bulbs.com, and www.topbulb.com show an average efficient lamp price of $6.56 and base lamp price of $3.11, for an incremental cost of $3.45.
3. Diode (LED) LED Fixture, Downlights, Accent Lights and Monopoint, ≤ 18 Watts, Common Area, derived from historical program data.
4. ENERGY STAR product list from October 13, 2015. Average measured wattage of Downlight Recessed, Downlight Solid State Retrofit, and Downlight Surface Mount fixture types, filtered by wattage limits.
5. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Table 3.2 Lighting Hours of Use in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. Tetra Tech. “ACES Deemed Savings Desk Review.” November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluation

report.pdf
Multifamily Applications for Common Areas (5,949.5 annual operating hours based on 16.3 hours/day * 365 days/year).

7. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3.2 Coincidence Factor for Lighting in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
8. The Energy Independence and Securities Act (EISA) of 2007 Lighting Facts Summary: http://www.lightingfacts.com/Library/Content/EISA

Revision History

Version Number	Date	Description of Change
01	10/13/2015	Initial TRM entry
02	10/2017	Updated EUL
03	12/2018	Updated incremental cost, removed MMID 3750

LED Downlight Fixtures > 18 Watts

	Measure Details
Measure Master ID	LED Fixture, Downlight, > 18 Watts, 3749, 3820
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost	$16.76[2]

Measure Description

LED downlight fixtures can replace existing incandescent fixtures without sacrificing performance, and save energy because they consume less wattage than the incandescent products they replace.

Description of Baseline Condition

Several wattage baselines are averaged together to produce a single baseline. An incandescent baseline of 72 watts is used due to EISA legislation stating that 72 is the maximum replacement wattage for a 100-watt general service incandescent lamp.[7] Systems with 50 watts to 100 watt HID lamps are also used.

Description of Efficient Condition

The efficient equipment is an ENERGY STAR-rated downlight fixture that consumes > 18 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000$

Where:

$Watts_{BASE}$ = Wattage of baseline incandescent fixtures; a weighted average of 25% 72-watt incandescent and 50-watt, 70-watt, and 100-watt HIDs was used to generate the baseline wattage; see Assumptions (= 88.8 watts)[8]

$Watts_{EE}$ = Wattage of efficient LED products (= 32 watts)[3]

HOU = Hours of use (= varies by sector; see table below)

1,000 = Kilowatt conversion factor

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{LED}) / 1,000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[6]	0.77
Industrial[6]	0.77
Agriculture[6]	0.67
Schools & Government[6]	0.64
Multifamily[6]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED Downlights > 18 Watts

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED Downlights > 18 Watts Replacing 100 Watt Incandescent or 50 Watt o 100 Watt HID	3749, 3820	212	0.0438	270	0.0438	267	0.0381	184	0.0364	338	0.0438

Average Lifecycle Deemed Savings for LED Downlights > 18 Watts

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Downlights > 18 Watts Replacing 100 Watt Incandescent or 50 Watt o 100 Watt HID	3749, 3820	2,120	2,700	2,670	1,840	3,380

Assumptions

Fixture lamp weightings are based on a combination of energy audit experience and feedback from Lighting Certified individuals through the National Council on Qualifications for the Lighting Professions and individuals with lighting sales experience. Incandescent and HID baselines are used because audit and market experience reveals that customers are likely to replace failed equipment with the same technology, as replacements are still available on the market with no changes to fixture performance.

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 8,139 LED downlight fixtures is 46,550 hours. With a sector-averaged HOU of 4,472, the EUL is 10 years.
2. August 2018 online lookups of four base and efficient models on www.1000bulbs.com, www.bulbs.com, and www.topbulb.com show an average efficient lamp price of $19.90 and base lamp price of $3.14, for an incremental cost of $16.76.
3. ENERGY STAR product list from October 13, 2015. Average measured wattage of Downlight Recessed, Downlight Solid State Retrofit and Downlight Surface Mount fixture types, filtered by wattage limits.
4. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Table 3.2 Lighting Hours of Use in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. “ACES Deemed Savings Desk Review.” November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
   Multifamily Applications for Common Areas (5,949.5 annual operating hours based on 16.3 hours/day * 365 days/year).
6. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Table 3.2 Coincidence Factor for Lighting in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
7. The Energy Independence and Securities Act (EISA) of 2007 Lighting Facts Summary: http://www.lightingfacts.com/Library/Content/EISA
8. *Focus on Energy Default Wattage Guide.* HID wattages based on metal halide technologies.

Revision History

Version Number	Date	Description of Change
01	10/13/2015	Initial TRM entry
02	10/2017	Updated EUL
03	12/2018	Updated incremental cost

LED Exterior Fixture, Lumen Based

	Measure Details
Measure Master ID	LED, Exterior Fixture: Low Output, ≤4,999 lumens, 4280, 4441 Mid Output, 5,000–9,999 lumens, 4281, 4442 High Output, 10,000–29,999 lumens, 4282, 4443 Very High Output, ≥30,000 lumens, 4283, 4444
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	13[1]
Incremental Cost ($/unit)	Low Output, ≤4,999 lumens = $91.99 (MMID 4280) Mid Output, 5,000–9,999 lumens = $192.94 (MMID 4281) High Output, 10,000–29,999 lumens = $279.30 (MMID 4282) Very High Output, ≥30,000 lumens = $415.38 (MMID 4283)[2,3]

Measure Description

Exterior LED fixtures are an energy-saving alternative to traditional standard wattage high intensity discharge (HID) light sources that have been used for the same applications. LED light sources can be applied in almost every common application type where HID light sources are currently used. These measures are for replacing existing HID fixtures and new construction applications.

Description of Baseline Condition

The baseline condition is any existing, exterior-mounted HID area luminaire, excluding stairwell passageway luminaires, up to 1,000 watts.

Description of Efficient Condition

The efficient condition is a complete DesignLights Consortium™ (DLC)-listed LED luminaire in the "Outdoor" General Application category, excluding stairwell and passageway luminaires.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000$

Where:

$Watts_{BASE}$ = Power consumption of baseline measure (= varies by lumen output, see table below and Assumptions)

$Watts_{EE}$ = Power consumption of efficient LED luminaire (= varies by lumen output, see table below)[3]

1,000 = Kilowatt conversion factor

HOU = Average annual run hours (= 4,380)[4]

Wattages Used for Deemed Savings Calculations

Measure	MMID	$Watts_{BASE}$	$Watts_{EE}$[3]
Low Output ≤4,999 lumens	4280	116	36
Mid Output 5,000–9,999 lumens	4281	227	72
High Output 10,000–29,999 lumens	4282	546	152
Very High Output ≥30,000 lumens	4283	1,079	360

Annual Deemed Savings

Measure	MMID	Commercial, Industrial, Agriculture, Schools & Gov, Multifamily	
		kWh	kW
Low Output ≤4,999 lumens	4280	351	N/A
Mid Output 5,000–9,999 lumens	4281	679	N/A
High Output 10,000–29,999 lumens	4282	1,723	N/A
Very High Output ≥30,000 lumens	4283	3,150	N/A

Summer Coincident Peak Savings Algorithm

There are no peak savings for these measures.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 13 years)[1]

Deemed Lifecycle Savings

Measure	MMID	Commercial, Industrial, Agriculture, Schools & Gov, Multifamily (kWh)
Low Output ≤4,999 lumens	4280	4,563
Mid Output 5,000–9,999 lumens	4281	8,827
High Output 10,000–29,999 lumens	4282	22,399
Very High Output ≥30,000 lumens	4283	40,950

Assumptions

Incremental costs are the average costs through internet research of typical baseline HID equipment inside lumen bins. Baseline equipment was then compared against average costs of DLC participating equipment through prescriptive program product code tracking in those respective lumen bins.

Baseline system wattages were averaged by common metal halide lamps in respective lumen bin categories taken from the Focus on Energy *Default Wattage Guide*.[5] Low output included 50 watt, 70 watt, 100 watt, and 150 watt; mid output included 150 watt,175 watt, and 250 watt; high output included 250 watt, 320 watt (pulse start metal halide),400 watt, and 1,000 watt; and high output was 1,000 watts.

Sources

1. Cadmus review of effective useful life based on MMID 3107 and 2017 year-to-date DesignLights Consortium™ product participation.
2. 1000 Bulbs. Website. Accessed September 2017. www.1000bulbs.com
E-conolight. Website. Accessed September 2017. www.e-conolight.com
Amazon. Website. Accessed September 2017. www.amazon.com
3. SPECTRUM. “SPECTRUM Lighting Participation Measure Participation Wattages.” January 2017–September 2017 application date ranges for Large Energy User Program, Business Incentive

Program, Small Business Program, and Multifamily Energy Savings Program. MMIDs included 3108, 3099, 3100, 3101, 3102, 3103, 3104, 3106, 3107, 3109, 3110, and 3407.

4. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. “NOAA Solar Calculator.” http://www.esrl.noaa.gov/gmd/grad/solcalc/
   This report includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
5. Wisconsin Focus on Energy. *Default Wattage Guide*. Version 1.0. 2013.

Revision History

Version No.	Date	Description of Change
01	09/20/2017	Initial TRM entry s

LED Fixture Downlights

	Measure Details
Measure Master ID	LED Fixture, Downlights, Interior, 4354, 4475 LED Fixture, Downlights, In Unit, 4355 LED Fixture, Downlights, Exterior, 4356, 4476
Measure Unit	Per watt reduced
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$1.52 per watt reduced for MMID 4354[2] $1.29 per watt reduced for MMID 4356;[9] $0.85 per watt reduced for MMID 4475;[10] $0.88 per watt reduced for MMID 4476[11] $1.10 per watt reduced for MMID 4355[12]

Measure Description

These LED upgrade measures are the replacement of incumbent light sources used in downlights with energy-efficient LED luminaires or retrofit kits, in both new construction and retrofit scenarios.

Description of Baseline Condition

The baseline equipment is any downlight with an incumbent lighting technology source. For new construction applications, the baseline wattage will be determined by multiplying the proposed LED wattage by 2.5 (see the Assumptions section).[3]

Description of Efficient Condition

The efficient condition is any complete LED luminaire or retrofit kit used to upgrade existing equipment on a one-for-one basis. LED products must be on the ENERGY STAR qualified product list to be eligible.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000$

$= Watts_{REDUCED} * HOU / 1,000$

Where:

$Watts_{BASE}$ = Power consumption (per fixture) of current installed lighting equipment

$Watts_{EE}$ = Power consumption (per fixture) of efficient LED equipment

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

$Watts_{REDUCED}$ = Watt reduction

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily – Common Area[5]	5,950
Multifamily – In Unit[6]	734
Exterior[7]	4,380

Summer Coincident Peak Savings Algorithm

$kW_{SAVED}= (Watts_{BASE} - Watts_{EE}) * CF / 1,000$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily – Common Area[8]	0.77
Multifamily – In Unit[6]	0.055
Exterior	0.00

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Annual Energy Savings (kWh per watt reduced)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Downlights Interior	4354	3.73	4.75	4.7	3.24	5.95
LED Downlights, In Unit	4355	N/A	N/A	N/A	N/A	0.73
LED Downlights Exterior	4356	4.38	4.38	4.38	4.38	4.38

Annual Demand Reduction (kW per watt reduced)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Downlights Interior	4354	0.0008	0.0008	0.0007	0.0006	0.0008
LED Downlights, In Unit	4355	N/A	N/A	N/A	N/A	0.0001
LED Downlights Exterior	4356	0.0000	0.0000	0.0000	0.0000	0.0000

Lifecycle Savings (kWh per watt reduced)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Downlights Interior	4354	37	48	47	32	60
LED Downlights, In Unit	4355	N/A	N/A	N/A	N/A	7
LED Downlights Exterior	4356	44	44	44	44	44

Assumptions

The incremental cost on a per-watt basis was calculated using the following:

Cost in $/W = [Actual Measure Cost Sum] / [First Year kWh Savings
* 1,000 / Average Sector Hours (4,472)]

For new construction scenarios, a photometric and input wattage analysis was performed comparing CFL upgrade options under MMIDs 3394 and 3395 ranging from one-lamp, 26-watt CFLs to two-lamp, 42 watt CFLs. Lumen outputs and input wattages were pulled from IES files and compared against ENERGY STAR-listed downlights. The average CFL to LED wattage ratio was 2.5, as shown in the table below.

LED Versus CFL Wattages

CFL Model	Rated Lamp Lumens	CFL Wattage	IES File Lumen Output	Selected Lumen Range	Average ENERGY STAR LED Wattage in Lumen Range	CFL vs LED Wattage Ratio
Lithonia						
6VF 1/26TRT 6O9AZ	1,800	29	953	≤ 955	10.9	2.66
6VF 1/32TRT 6O9AZ	2,400	36	1,285	956–1,290	15.1	2.38
6VF 1/42TRT 6O9AZ	3,200	48	1,601	1,291–1,605	20.8	2.31
6HF 2/26DTT F6O2AZ	1,800	62	1,753	1,606–1,755	23	2.7
Gotham						
AF 2/32TRT 10AR	2,400	69	2,975	1,756–2,980	31.5	2.19
AF 2/42TRT 8AR	3,200	93	4,010	2,981–4,015	44.5	2.09
Average						**2.5**

Sources

1. ENERGY STAR. *Qualified Product List*. Accessed November 2017. https://www.energystar.gov/productfinder/
   Average rated life of 8,402 LED downlight fixtures is 46,324 hours. With a sector-averaged HOU of 4,472, the EUL is 10 years.
2. Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 120,239 watts reduced over 84 projects from 2016 to 2018 is $1.57. August 2018 online lookups of 12 baseline lamps on www.1000bulbs.com, www.topbulb.com, www.lowes.com, and www.homedepot.com show a baseline cost of $0.05 per watt for a halogen replacement bulb. The incremental cost is therefore $1.52.
3. ENERGY STAR. *Qualified Product List*. Accessed November 2017. https://www.energystar.gov/productfinder/
4. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Table 3.2 Lighting Hours of Use and Coincidence Factors by Sector. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

5. Tetra Tech. "ACES Deemed Savings Desk Review." November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
   Multifamily Applications for Common Areas (5,949.5 annual operating hours based on 16.3 hours/day * 365 days/year).
6. Cadmus. "Focus on Energy Evaluated Deemed Savings Changes." November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
   Report lists 2.01 hours per day for multifamily housing.
   Report lists coincidence factor of 5.5% for multifamily housing.
7. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. *NOAA Solar Calculator*. http://www.esrl.noaa.gov/gmd/grad/solcalc/
   This also includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
8. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. Table 4-1. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs; table shows multifamily housing (in unit) coincidence factor of 65% to 83%.
9. Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 11,460 watts reduced over 12 projects from 2016 to 2018 is $1.34. August 2018 online lookups of 12 baseline lamps on www.1000bulbs.com, www.topbulb.com, www.lowes.com, and www.homedepot.com show a baseline cost of $0.05 per watt for a halogen replacement bulb. The incremental cost is therefore $1.29.
10. Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 2,701 watts reduced over two projects from 2016 to 2018 is $0.90. August 2018 online lookups of 12 baseline lamps on www.1000bulbs.com, www.topbulb.com, www.lowes.com, and www.homedepot.com show a baseline cost of $0.05 per watt for a halogen replacement bulb. The incremental cost is therefore $0.85.

11. Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 390 watts reduced over one project from 2016 to 2018 is $0.93. August 2018 online lookups of 12 baseline lamps on www.1000bulbs.com, www.topbulb.com, www.lowes.com, and www.homedepot.com show a baseline cost of $0.05 per watt for a halogen replacement bulb. The incremental cost is therefore $0.88.
12. Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 30,140 watts reduced over 17 projects from 2016 to 2018 is $1.15. August 2018 online lookups of 12 baseline lamps on www.1000bulbs.com, www.topbulb.com, www.lowes.com, and www.homedepot.com show a baseline cost of $0.05 per watt for a halogen replacement bulb. The incremental cost is therefore $1.10.

Revision History

Version Number	Date	Description of Change
01	11/08/2017	Initial TRM entry
02	12/2018	Updated incremental cost

LED Fixtures, High Bay

	Measure Details
Measure Master ID	LED Fixture, High Bay: < 155 Watts, Replacing 250 Watt HID, 3091 < 250 Watts, Replacing 320–400 Watt HID, 3092 < 250 Watts, Replacing 400 Watt HID, 3093 < 365 Watts, Replacing 400 Watt HID, 3094 < 500 Watts, Replacing 1,000 Watt HID, 3095 < 800 Watts, Replacing 1,000 Watt HID, 3096
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by wattage and sector
Peak Demand Reduction (kW)	Varies by wattage and sector
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by measure and sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	20 (MMIDs 3091, 3092, 3094);[1] 15 (MMIDs 3093, 3095, 3096)[2]
Incremental Cost ($/unit)	< 155 Watts = $86.26 (MMID 3091)[3] < 250 Watts and < 365 Watts = $229.19 (MMIDs 3092, 3093, and 3094)[3] < 500 Watts and < 800 Watts = 190.96 (MMIDs 3095 and 3096)[3]

Measure Description

High-bay LED fixtures are an energy-saving alternative to traditional standard wattage HID light sources used for the same applications. LED light sources can be used in almost every common type of application where HID light sources are currently found.

LED options have become popular for dairy facilities' upgrades to long daylighting (LDL), a process used to help increase cows' milk production by simulating longer days and therefore increasing the animal food intake and milk production. LDL requires a minimum of 15 foot-candles of photopic light being present at cow eye level for 16 to 18 hours each day.[4] Agriculture measures under MMIDs 3091, 3092, and 3094 assume LDL operations, while other measures assume the general hours of use for the agriculture sector.

Description of Baseline Condition

The baseline is standard HID lamps that range from 250 watts to 1,000 watts.

Description of Efficient Condition

To meet program requirements, the LED replacements must be complete fixtures that are DesignLights Consortium™ listed. Lamp-only replacements are not eligible for incentive.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = [(Qty_{BASE} * Watts_{BASE}) – (Qty_{EE} * Watts_{EE})] / 1,000 * HOU$

Where:

Qty_{BASE} = Quantity of standard HID fixture

$Watts_{BASE}$ = Baseline consumption of standard HID fixture (= varies by sector; see table below)

Qty_{EE} = Quantity of LED fixture

$Watts_{EE}$ = Efficient consumption of LED fixture (= varies by sector; see table below)

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Baseline and Efficient Lamp Consumption

Measure	$Watts_{BASE}$[5]	$Watts_{EE}$[6]
LED Fixture, High Bay, < 155 Watts Replacing 250-Watt HID	293	106
LED Fixture, High Bay, < 250 Watts Replacing 400-Watt HID	455	154
LED Fixture, High Bay, < 250 Watts Replacing 320-Watt to 400-Watt HID	356	164
LED Fixture, High Bay, < 365 Watts Replacing 400-Watt HID	455	254
LED Fixture, High Bay, < 800 Watts Replacing 1,000-Watt HID	1,079	264
LED Fixture, High Bay, < 500 Watts Replacing 1,000-Watt HID	1,079	268

Hours of Use by Sector

Sector	HOU[7]
Commercial	3,730
Industrial	4,745
Agriculture	4,698 (standard applications, MMIDs 3093, 3095, and 3096) 6,205 (Long Day Lighting applications, MMIDs 3091, 3092, and 3094)*
Schools & Government	3,239

* 365 days * 17 hours/day = 6,205 hours.

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = [(Qty_{BASE} * Watts_{BASE} – (Qty_{EE} * Watts_{EE})] / 1,000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF[7]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 20 years for MMIDs 3091, 3092, and 3094;[1] = 15 years for MMIDs 3093, 3095, and 3096[6])

Deemed Savings

Average Annual Deemed Savings for High Bay LED Fixtures

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED Fixture, High Bay									
< 155 Watts Replacing 250-Watt HID	3091	698	0.1440	887	0.1440	879	0.1338	606	0.1197
< 250 Watts Replacing 400-Watt HID	3093	1,123	0.2318	1,428	0.2318	1,414	0.2017	975	0.1926
< 250 Watts Replacing 320-Watt to 400-Watt HID	3092	716	0.1478	911	0.1478	902	0.1498	622	0.1229
< 365 Watts Replacing 400-Watt HID	3094	750	0.1548	954	0.1548	944	0.1416	651	0.1286
< 800 Watts Replacing 1,000-Watt HID	3096	3,040	0.6276	3,867	0.6276	3,829	0.5461	2,640	0.5216
< 500 Watts Replacing 1,000-Watt HID	3095	3,025	0.6245	3,848	0.6245	3,810	0.5434	2,627	0.5190

Average Lifecycle Deemed Savings for High Bay LED Fixtures (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov
LED Fixture, High Bay					
< 155 Watts Replacing 250-Watt HID	3091	13,960	17,740	17,580	12,120
< 250 Watts Replacing 400-Watt HID	3093	16,845	21,420	21,210	14,625
< 250 Watts Replacing 320-Watt to 400-Watt HID	3092	14,320	18,220	18,040	12,440
< 365 Watts Replacing 400-Watt HID	3094	15,000	19,080	18,880	13,020
< 800 Watts Replacing 1,000-Watt HID	3096	45,600	58,005	57,435	39,600
< 500 Watts Replacing 1,000-Watt HID	3095	45,375	57,720	57,150	39,405

Sources

1. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. January 2017 through December 2017.
   Participation data for MMID 3091 and online lookups performed in February 2018 show that 16 models, comprising 2,709 units and 60% of total measure participation, have an average specification sheet rated life of 124,063 hours. With an average HOU of 6,205, the EUL is 20 years.
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. January 2017 through December 2017.
   Participation data for MMID 3093 and online lookups performed in February 2018 show that four models, comprising 15,344 units and 63% of total measure participation, have an average specification sheet rated life of 70,000 hours. With an average HOU of 4,698, the EUL is 15 years.
3. Zoro. Website. Accessed February 2018. www.zoro.com
   Warehouse Lighting. Website. Accessed February 2018. www.warehouse-lighting.com
   LBC Lighting. Website. Accessed February 2018. www.lbclighting.com
   Access Fixtures. Website. Accessed February 2018. www.accessfixtures.com
   Direct-Lighting. Website. Accessed February 2018. www.direct-lighting.com
   Lightbulbs.com. Website. Accessed February 2018. www.lightbulbs.com
   Light Store USA. Website. Accessed February 2018. www.lightstoreusa.com
   Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. January 2017 through December 2017.
   Participation data for MMIDs 3091 through 3096 and online lookups performed in February 2018 show that the average costs of participating products are $324.29 (3091), $383.07 (3092),

$276.53 (3093), $598.52 (3094), $445.47 (3095), and $631.73 (3096). For measures with the same baseline equipment, an average incremental cost was taken.

4. University of Wisconsin Madison, Healthy Farmers, Healthy Profits Project. "Work Efficiency Tip Sheet: Long-Day Lighting in Dairy Barns." Second Edition. August 2000. https://fyi.uwex.edu/energy/files/2016/05/lighting4web.pdf
5. Wisconsin Focus on Energy. *Focus on Energy Default Wattage Guide 2013*. Version 1.0. All values are based on metal halide fixtures, except as otherwise noted.
6. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. January 2017 through December 2017. Participation data for MMIDs 3091 through 3096 and online lookups performed in February 2018 show that the average wattages of participating products are 106 watts (3091), 164 watts (3092), 154 watts (3093), 254 watts (3094), 268 watts (3095), and 264 watts (3096).
7. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Updated March 22, 2010. Table 3.2 for nonresidential HOU and CF. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
8. Wisconsin Focus on Energy. "LED Fixtures High Bay Agriculture LDL Supplemental Data." Excel workbook. Adjustment calculation tab shows historical data from 259 projects from July 2013 to September 2016, which were used to weight savings for Agricultural LDL and non-LDL high-bay applications.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	11/2016	Incorporated LDL savings for agriculture sector
03	10/2017	Updated EUL
04	2/2017	Updated savings and EUL

LED Fixture, Quantity Modification

	Measure Details
Measure Master ID	LED Fixture, Quantity Modification, Interior, 4357, 4477 LED Fixture, Quantity Modification, Exterior, 4358, 4478
Measure Unit	Per watt reduced
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$1.41 per watt reduced, interior; $1.36 per watt reduced, exterior[2]

Measure Description

These LED upgrade measures are the replacement of incumbent light sources with energy-efficient LEDs on a non-one-for-one replacement fixture basis (for example, there may be one LED fixture replacing two non-LED fixtures).

Description of Baseline Condition

The baseline equipment is any incumbent lighting technology source within complete luminaires.

Description of Efficient Condition

The efficient condition is any complete LED luminaire or retrofit kit that is upgrading existing equipment on a non-one-for-one basis. Replacement lamp products are not eligible for these measures. LED products must be on a qualified product list when applicable.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = Watts_{REDUCED} * HOU / 1{,}000$

$Watts_{REDUCED} = Qty_{BASE} * Watts_{BASE} – Qty_{EE} * Watts_{EE}$

Where:

Qty_{BASE} = Quantity of currently installed fixtures

$Watts_{BASE}$ = Per-fixture power consumption of current installed lighting equipment

Qty_{EE} = Quantity of efficient LED fixtures

$Watts_{EE}$ = Per-fixture power consumption of efficient LED equipment

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

$Watts_{REDUCED}$ = Watt reduction

Hours of Use by Sector

Sector	HOU
Commercial[3]	3,730
Industrial[3]	4,745
Agriculture[3]	4,698
Schools & Government[3]	3,239
Multifamily[4]	5,950
Exterior[5]	4,380

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1{,}000$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[3]	0.77
Industrial[3]	0.77
Agriculture[3]	0.67
Schools & Government[3]	0.64
Multifamily[6]	0.77
Exterior	0.00

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 12 years)[1]

Deemed Savings

Annual Energy Savings (kWh per watt reduced)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Downlights Interior	4357	3.73	4.75	4.7	3.24	5.95
LED Downlights, Exterior	4358	4.38	4.38	4.38	4.38	4.38

Annual Demand Reduction (kW per watt reduced)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Downlights Interior	4357	0.0008	0.0008	0.0007	0.0006	0.0008
LED Downlights, Exterior	4358	0.0000	0.0000	0.0000	0.0000	0.0000

Lifecycle Savings (per kWh reduced)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Non-1-for-1 Interior	4357	56	71	71	49	89
LED Non-1-for-1 Exterior	4358	66	66	66	66	66

Assumptions

The incremental cost on a per-watt basis was calculated using the following:

Interior = (Actual Interior LED Fixture Measure Cost Sum) / (First Year kWh Savings / Average Sector Hours (4,472)) / 1,000

Exterior = (Actual Exterior LED Fixture Measure Cost Sum) / (First Year kWh Savings / Exterior Hours (4,380)) / 1,000

Sources

1. Engineering judgement. The model mix for this measure is not yet known. In future program years, this will be adjusted based on known product mix and their rated lifetimes.
2. SPECTRUM. Average cost of 12,093 interior fixture units and 4,692 exterior fixture units in Small Business Program. January 2017–December 2017 application date ranges.
3. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Table 3.2 Lighting Hours of Use and Coincidence Factors by Sector. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. Tetra Tech. “ACES Deemed Savings Desk Review.” November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
   Multifamily Applications for Common Areas (5,949.5 annual operating hours based on 16.3 hours/day * 365 days/year).
5. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. *NOAA Solar Calculator*. http://www.esrl.noaa.gov/gmd/grad/solcalc/
   This also includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
6. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review.” Final Report. Table 4-1. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs; table shows multifamily housing (in unit) coincidence factor of 65% to 83%.

Revision History

Version Number	Date	Description of Change
01	11/07/2017	Initial TRM entry

LED Linear Ambient Fixture, Replacing T5 Lamp(s) in Cross Section

	Measure Details
Measure Master ID	LED Fixture, Linear Ambient, Replacing: 1 or 2 T5 Lamp(s) in Cross Section, 3738, 4618 3 or 4 T5 Lamps in Cross Section, 3739, 4619 1 or 2 T5 Lamp(s) in Cross Section, In Unit, 4791 3 or 4 T5 Lamps in Cross Section, In Unit, 4792 1 or 2 T5 Lamp(s) in Cross Section, Exterior, 24 hour, 4785 1 or 2 T5 Lamp(s) in Cross Section, Exterior, 12 hour, 4786 3 or 4 T5 Lamps in Cross Section, Exterior, 24 hour, 4787 3 or 4 T5 Lamps in Cross Section, Exterior, 12 hour, 4788
Measure Unit	Per linear foot of fixture(s)
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agricultural, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure and sector
Peak Demand Reduction (kW)	Varies by measure and sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure and sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/day)	0
Effective Useful Life (years)	Interior = 11 (MMIDs 3738, 3739, 4618, 4619, 4791, 4792), Exterior 24 hour = 6 (MMIDs 4785, 4787), Exterior 12 hour = 12 (MMIDs 4786, 4788)[1]
Incremental Cost ($/unit)	1 or 2 T5 Lamp(s) = $12.59 (MMIDs 3738, 4618, 4791, 4785, 4786), 3 or 4 T5 Lamps = $29.38 (MMIDs 3739, 4619, 4792, 4787, 4788)[2]

Measure Description

LED linear ambient luminaires save energy when replacing T5 products by providing a similar lumen output with lower input wattage. These products can be installed on a one-for-one basis to replace T5 luminaires.

Description of Baseline Condition

The baseline condition is one, two, three, or four interior or exterior lamp(s) in cross section T5 surface-mount or suspended fixtures in existing and new construction buildings.

Description of Efficient Condition

The efficient condition is LED products that are DLC listed in the interior or exterior Linear Ambient General Application category.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{LED}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Average per-foot power consumption of baseline fixture (=11.9 watts for 1- and 2-lamp T5 products, weighted 50% each, = 27.7 watts for 3- and 4-lamp T5 products, weighted 50% each; see Assumptions)[3]

$Watts_{LED}$ = Efficient per-foot power consumption of DLC-listed LED fixture (= 4.4 watts)[4]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use for Interior Fixtures

Sector	HOU
Commercial[5]	3,730
Industrial[5]	4,745
Agriculture[5]	4,698
Schools & Government[5]	3,239
Multifamily – Common Area[6]	5,950
Multifamily – In Unit[8]	734

Hours of Use for Exterior Fixtures

MMID	HOU
4785, 4787	8,760
4786, 4788	4,380

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{LED}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor

Sector	CF
Commercial[5]	0.77
Industrial[5]	0.77
Agriculture[5]	0.67
Schools & Government[5]	0.64
Multifamily – Common Area[7]	0.77
Multifamily – In Unit[8]	0.055
24 hour	1.0
12 hour	0

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years for MMIDs 3738, 3739, 4618, 4619, 4791, and 4792; = 6 years for MMIDs 4785 and 4787; = 12 years for MMIDs 4786 and 4788)[1]

Deemed Savings

Annual Savings, Non-Res

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED Linear Ambient Fixture, Replacing T5 Lamps in Cross Section									
1 or 2 T5 Lamps	3738, 4618	28	0.0058	36	0.0058	35	0.0050	24	0.0048
	4785	66	0.0075	66	0.0075	66	0.0075	66	0.0075
	4786	33	0	33	0	33	0	33	0
3 or 4 T5 Lamps	3739, 4619	87	0.0179	110	0.0179	109	0.0156	75	0.0149
	4787	204	0.0233	204	0.0233	204	0.0233	204	0.0233
	4788	102	0	102	0	102	0	102	0

Annual Savings, Multifamily

Measure	MMID	Multifamily		Multifamily – In Unit	
		kWh	kW	kWh	kW
LED Linear Ambient Fixture, Replacing T5 Lamps in Cross Section					
1 or 2 T5 Lamps	3738, 4618, 4791 (in-unit)	45	0.0058	6	0.0004
	4785	66	0.0075	--	--
	4786	33	0	--	--
3 or 4 T5 Lamps	3739, 4619, 4792 (in-unit)	138	0.0179	17	0.0013
	4787	204	0.0233	--	--
	4788	102	0	--	--

Lifecycle Savings (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily	Multifamily – In Unit
LED Linear Ambient Fixture, Replacing T5 Lamps in Cross Section							
1 or 2 T5 Lamps	3738, 4618, 4791 (in-unit)	308	396	385	264	495	66
	4785	396	396	396	396	396	--
	4786	396	396	396	396	396	--
3 or 4 T5 Lamps	3739, 4619, 4792 (in-unit)	957	1,210	1,199	825	1,518	187
	4787	1,224	1,224	1,224	1,224	1,224	--
	4788	1,224	1,224	1,224	1,224	1,224	--

Assumptions

Fixture lamp weightings (50%/50%) are based on a combination of feedback from energy audit experience, Lighting Certified individuals through the NCQLP, and individuals with lighting sales experience.

Baseline wattages were obtained from the 2013 Focus on Energy *Default Wattage Guide,*[3] with input wattages based on 4-foot, 28-watt T5 reference lamps with a normal ballast factor. The average per-foot power consumptions are 8.1 watts for 1-lamp, 15.8 watts for 2-lamp, 23.9 watts for 3-lamp, and 31.5 watts for 4-lamp fixtures. The weighted average of 1-lamp and 2-lamp fixtures is 11.9 watts. The weighted average of 3-lamp and 4-lamp fixtures is 27.7 watts.

Sources

1. DesignLights Consortium. *Qualified Product List.* Accessed August 2017. https://www.designlights.org/lighting-controls/download-the-qpl/
   Average rated life of models participating in linear LED measures is 51,160 hours. For interior measures with an average HOU of 4,472, the EUL is 11 years. For exterior 24-hour measures, the EUL is 51,160 / 8,760 = 5.84 years, rounding to six years. EUL for 12-hour measures is 12 years.
2. 1000 Bulbs. Website. Accessed July 2018. www.1000bulbs.com
   Top Bulb. Website. Accessed July 2018. www.topbulb.com
   Average efficient cost of $16.35 and base cost of $3.76 for MMIDs 3738, 4618, 4791, 4785, and 4786. Average efficient cost of $38.15 and base cost of $8.77 for MMIDs 3739, 4619, 4792, 4787, and 4788.
3. Focus on Energy. *Default Wattage Guide*. 2013.
4. DesignLights Consortium. *Technical Requirements*. Table v3.0. https://www.designlights.org/resources/file/TRT_V3_FULLTABLE_Final_9-1-15
   Minimum lumens per foot is 375 and minimum lumens per watt is 85 (375 / 85 = 4.4 watts per foot)
5. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3-2. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. Tetra Tech. "ACES Deemed Savings Desk Review." November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
   Table 1 lists 16.3 hours per day for multifamily common areas.
7. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs; Table 4-1 shows multifamily housing (in unit) CF of 65% to 83%.
8. Cadmus. "Focus on Energy Evaluated Deemed Savings Changes." November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
   Report lists 2.01 hours per day for multifamily housing. Report lists coincidence factor of 5.5% for multifamily housing.

Revision History

Version Number	Date	Description of Change
01	10/16/2015	Initial TRM entry
02	10/10/18	Added exterior and in-unit measures, updated cost

LED Linear Ambient Fixture, Replacing T8/T12 Lamps in Cross Section

	Measure Details
Measure Master ID	LED Fixture, Linear Ambient, Replacing: 1 or 2 T8/T12 Lamp(s) in Cross Section, 3740, 4620 3 or 4 T8/T12 Lamps in Cross Section, 3741, 4621 1 or 2 T8/T12 Lamp(s) in Cross Section, In Unit, 4789 3 or 4 T8/T12 Lamps in Cross Section, In Unit, 4790 1 or 2 T8/T12 Lamp(s) in Cross Section, Exterior, 24 hour, 4781 1 or 2 T8/T12 Lamp(s) in Cross Section, Exterior, 12 hour, 4782 3 or 4 T8/T12 Lamps in Cross Section, Exterior, 24 hour, 4783 3 or 4 T8/T12 Lamps in Cross Section, Exterior, 12 hour, 4784
Measure Unit	Per linear feet of fixture(s)
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agricultural, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure and sector
Peak Demand Reduction (kW)	Varies by measure and sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure and sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Interior = 11 (MMIDs 3740, 3741, 4620, 4621, 4789, 4790), Exterior 24 hour = 6 (MMIDs 4781, 4783), Exterior 12 hour = 12 (MMIDs 4782, 4784)[1]
Incremental Cost ($/unit)	1 or 2 T8/12 Lamp(s) = $9.89 (MMIDs 3740, 4620, 4789, 4781, 4782), 3 or 4 T8/12 Lamps = $23.08 (MMIDs 3741, 4621, 4790, 4783, 4784)[2]

Measure Description

LED linear ambient fixtures save energy when replacing one to four T8/T12 lamps in cross section by providing a similar lumen output with lower input wattage. These products can be installed on a one-for-one basis to replace one- to four-lamp T8/T12 luminaires.

Description of Baseline Condition

The baseline condition is one to four lamp(s) in cross section T8/T12 surface-mount or suspended fixtures in existing and new construction buildings.

Description of Efficient Condition

The efficient condition is LED products that are DLC listed in the Linear Ambient General Application category.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{LED}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Average per-foot power consumption of baseline fixture (= 10.9 watts for one and two-lamp T8 products, weighted 50% each, = 24.3 watts for three and four-lamp T8 products, weighted 50% each; see Assumptions)[3]

$Watts_{LED}$ = Baseline per foot power consumption of DLC-listed LED fixture (= 4.4 watts)[4]

1,000 = Kilowatt conversion factor

HOU = Hours-of-use (= varies by sector; see tables below for interior and exterior fixtures)

Hours of Use for Interior Fixtures

Sector	HOU
Commercial[5]	3,730
Industrial[5]	4,745
Agriculture[5]	4,698
Schools & Government[5]	3,239
Multifamily – Common Area[6]	5,950
Multifamily – In Unit[8]	734

Hours of Use for Exterior Fixtures

MMID	HOU
4781, 4783	8,760
4782, 4784	4,380

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{LED}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[5]	0.77
Industrial[5]	0.77
Agriculture[5]	0.67
Schools & Government[5]	0.64
Multifamily – Common Area[7]	0.77
Multifamily – In Unit[8]	0.055
24 hour	1.0
12 hour	0

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years for interior MMIDs 3740, 3741, 4620, 4621, 4789, and 4790; = 6 years for 24-hour exterior MMIDs 4781 and 4783; = 12 years for exterior 12-hour MMIDs 4782 and 4784)[1]

Deemed Savings

Annual Savings, Non-Res

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED Linear Ambient Fixture, Replacing T8/T12 Lamps in Cross Section									
1 or 2 T8/T12 Lamps	3740, 4620	24	0.0050	31	0.0050	30	0.0043	21	0.0041
	4781	57	0.0065	57	0.0065	57	0.0065	57	0.0065
	4782	28	0	28	0	28	0	28	0
3 or 4 T8/T12 Lamps	3741, 4621	74	0.0153	95	0.0153	94	0.0133	65	0.0128
	4783	175	0.0199	175	0.0199	175	0.0199	175	0.0199
	4784	87	0	87	0	87	0	87	0

Annual Savings, Multifamily

Measure	MMID	Multifamily		Multifamily – In Unit	
		kWh	kW	kWh	kW
LED Linear Ambient Fixture, Replacing T8/T12 Lamps in Cross Section					
1 or 2 T8/T12 Lamps	3740, 4620, 4789 (in-unit)	39	0.0050	5	0.0004
	4781	57	0.0065	--	--
	4782	28	0	--	--
3 or 4 T8/T12 Lamps	3741, 4621, 4790 (in-unit)	119	0.0153	15	0.0011
	4783	175	0.0199	--	--
	4784	87	0	--	--

Lifecycle Savings (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily	Multifamily – In Unit
LED Linear Ambient Fixture, Replacing T8/T12 Lamps in Cross Section							
1 or 2 T8/T12 Lamps	3740, 4620, 4789 (in-unit)	264	341	330	231	429	55
	4781	342	342	342	342	342	342
	4782	336	336	336	336	336	336
3 or 4 T8/T12 Lamps	3741, 4621, 4790 (in-unit)	814	1,045	1,034	715	1,309	165
	4783	1,050	1,050	1,050	1,050	1,050	1,050
	4784	1,044	1,044	1,044	1,044	1,044	1,044

Assumptions

Fixture lamp weightings (50%/50%) were based on a combination of feedback from energy audit experience, Lighting Certified individuals through the NCQLP, and individuals with lighting sales experience.

Baseline wattages were obtained from the 2015 CEE Legacy Ballast list using the normal ballast factor only.[3] CEE's input wattages are based on a 4-foot, 32-watt T8 reference lamp. The average per-foot power consumptions are 7.5 watts for 1-lamp, 14.3 watts for 2-lamp, 21.4 watts for 3-lamp, and 27.2 watts for 4-lamp. The weighted average of 1-lamp and 2-lamp fixtures is 10.9 watts. The weighted average of 3-lamp and 4-lamp fixtures is 24.3 watts.

Sources

1. DesignLights Consortium. *Qualified Product List*. Accessed August 2017. https://www.designlights.org/lighting-controls/download-the-qpl/
   Average rated life of models participating in linear LED measures is 51,160 hours. For interior measures with an average HOU of 4,472, the EUL is 11 years. For exterior 24-hour measures, the EUL is 51,160 / 8,760 = 5.84 years, rounding to six years. The EUL for 12-hour measures is 12 years.
2. 1000 Bulbs. Website. Accessed July 2018. www.1000bulbs.com
   Average efficient cost of $12.82 and base cost of $2.94 for 1 or 2 T8/12 Lamp measures.
   Average efficient cost of $29.93 and base cost of $6.85 for 3 or 4 T8/12 Lamp measures.
3. Consortium for Energy Efficiency. *Legacy Ballast List*. Normal ballast factor. 2015. http://library.cee1.org/content/commercial-lighting-qualifying-products-lists
4. DesignLights Consortium. *Technical Requirements*. Table v3.0. https://www.designlights.org/resources/file/TRT_V3_FULLTABLE_Final_9-1-15
   Minimum lumens is 375 per foot and 85 per watt (375 / 85 = 4.4 watts per foot)
5. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3-2. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. Tetra Tech. "ACES Deemed Savings Desk Review." November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
   Table 1 lists 16.3 hours per day for multifamily common areas.
7. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. Table 4-1. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 83%.
8. Cadmus. "Focus on Energy Evaluated Deemed Savings Changes." November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
   Report lists 2.01 hours per day for multifamily housing. Report lists coincidence factor of 5.5% for multifamily housing.

Revision History

Version Number	Date	Description of Change
01	10/16/2015	Initial TRM entry
02	10/10/2018	Added exterior and in-unit measures, updated cost

LED Replacement of 4-Foot T8 Lamps, Direct Wire

	Measure Details
Measure Master ID	LED Replacement of 4-Foot T8 Lamps, Direct Wire, 3759, 3839 LED Replacement of 4-Foot T8 Lamps, Direct Wire, Exterior, 4350, 4471 LED Replacement of 4-Foot T8 Lamps, Direct Wire, Exterior, 24/7, 4351, 4472
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	15[1]
Incremental Cost	$6.29[2]

Measure Description

Four-foot T8 LEDs are an energy-efficient alternative to standard 4-foot 32-watt, 28-watt, and 25-watt T8 fluorescent lamps found commonly throughout commercial, industrial, agriculture, schools and government, and multifamily sectors. These products can replace 32-watt, 28-watt, and 25-watt T8 lamps one for one, and this measure incorporates those that replace the existing fluorescent lamp(s) and remove the ballast(s).

Description of Baseline Condition

The baseline condition is 4-foot standard 32-watt, 28-watt, and 25-watt T8 lamps on low (0.78), normal (0.88), and high (1.15) ballast factor ballasts. Lamps are weighted 60%, 30%, and 10%, respectively, in the savings calculations. Also, 32-watt lamp ballast factors are weighted 10%, 70%, and 20% with respect to low, normal, and high ballast factors; and 28-watt and 25-watt lamp ballast factors are weighted 5%, 90%, and 5% in the savings calculations (see the Assumptions section).

Description of Efficient Condition

The efficient condition is DLC-listed equipment with a measured wattage less than 24 and direct wires to line voltage, not operating off the existing fluorescent ballast(s) or external driver. This measure is not intended to be used in refrigerated case lighting applications. Products must carry a safety certification from a NRTL, such as UL or ETL, and use non-shunted sockets for products that are single-end feed and sockets that are twist-lock and warrantied for line voltage, and be installed by a licensed electrician and have a re-lamp label applied to modified fixture.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{FLUORESCENT} - Watts_{LED}) / 1{,}000 * HOU$

Where:

$Watts_{FLUORESCENT}$ = Weighted electricity consumption of standard 4-foot 32-watt, 28-watt, and 25-watt T8 fluorescent lamp operating on low, normal, and high ballast factor ballasts (= 27.43 watts)

$Watts_{LED}$ = Weighted average annual electricity consumption of DLC-listed 4-foot linear LEDs above 24 watts, UL Type B (= 17.78 watts)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950
Exterior[6]	4,380
Exterior 24/7	8,760

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{FLUORESCENT} - Watts_{LED}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[7]	0.77
Exterior	0.00
Exterior 24/7	1.00

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Annual Savings for LED Replacement of 4-Foot T8 Lamps

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Direct Wire	3759, 3839	36	0.0074	46	0.0074	45	0.0065	31	0.0062	57	0.0074
Direct Wire, Exterior	4350	42	N/A	42	N/A	42	N/A	42	N/A	42	N/A
Direct Wire, Exterior 24/7	4351	85	0.0097	85	0.0097	85	0.0097	85	0.0097	85	0.0097

Lifecycle Savings (kWh) for LED Replacement of 4-Foot T8 Lamps

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
Direct Wire	3759, 3839	540	690	675	465	855
Direct Wire, Exterior	4350	630	630	630	630	630
Direct Wire, Exterior 24/7	4351	1,275	1,275	1,275	1,275	1,275

Assumptions

Lamp weightings are based on a combination of energy audit experience, feedback from Lighting Certified individuals through the National Council on Qualifications for the Lighting Professions, and from individuals with lighting sales experience.

It is assumed that an exterior lamp is on for a nighttime average of 4,380 hours, while 8,760 hours are assumed for 24/7 parking garage.

In discussions with the DesignLights Consortium (DLC), it was determined that the Rated Lifetime hours reported in the DLC Qualified Product List[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer spec sheets often do list actual L70 test data, so these data were used to obtain an average rated lifetime for participating models.[1]

Sources

1. SPECTRUM. Online lookups from January 2018 and MMID 3512 participation data from January through December 2017 show that 20 participating models, comprising 140,570 units and 50% of total measure participation, have an average spec sheet rated life of 69,000 hours. With an average HOU of 4,472, the EUL is 15 years.
2. August 2018 online lookups of six base and efficient models on www.1000bulbs.com and www.topbulb.com show an average efficient lamp price of $8.21 and base lamp price of $1.92, for an incremental cost of $6.29.
3. DesignLights Consortium. *Product List.* Accessed November 10, 2016. https://www.designlights.org/search/
4. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3.2 Lighting Hours of Use and Coincidence Factor by Sector. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. "ACES Deemed Savings Desk Review." November 3, 2010. Common Area Lighting Section, p. 9–11. http://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf

6. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/
   Report includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
7. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs.

Revision History

Version Number	Date	Description of Change
01	03/24/2015	Initial TRM entry
02	10/12/2017	Added 12-hour and 24-hour measures
03	12/2018	Updated incremental cost, removed MMID 4094

LED Replacement of 4-Foot T8 Lamps Using Existing Ballast

	Measure Details
Measure Master ID	LED Replacement of 4-Foot T8 Lamps: Using Existing Ballast, 3512, 3823 Using Existing Ballast, Exterior, 4348, 4469 Using Existing Ballast, Exterior 24/7, 4349, 4470
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	11[1]
Incremental Cost	$5.48[2]

Measure Description

Four-foot T8 LEDs are an energy-efficient alternative to standard 4-foot 32-watt, 28-watt, and 25-watt T8 fluorescent lamps found commonly throughout commercial, industrial, agriculture, school and government, and multifamily sectors. These products can replace 32-watt, 28-watt, and 25-watt T8 lamps one-for-one operating off the existing fluorescent ballast.

Description of Baseline Condition

The baseline condition is 4-foot standard 32-watt, 28-watt, and 25-watt T8 lamps on low (0.78), normal (0.88), and high (1.15) ballast factor ballasts (weighted 60%, 30%, and 10%, respectively, in the savings calculations). The 32-watt lamps are weighted 10%, 70%, and 20% with respect to low, normal, and high ballast factors, while 28-watt and 25-watt lamps are weighted 5%, 90%, and 5% for the same ballast factors in the savings calculations (see the Assumptions section).

Description of Efficient Condition

The efficient condition is DesignLights Consortium-listed equipment in the Linear Replacement Lamps category, with a UL Type A primary use category, and a tested or reported wattage of 24 or less. This measure is not intended to be used in refrigerated case lighting applications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1{,}000$

Where:

$Watts_{BASE}$ = Weighted electricity consumption of standard 4-foot 32-watt, 28-watt, and 25-watt T8 fluorescent lamp operating on low, normal, or high ballast factor ballasts (= 27.4 watts)

$Watts_{EE}$ = Weighted average annual electricity consumption of DLC-listed 4-foot linear LED of 24 watts or less, UL Type A (= 17.9 watts)[3]

HOU = Hours of use (= varies by sector; see table below)

1,000 = Kilowatt conversion factor

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950
Exterior[6]	4,380
Exterior 24/7	8,760

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{LED}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[7]	0.77
Exterior	0.00
Exterior 24/7	1.00

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Average Annual Deemed Savings for In Unit LED T8 Lamp

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED Replacement of 4-Foot T8 Lamps											
Using Existing Ballast	3512, 3823	35	0.0073	45	0.0073	45	0.0064	31	0.0061	56	0.0073
Using Existing Ballast, Exterior	4348	42	N/A	42	N/A	42	N/A	42	N/A	42	N/A
Using Existing Ballast, Exterior 24/7	4349	83	0.0095	83	0.0095	83	0.0095	83	0.0095	83	0.0095

Average Lifecycle Deemed Savings for In Unit LED T8 Lamp

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Replacement of 4-Foot T8 Lamps						
Using Existing Ballast	3512, 3823	385	495	495	341	616
Using Existing Ballast, Exterior	4348	462	462	462	462	462
Using Existing Ballast, Exterior 24/7	4349	913	913	913	913	913

Assumptions

Lamp weightings are based on a combination of energy audit experience, feedback from Lighting Certified individuals through the National Council on Qualifications for the Lighting Professions, and from individuals with lighting sales experience.

It is assumed that an exterior lamp is on for a nighttime average of 4,380 hours; 8,760 hours are assumed for 24/7 parking garage.

In discussions with the DesignLights Consortium, it was determined that the rated lifetime hours reported in the DLC Qualified Product List[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer spec sheets often do list actual L70 test data, so these data were used to obtain an average rated lifetime for participating models.[1]

Sources

1. SPECTRUM. Online lookups from January 2018 and MMID 3512 participation data from January through December 2017 show that 13 participating models, comprising 162,906 units and 51% of total measure participation, all have a spec sheet rated life of 50,000 hours. With an average HOU of 4,472, the EUL is 11 years.
2. August 2018 online lookups of six base and efficient models on www.1000bulbs.com, www.superiorlighting.com, www.topbulb.com, and www.beeslighting.com show an average efficient lamp price of $7.40 and base lamp price of $1.92, for an incremental cost of $5.48.
3. DesignLights Consortium. *Product List.* Accessed November 10, 2016. https://www.designlights.org/search/
4. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” March 22, 2010. Table 3-2. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. “ACES Deemed Savings Desk Review.” November 3, 2010. Table 1. www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
6. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. “NOAA Solar Calculator.” http://www.esrl.noaa.gov/gmd/grad/solcalc/
   Report includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
7. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review.” Final Report. Table 4-1. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 83%.

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	11/11/2016	Updated savings
03	10/12/2017	Added 12-hour and 24-hour measures
04	12/2018	Updated incremental cost

LED Replacement of 4-Foot T8 Lamps w/ External Driver

	Measure Details
Measure Master ID	LED Replacement of 4-Foot T8 Lamps: w/ External Driver, 3511, 3822 w/ External Driver, Exterior, 4352, 4473 w/ External Driver, Exterior 24/7, 4353, 4474
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	11[1]
Incremental Cost	$14.11[2]

Measure Description

Four-foot T8 LEDs are an energy-efficient alternative to standard 4-foot 32-watt, 28-watt, and 25-watt T8 fluorescent lamps found commonly throughout commercial, industrial, agriculture, school, government, and multifamily spaces. These products can replace 32-watt, 28-watt, and 25-watt T8 lamps one-for-one, and this measure incorporates those that replace the existing fluorescent lamp(s), remove the ballast(s), and use an external driver.

Description of Baseline Condition

The baseline condition is 4-foot standard 32-watt, 28-watt, and 25-watt T8 lamps on low (0.78), normal (0.88), and high (1.15) ballast factor ballasts. Lamps are weighted 60%, 30%, and 10%, respectively, in the savings calculations. The 32-watt lamp ballast factors are weighted 10%, 70%, and 20% with respect to low, normal, and high. The 28-watt and 25-watt lamp ballast factors are weighted 5%, 90%, and 5% in the savings calculations (see Assumptions section).

Description of Efficient Condition

Efficient equipment must be DesignLights Consortium-listed in the Linear Replacement Lamps category, with a UL Type C primary use category and a tested or reported wattage of 24 or less. This measure is not intended to be used in refrigerated case lighting applications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{FLUORESCENT} - Watts_{LED}) / 1{,}000 * HOU$

Where:

$Watts_{FLUORESCENT}$ = Weighted electricity consumption of standard 4-foot 32-watt, 28-watt, or 25-watt T8 fluorescent lamp operating on low/normal/high ballast factor ballasts (= 27.43 watts)

$Watts_{LED}$ = Weighted average annual electricity consumption of DLC-listed 4-foot linear LED < 24 watts, UL Type C (= 15.56 watts)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950
Exterior[6]	4,380
Exterior 24/7	8,760

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{FLUORESCENT} - Watts_{LED}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[7]	0.77
Industrial[7]	0.77
Agriculture[7]	0.67
Schools & Government[7]	0.64
Multifamily[8]	0.77
Exterior	0.00
Exterior 24/7	1.00

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Annual Savings for LED Replacement of 4-Foot T8

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
w/ External Driver	3511, 3822	44	0.0091	56	0.0091	56	0.0080	38	0.0076	71	0.0091
w/ External Driver, Exterior	4352	52	N/A	52	N/A	52	N/A	52	N/A	52	N/A
w/ External Driver, Exterior 24/7	4353	104	0.0119	104	0.0119	104	0.0119	104	0.0119	104	0.0119

Lifecycle Savings for LED Replacement of 4-Foot T8 (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
w/ External Driver	3511, 3822	484	616	616	418	781
w/ External Driver, Exterior	4352	572	572	572	572	572
w/ External Driver, Exterior 24/7	4353	1,144	1,144	1,144	1,144	1,144

Assumptions

Lamp weightings are based on a combination of energy audit experience, feedback from Lighting Certified individuals through the National Council on Qualifications for the Lighting Professions, and from individuals with lighting sales experience.

It is assumed that an exterior lamp is on for a nighttime average of 4,380 hours, and 8,760 hours are assumed for a 24/7 parking garage.

In discussions with the DesignLights Consortium, it has been determined that the rated lifetime hours reported in the DLC *Qualified Product List*[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC-certified. However, in these cases, manufacturer spec sheets often do list actual L70 test data. Therefore, these data were used to obtain an average rated lifetime for participating models.[1]

Sources

1. SPECTRUM. Online lookups from January 2018 and MMID 3511 participation data from January through December 2017 show that two participating models, comprising 3,950 units and 51% of total measure participation, have a spec sheet rated life of 50,000 hours. With an average HOU of 4,472, the EUL is 11 years.
2. Energy Avenue. Website. Philips Advance ICN-2P32-N. www.energyavenue.com
   ASL Supply. Website. Philips ICN-2P32-N. www.adlsupply.com
   The Lighting Spot. Website. GE-232-MV-N. http://www.lighting-spot.com
   Bulb America. Website. SKU 49853. www.bulbamerica.com
   1000Bulbs. Website. Philips 281535. www.1000bulbs.com
   ALB. Website. Halco F32T8/835/ECO. www.atlantalightbulbs.com
   Bulbs.com. Website. SKU U3000100. www.bulbs.com
   Average baseline cost data from retail sources is $10.79. SPECTRUM measure participation from January 2017 through December 2017 shows that the average cost for participating products is $24.90 for MMID 3511. Therefore, the incremental cost is $14.11 ($24.90 - $10.79).
3. DesignLights Consortium. *Product List.* https://www.designlights.org/search/
4. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3.2 Lighting Hours of Use in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

5. Tetra Tech. “ACES Deemed Savings Desk Review.” November 3, 2010. Common Area Lighting Section, pages 9-11. http://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
6. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. “NOAA Solar Calculator.” http://www.esrl.noaa.gov/gmd/grad/solcalc/
This report includes times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
7. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Table 3.2 Coincidence Factor for Lighting in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
8. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review.” Final Report. Table 4-1. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
Coincidence factor is within range of similar programs.

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	04/2017	Added MMID 4093
03	10/12/2017	Added 12-hour and 24-hour measures
04	01/2019	Removed MMID 4093

LED Replacement of 4-Foot T5 or T5HO Lamps, Direct Wire

	Measure Details
Measure Master ID	LED Replacement of 4-Foot T5 Lamps, Direct Wire, 4805 LED Replacement of 4-Foot T5HO Lamps, Direct Wire, 4806
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	15[1]
Incremental Cost	$10.65[2]

Measure Description

Four-foot T5 or T5HO LEDs are an energy-efficient alternative to standard 4-foot 28-watt T5 or 54-watt T5HO fluorescent lamps found commonly throughout commercial, industrial, agriculture, school and government, and multifamily sectors. These products can replace 28-watt T5 or 54-watt T5HO lamps one for one, and this measure incorporates those that replace the existing fluorescent lamp(s) and remove the ballast(s).

Description of Baseline Condition

The baseline condition is 4-foot standard 28-watt T5 or 54-watt T5HO lamps.

Description of Efficient Condition

The efficient condition is DLC-listed equipment that is direct wired to line voltage, not operating off the existing fluorescent ballast(s) or external driver. This measure is not intended for use in refrigerated case lighting applications. Products must carry a safety certification from a NRTL (such as UL or ETL), must use non-shunted sockets for products that are single-end feed as well as sockets that are twist-lock and warrantied for line voltage, must be installed by a licensed electrician, and must have a re-lamp label applied to modified fixture.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * HOU$

Where:

$Watts_{BASE}$ = Annual electricity consumption of standard 4-foot, 28-watt T5 or 54-watt T5HO lamps (= 33 watts for T5, = 62 watts for T5HO; see Assumptions)

$Watts_{EE}$ = Average annual electricity consumption of DLC-listed 4-foot linear LED, UL Type B (= 17.1 watts for T5, = 24.8 watts for T5HO)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1,000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[6]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Annual Savings for LED Replacement of 4-Foot T5 or T5HO Lamps

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
4-Foot T5 Lamps, Direct Wire	4805	59	0.0122	75	0.0122	75	0.0106	51	0.0102	94	0.0122
4-Foot T5HO Lamps, Direct Wire	4806	139	0.0286	176	0.0286	175	0.0249	120	0.0238	221	0.0286

Lifecycle Savings (kWh) for LED Replacement of 4-Foot T5 or T5HO Lamps

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
4-Foot T5 Lamps, Direct Wire	4805	885	1,125	1,125	765	1,410
4-Foot T5HO Lamps, Direct Wire	4806	2,085	2,640	2,625	1,800	3,315

Assumptions

In discussions with the DLC, it was determined that the rated lifetime hours reported in the DLC Qualified Product List[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC-certified. However, in these cases, manufacturer specification sheets often list actual L70 test data, so these data were used to obtain an average rated lifetime for participating models.[1]

Each baseline lamp wattage is sourced from the Focus on Energy Default Wattage Guide, where a 4-foot, 28-watt T5 equals 33 watts and a 4-foot T5HO lamp equals 62 watts.

Sources

1. EUL based on LED 4-foot T8 lamps, Direct Wire SPECTRUM data.
   Online lookups from MMID 3759 participation data and January through December 2017 show that 20 participating models, comprising 140,570 units and 50% of total measure participation, have an average specification sheet rated life of 69,000 hours. With an average HOU of 4,472, the EUL is 15 years.
2. 1000bulbs. Website. Accessed September 2018. 1000bulbs.com
   Warehouse-lighting. Website. Accessed September 2018. warehouse-lighting.com
   Payless-4-lighting. Website. Accessed September 2018. payless-4-lighting.com
   Ledt8bulbs. Website. Accessed September 2018. ledt8bulb.com
   Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com
   Bulbs. Website. Accessed September 2018. bulbs.com
   Average cost from retail sources. Baseline lamps cost $3.26. Efficient lamps cost $13.91. Therefore, the incremental cost is $10.65.
3. DesignLights Consortium. *Product List.* Accessed September 18, 2018.
   https://www.designlights.org/search/
4. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Table 3.2 Lighting Hours of Use and Coincidence Factor by Sector. Updated March 22, 2010.
   https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. “ACES Deemed Savings Desk Review.” Common Area Lighting Section, p. 9–11. November 3, 2010. http://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
6. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review.” Final Report. June 24, 2008.
   https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs; see Table 4-1 showing multifamily housing (in unit) CF of 65% to 83%.

Revision History

Version Number	Date	Description of Change
01	09/2018	Initial TRM entry

LED Replacement of 4-Foot T5 or T5HO Lamps Using Existing Ballast

	Measure Details
Measure Master ID	LED Replacement of 4-Foot T5 Lamps Using Existing Ballast, 4807 LED Replacement of 4-Foot T5HO Lamps Using Existing Ballast, 4808
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$10.12[2]

Measure Description

Four-foot T5 or T5HO LEDs are an energy-efficient alternative to standard 4-foot 28-watt T5 or 54-watt T5HO fluorescent lamps found commonly throughout commercial, industrial, agriculture, school and government, and multifamily sectors. These products can replace 28-watt T5 or 54-watt T5HO lamps one-for-one operating off the existing fluorescent ballast.

Description of Baseline Condition

The baseline condition is 4-foot standard 28-watt T5 or 54-watt T5HO lamps.

Description of Efficient Condition

The efficient condition is DLC-listed equipment in the Linear Replacement Lamps category, with a UL Type A primary use category. This measure is not intended to be used in refrigerated case lighting applications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000$

Where:

$Watts_{BASE}$ = Annual electricity consumption of standard 4-foot 28-watt T5 or 54-watt T5HO lamps (= 33 watts for T5, = 62 watts for T5HO; see Assumptions)

$Watts_{EE}$ = Average annual electricity consumption of DLC-listed 4-foot linear LED, UL Type A (= 19.5 watts for T5, = 28.5 watts for T5HO)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[6]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1,000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[6]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED T5 or T5HO Lamp

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED Replacement of 4-Foot T5 Lamps Using Existing Ballast	4807	50	0.0104	64	0.0104	64	0.0091	44	0.0087	80	0.0104
LED Replacement of 4-Foot T5HO Lamps Using Existing Ballast	4808	125	0.0258	159	0.0258	157	0.0224	108	0.0214	199	0.0258

Average Lifecycle Deemed Savings for LED T5 or T5HO Lamp

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Replacement of 4-Foot T5 Lamps Using Existing Ballast	4807	550	704	704	484	880
LED Replacement of 4-Foot T5HO Lamps Using Existing Ballast	4808	1,375	1,749	1,727	1,188	2,189

Assumptions

In discussions with the DLC, it was determined that the rated lifetime hours reported in the DLC Qualified Product List[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer specification sheets often list actual L70 test data, so these data were used to obtain an average rated lifetime for participating models.[1]

Each baseline lamp wattage is sourced from the Focus on Energy Default Wattage Guide, where a 4-foot 28-watt T5 equals 33 watts and a 4-foot T5HO lamp equals 62 watts.

Sources

1. EUL based on LED 4-Foot T8 Lamps Using Existing Ballast SPECTRUM data. Online lookups from January 2018 and MMID 3512 participation data from January through December 2017 show that 13 participating models, comprising 162,906 units and 51% of total measure participation, all have a specification sheet rated life of 50,000 hours. With an average HOU of 4,472, the EUL is 11 years.
2. 1000bulbs. Website. Accessed September 2018. 1000bulbs.com
   Warehouse-lighting. Website. Accessed September 2018. warehouse-lighting.com
   Payless-4-lighting. Website. Accessed September 2018. payless-4-lighting.com
   1000bulbs. Website. Accessed September 2018. 1000bulbs.com
   Bulbs. Website. Accessed September 2018. bulbs.com
   LEDt8bulb. Website. Accessed September 2018. ledt8bulb.com
   Average cost from retail sources. Baseline lamps cost $3.26. Efficient lamps cost $13.38. Therefore, the incremental cost is $10.12.
3. DesignLights Consortium. *Product List.* Accessed September 18, 2018. https://www.designlights.org/search/
4. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3-2. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. "ACES Deemed Savings Desk Review." Table 1. November 3, 2010. www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
6. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. Table 4-1. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 83%.

Revision History

Version Number	Date	Description of Change
01	09/2018	Initial TRM entry

LED Replacement of 4-Foot T5 or T5HO Lamps w/ External Driver

	Measure Details
Measure Master ID	LED Replacement of 4-Foot T5 Lamps w/ External Driver, 4803 LED Replacement of 4-Foot T5HO Lamps w/ External Driver, 4804
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$49.32[2]

Measure Description

Four-foot T5 or T5HO LEDs are an energy-efficient alternative to standard 4-foot 28-watt T5 or 54-watt T5HO fluorescent lamps found commonly throughout commercial, industrial, agriculture, school and government, and multifamily sectors. These products can replace 28-watt T5 or 54-watt T5HO lamps one-for-one, and this measure incorporates those that replace the existing fluorescent lamp(s), remove the ballast(s), and use an external driver.

Description of Baseline Condition

The baseline condition is 4-foot standard 28-watt T5 or 54-watt T5HO lamps.

Description of Efficient Condition

Efficient equipment must be DLC-listed in the Linear Replacement Lamps category, with a UL Type C primary use category. This measure is not intended to be used in refrigerated case lighting applications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1,000 * HOU$

Where:

$Watts_{BASE}$ = Annual electricity consumption of standard 4-foot 28-watt T5 or 54-watt T5HO lamps (= 33 watts for T5, = 62 watts for T5HO; see Assumptions)

$Watts_{EE}$ = Average annual electricity consumption of DLC-listed 4-foot linear LED, UL Type C (= 21.7 watts for T5, = 26.7 watts for T5HO)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1,000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[6]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Annual Savings for LED Replacement of 4-Foot T5 or T5HO

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
4-Foot T5 Lamps w/ External Driver	4803	42	0.0087	54	0.0087	53	0.0076	37	0.0072	67	0.0087
4-Foot T5HO Lamps w/ External Driver	4804	132	0.0272	168	0.0272	166	0.0237	114	0.0226	210	0.0272

Lifecycle Savings for LED Replacement of 4-Foot T5 or T5HO (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
4-Foot T5 Lamps w/ External Driver	4803	462	594	583	407	737
4-Foot T5HO Lamps w/ External Driver	4804	1,452	1,848	1,826	1,254	2,310

Assumptions

In discussions with the DLC, it has been determined that the rated lifetime hours reported in the DLC *Qualified Product List*[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC-certified. However, in these cases, manufacturer specification sheets often list actual L70 test data. Therefore, these data were used to obtain an average rated lifetime for participating models.[1]

Each baseline lamp wattage is sourced from the Focus on Energy Default Wattage Guide, where a 4-foot, 28-watt T5 equals 33 watts and a 4-foot T5HO lamp equals 62 watts.

Sources

1. EUL based on LED 4-Foot T8 Lamps w/ External Driver SPECTRUM data. Online lookups from January 2018 and MMID 3511 participation data from January through December 2017 show that two participating models, comprising 3,950 units and 51% of total measure participation, have a specification sheet rated life of 50,000 hours. With an average HOU of 4,472, the EUL is 11 years.
2. 1000Bulbs. Website. Accessed September 2018. 1000bulbs.com
   Warehouse-lighting. Website. Accessed September 2018. warehouse-lighting.com
   Payless-4-lighting. Website. Accessed September 2018. payless-4-lighting.com
   Ledt8bulb. Website. Accessed September 2018. ledt8bulb.com
   Bulbsdepot. Website. Accessed September 2018. bulbsdepot.com
   Ledt8bulb. Website. Accessed September 2018. ledt8bulb.com
   Average cost from retail sources. Baseline lamps cost $3.26. Efficient lamps cost $20.63. Efficient lamp driver cost $31.95. Therefore, the incremental cost is $49.32.
3. DesignLights Consortium. *Product List.* Accessed September 18, 2016. https://www.designlights.org/search/
4. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3.2 Lighting Hours of Use and Coincidence Factor by Sector. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. "ACES Deemed Savings Desk Review." Common Area Lighting section, pp. 9–11. November 3, 2010. http://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
6. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs; see Table 4-1 showing multifamily housing (in unit) CF of 65% to 83%.

Revision History

Version Number	Date	Description of Change
01	09/2018	Initial TRM entry

LED Replacement of 8-Foot T8 Lamps, Direct Wire

	Measure Details
Measure Master ID	LED Replacement of 8’ T8 or T12 Lamps, Direct Wire (UL Type B), 4810 LED Replacement of 8’ T8 or T12 Lamps, Direct Wire (UL Type B), Exterior, 4832 LED Replacement of 8-Foot T8 Lamps, Direct Wire (UL Type B), Exterior 24/7, 4835
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$23.29[2]

Measure Description

Eight-foot T8 LEDs are an energy-efficient alternative to standard eight-foot 59-watt T8 fluorescent lamps found commonly throughout commercial, industrial, agriculture, school and government, and multifamily sectors. These products can replace 59-watt T8 lamps one-for-one, and this measure incorporates those that replace the existing fluorescent lamp(s) and remove the ballast(s).

Description of Baseline Condition

The baseline condition is 8-foot standard 59-watt T8 lamp.

Description of Efficient Condition

The efficient condition is DLC-listed equipment direct wired to line voltage, not operating off the existing fluorescent ballast(s) or external driver. This measure is not intended to be used in refrigerated case lighting applications. Products must carry a safety certification from a NRTL, such as UL or ETL, and use non-shunted sockets for products that are single-end feed and sockets that are twist-lock and warrantied for line voltage, and must be installed by a licensed electrician and have a re-lamp label applied to modified fixture.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * HOU$

Where:

$Watts_{BASE}$ = Annual electricity consumption of standard 8-foot 59-watt T8 fluorescent lamp (= 61 watts; see Assumptions)

$Watts_{EE}$ = Average annual electricity consumption of DLC-listed 8-foot linear LED, UL Type B (= 39.0 watts)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950
Exterior[6]	4,380
Exterior 24/7	8,760

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * CF$

Where:

CF = Coincidence factor (varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[7]	0.77
Exterior	0.00
Exterior 24/7	1.00

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Annual Savings for LED Replacement of 8-Foot T8 Lamps

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Direct Wire	4810	82	0.0169	104	0.0169	103	0.0147	71	0.0141	131	0.0169
Direct Wire, Exterior	4832	96	0	96	0	96	0	96	0	96	0
Direct Wire, Exterior 24/7	4835	192	0.022	192	0.022	192	0.022	192	0.022	192	0.022

Lifecycle Savings (kWh) for LED Replacement of 8-Foot T8 Lamps

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
Direct Wire	4810	1,230	1,560	1,545	1,065	1,965
Direct Wire, Exterior	4832	1,440	1,440	1,440	1,440	1,440
Direct Wire, Exterior 24/7	4835	2,880	2,880	2,880	2,880	2,880

Assumptions

In discussions with the DLC, it was determined that the Rated Lifetime hours reported in the DLC Qualified Product List[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer specification sheets often list actual L70 test data, so these data were used to obtain an average rated lifetime for participating models.[1]

Each baseline lamp wattage is sourced from the Focus on Energy Default Wattage Guide, where an 8-foot, 59-watt T8 lamp equals 61 watts.

It is assumed that an exterior lamp is on for a nighttime average of 4,380 hours per year; 8,760 hours are assumed for 24/7 lighting use.

Sources

1. EUL based on LED 4-Foot T8 Lamps, Direct Wire SPECTRUM data. Online lookups from January 2018 and MMID 3759 participation data from January through December 2017 show that 20 models, comprising 140,570 units and 50% of total measure participation, have an average specification sheet rated life of 69,000 hours. With an average HOU of 4,472, the EUL is 15 years.
2. 1000Bulbs. Website. Accessed September 2018. 1000bulbs.com
   Bulbs. Website. Accessed September 2018. bulbs.com
   Ledt8bulb. Website. Accessed September 2018. ledt8bulb.com
   1000bulbs. Website. Accessed September 2018. 1000bulbs.com
   Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com
   LEDt8bulb. Website. Accessed September 2018. ledt8bulb.com
   Average cost from retail sources. Baseline lamps cost $10.37. Efficient lamps cost $33.66. Therefore, the incremental cost is $23.29.
3. DesignLights Consortium. *Product List.* Accessed September 18, 2018. https://www.designlights.org/search/
4. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3.2 Lighting Hours of Use and Coincidence Factor by Sector. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. "ACES Deemed Savings Desk Review." November 3, 2010. Common Area Lighting Section, p. 9–11. http://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
6. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/
   Report includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting, as well as time clock scheduled lighting.
7. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs; see Table 4-1 showing multifamily housing (in unit) CF of 65% to 83%.

Revision History

Version Number	Date	Description of Change
01	09/2018	Initial TRM entry

LED Replacement of 8-Foot T8 Lamps Using Existing Ballast

	Measure Details
Measure Master ID	LED Replacement of 8’ T8 or T12 Lamp: Utilizing Existing Ballast (UL Type A), 4811 Utilizing Existing Ballast (UL Type A), Exterior, 4830 Utilizing Existing Ballast (UL Type A), Exterior 24/7, 4833
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$16.69[2]

Measure Description

Eight-foot T8 LEDs are an energy-efficient alternative to standard eight-foot 59-watt T8 fluorescent lamps found commonly throughout commercial, industrial, agriculture, school and government, and multifamily sectors. These products can replace 59-watt T8 lamps one-for-one operating off the existing fluorescent ballast.

Description of Baseline Condition

The baseline condition is an 8-foot standard 59-watt T8 lamp.

Description of Efficient Condition

The efficient condition is 8-foot LED DLC-listed equipment in the Linear Replacement Lamps category, with a UL Type A primary use category. This measure is not intended to be used in refrigerated case lighting applications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000$

Where:

$Watts_{BASE}$ = Annual electricity consumption of standard 8-foot 59-watt T8 fluorescent lamp (= 61 watts; see Assumptions)

$Watts_{EE}$ = Average annual electricity consumption of DLC-listed 8-foot linear LED, UL Type A (= 34.5 watts)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950
Exterior[6]	4,380
Exterior 24/7	8,760

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1,000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[7]	0.77
Exterior	0.00
Exterior 24/7	1.00

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED T8 Lamp

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED Replacement of 8-Foot T8 Lamps											
Using Existing Ballast	4811	99	0.0204	126	0.0204	124	0.0178	86	0.017	158	0.0204
w/External Driver, Exterior	4830	116	0	116	0	116	0	116	0	116	0
w/External Driver, Exterior 24/7	4833	232	0.0265	232	0.0265	232	0.0265	232	0.0265	232	0.0265

Average Lifecycle Deemed Savings for LED T8 Lamp

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Replacement of 8-Foot T8 Lamps						
Using Existing Ballast	4811	1,089	1,386	1,364	946	1,738
w/External Driver, Exterior	4830	1,276	1,276	1,276	1,276	1,276
w/External Driver, Exterior 24/7	4833	2,552	2,552	2,552	2,552	2,552

Assumptions

In discussions with the DLC, it was determined that the rated lifetime hours reported in the DLC Qualified Product List[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer specification sheets often list actual L70 test data, so these data were used to obtain an average rated lifetime for participating models.[1]

Each baseline lamp wattage is sourced from the Focus on Energy Default Wattage Guide, where an 8-foot, 59-watt T8 lamp equals 61 watts.

Sources

1. EUL based on LED 4-Foot T8 Lamps Using Existing Ballast SPECTRUM data. Online lookups from January 2018 and MMID 3512 participation data from January through December 2017 show that 13 models, comprising 162,906 units and 51% of total measure participation, all have a specification sheet rated life of 50,000 hours. With an average HOU of 4,472, the EUL is 11 years.
2. 1000Bulbs. Website. Accessed September 2018. 1000bulbs.com
   Bulbs. Website. Accessed September 2018. bulbs.com
   Ledt8bulb. Website. Accessed September 2018. ledt8bulb.com
   1000bulbs. Website. Accessed September 2018. 1000bulbs.com
   Greenelectricalsupply. Website. Accessed September 2018. greenelectricalsupply.com
   Lighting-spot. Website. Accessed September 2018. lighting-spot.com
   Average cost from retail sources. Baseline lamps cost $10.37. Efficient lamps cost $27.06. Therefore, the incremental cost is $16.69.
3. DesignLights Consortium. *Product List.* Accessed September 18, 2016. https://www.designlights.org/search/
4. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3-2. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. "ACES Deemed Savings Desk Review." Common Area Lighting section, p. 9–11. November 3, 2010. www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
6. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/
   Report includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting, as well as time clock scheduled lighting.
7. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. Table 4-1. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 83%.

Revision History

Version Number	Date	Description of Change
01	09/2018	Initial TRM entry

LED Replacement of 8-Foot T8 Lamps w/ External Driver

	Measure Details
Measure Master ID	LED Replacement of 8' T8 or T12 Lamp: w/ External Driver (UL Type C), 4809 w/ External Driver (UL Type C), Exterior, 4831 w/ External Driver, (UL Type C) Exterior 24/7, 4834
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$57.68[2]

Measure Description

Eight-foot T8 LEDs are an energy-efficient alternative to standard eight-foot 59-watt T8 fluorescent lamps found commonly throughout commercial, industrial, agriculture, school and government, and multifamily sectors. These products can replace 59-watt T8 lamps one-for-one, and this measure incorporates those that replace the existing fluorescent lamp(s), remove the ballast(s), and use an external driver.

Description of Baseline Condition

The baseline condition is 8-foot standard 59-watt T8 lamp.

Description of Efficient Condition

Efficient equipment must be DLC-listed in the Linear Replacement Lamps category, with a UL Type C primary use category. This measure is not intended to be used in refrigerated case lighting applications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE})\ /1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Annual electricity consumption of standard 8-foot, 59-watt T8 fluorescent lamp (= 61 watts; see Assumptions)

$Watts_{EE}$ = Average annual electricity consumption of DLC-listed 8-foot linear LED, UL Type C (= 32.7 watts)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950
Exterior[6]	4,380
Exterior 24/7	8,760

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE})\ /1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[7]	0.77
Exterior	0.00
Exterior 24/7	1.00

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Annual Savings for LED Replacement of 8-Foot T8

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
w/ External Driver	4809	106	0.0218	134	0.0218	133	0.019	92	0.0181	168	0.0218
w/ External Driver, Exterior	4831	124	0	124	0	124	0	124	0	124	0
w/ External Driver, Exterior 24/7	4834	248	0.0283	248	0.0283	248	0.0283	248	0.0283	248	0.0283

Lifecycle Savings for LED Replacement of 8-Foot T8 (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
w/ External Driver	4809	1,166	1,474	1,463	1,012	1,848
w/ External Driver, Exterior	4831	1,364	1,364	1,364	1,364	1,364
w/ External Driver, Exterior 24/7	4834	2,728	2,728	2,728	2,728	2,728

Assumptions

In discussions with the DLC, it has been determined that the rated lifetime hours reported in the DLC *Qualified Product List*[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer specification sheets often list actual L70 test data. Therefore, these data were used to obtain an average rated lifetime for participating models.[1]

Each baseline lamp wattage is sourced from the Focus on Energy Default Wattage Guide, where an 8-foot, 59-watt T8 lamp equals 61 watts.

Sources

1. EUL based on LED 4-Foot T8 Lamps w/ External Driver SPECTRUM data. Online lookups from January 2018 and MMID 3511 participation data from January through December 2017 show that two models, comprising 3,950 units and 51% of total measure participation, have a specification sheet rated life of 50,000 hours. With an average HOU of 4,472, the EUL is 11 years.
2. 1000Bulbs. Website. Accessed September 2018. 1000bulbs.com
   Bulbs. Website. Accessed September 2018. bulbs.com
   Ledt8bulb. Website. Accessed September 2018. ledt8bulb.com
   Itsthyme. Website. Accessed September 2018. itsthyme.com
   Ledt8bulb. Website. Accessed September 2018. ledt8bulb.com
   Ledt8bulb. Website. Accessed September 2018. ledt8bulb.com
   Average cost from retail sources. Baseline lamps cost $10.37. Efficient lamps cost $36.10. Efficient lamp driver cost $31.95. Therefore, the incremental cost is $57.68.
3. DesignLights Consortium. *Product List.* Accessed September 18, 2016. https://www.designlights.org/search/
4. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3.2 Lighting Hours of Use and Coincidence Factor by Sector. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. "ACES Deemed Savings Desk Review." Common Area Lighting section, pp. 9–11. November 3, 2010. http://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
6. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/
   This report includes times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting, as well as time clock scheduled lighting.
7. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs; see Table 4-1 showing multifamily housing (in unit) CF of 65% to 83%.

Revision History

Version Number	Date	Description of Change
01	09/2018	Initial TRM entry

LED Replacement of U-Bend or 2-Foot T8 Lamps, Direct Wire

	Measure Details
Measure Master ID	LED Replacement of U-Bend T8 Lamps, Direct Wire, 4801 LED Replacement of 2-Foot T8 Lamps, Direct Wire, 4798
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	U-Bend T8 Lamps = $12.39 (4801),[2] 2-Foot T8 Lamps = $7.41 (4798)[3]

Measure Description

U-bend or 2-foot LEDs are an energy-efficient alternative to standard 32-watt U-bend T8 or 17-watt T8 fluorescent lamps found commonly throughout commercial, industrial, agriculture, school and government, and multifamily sectors. These products can replace 32-watt U-bend T8 or 17-watt T8 lamps one-for-one, and this measure incorporates those that replace the existing fluorescent lamp(s) and remove the ballast(s).

Description of Baseline Condition

The baseline condition is 32-watt U-bend T8 or 2-foot 17-watt T8 lamps.

Description of Efficient Condition

The efficient condition is DLC-listed equipment direct wired to line voltage, not operating off the existing fluorescent ballast(s) or external driver. This measure is not intended to be used in refrigerated case lighting applications. Products must carry a safety certification from a NRTL, such as UL or ETL, and use non-shunted sockets for products that are single-end feed and sockets that are twist-lock and warrantied for line voltage, and must be installed by a licensed electrician and have a re-lamp label applied to the modified fixture.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * HOU$

Where:

$Watts_{BASE}$ = Annual electricity consumption of standard 32-watt U-bend T8 or 17-watt T8 lamps (= 29 watts for U-bend T8, = 20 watts for 2-foot T8; see Assumptions)

$Watts_{EE}$ = Annual electricity consumption of DLC-listed U-bend LED or 2-foot T8, UL Type B (= 16.1 watts for U-bend T8, = 9.6 watts for 2-foot T8)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1,000 * CF$

Where:

CF = Coincidence factor (varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[6]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Annual Savings for LED Replacement of LED U-Bend or 2-Foot Lamps

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
U-Bend T8 Lamps, Direct Wire	4801	48	0.01	61	0.01	61	0.0087	42	0.0083	77	0.01
2-Foot T8 Lamps, Direct Wire	4798	39	0.008	49	0.008	49	0.007	34	0.0067	62	0.008

Lifecycle Savings for LED Replacement of LED U-Bend or 2-Foot Lamps (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
U-Bend T8 Lamps, Direct Wire	4801	720	915	915	630	1,155
2-Foot T8 Lamps, Direct Wire	4798	585	735	735	510	930

Assumptions

In discussions with the DLC, it was determined that the Rated Lifetime hours reported in the DLC *Qualified Product List*[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer specification sheets often list actual L70 test data, so these data were used to obtain an average rated lifetime for participating models.[1]

Each baseline lamp wattage is sourced from the Focus on Energy Default Wattage Guide, where a 32-watt T8 U-bend lamp is 29 watts and a 2-foot, 17-watt T8 lamp is 20 watts.

Sources

1. EUL based on LED 4-Foot T8 Lamps, Direct Wire SPECTRUM data. Online lookups from January 2018 and MMID 3759 participation data from January through December 2017 show that 20 participating models, comprising 140,570 units and 50% of total measure participation, have an average specification sheet rated life of 69,000 hours. With an average HOU of 4,472, the EUL is 15 years.

2. 1000bulbs. Website. Accessed September 2018. 1000bulbs.com
Warehouse-lighting. Website. Accessed September 2018. warehouse-lighting.com
Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com
1000bulbs. Website. Accessed September 2018. 1000bulbs.com
Topbulb. Website. Accessed September 2018. topbulb.com
LEDt8bulb. Website. Accessed September 2018. ledt8bulb.com
Average U-bend LED cost from retail sources. Baseline lamps cost $7.31. Efficient lamps cost $19.69. Therefore, the incremental cost is $12.39.
3. 1000bulbs. Website. Accessed September 2018. 1000bulbs.com
Warehouse-lighting. Website. Accessed September 2018. warehouse-lighting.com
Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com
1000bulbs. Website. Accessed September 2018. 1000bulbs.com
Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com
LEDt8bulb. Website. Accessed September 2018. ledt8bulb.com
Average 2-Foot LED cost from retail sources. Baseline lamps cost $2.71. Efficient lamps cost $10.11. Therefore, the incremental cost is $7.41.
4. DesignLights Consortium. *Product List.* Accessed September 18, 2018. https://www.designlights.org/search/
5. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3.2 Lighting Hours of Use and Coincidence Factor by Sector. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. Tetra Tech. "ACES Deemed Savings Desk Review." Common Area Lighting Section, p. 9–11. November 3, 2010. http://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
7. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
Coincidence factor is within range of similar programs; see Table 4-1 showing multifamily housing (in unit) CF of 65% to 83%.

Revision History

Version Number	Date	Description of Change
01	09/2018	Initial TRM entry

LED Replacement of U-Bend or 2-Foot T8 Lamps Using Existing Ballast

	Measure Details
Measure Master ID	LED Replacement of U-Bend T8 Lamps Using Existing Ballast, 4802 LED Replacement of 2-Foot Lamps Using Existing Ballast, 4799
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	U-Bend Lamps = $13.49 (4802),[2] 2-Foot Lamps = $9.66 (4799)[3]

Measure Description

U-bend or 2-foot LEDs are an energy-efficient alternative to standard 32-watt U-bend T8 or 17-watt T8 fluorescent lamps found commonly throughout commercial, industrial, agriculture, school and government, and multifamily sectors. These products can replace 32-watt U-bend T8 or 17-watt T8 lamps one-for-one operating off the existing fluorescent ballast.

Description of Baseline Condition

The baseline condition is standard 32-watt U-bend T8 or 2-foot 17-watt T8 lamps.

Description of Efficient Condition

The efficient condition is DLC-listed equipment in the Linear Replacement Lamps category, with a UL Type A primary use category. This measure is not intended to be used in refrigerated case lighting applications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) * HOU / 1{,}000$

Where:

$Watts_{BASE}$ = Annual electricity consumption of standard 32-watt U-bend T8 or 17-watt T8 lamps (= 29 watts for U-bend T8, = 20 watts for 2-foot T8; see Assumptions)

$Watts_{EE}$ = Average annual electricity consumption of DLC-listed U-bend LED or 2-foot T8, UL Type A (= 16.4 watts for U-bend T8, = 10.3 watts for 2-foot T8)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[6]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED U-Bend or 2-Foot Lamp

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED Replacement of U-Bend T8 Lamps Using Existing Ballast	4802	47	0.0097	60	0.0097	59	0.0084	41	0.0081	75	0.0097
LED Replacement of 2-Foot T8 Lamps Using Existing Ballast	4799	38	0.0079	49	0.0079	48	0.0069	33	0.0066	61	0.0079

Average Lifecycle Deemed Savings for LED U-Bend or 2-Foot Lamp (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Replacement of U-Bend T8 Lamps Using Existing Ballast	4802	517	660	649	451	825
LED Replacement of 2-Foot T8 Lamps Using Existing Ballast	4799	418	539	528	363	671

Assumptions

In discussions with the DLC, it was determined that the rated lifetime hours reported in the DLC Qualified Product List[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer specification sheets often list actual L70 test data, so these data were used to obtain an average rated lifetime for participating models.[1]

Each baseline lamp wattage is sourced from the Focus on Energy Default Wattage Guide, where a 32-watt T8 U-bend lamp is 29 watts and a 2-foot, 17-watt T8 lamp is 20 watts.

Sources

1. EUL based on LED 4-Foot T8 Lamps Using Existing Ballast SPECTRUM data. Online lookups from January 2018 and MMID 3512 participation data from January through December 2017 show

that 13 models, comprising 162,906 units and 51% of total measure participation, all have a specification sheet rated life of 50,000 hours. With an average HOU of 4,472, the EUL is 11 years.

2. 1000bulbs. Website. Accessed September 2018. 1000bulbs.com
Warehouse-lighting. Website. Accessed September 2018. warehouse-lighting.com
Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com
1000bulbs. Website. Accessed September 2018. 1000bulbs.com
Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com
LEDt8bulb. Website. Accessed September 2018. ledt8bulb.com
Average U-bend LED cost from retail sources. Baseline lamps cost $7.31. Efficient lamps cost $20.79. Therefore, the incremental cost is $13.49.
3. 1000bulbs. Website. Accessed September 2018. 1000bulbs.com
Warehouse-lighting. Website. Accessed September 2018. warehouse-lighting.com
Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com
1000bulbs. Website. Accessed September 2018. 1000bulbs.com
Warehouse-lighting. Website. Accessed September 2018. warehouse-lighting.com
LEDt8bulb. Website. Accessed September 2018. ledt8bulb.com
Average 2-foot LED cost from retail sources. Baseline lamps cost $2.71. Efficient lamps cost $12.36. Therefore, the incremental cost is $9.66.
4. DesignLights Consortium. *Product List.* Accessed September 18, 2018. https://www.designlights.org/search/
5. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Table 3-2. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. Tetra Tech. “ACES Deemed Savings Desk Review.” Table 1. November 3, 2010. www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
7. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review.” Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
Coincidence factor is within range of similar programs; see Table 4-1 showing multifamily housing (in unit) CF of 65% to 83%.

Revision History

Version Number	Date	Description of Change
01	09/2018	Initial TRM entry

LED Replacement of U-Bend or 2-Foot T8 Lamps w/ External Driver

	Measure Details
Measure Master ID	LED Replacement of U-Bend T8 Lamps w/ External Driver, 4800 LED Replacement of 2-Foot T8 Lamps w/ External Driver, 4797
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	11[1]
Incremental Cost	U-Bend T8 Lamps = $39.53 (4800),[2] 2-Foot T8 Lamps = $31.39 (4797)[3]

Measure Description

U-bend and 2-foot LEDs are an energy-efficient alternative to standard 32-watt U-bend T8 or 17-watt T8 fluorescent lamps found commonly throughout commercial, industrial, agriculture, school and government, and multifamily sectors. These products can replace 32-watt U-bend T8 or 17-watt T8 lamps one-for-one, and this measure incorporates those that replace the existing fluorescent lamp(s), remove the ballast(s), and use an external driver.

Description of Baseline Condition

The baseline condition is standard 32-watt, U-bend T8 or 2-foot, 17-watt T8 lamps.

Description of Efficient Condition

Efficient equipment must be DLC-listed in the Linear Replacement Lamps category, with a UL Type C primary use category. This measure is not intended to be used in refrigerated case lighting applications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Annual electricity consumption of standard 32-watt U-bend T8 or 17-watt T8 lamps (= 29 watts for U-bend T8, = 20 watts for 2-foot T8; see Assumptions)

$Watts_{EE}$ = Average annual electricity consumption of DLC-listed U-bend LED or 2-foot T8, UL Type C (= 15.2 watts for U-bend T8, = 11.1 watts for 2-foot T8)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[6]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Annual Savings for LED Replacement of LED U-Bend or 2-Foot Lamp

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
U-Bend T8 Lamps w/ External Driver	4800	52	0.0106	66	0.0106	65	0.0093	45	0.0088	82	0.0106
2-Foot T8 Lamps w/ External Driver	4797	33	0.0069	42	0.0069	42	0.006	29	0.0057	53	0.0069

Lifecycle Savings for LED Replacement of LED U-Bend or 2-Foot Lamp (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
U-Bend T8 Lamps w/ External Driver	4800	572	726	715	495	902
2-Foot T8 Lamps w/ External Driver	4797	363	462	462	319	583

Assumptions

In discussions with the DLC, it has been determined that the rated lifetime hours reported in the DLC *Qualified Product List*[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC-certified. However, in these cases, manufacturer specification sheets often list actual L70 test data. Therefore, these data were used to obtain an average rated lifetime for participating models.[1]

Each baseline lamp wattage is sourced from the Focus on Energy Default Wattage Guide, where a 32-watt, T8 U-bend lamp is 29 watts and a 2-foot, 17-watt T8 lamp is 20 watts.

Sources

1. EUL based on LED 4-Foot T8 Lamps w/ External Driver SPECTRUM data. Online lookups from January 2018 and MMID 3511 participation data from January through December 2017 show that two participating models, comprising 3,950 units and 51% of total measure participation, have a specification sheet rated life of 50,000 hours. With an average HOU of 4,472, the EUL is 11 years.

2. 1000Bulbs. Website. Accessed September 2018. 1000bulbs.com
Warehouse-lighting. Website. Accessed September 2018. warehouse-lighting.com
Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com
Prolighting. Website. Accessed September 2018. prolighting.com
Bulbsdepot. Website. Accessed September 2018. bulbsdepot.com
LEDt8bulb. Website. Accessed September 2018. ledt8bulb.com
Average U-bend LED cost from retail sources. Baseline lamps cost $7.31. Efficient lamps cost $17.88. Efficient lamp driver cost $28.95. Therefore, the incremental cost is $39.53.
3. 1000bulbs. Website. Accessed September 2018. 1000bulbs.com
Warehouse-lighting. Website. Accessed September 2018. warehouse-lighting.com
Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com
Prolighting. Website. Accessed September 2018. prolighting.com
Bulbsdepot. Website. Accessed September 2018. bulbsdepot.com
LEDt8bulb. Website. Accessed September 2018. ledt8bulb.com
Average 2-foot LED cost from retail sources. Baseline lamps cost $2.71. Efficient lamps cost $10.60. Efficient lamp driver cost $23.50. Therefore, the incremental cost is $31.39.
4. DesignLights Consortium. *Product List.* Accessed September 18, 2016. https://www.designlights.org/search/
5. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Table 3.2 Lighting Hours of Use and Coincidence Factor by Sector. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. Tetra Tech. “ACES Deemed Savings Desk Review.” Common Area Lighting Section, pp. 9–11. November 3, 2010. http://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
7. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review.” Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
Coincidence factor is within range of similar programs; see Table 4-1 showing multifamily housing (in unit) CF of 65% to 83%.

Revision History

Version Number	Date	Description of Change
01	09/2018	Initial TRM entry

LED Track/Mono/Accent Fixtures

	Measure Details
Measure Master ID	LED Fixture, Track/Mono/Accent, 4813 LED Fixture, Track/Mono/Accent, In-Unit, 4814
Measure Unit	Per watt reduced
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$2.29[2]

Measure Description

LED track, mono-point, and accent fixtures can replace existing non-solid-state fixtures without sacrificing performance, and these fixtures save energy because they consume less wattage than non-solid-state lighting products.

Description of Baseline Condition

The baseline is the power consumption of the existing lighting equipment.

Description of Efficient Condition

The efficient equipment is an ENERGY STAR or DLC rated fixture

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{LEDEE}) * HOU / 1{,}000$

Where:

$Watts_{BASE}$ = Per-fixture power consumption of current installed lighting equipment (= actual; provided by the Trade Ally for each project)

$Watts_{LEDEE}$ = Power consumption of qualified LED fixture (= actual; provided by the Trade Ally for each project)

1,000 = Kilowatt conversion factor
HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[3]	3,730
Industrial[3]	4,745
Agriculture[3]	4,698
Schools & Government[3]	3,239
Multifamily – Common Area[4]	5,950
Multifamily – In Unit[5]	734

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{LEDEE}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (+ varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[3]	0.77
Industrial[3]	0.77
Agriculture[3]	0.67
Schools & Government[3]	0.64
Multifamily – Common Area[6]	0.77
Multifamily – In Unit[5]	0.055

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 13 years)[1]

Deemed Savings

Average Annual Deemed Savings per Watt Reduced, Non-Res

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED Track/Mono/Accent	4813	3.73	0.0008	4.75	0.0008	4.70	0.0007	3.24	0.0006

Average Annual Deemed Savings per Watt Reduced, Multifamily

Measure	MMIDs	Multifamily – Common Area		Multifamily – In Unit	
		kWh	kW	kWh	kW
LED Track/Mono/Accent	4813, 4814	5.95	0.0008	0.734	0.0006

Average Lifecycle Deemed Savings Per Watt Reduced, Non-Res

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov
LED Track/Mono/Accent	4813	41.03	52.25	51.70	35.64

Average Lifecycle Deemed Savings Per Watt Reduced, Multifamily

Measure	MMIDs	Multifamily – Common Area	Multifamily – In Unit
LED Track/Mono/Accent	4813, 4814	65.45	8.07

Assumptions

Incremental cost was calculated on a per-watt basis from the Focus on Energy historical program data from January 2015 to October 2018 for MMIDs 3736 and 3737. The average of the sector hours is from the Hours of Use by Sector table above, excluding the in-unit sector since the historical program data does not exist.

Cost in $/W = [Actual Measure Cost Sum] / [First Year kWh Savings * 1,000 / Average Sector Hours (4,472)]

For multifamily new construction projects, a 2.0 factor of the proposed LED wattage was assumed to obtain the baseline wattage. This was based on ENERGY STAR qualified products' average source efficacy (83 LPW) for fixtures that fall under the measure scope (Accent Light Line-Voltage, Chandelier, Close to Ceiling Mount, Decorative Pendant, LED Surface Mount Wall Sconce Retrofit, Other, Pendant, and Wall Sconces) from October 2018, divided by the EISA 2020 45 lumen/watt screw-in source standard. The ratio of 1.84 was rounded to 2.0 to be conservative, and in recognition that Wisconsin residential code only requires 50% of installed lamps to be high efficiency. January through September

2018 multifamily program data indicates that there was no participation from any DLC products, hence an ENERGY STAR exclusive product list was used.

Sources

1. Average rated life of ENERGY STAR and DLC listed products divided by average nonresidential sector hours (47,051 / 4,472 = 10.52 years, rounded to 11 years). Qualifying equipment are complete luminaires and not replacement lamps.
2. SPECTRUM. Historical program data for MMIDs 3736 and 3737 based on 9,720 units from January 2015 to October 2018 applications.
3. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3-2. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. Tetra Tech. "ACES Deemed Savings Desk Review." Table 1. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
5. Cadmus. "Focus on Energy Evaluated Deemed Savings Changes." November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
   2.01 hours per day and 5.5% coincidence factor for multifamily housing.
6. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. Table 4-1. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing CF of 65% to 83%.

Revision History

Version Number	Date	Description of Change
01	10/10/2018	Initial TRM entry, replacing MMIDs 3736 and 3737

LED Troffer, 1x4, Replacing 4’ 1- and 2-Lamp T8 Troffer

	Measure Details
Measure Master ID	LED Troffer, 1x4, Replacing 4-Foot 1- or 2-Lamp T8 Troffer, 3760 LED Troffer, 1x4, Replacing 4-Foot 1- or 2-Lamp Troffer with Luminaire Level Lighting Controls, 4334, 4465
Measure Unit	Per luminaire or retrofit kit
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Schools & Government, Agricultural, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	11[1]
Measure Incremental Cost ($/unit)	$49.57 for MMID 3760[2]; $144.57 for MMID 4334[3]

Measure Description

LED 1x4 troffers save energy when replacing 1- or 2-lamp T8 products by providing a similar lumen output with lower input wattage. These products can be installed on a one-for-one basis to replace 1- or 2-lamp T8 luminaires and may incorporate Luminaire Level Lighting Controls (LLLCs), which are integrated into luminaires and provide occupancy, daylight, high-end trim, and potentially other sensory functions such as air temperature and space utilization. This granular control can yield additional savings, easier control commissioning, and occupant comfort.

Description of Baseline Condition

The baseline condition is 4-foot 1- and 2-lamp T8 troffers in existing buildings and new construction.

Description of Efficient Condition

The efficient condition is LED products that are DesignLights Consortium-listed in the “1x4 Luminaires for Ambient Lighting of Interior Commercial Spaces,” “Integrated Retrofit Kits for 1x4 Luminaires,” or “Linear Retrofit Kits for 1x4 Luminaires” primary use categories, which consume ≤ 43 watts and may contain LLLCs.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = [Watts_{BASE} – Watts_{LED} * (1 – SF)] / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Baseline wattage, or the average power consumption of a 1-lamp 32-watt T8 and a 2-lamp 32-watt T8, weighted 50%/50% (= 43.56 watts)[4]

$Watts_{LED}$ = Energy efficient wattage, or the average power consumption of a DLC-listed LED fixture (= 29.8 watts)[5]

SF = LLLC savings factor, deemed (= 0% for MMID 3760; = 41% for MMID 4334)[6]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[6]	3,730
Industrial[6]	4,745
Agriculture[6]	4,698
Schools & Government[6]	3,239
Multifamily[7]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{LED}) * CF_{WATTAGE} / 1{,}000 + Watts_{LED} * CF_{WATTAGE} * CF_{CONTROLS} / 1{,}000$

Where:

$CF_{WATTAGE}$ = Coincidence factor for wattage reduction (= varies by sector; see table below)

$CF_{CONTROLS}$ = Coincidence factor for controls (= 0 for MMID 3760; = varies by sector for MMID 4334, see table below)

Coincidence Factor by Sector

Sector	$CF_{WATTAGE}$	$CF_{CONTROLS}$
Commercial[8,6]	0.77	0.14
Industrial[8,6]	0.77	0.18
Agriculture[8,6]	0.67	0.14
Schools & Government[8,6]	0.64	0.14
Multifamily[8,8]	0.77	0.14

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Annual Savings

Measure	MMID	Savings	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Troffer, 1x4, Replacing 4’ 1- and 2-Lamp T8 Troffer	3760	kWh	51	65	65	45	82
		kW	0.0106	0.0106	0.0092	0.0088	0.0106
LED Troffer, 1x4, Replacing 4’ 1- and 2-Lamp T8 Troffer w/LLLC	4334	kWh	97	123	122	84	155
		kW	0.0138	0.0147	0.0120	0.0115	0.0138

Lifecycle Savings (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Troffer, 1x4, Replacing 4’ 1- and 2-Lamp T8 Troffer	3760	561	715	715	495	902
LED Troffer, 1x4, Replacing 4’ 1- and 2-Lamp T8 Troffer w/LLLC	4334	1,067	1,353	1,342	924	1,705

Sources

1. DesignLights Consortium. "Qualified Product List." Accessed August 2017. https://www.designlights.org/search
   Average rated life of models participating in linear LED measures is 51,160 hours. With an average HOU of 4,472, the EUL is rounded to 11 years.
2. LBC Lighting. Website. Accessed December 2017. www.lbclighting.com
   Home Depot. Website. Accessed December 2017. www.homedepot.com
   Lightmart.com. Website. Accessed December 2017. www.lightmart.com
   Average baseline cost data was $57.03. SPECTRUM measure participation data from January 2017 through December 2017 shows that the average cost for participating products was $106.60 for MMID 3760. Therefore, the incremental cost is $49.57 ($106.60 - $57.03).
3. The incremental cost of $144.57 for MMID 4334 reflects the cost for MMID 3760 ($49.57) plus the cost for occupancy sensors ($70.00 per WESCO Distribution Pricing) and labor ($25.00).
4. Consortium for Energy Efficiency. "Legacy Ballast List." 2015.
5. SPECTRUM. Measure participation data from January 2017 through December 2017 shows that the average participating model was 29.8 watts for MMID 3760.
6. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3-2, Table 4-161, and Table 4-206. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
7. Tetra Tech. "ACES Deemed Savings Desk Review." Table 1. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
8. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. Table 4-1. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs (with multifamily housing in unit CF of 65% to 83%).

Revision History

Version Number	Date	Description of Change
01	01/01/2013	Initial TRM entry
02	08/14/2015	Updated savings information
03	09/29/2017	Updated to include 1x4 LED troffer without controls (MMID 3760) and with controls (MMID 4334)

LED Troffer, 2x4, Replacing 4-Foot, 3-4 Lamp T8 Troffer

	Measure Details
Measure Master ID	LED Troffer, 2x4, Replacing 4-Foot, 3-4 Lamp T8 Troffer, 3111 LED Troffer, 2x4, Replacing 4-Foot, 3-4 Lamp T8 Troffer w/LLLC, 4335, 4466
Measure Unit	Per luminaire or retrofit kit
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	N/A
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	N/A
Water Savings (gal/yr)	N/A
Effective Useful Life (years)	14[1]
Incremental Cost	Without LLLC = $49.24 (MMID 3111);[2] With LLLC = $144.24 (MMID 4335)[3]

Measure Description

LED 2x4 troffers save energy when replacing three-lamp or four-lamp T8 products by providing a similar lumen output with lower input wattage. These products can be installed on a one-for-one basis to replace three-lamp or four-lamp T8 luminaires and may incorporate Luminaire Level Lighting Controls (LLLC). LLLCs are sensors and controls integrated into luminaires that provide occupancy, daylight, high-end trim, and potential other sensory functions such as air temperature and space utilization. This granular control can yield additional savings, easier control commissioning, and occupant comfort.

Description of Baseline Condition

The baseline measure is 4-foot, three-lamp and four-lamp T8 troffers for existing buildings and new construction buildings.

Description of Efficient Condition

The efficient measures are LED products that are DesignLights Consortium-listed in the Troffer general application column of technical requirements Table v4.1 and 2x4 primary use categories,[4] which consume 55 watts or less and may contain LLLC.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = [Watts_{BASE} – Watts_{EE} * (1 – SF)] / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Average power consumption of three-lamp, 32-watt T8 and 4-lamp, 32-watt T8, weighted 50% each (= 97.3 watts)[5]

$Watts_{EE}$ = Average power consumption of DLC-listed LED product (= 42.8 watts)[4]

SF = LLLC savings factor, deemed (= 0% for MMID 3111, = 41% for MMID 4335)[6]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[7]	3,730
Industrial[7]	4,745
Agriculture[7]	4,698
Schools & Government[7]	3,239
Multifamily[8]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF_{WATTAGE} / 1{,}000 + Watts_{EE} * CF_{WATTAGE} * CF_{CONTROLS} / 1{,}000$

Where:

$CF_{WATTAGE}$ = Coincidence factor for wattage reduction (= varies by sector; see table below)

$CF_{CONTROLS}$ = Coincidence factor for controls (= 0 for MMID 3111, = varies by sector for MMID 4335; see table below)

Coincidence Factor by Sector

Sector	$CF_{WATTAGE}$	$CF_{CONTROLS}$
Commercial[7]	0.77	0.14
Industrial[7]	0.77	0.18
Agriculture[7]	0.67	0.14
Schools & Government[7]	0.64	0.14
Multifamily[8]	0.77	0.14

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 14 years)[1]

Deemed Savings

Annual Savings for LED Replacement of 4-Foot T8

Measure	MMID	Savings	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Troffer, 2x4, Replacing 4-Foot 3-4 Lamp T8 Troffer	3111	kWh	203	259	256	177	324
		kW	0.0420	0.0420	0.0365	0.0349	0.0420
LED Troffer, 2x4, Replacing 4-Foot 3-4 Lamp T8 Troffer w/ LLLC	4335	kWh	269	342	339	233	429
		kW	0.0466	0.0479	0.0406	0.0387	0.0466

Lifecycle Savings for LED Replacement of 4-Foot T8 (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Troffer, 2x4, Replacing 4-Foot 3-4 Lamp T8 Troffer	3111	2,842	3,626	3,584	2,478	4,536
LED Troffer, 2x4, Replacing 4-Foot 3-4 Lamp T8 Troffer w/ LLLC	4335	3,766	4,788	4,746	3,262	6,006

Sources

1. SPECTRUM. Online lookups from January 2018 and MMID 3111 participation data from January through December 2017 show that seven participating models, comprising of 26,153 units and 61% of total measure participation, have an average spec sheet rated life of 63,000 hours. With an average HOU of 4,472, the EUL is 14 years.
2. Home Depot. Website. Accessed December 2017. www.homedepot.com
LBC Lighting. Website. Accessed December 2017. www.lbclighting.com
Warehouse-Lighting. Website. Accessed December 2017. www.warehouse-lighting.com
Average baseline cost data was $78.15. SPECTRUM measure participation data from January 2017 through December 2017 shows that the average cost for participating products is $127.39 for MMID 3111. Therefore, the incremental cost is $49.24 ($127.39 - $78.15).

3. Incremental cost of $144.24 for MMID 4335 reflects the cost for MMID 3111 plus the cost for occupancy sensors (MMID 2474), which according to WESCO Distribution Pricing is $70.00, plus $25.00 in labor.
4. SPECTRUM. Measure participation data from January 2017 through December 2017 shows that participating models average 42.8 watts for MMID 3111.
5. Consortium for Energy Efficiency. *Legacy Ballast List*. 2015.
6. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3-2, Table 4-161, and Table 4-206. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
7. Tetra Tech. "ACES Deemed Savings Desk Review." Table 1. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
8. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. Table 4-1. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
Coincidence factor is within 65% to 83% range of similar programs for in-unit multifamily housing.

Revision History

Version Number	Date	Description of Change
01	01/01/2013	Intial TRM measure
02	08/14/2015	Updated savings information
03	11/11/2016	Updated savings information and definitions
04	10/2017	Updated EUL
05	11/2017	Added 2x4 measure with LLLC

LED Troffer, 2x4, Replacing 4’ 1- or 2-Lamp T8 Troffer

	Measure Details
Measure Master ID	LED Troffer, 2x4, Replacing 4-Foot 1- or 2-Lamp T8 Troffer, 4793 LED Troffer, 2x4, Replacing 4-Foot 1- or 2-Lamp Troffer with Luminaire Level Lighting Controls, 4794
Measure Unit	Per luminaire or retrofit kit
Measure Type	Prescriptive
Sector(s)	Commercial, Industrial, Schools & Government, Agricultural, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	14[1]
Measure Incremental Cost ($/unit)	T8 Troffer = $49.24 (MMID 4793),[2] Troffer with Luminaire Level Lighting Controls = $144.24 (MMID 4794)[3]

Measure Description

LED 2x4 troffers save energy when replacing 1- or 2-lamp T8 products by providing a similar lumen output with lower input wattage. These products can be installed on a one-for-one basis to replace 1- or 2-lamp T8 luminaires and may incorporate Luminaire Level Lighting Controls (LLLCs), which are integrated into luminaires and provide occupancy, daylight, high-end trim, and potentially other sensory functions such as air temperature and space utilization. This granular control can yield additional savings, easier control commissioning, and occupant comfort.

Description of Baseline Condition

The baseline condition is 4-foot 1- and 2-lamp T8 troffers in existing buildings and new construction.

Description of Efficient Condition

The efficient condition is LED products that are DLC-listed in the “2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces,” “Integrated Retrofit Kits for 2x4 Luminaires,” or “Linear Retrofit Kits for 2x4 Luminaires” primary use categories, which consume less than 44 watts and may contain LLLCs.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = [Watts_{BASE} - Watts_{LED} * (1 – SF)] / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Baseline wattage, or the average power consumption of a 1-lamp 32-watt T8 and a 2-lamp 32-watt T8, weighted 50% each (= 43.56 watts)[4]

$Watts_{LED}$ = Energy-efficient wattage, or the average power consumption of a DLC-listed LED fixture (= 34.6 watts)[5]

SF = LLLC savings factor, deemed (= 0% for MMID 4793; = 41% for MMID 4794)[6]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[6]	3,730
Industrial[6]	4,745
Agriculture[6]	4,698
Schools & Government[6]	3,239

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{LED}) * CF_{WATTAGE} / 1{,}000 + Watts_{LED} * CF_{WATTAGE} * CF_{CONTROLS} / 1{,}000$

Where:

$CF_{WATTAGE}$ = Coincidence factor for wattage reduction (= varies by sector; see table below)

$CF_{CONTROLS}$ = Coincidence factor for controls (= 0 for MMID 4793, = varies by sector for MMID 4794; see table below)

Coincidence Factor by Sector

Sector	$CF_{WATTAGE}$	$CF_{CONTROLS}$
Commercial[6]	0.77	0.14
Industrial[6]	0.77	0.18
Agriculture[6]	0.67	0.14
Schools & Government[6]	0.64	0.14

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 14 years)[1]

Deemed Savings

Annual Savings

Measure	MMID	Savings	Commercial	Industrial	Agriculture	Schools & Gov
LED Troffer, 2x4, Replacing 4’ 1- and 2-Lamp T8 Troffer	4793	kWh	33	42	42	29
		kW	0.0069	0.0069	0.0060	0.0057
LED Troffer, 2x4, Replacing 4’ 1- and 2-Lamp T8 Troffer w/LLLC	4794	kWh	86	110	109	75
		kW	0.0106	0.0117	0.0092	0.0088

Lifecycle Savings (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov
LED Troffer, 2x4, Replacing 4’ 1- and 2-Lamp T8 Troffer	4793	462	588	588	406
LED Troffer, 2x4, Replacing 4’ 1- and 2-Lamp T8 Troffer w/LLLC	4794	1,204	1,540	1,526	1,050

Sources

1. Effective useful life based on MMID 3111 SPECTRUM data. Online lookups from January 2018 and MMID 3111 participation data from January through December 2017 show that seven participating models, comprising of 26,153 units and 61% of total measure participation, have an average specification sheet rated life of 63,000 hours. With an average HOU of 4,472, the EUL is 14 years.
2. The incremental cost is based on measure MMID 3111. Average baseline cost data was $78.15. SPECTRUM measure participation data from January through December 2017 shows that the average cost for participating products is $127.39 for MMID 3111. Therefore, the incremental cost is $49.24 ($127.39 - $78.15).
3. The incremental cost of $144.24 reflects the cost for MMID 3111 plus the cost for occupancy sensors ($70.00 per WESCO Distribution Pricing) and labor ($25.00).
4. Consortium for Energy Efficiency. “Legacy Ballast List.” 2015.
5. DesignLights Consortium. “Qualified Product List.” Accessed October 2018. https://www.designlights.org/search
6. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Table 3-2, Table 4-161, and Table 4-206. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	01/01/2019	Initial TRM entry

Mogul Screw-Base (E39) Light Emitting Diode Lamp

	Measure Details
Measure Master ID	LED Lamp, DLC: High/Low-Bay Mogul Screw-Base (E39), 3962, 4644 Mogul Screw-Base (E39), Exterior, 3963, 4645
Measure Unit	Per watt reduced
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	13[1]
Incremental Cost ($/unit)	$66.05[2]

Measure Description

This measure is replacing interior HID lighting with wattages ranging from 150 watts to 400 watts and exterior HID lighting with wattages ranging from 70 watts to 400 watts.

Description of Baseline Condition

The baseline equipment is interior HID lighting with wattages ranging from 150 watts to 400 watts or exterior HID lighting with wattages ranging from 70 watts to 400 watts.

Description of Efficient Condition

The efficient condition is a Design Lights Consortium-listed mogul screw-base (E39) LED lamp, in the Mogul Screw-Base (E39) Replacements for HID Lamps category.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) * HOU / 1{,}000 = Watts_{REDUCED} * HOU / 1{,}000$

Where:

$Watts_{BASE}$ = Power consumption of baseline lamp

$Watts_{EE}$ = Power consumption of DLC-listed LED product

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

$Watts_{REDUCED}$ = Watt reduction

Hours of Use

Sector	HOU
Commercial[3]	3,730
Industrial[3]	4,745
Agriculture[3]	4,698
Schools & Government[3]	3,239
Multifamily[4]	5,950
Exterior[5]	4,380

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) * CF / 1{,}000$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor

Sector	CF
Commercial[3]	0.77
Industrial[3]	0.77
Agriculture[3]	0.67
Schools & Government[3]	0.64
Multifamily[6]	0.77
Exterior	0

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 13 years)[1]

Deemed Savings

Here, deemed savings are calculated on a per-$Watts_{REDUCED}$ basis. The values in the table indicates the savings from defining $Watts_{REDUCED}=1$ in the algorithm above for each sector.

Annual Savings (per Watt reduced)

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Interior	3962	3.73	0.0008	4.75	0.0008	4.7	0.0007	3.24	0.0006	5.95	0.0008
Exterior	3963	4.38	N/A	4.38	N/A	4.38	N/A	4.38	N/A	4.38	N/A

Lifecycle Savings (kWh per Watt reduced)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
Interior	3962	49	62	61	42	77
Exterior	3963	57	57	57	57	57

Sources

1. DesignLights Consortium. Qualified Product List. Accessed August 2017. https://www.designlights.org/lighting-controls/download-the-qpl/
   Average rated life of models participating in high-bay HID to LED measures is 57,667 hours. With an HOU of 4,457 or 4,380, the EUL is 13 years.
2. 1000 Bulbs. Website. Accessed November 2016. www.1000bulbs.com
   Lighting Supply. Website. Accessed November 2016. www.lightingsupply.com
   Amazon. Website. Accessed November 2016. www.amazon.com
3. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. Tetra Tech. "ACES Deemed Savings Desk Review." Table 1. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf

5. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/
This report includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
6. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
Coincidence factor is within range of similar programs; see Table 4-1 showing multifamily housing (in unit) CF of 65% to 83%.

Revision History

Version Number	Date	Description of Change
01	11/03/2016	Initial TRM entry
02	10/2017	Updated EUL

Bi-Level Controls for Interior, Exterior, and Parking Garages

	Measure Details
Measure Master ID	LED Fixture, Bi-Level: Stairwell and Passageway, 3097 Lighting Controls, Bi-Level: Exterior and Parking Garage Fixtures, Dusk to Dawn, 3251 Parking Garage Fixtures, 24 Hour, 3252
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	MMID 3097 = Light Emitting Diode (LED) MMIDs 3251 and 3252 = Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	8[1]
Incremental Cost ($/unit)	Varies by measure, see Appendix D

Measure Description

Numerous existing installations use LED, induction, fluorescent, CMH, and PSMH fixtures to light their high-bay interiors, exteriors, and parking garages. These fixtures commonly operate in full light output 24 hours a day. Bi-level controls and replacement products use ultrasonic and PIR sensors to adjust the light output to a safe but energy-conserving low light level when these spaces become unoccupied. These products save energy by more efficiently lighting spaces based on occupancy.

Description of Baseline Condition

The baseline condition is LED, induction, fluorescent, CMH, and PSMH fixture input wattages with no lighting controls at building interiors, exteriors, and parking garages.

Description of Efficient Condition

The efficient condition is individually controlled light fixtures that may include dimming, stepped dimming, and/or hi-low ballast controls. Control must include a PIR and/or ultrasonic occupancy sensor with a fail-safe feature (fails in “on” position in case of sensor failure). Fixtures must operate in low-standby light level during vacancy and switch to full light output upon occupancy. The fixture cannot exceed 50% of full wattage during unoccupied periods.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{BASE} - kWh_{EE}$

$kWh_{BASE} = Watts_{FIXTURES} * HOU / 1,000$

$kWh_{EE} = Watts_{FIXTURES} * HOU * 0.60/1,000$

Where:

kWh_{BASE} = Energy consumption of baseline equipment (standard non-controlled fixture)

kWh_{EE} = Energy consumption of efficient equipment (bi-level controlled fixture)

$Watts_{FIXTURES}$ = Input wattage of fixture(s) being controlled

HOU = Hours of use (= 8,760 for parking garages; = 4,380 for exterior; = varies by sector for interior, see table below)

1,000 = Kilowatt conversion factor

0.60 = 40% savings potential from bi-level controls

Interior Hours of Use by Sector

Sector	Hours of Use[2]
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = Watts_{FIXTURES} / 1,000 * SF * CF$

Where:

SF = Savings factor (= 40%)[3]

CF = Coincidence factor (= 1 for parking; = 0 for exterior; = varies by sector for interior, see table below)

Interior Coincidence Factor by Sector

Sector	CF[2]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 8 years)[1]

Deemed Savings

Bi-Level Controls in Parking Garage

Savings per Fixture	MMID	All Sectors
kWh	3252	1,135
kW		0.1296
$kWh_{LIFECYCLE}$		9,080

Bi-Level Controls in Exterior

Savings per Fixture	MMIDs	All Sectors
kWh	3251 and 3343	568
kW		0
$kWh_{LIFECYCLE}$		4,544

Bi-Level Controls in Interior

Savings per Fixture	MMID	Commercial	Industrial	Agriculture	Schools & Government
kWh	3097	483	615	609	420
kW		0.0998	0.0998	0.0868	0.0829
$kWh_{LIFECYCLE}$		3,864	4,920	4,872	3,360

Assumptions

It is assumed that an exterior lamp is on for a nighttime average of 4,380 hours. 8,760 hours are assumed for 24/7 parking garage. Savings for interior are based on the sector for interior high-bay applications.

While bi-level controls can achieve a 50% reduction in power requirements, a 40% reduction is used for Focus on Energy programs as a conservative estimate. No kilowatt savings are assigned to exterior lighting due to reduced hours of use for the same wattage.

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin. Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Table 3.2 Lighting Hours of Use in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
3. The program directs that wattage must be reduced by a minimum of 50%, however 40% was is applied to account for any other power factors or unforeseen power consumption.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	10/2017	Updated EUL
03	01/2019	Removed MMIDs 3117, 3596, and 3597

Delamping, T12 to T8, T8 to T8

	Measure Details
Measure Master ID	Delamping: T12 to T8, 4-Foot, 2276 T8 to T8, 2277 T12 to T8, 8-Foot, 3320
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	MMIDs 2276 and 2277 = Delamping MMID 3320 = Fluorescent, Linear
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	Varies by measure, see Appendix D

Measure Description

This measure is the permanent removal of standard T12 and T8 lamps from two, three, and four lamp 4-foot and 8-foot fixtures. Although the savings are not accounted for here, the measure requires:

- Delamped fixtures must also include upgrading the remaining lamps to HPT8 or RWT8 lamps.
- If a qualifying combination of lamps and ballast are installed, delamped fixtures can also qualify for incentives for HPT8 or RWT8 systems based on the number of lamps in the delamped fixture.

If the existing fixture contains standard T8 ballasts, the ballast is not required to be replaced. Only the lamps must be upgraded. In this case, the project would only qualify for a reduced watt lamp incentive if reduced watt lamps are used. The project would not qualify for a system upgrade incentive.

Description of Baseline Condition

The baseline condition is a weighted average of two, three, and four lamp T12 and T8 fixtures (see Assumptions for weighting metrics).

Description of Efficient Condition

The efficient condition is a weighted average of one, two, and three lamp low, normal, and high ballast factor T8 fixtures with 32-watt lamps (see Assumptions for weighting metrics).

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * HOU$

Where:

$Watts_{BASE}$ = Watts of baseline equipment (existing standard T12 and T8 fixture(s))
$Watts_{EE}$ = Power consumption of efficient measure (delamped T8 fixture(s))
1,000 = Kilowatt conversion factor
HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU[2]
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239
Multifamily	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF[2]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64
Multifamily	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Average Annual Deemed Savings for Linear Fluorescent Delamping

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Delamping T12 to T8 (4-Foot)	2276	192	0.040	244	0.040	242	0.035	167	0.033	306	0.040
Delamping T8 to T8 (4-Foot)	2277	96	0.020	122	0.020	121	0.017	83	0.017	153	0.020
Delamping T12 to T8 (8-Foot)	3320	357	0.074	454	0.074	450	0.064	310	0.061	N/A	N/A

Average Lifecycle Deemed Savings for Linear Fluorescent Delamping

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
		kWh	kWh	kWh	kWh	kWh
Delamping T12 to T8 (4-Foot)	2276	1,920	2,440	2,420	1,670	3,060
Delamping T8 to T8 (4-Foot)	2277	960	1,220	1,210	830	1,530
Delamping T12 to T8 (8-Foot)	3320	3,570	4,540	4,500	3,100	N/A

Assumptions

Weighting of delamping quantities is based on historical program data.

The baseline condition is a weighted average of two, three, and four lamp T12 and T8 fixtures:

- Delamping T12 to T8 (4-Foot)
    - 2 Lamp (10%)
    - 3 Lamp (30%)
    - T12 - 4 Lamp (60%)
- Delamping T8 to T8
    - 2 Lamp (10%)
    - 3 Lamp (30%)
    - T8 - 4 Lamp (60%)
- Delamping T12 to T8 (8-Foot)
    - T12 - 2 Lamp (80%)
    - HOT12 - 2 Lamp (20%)

Efficient Condition:

- Delamping T12 to T8 (4-Foot)
    - 2 to 1 Lamp (10%)
    - 3 to 1 Lamp (5%)
    - 3 to 2 Lamp (25%)
    - 4 to 2 Lamp (50%)
    - T8 - 4 to 3 Lamp (10%)
- Delamping T8 to T8
    - 2 to 1 Lamp (10%)
    - 3 to 1 Lamp (5%)
    - 3 to 2 Lamp (25%)
    - 4 to 2 Lamp (50%)
    - T8 - 4 to 3 Lamp (10%)
- Delamping T12 to T8 (8-Foot)
    - T8 – 2 Lamp (8-Foot) to 2 Lamp (4-Foot) (100%)

Sources

1. Vermont Energy Investment Corporation. *State of Ohio Energy Efficiency Technical Reference Manual*. p. 169. August 6, 2010. http://s3.amazonaws.com/zanran_storage/amppartners.org/ContentPages/2464316647.pdf.
2. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3.2 Lighting Hours of Use in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
3. Tetra Tech. "ACES Deemed Savings Desk Review." November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	01/2019	Removed MMID 3184

LED Signage Retrofit

	Measure Details
Measure Master ID	LED, Signage Retrofit, Interior, 3903 LED, Signage Retrofit, Exterior, 3904
Measure Unit	Per watt reduced
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$0.48[2]

Measure Description

This interior or exterior LED signage measure is intended for the replacement of incumbent signage light sources with an energy-efficient LED. Using LED technology saves energy over standard products by providing a similar lumen output at a lower input wattage.

Description of Baseline Condition

Baseline equipment is intended to be any incandescent, HID, fluorescent, or neon-lighted interior or exterior commercial signage. Replacement lamp products that intend to use existing sockets or lamp holders for electrical connection are not eligible.

Description of Efficient Condition

The efficient condition is LED products intended for use in sign lighting. Applications include, but are not limited to, channel lettering, backlit displays, and menu boards. A minimum 30% wattage reduction is required in order to be eligible. A qualified product list is not applicable at this time.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1{,}000 = Watts_{REDUCED} * HOU / 1{,}000$

Where:

$Watts_{BASE}$ = Power consumption of baseline installed signage system

$Watts_{EE}$ = Power consumption of LED signage product

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

$Watts_{REDUCED}$ = Watt reduction

Hours of Use by Sector

Sector	HOU
Commercial[3]	3,730
Industrial[3]	4,745
Agriculture[3]	4,698
Schools & Government[3]	3,239
Multifamily[4]	5,950
Exterior[5]	4,380

Summer Coincident Peak Savings Algorithm

Exterior applications have no summer coincident peak savings.

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1{,}000$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[3]	0.77
Industrial[3]	0.77
Agriculture[3]	0.67
Schools & Government[3]	0.64
Multifamily[6]	0.77
Exterior	0.00

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Annual Savings (per watt reduced)

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED Signage Retrofit, Interior	3903	3.73	0.0008	4.75	0.0008	4.7	0.0007	3.24	0.0006	5.95	0.0008
LED Signage Retrofit, Exterior	3904	4.38	0.0000	4.38	0.0000	4.38	0.0000	4.38	0.0000	4.38	0.0000

Lifecycle kWh Savings (per watt reduced)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Signage Retrofit, Interior	3903	41	52	51	36	65
LED Signage Retrofit, Exterior	3904	48	48	48	48	48

Assumptions

Reference workpapers[1,2] give incremental costs and savings on a per foot basis. The following formula was used to convert to a per-watt reduced cost metric, then averaged between sources:

$(kWh_{SAVED} / \text{Incremental Cost per foot}) / HOU * 1{,}000$

Sources

1. DesignLights Consortium. Qualified Product List. Accessed August 2017. https://www.designlights.org/lighting-controls/download-the-qpl/
   Average rated life of models participating in LED signage measures is 50000 hours. With an HOU of 4,472, the EUL is 11 years.
2. KEMA. "Appendix A – Prescriptive Measures." LED Channel Signs workpaper, p. 64. February 20, 2009. http://ilsagfiles.org/SAG_files/Evaluation_Documents/Ameren/AIU%20Evaluation%20Reports%20EPY2/AIU%20EPY2%20Final/AIU_Appendix_A_Prescriptive_Measures.pdf

3. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3.2 Lighting Hours of Use in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. Tetra Tech. "ACES Deemed Savings Desk Review." Table 1. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
5. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/
   This also includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
6. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs; see Table 4-1 showing multifamily housing (in unit) CF of 65% to 83%

Revision History

Version Number	Date	Description of Change
01	06/15/2016	Initial TRM entry
02	10/2017	Updated EUL

LED Fixture, Downlights, ≤ 18 Watts, Replacing Incandescent Downlight, Exterior

	Measure Details
Measure Master ID	LED Fixture, Downlights, ≤ 18 Watts, Replacing Incandescent Downlight, Exterior, 3405
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	193
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	1,932
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$2.18[3]

Measure Description

LED downlight luminaires can replace existing incandescent luminaires without sacrificing performance; they save energy because they consume less wattage than the incandescent luminaries they replace. There is no demand reduction since this measure is used during evening and night lighting hours.

Description of Baseline Condition

The baseline measure is 50-watt to 72-watt incandescent luminaires.

Description of Efficient Condition

The efficient measure is ENERGY STAR-rated LED downlights that consume ≤ 18 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{INC} - Watts_{LED}) / 1{,}000 * HOU * Con_{FACT}$

Where:

$Watts_{INC}$ = Wattage of standard incandescent fixture (= 62)

$Watts_{LED}$ = Wattage of LED product (= 13)

1,000 = Kilowatt conversion factor

HOU = Hours of use (= 4,380)

Con_{FACT} = Control factor (= 0.90)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (10 years)[1]

Assumptions

A weighted average of 16.66% each for 50-watt, 53-watt, 60-watt, 65-watt, 70-watt, and 72-watt incandescent luminaires was used to generate the baseline wattage. 4,380 hours run time of fixtures based on an annual average of 12 hours per day from NOAA data.[2] This also includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting. Applying a controls factor allows for a more conservative estimate of savings. Based on project experience, less than 10% of the exterior fixtures on the market have additional controls that may operate at conditions other than dusk to dawn.

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 8,139 LED downlight fixtures is 46,550 hours. With an HOU of 4,380, the EUL is 11 years.
2. U.S. Department of Commerce National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/
3. August 2018 online lookups of four base and efficient models show an average efficient lamp price of $3.97 and base lamp price of $1.79, for an incremental cost of $2.18.

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	10/2017	Updated EUL
03	12/2018	Updated incremental cost

Exterior LED Downlights Luminaires > 18 Watts

	Measure Details
Measure Master ID	Exterior LED Downlights Luminaires > 18 Watts, 3404
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	226.3
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	2,263
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$20.03[3]

Measure Description

LED downlight luminaires can replace existing incandescent luminaires used for the same application without sacrificing performance. LED downlights save energy because they consume less wattage than the incandescent luminaries they replace.

Description of Baseline Condition

The baseline condition is 80-watt halogen and 50-watt to 100-watt HID luminaires.

Description of Efficient Condition

The efficient condition is ENERGY STAR-rated LED downlights that consume less than 18 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{INC} - kWh_{LED}$

$kWh_{INC} = Wattage_{INC} / 1{,}000 * HOU * CF$

$kWh_{LED} = Wattage_{LED} / 1{,}000 * HOU * CF$

Where:

kWh_{INC} = Annual electricity consumption of standard wattage incandescent fixtures

kWh_{LED} = Annual electricity consumption of LED products

Wattage = Instantaneous electric consumption of lamp or fixture

1,000 = Kilowatt conversion factor

HOU = Average annual run hours (= 4,380)[3]

CF = Controls factor that accounts for the small percentage of systems in the market with additional controls (= 0.9)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED Downlights > 18 Watts

Measure	Exterior 4380 (0.00)	
	Savings (kWh)	Savings (kW)
LED Downlights > 18 watts	226.3	0.0

Average Lifecycle Deemed Savings for LED Downlights > 18 Watts

Measure	Exterior 4380 (0.00)
	Savings (kWh)
LED Downlights > 18 watts	2,489

Assumptions

A weighted average of 25% each for 80-watt halogen, 50-watt HID, 70-watt HID, and 100-watt HID luminaires was used to generate the baseline wattage.

The 4,380 HOU was based on an annual average of 12 hours per day from NOAA data.[2] This includes when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.

Applying a controls factor allows for a more conservative savings estimate. Based on project experience, less than 10% of the exterior fixtures on the market have additional controls that may operate at conditions other than dusk to dawn.

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 8,139 LED downlight fixtures is 46,550 hours. With an HOU of 4,380, the EUL is 11 years.
2. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. NOAA Solar Calculator. http://www.esrl.noaa.gov/gmd/grad/solcalc/
3. August 2018 online lookups of four base and efficient models show an average efficient lamp price of $29.32 and base lamp price of $9.29, for an incremental cost of $20.03.

Revision History

Version Number	Date	Description of Change
01	04/2014	Initial TRM entry
02	10/2017	Updated EUL source
03	12/2018	Updated incremental cost

Exterior LED Fixtures Replacement

	Measure Details
Measure Master ID	LED Fixture, Exterior: Replacing 150–175 Watt HID, 3099, 3824 Replacing 250 Watt HID, 3102, 3825 Replacing 320–400 Watt HID, 3826 Replacing 400 Watt HID, 3107, 3827 Replacing 70–100 Watt HID, 3108, 3828
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by wattage
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by wattage
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	13[1]
Incremental Cost ($/unit)	Varies by measure, see Appendix D

Measure Description

Exterior LED fixtures are an energy-saving alternative to traditional standard wattage HID light sources that have been used for the same applications. LED light sources can be applied in almost every common application type where HID light sources are currently found. This measure is only for replacing existing HID fixtures.

Description of Baseline Condition

The baseline condition is existing HID lamps between 70 watts and 400 watts.[2]

Description of Efficient Condition

The efficient condition is LED fixtures that meet program requirements. Replacements must be complete fixtures or a retrofit of interior components with a total power reduction of 40% or more. Lamp-only replacements are not eligible for an incentive. LEDs must be on the qualifying DLC list.[3]

Annual Energy-Savings Algorithm

kWh_{SAVED} = ($Watts_{BASE}$ - $Watts_{EE}$) /1,000 * HOU

Where:

$Watts_{BASE}$ = Wattage of standard HID fixture (= varies by measure; see table below)
$Watts_{EE}$ = Wattage of LED fixture (= varies by measure; see table below)
1,000 = Kilowatt conversion factor
HOU = Hours of use (= 4,380)

Wattages Used for Deemed Savings Calculations[4]

Measure	MMID	$Watts_{BASE}$	$Watts_{EE}$
Exterior LED replacing 70-watt to 100-watt HID Average	3108, 3828	111.5	31
Exterior LED replacing 150-watt to 175-watt HID Average	3099, 3824	194.5	59
Exterior LED replacing 250-watt HID Average	3102, 3825	299.0	94
Exterior LED replacing 400-watt HID	3107, 3827	463.0	178

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

Where:

EUL = Effective useful life (= 13 years)[1]

Deemed Savings

Average Annual Deemed Savings for Exterior LED Fixtures

Measure	MMID	kWh	kW
Exterior LED replacing 70-watt to 100-watt HID Average	3108, 3828	353	0
Exterior LED replacing 150-watt to 175-watt HID Average	3099, 3824	593	0
Exterior LED replacing 250-watt HID Average	3102, 3825	898	0
Exterior LED replacing 400-watt HID	3826, 3107, 3827, 3290	1,248	0

Average Lifecycle Deemed Savings for Exterior LED Fixtures

Measure	MMID	kWh
Exterior LED replacing 70-watt to 100-watt HID Average	3108, 3828	4,589
Exterior LED replacing 150-watt to 175-watt HID Average	3099, 3824	7,709
Exterior LED replacing 250-watt HID Average	3102, 3825	11,674
Exterior LED replacing 400-watt HID	3826, 3107, 3827, 3290	16,224

Assumptions

Calculations are based on exterior lighting that operates 4,380 hours annually, 12 hours per day (dusk to dawn).

LED lamps can achieve a 40% reduction in power requirements.

Sources

1. DesignLights Consortium. *Qualified Product List.* Accessed August 2017. https://www.designlights.org/lighting-controls/download-the-qpl/
   Average rated life of models participating in exterior HID to LED measures is 57,025 hours. With an HOU of 4,380, the EUL is 13 years.
2. Online research.
3. Design Lights Consortium. *Qualified Products List*.
4. Wisconsin Focus on Energy. *Default Wattage Guide*. Version 1.0. 2013.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	10/2017	Updated EUL
03	05/2018	Corrected savings values per 2017 deemed savings
04	01/2019	Removed MMIDs 3289, 3301, 3105, 3106, 3303, and 3304

LED Replacing Incandescent, Exterior

	Measure Details
Measure Master ID	LED Lamp, ENERGY STAR, Exterior, Replacing Incandescent Lamp > 40 Watts, 3403
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by baseline[2]
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by baseline
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$2.93[3]

Measure Description

ENERGY STAR-rated LED replacement lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with standard wattage incandescent lamps. This measure provides an energy-efficient alternative to using incandescent lamps in several exterior applications.

Description of Baseline Condition

Less than or Equal to 40 Watts

One baseline condition is for standard incandescent lamps. The baseline wattage is generated using an average of 50% 25-watt incandescents and 50% 40-watt incandescents.

Greater than 40 Watts

Another baseline condition is for standard and EISA compliant incandescent lamps of 53 watts, 60 watts, 65 watts, 70 watts, 72 watts, and 80 watts. The baseline wattage is generated using an average of 16.66% each of 53-watt incandescent, 60-watt incandescent and halogen, 65-watt incandescent, 70-watt halogen, 72-watt halogen, and 80-watt halogen lamps.

Description of Efficient Condition

The efficient equipment must be an ENERGY STAR-rated LED lamp. The efficient wattage is generated using an average of 33% each of 11.68-watt, 16.70-watt, and 17.81-watt ENERGY STAR-rated LEDs.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{INCANDESCENT} - Watts_{EXT\ LED})/1{,}000 * HOU$

Where:

$Watts_{INCANDESCENT}$ = Wattage of standard incandescent lamps = 67 if > 40 watts; = 32.5 if ≤ 40 watts)

$Watts_{EXT\ LED}$ = Wattage of ENERGY STAR-rated LED lamp with a lumen output rating equivalent to the lumen output of incandescent being replaced (= 15.4)

1,000 = Kilowatt conversion factor

HOU = Hours of use (= 4,380)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED Lamp Replacing Incandescent

Measure	MMID	kWh Saved
LED Lamp, ENERGY STAR, Replacing Incandescent Lamp > 40 Watts, Exterior	3403	202

Average Lifecycle Deemed Savings for LED Lamp Replacing Incandescent

Measure	MMID	kWh Saved
LED Lamp, ENERGY STAR, Replacing Incandescent Lamp > 40 Watts, Exterior	3403	1,010

Assumptions

4,380 hours run time of fixtures based on an annual average of 12 hours per day from NOAA data.[3] This also includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 3,453 omnidirectional and decorative LEDs is 21,787 hours. With an HOU of 4,380, the EUL is five years.
2. U.S. Department of Commerce National Oceanic & Atmospheric Administration. “NOAA Solar Calculator.” http://www.esrl.noaa.gov/gmd/grad/solcalc/
3. August 2018 online lookups of six base and efficient models show an average efficient lamp price of $5.48 and base lamp price of $2.55, for an incremental cost of $2.93.

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	10/2017	Updated EUL
03	12/2018	Updated incremental cost, removed MMID 3402

LED, Horizontal Case Lighting

	Measure Details
Measure Master ID	LED, Horizontal Case Lighting, 3114
Measure Unit	Linear foot of lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	134
Peak Demand Reduction (kW)	0.015
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	2,686
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	7[1]
Incremental Cost ($/unit)	$40.09[2]

Measure Description

Light emitting diode (LED) fixtures use less electricity than fluorescent fixtures to produce an equivalent amount of light, and they produce less heat, reducing the amount of cooling load on the refrigeration system and the energy needed to the refrigeration compressor. Additionally, LEDs offer a more even light distribution on the refrigerated product, better showcasing it and making it appear to "pop" in the case.

Description of Baseline Condition

The baseline condition is horizontal F58 T8 linear fluorescent lamp with normal ballast factor electronic ballast in refrigerated display cases.

Description of Efficient Condition

The efficient condition is DLC-qualified horizontal LED lighting in refrigerated display cases.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = ((Watts_{BASE} – Watts_{EE}) + (Watts_{BASE} – Watts_{EE}) / COP) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Wattage of the linear fluorescent case lighting (= 15 watts for 4 feet of 60-watt fixtures)[3]

$Watts_{EE}$ = Wattage of the LED case lighting (= 4.419 watts)[4]

COP = Coefficient of performance (= 2.225 weighted average, = 2.3 for non-self-contained coolers, = 1.4 for non-self-contained freezers)[5]

1,000 = Kilowatt conversion factor

HOU = Average annual run hours (= 8,760)[6]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = ((Watts_{BASE} – Watts_{EE}) + (Watts_{BASE} – Watts_{EE}) / COP) / 1{,}000$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=7 years)[1]

Assumptions

The majority of open multideck-style cases in the market are cooler cases; however, there are also open multideck-style cases for freezer applications present in Wisconsin, although very rare to find in stores. In order to accurately portray the market, a weighted average of 95% cooler cases and 5% freezer cases, based on historical site audits and discussions with grocery owner and store managers in Wisconsin since 2008.

The low temperature and medium temperature system coefficient of performances are derived from the information on Table 3-7 of the U.S. DOE Publication ID 6180. The capacity and power values were calculated to yield the EER, then converted to coefficient of performance (based on COP = EER / 3.412).

Sources

1. DesignLights Consortium. Qualified Product List. Accessed August 2017. https://www.designlights.org/lighting-controls/download-the-qpl/
   Average rated life of models participating in LED refrigeration lighting measures is 63,940 hours. With an HOU of 8,760, the EUL is 7 years.
2. Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 26,555 feet over 202 projects from 2016 to 2018 is $40.82. The base cost is $0.73 per foot. The incremental cost is therefore $40.09.
3. Philips Advance. "2016-2017 Atlas Full Line Guide to LED Drivers, LED Modules, Ballasts and Lighting Controls." p. 3-68. March2016. http://images.philips.com/is/content/PhilipsConsumer/PDFDownloads/United%20States/ODLI20160307_001_UPD_en_US_PAd-1522BR_Atlas2016.pdf
   F58T8 Refrigeration Lamps using ICN-2S54-N ballast.
4. DesignLights Consortium. Product List. March 30, 2016. https://www.designlights.org/QPL
   Average measured wattage taken from listed products in the Horizontal Refrigerated Case Luminaires primary use category.
5. U.S. Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Office. "Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration." DOE Publication ID 6180. Table 3-7. September 2009. https://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf
6. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	03/2017	Removed MMID 3335, modified savings
03	10/2017	Updated EUL
04	12/2018	Updated incremental cost

LED, Vertical Case Lighting, Replacing Linear Fluorescent

	Measure Details
Measure Master ID	LED, Reach-In Refrigerated Case, Replacing T12 or T8, 2456
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	650
Peak Demand Reduction (kW)	0.074
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	4,550
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	7[1]
Incremental Cost ($/unit)	$141.71[6]

Measure Description

LED fixtures use less electricity than fluorescent fixtures to produce an equivalent amount of light, and they produce less heat, reducing the amount of cooling load on the refrigeration system and the energy needed to the refrigeration compressor. Additionally, LEDs offer a more even light distribution on the refrigerated product, showcasing it better and making it appear to “pop” in the case.

Description of Baseline Condition

The baseline condition is vertical F58 T8 linear fluorescent lamp with normal ballast factor electronic ballast in refrigerated display cases.

Description of Efficient Condition

The efficient condition is DLC-qualified vertical LED lighting in refrigerated display cases.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = ((Watts_{BASE} – Watts_{EE}) + (Watts_{BASE} – Watts_{EE}) / COP) / 1,000 * HOU$

Where:

$Watts_{BASE}$ = Wattage of the linear fluorescent case lighting (= 60)[2]

$Watts_{EE}$ = Wattage of the LED case lighting (= 17.73)[3]

COP = Coefficient of performance (= 1.52 weighted average: 2.3 for non-self-contained coolers,[4] 1.4 for non-self-contained freezers,[4] 0.5 for self-contained coolers,[5] and 0.6 for self-contained freezers)[5]
1,000 = Kilowatt conversion factor
HOU = Average annual run hours (= 8,760)[5]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * (1 + 1 / COP) / 1,000$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 7 years)[1]

Assumptions

Based on historical Wisconsin program installations, it is assumed that the fixtures are upgraded to LEDs in self-contained cases 10% of the time and in non-self-contained cases 90% of the time. It is also assumed that the fixtures are upgraded to LEDs in coolers 25% of the time and freezers 75% of the time as the majority of cases with doors are still freezer cases; however, more and more customers are beginning to install cases with doors for cooler applications.

The self-contained coefficient of performance is converted from the kW per horsepower of each size tier in Tables 4-71 and 4-72 of the Business Programs: Deemed Savings Manual V1.0. The kW per horsepower is converted to kW per ton, where 1 ton of refrigeration = 4.7143 hp, then is converted to COP, where COP = 12 / kW per ton / 3.412. The average COP for self-contained coolers and freezers is calculated based on the weighting from Tables 4-71 and 4-72.

Sources

1. DesignLights Consortium. Qualified Product List. Accessed August 2017. https://www.designlights.org/lighting-controls/download-the-qpl/
   Average rated life of models participating in LED refrigeration lighting measures is 63,940 hours. With an HOU of 8,760, the EUL is 7 years.
2. Philips Advance. "Lighting Electronics Atlas 2016-2017." F58T8 Refrigeration Lamps using ICN-2S54-N ballast, p. 3-68. http://images.philips.com/is/content/PhilipsConsumer/PDFDownloads/United%20States/ODLI20160307_001_UPD_en_US_PAd-1522BR_Atlas2016.pdf
3. DesignLights Consortium. *Qualified Product List for Vertical Refrigerated Case Luminaires.* Average of rated wattages. March 30, 2016.

4. U.S. Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Office. "Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration." DOE Publication ID 6180. Table 3-7. September 2009. http://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf
The capacity and power values were calculated to yield the EER, then converted to COP based on COP = EER / 3.412.
5. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 11,599 units over 454 projects from 2016 to 2018.

Revision History

Version Number	Date	Description of Change
01	03/11/2016	Update from Focus on Energy Deemed Savings Manual
02	04/2017	Added MMID 4095
03	10/2017	Updated EUL
04	12/2018	Updated incremental cost, removed MMID 4095

LED Lamp Replacing Incandescent Lamp ≤ 40 Watts

	Measure Details
Measure Master ID	LED, ≤ 40 Watt, ENERGY STAR, Replacing Incandescent, 3112
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$2.12[4]

Measure Description

ENERGY STAR-rated LED replacement lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with standard wattage incandescent lamps. This measure will provide an energy-efficient alternative to using incandescent lamps in several applications.

Description of Baseline Condition

The baseline condition is standard 25-watt and 40-watt incandescent lamps.

Description of Efficient Condition

Efficient equipment must be an ENERGY STAR-rated LED lamp.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Average consumption of standard 25-watt or 40-watt incandescent lamp (= 32.5 watts)

$Watts_{EE}$ = Consumption of reduced ENERGY STAR-rated lamp of equivalent lumen output to ≤ 40-watt incandescent (= 6 watts)

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU[2]
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF[3]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED Lamp Replacing Incandescent Lamp ≤ 40 Watts

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED Lamps ENERGY STAR ≤ 40 Watts	3112	100	0.0204	127	0.0204	126	0.0178	87	0.0169

Average Lifecycle Deemed Savings for LED Lamp Replacing Incandescent Lamp ≤ 40 Watts

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov
		kWh	kWh	kWh	kWh
LED Lamps ENERGY STAR ≤ 40 Watts	3112	500	635	630	435

Assumptions

Assumes an average of 25-watt and 40-watt incandescent lamps in calculation of baseline usage.

Assumes that average ENERGY STAR-rated LED of 5.64 watts for ≤ 40-watt replacement products.

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 3,453 omnidirectional and decorative LEDs is 21787 hours. With a sector-averaged HOU of 4,103, the EUL is 5 years.
2. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3.2 Lighting Hours of Use and Coincidence Factors by Sector. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
3. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3.2 Lighting Hours of Use and Coincidence Factors by Sector. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. August 2018 online lookups of four base and efficient models on www.1000bulbs.com and www.bulbs.com show an average efficient lamp price of $2.88 and base lamp price of $0.76, for an incremental cost of $2.12.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	10/2017	Updated EUL
03	12/2018	Updated incremental cost

LED Lamp Replacing Incandescent Lamp > 40 Watts

	Measure Details
Measure Master ID	LED, > 40 Watt, ENERGY STAR, Replacing Incandescent, 3113, 3821
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$1.64[4]

Measure Description

ENERGY STAR-rated LED replacement lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with standard wattage incandescent lamps. This measure will provide an energy-efficient alternative to using incandescent lamps in several applications.

Description of Baseline Condition

The baseline condition is standard 53-watt, 60-watt, 65-watt, 70-watt, 72-watt, and 80-watt incandescent lamps.

Description of Efficient Condition

Efficient equipment must be an ENERGY STAR-rated LED lamp.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * HOU$

Where:

$Watts_{BASE}$ = Average power consumption of standard incandescent lamps (= 66.7 watts)

$Watts_{EE}$ = Power consumption of ENERGY STAR-rated LED lamp with a lumen output rating equivalent to a > 40-watt incandescent (= 14.2 watts)

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU[2]
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF[3]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED Lamp Replacing Incandescent Lamp > 40 Watts

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED Lamps ENERGY STAR > 40 Watts	3113, 3821	196	0.0404	249	0.0404	247	0.0352	170	0.0336

Average Lifecycle Deemed Savings for LED Lamp Replacing Incandescent Lamp > 40 Watts

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov
		kWh	kWh	kWh	kWh
LED Lamps ENERGY STAR > 40 Watts	3113, 3821	980	1,245	1,235	850

Assumptions

An average of 16.67% each of 53-watt incandescent, 60-watt incandescent and halogens, 65-watt incandescent, 70-watt halogens, 80-watt halogens, and 100-watt halogen lamps was used to generate the baseline wattage.[3]

An average of 20% each of 9-watt, 11-watt, 13-watt, 18-watt, and 20-watt ENERGY STAR-rated LED lamps was used to generate the new wattage.[3]

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017.
   https://www.energystar.gov/productfinder/
   Average rated life of 3,453 omnidirectional and decorative LEDs is 21,787 hours. With a sector-averaged HOU of 4,103, the EUL is 5 years.
2. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
3. Based on market knowledge.
4. August 2018 online lookups of four base and efficient models on www.1000bulbs.com and www.bulbs.com show an average efficient lamp price of $2.88 and base lamp price of $1.24, for an incremental cost of $1.64.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	10/2017	Updated EUL
03	12/2018	Updated incremental cost

Horticultural Lighting, Agriculture

	Measure Details
Measure Master ID	Horticultural Lighting: Vertical Farming, Agriculture, 4841 Non-Stacked Indoor, Agriculture, 4842 Supplemented Greenhouse, Agriculture, 4843
Measure Unit	Per watt reduced
Measure Type	Hybrid
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Agriculture
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	Varies
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Vertical = 11 (MMID 4841), Non-Stacked = 13 (MMID 4842), Supplemented = 20 (MMID 4843)[1]
Incremental Cost ($/unit)	$361.00[2]

Measure Description

This measure is replacing interior horticultural HID and fluorescent lighting with lighting ranging from 400 watts to 1,000 watts. A mix of vertical, supplemented, and non-stacked indoor greenhouses is anticipated, and customer inputs will be used to calculate savings (see Assumptions). Supplemented greenhouses use electric lighting to extend the hours of daylight, supplement low levels of sunlight on cloudy days, or disrupt periods of darkness to alter plant growth. Vertical farms include shelving from floor to ceiling, where lighting is typically mounted within the shelving units and is much closer to the plants. Non-stacked indoor greenhouses grow plants in a single layer on the floor under ceiling-mounted lighting.[3]

Description of Baseline Condition

The baseline equipment is interior HID and fluorescent lighting ranging from 400 watts to 1,000 watts.[3]

Description of Efficient Condition

The efficient condition is a Design Lights Consortium (DLC)–listed horticultural lighting fixture, in the Horticultural Lighting category. At the time of writing, DLC has not published the Horticultural Lighting qualified product list (QPL), so the following DLC Horticultural Lighting Technical Requirements[4] are being used to qualify products in the meantime:

- Fixture Photosynthetic Photon Efficacy (PPE) ≥ 1.9 µmol/J
- Five-year minimum warranty
- Appropriate Horticultural Lighting designation by OSHA NRTL or SCC-recognized body

Annual Energy-Savings Algorithm

$kWh_{SAVED} = Watts_{REDUCED} * HOU / 1,000$

$Watts_{REDUCED} = (Watts_{BASE} – Watts_{EE})$

Where:

$Watts_{BASE}$ = Power consumption of baseline lighting system (= customer input)

$Watts_{EE}$ = Power consumption of DLC-listed LED product system

HOU = Hours of use (= 2,120 for supplemented [MMID 4843], = 6,278 for vertical [MMID 4841], = 5,475 for non-stacked indoor [MMID 4842]; see Assumptions)[3]

1,000 = Kilowatt conversion factor

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1,000$

Where:

CF = Coincidence factor (= customer input for supplemented [MMID 4843], = 1.0 for vertical and non-stacked indoor [MMIDs 4841 and 4842]; see Assumptions)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 20 years for supplemented [MMID 4843], = 13 years for non-stacked indoor [MMID 4842], = 11 years for vertical [MMID 4841])[1]

Assumptions

Since this is a new measure without historical project data, the LED high-bay fixture measures replacing 400 watt and 1,000 watt fixtures (MMIDs 3093 and 3095, respectively) were used as a starting point for determining the EUL and incremental costs. Final values were determined using an average of the two measures. After the measure has been active for one year, actual project data will be used to evaluate and update the EUL and incremental cost as needed.

The hours of use are based on supplemented greenhouses, vertical farms, and non-stacked indoor greenhouses. With greater potential for energy savings in indoor applications, we anticipate more LED lighting upgrades in this type of facility. Again, after the measure has been active for one year, actual project data will be used to evaluate the hours of use and this measure may be converted from hybrid to prescriptive.

The coincidence factor for a supplemented greenhouse that uses natural sunlight as their primary source of light will use a fraction of their lights during peak hours (cloudy days only). For these cases we will use customer input regarding what percentage of the time the artificial lighting will be on during peak times. Both vertical farms and non-stacked indoor greenhouses with 100% artificial lighting will use 100% of their lights during peak hours in the summer.

Sources

1. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. January 2017 through December 2017.
   Participation data and online lookups performed in February 2018 show that four models, comprising 15,344 units and 63% of total measure participation, have an average specification sheet rated life of 70,000 hours for MMID 3093. With an HOU of 5,475 for non-stacked indoor units, their EUL is 13 years. With an HOU of 6,278 for vertical farming, their EUL is 11 years. With an HOU of 2,120 for supplemented units, their EUL is capped at 20 years.
2. Zoro. Website. Accessed February 2018. www.zoro.com
   Warehouse Lighting. Website. Accessed February 2018. www.warehouse-lighting.com
   LBC Lighting. Website. Accessed February 2018. www.lbclighting.com
   Access Fixtures. Website. Accessed February 2018. www.accessfixtures.com
   Direct-Lighting. Website. Accessed February 2018. www.direct-lighting.com
   Lightbulbs.com. Website. Accessed February 2018. www.lightbulbs.com
   Light Store USA. Website. Accessed February 2018. www.lightstoreusa.com
   Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. January 2017 through December 2017.
   Participation data for MMIDs 3091 through 3096 and online lookups performed in February 2018 show that the average costs of participating products are $324.29 (3091), $383.07 (3092),

$276.53 (3093), $598.52 (3094), $445.47 (3095), and $631.73 (3096). The average of MMID 3093 and MMID 3095 were used for the horticultural lighting measure.

3. U.S. Department of Energy Office of Energy Efficiency & Renewable Energy. "Energy Savings Potential of SSL in Horticultural Applications." p. ii (HOU), 2 (definitions), and 5 (baseline condition). December 2017. https://www.energy.gov/sites/prod/files/2017/12/f46/ssl_horticulture_dec2017.pdf
4. DesignLights Consortium. "Technical Requirements for Horticultural Lighting." Accessed January 2019. https://www.designlights.org/horticultural-lighting/technical-requirements/

Revision History

Version Number	Date	Description of Change
01	02/2019	Initial TRM entry

LED Exit Signs

	Measure Details
Measure Master ID	LED Exit Sign, Retrofit, 2768 LED Exit Sign, Retrofit, Pack-Based, 4687
Measure Unit	Per sign
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	Varies
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[5]
Incremental Cost ($/unit)	Prescriptive = $16.24 (MMID 2768)[6] Pack-Based = $10.49 (MMID 4687)[7]

Measure Description

Exit signs that have earned the ENERGY STAR label use 5 watts or less, compared to standard signs that use up to 40 watts.[1] Savings result from replacing incandescent or fluorescent exit signs with LED exit signs, which use significantly less electricity. The savings estimate assumes that both incandescent and fluorescent exit signs undergo early replacement rather than replacement at failure.

Description of Baseline Condition

The baseline condition is an incandescent (40 watt) or CFL (16 watt) exit sign with one or two bulbs.

Description of Efficient Condition

The efficient condition is an LED exit sign where the fixture meets ENERGY STAR v2.0 specifications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * HOU * ISR$

Where:

$Watts_{BASE}$ = Wattage of baseline measure (= 11 for CFL exit sign; = 35 for incandescent exit sign)[3]

$Watts_{EE}$ = Wattage of LED exit sign (= 1.67 for MMID 2768;[9] = 4.0 for MMID 4687[2])

1,000 = Kilowatt conversion factor

HOU = Hours of use (= 8,760)[4]

ISR = In-service rate (= 1 for prescriptive measures, = 0.66 for pack-based measures)[8]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * CF * ISR$

Where:

CF = Coincidence factor (= 1.0)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[5]

Deemed Savings

Annual and Lifecycle Savings for LED Exit Signs

Type of Savings	MMID	Baseline Measure Type		
		CFL	Incandescent	Default
Annual Energy Savings (kWh)	2768	82	292	187
	4687, Pack Based	--	--	110
Peak Demand Reduction (kW)	2768	0.0093	0.0333	0.02115
	4687, Pack Based	--	--	0.0125
Lifecycle Energy Savings (kWh)	2768	820	2,920	1,870
	4687, Pack Based	--	--	1,100

Assumptions

The default assumption is generated using 50% CFL replacements and 50% incandescent replacements. For comparison, the Illinois TRM[10] assumes a 70% incandescent versus 30% CFL split, so using a 50/50 split is more conservative (lower savings).

Sources

1. ENERGY STAR. “ENERGY STAR Savings Calculator.” http://www.energystar.gov/index.cfm?c=exit_signs.pr_exit_signs
2. AM Conservation. “LED Screw-In Exit Sign Retrofit Kit.” Website. Accessed March 2018. http://www.amconservationgroup.com/products/energy-efficient-lighting/led-screw-in-exit-sign-retrofit-kit/?variation_id=2195
   Pack-based measures are 4.0 watts.
3. Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency*. Version 6.0, Volume 2. February 8, 2017. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_2_C_and_I_020817_Final.pdf
4. Shelter Analytics and Northeast Energy Efficiency Partnership. *Mid-Atlantic Technical Reference Manual*. Version 7.0. May 2017. http://www.neep.org/sites/default/files/resources/Mid_Atlantic_TRM_V7_FINAL.pdf
5. Lithonia. Website. Accessed March 2018. http://www.lithonia.com/commercial/lqm.html#.WXzqHVGQyM8

   Cooper Industries. Website. Accessed March 2018. http://www.cooperindustries.com/content/dam/public/lighting/products/documents/sure_lites/spec_sheets/sure-lites-apxel-adx121365-sss.pdf
   Grainger Exit Signs. Website. Accessed March 2018. https://www.grainger.com/ec/pdf/COMPASS-CCE-Exit-Series-Spec-Sheet.pdf
   Lifetime of 10 years is cited for above products.
6. October 2018 online lookups of 6 base and efficient models show an average efficient fixture price of $18.31 and base bulb price of $2.07, for an incremental cost of $16.24.
7. Quote from Resource Action Programs. March 2018.
8. Navigant. *ComEd Rural Small Business Energy Efficiency Kits IPA Program Impact Evaluation Report*. Table 7.1, p. 10. August 1, 2018. http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY9_Evaluation_Reports_Final/ComEd_PY9_Rural_SB_EE_Kits_IPA_Program_Impact_Evaluation_Report_2018-08-01.pdf
   In-service rate for MR-16 lamp used as subsititute for LED exit sign retrofit to represent a more difficult installation process than a typical A-lamp LED.

9. Historical Focus on Energy project data. SPECTRUM. January 1, 2017 to June 29, 2018. Multifamily Energy Savings Program MMID 2768 had 57 projects with 755 exit signs (note that three projects with 45 exit signs were excluded due to not being able to determine wattage from specification sheet provided for the project). Weighted average of the installed exit signs was 1.67 watts.
10. Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 6.0, Volume 2: Commercial and Industrial*. February 8, 2017. p. 377. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_2_C_and_I_020817_Final.pdf

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	03/2018	Added pack-based measure

DLC High Bay < 18,500 Lumens Replacing or Instead of 6L T8 or 4L T5HO

	Measure Details
Measure Master ID	DLC HB <18,500 Lumens, Replacing or Instead of 6L T8 or 4L T5HO, 3809
Measure Unit	Per luminaire
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$224.14[2]

Measure Description

LED high bay fixtures save energy when replacing 4-lamp T5HO or 6-lamp T8 high bay products by providing a similar lumen output with lower input wattage. These products can be installed on a one-for-one basis to replace 4-lamp T5HO or 6-lamp T8 high bay luminaires.

Description of Baseline Condition

The baseline condition is a combination of 4-foot 4-lamp T5HO and 6-lamp T8 high/low bay fixtures for existing buildings and new construction buildings. An average of 25% 4-foot 4-lamp T5HO and 75% 6-lamp T8 high/low bay luminaires was used to generate the baseline wattage (see Assumptions).

Description of Efficient Condition

The efficient condition is a DesignLights Consortium-listed LED fixture in the High-Bay General Application, outputting less than 18,500 lumens.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1{,}000$

Where:

$Watts_{BASE}$ = Average power consumption of current 4-lamp T5HO and 6-lamp T8 high/low bay luminaires (= 226.5 watts; see Assumptions)

$Watts_{EE}$ = Average power consumption of DLC-listed LED high/low bay luminaire (= 118 watts)

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	$HOU^{3,4}$
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239
Multifamily	5,950

Summer Coincident Peak Savings Algorithm

Exterior applications have no summer coincident peak savings.

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1{,}000$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	$CF^{3,5}$
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64
Multifamily	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Annual Savings for DLC HB < 18,500 Lumens Replacing or Instead of 6L T8 or 4L T5HO

Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
405	0.0837	516	0.0837	511	0.0728	352	0.0696	647	0.0837

Lifecycle Savings for DLC HB < 18,500 Lumens Replacing or Instead of 6L T8 or 4L T5HO

Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
4,455	5,676	5,621	3,872	7,117

Assumptions

Fixture weightings are based on a combination of feedback from energy audit experience, Lighting Certified individuals through the National Council on Qualifications for the Lighting Professions, and individuals with lighting sales experience. Each fixture wattage is sourced from the Focus on Energy Default Wattage Guide.

Sources

1. DesignLights Consortium. Qualified Product List. Accessed August 2017. https://www.designlights.org/lighting-controls/download-the-qpl/
   Average rated life of models participating in linear LED measures is 51,160 hours. With an HOU of 4,472, the EUL is 11 years.
2. August 2018 online lookups of four base and efficient models on www.1000bulbs.com, www.bulbs.com, www.lightbulbsupply.com, www.topbulb.com, and www.warehouse-lighting.com show an average efficient fixture price of $236.90 and base bulb price of $12.76, for an incremental cost of $224.14.
3. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3.2 Lighting Hours of Use in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

4. Tetra Tech. "ACES Deemed Savings Desk Review." Table 1. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
5. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf Coincidence factor is within range of similar programs; see Table 4-1 showing multifamily housing (in unit) CF of 65% to 83%

Revision History

Version Number	Date	Description of Change
01	07/29/2016	Replaces MMID 3393
02	10/2017	Updated EUL
03	12/2018	Updated incremental cost, removed MMID 3901

High Bay Fluorescent Lighting

	Measure Details
Measure Master ID	High Bay Fluorescent Lighting: T8 4L Replacing 250-399 W HID, 3811 T8 6L Replacing 400-999 W HID, 3812 T5HO 4L Replacing 400-999 W HID, 3813 T5HO 6L Replacing 400-999 W HID, 3814
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Fluorescent, Linear
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Varies by measure
Incremental Cost ($/unit)	Varies by measure, see Appendix D

Measure Description

In high-bay lighting applications (ceiling heights generally over 15 feet), HID fixtures have typically been used due to their high lumen output. In recent years, however, improvements in fluorescent lamps and the emergence of new high-intensity fluorescent fixtures have made fluorescent lighting the most cost-effective choice for lighting high indoor spaces. These high-intensity fluorescent systems are more energy efficient than HID solutions and feature lower lumen depreciation rates, better dimming options, virtually instant start-up and re-strike, better color rendition, and reduced glare. Similar high-intensity fluorescent lighting fixtures are also available for low bay applications, generally with equipment available in the same product family as the manufacturers' high bay products.

Description of Baseline Condition

The baseline condition is HID fixtures and lamps.

Description of Efficient Condition

The efficient condition varies by the wattage of the baseline lamp (see table below).

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * HOU$

Where:

$Watts_{BASE}$ = Wattage of a HID lamp (= varies by measure; see table below)

$Watts_{EE}$ = Wattage of HOT5 or HOT8 lamp (= varies by measure; see table below)

Wattages Used for Deemed Savings Calculations

Measure	$Watts_{BASE}$	$Watts_{EE}$
2L HOT5	293	117
3L HOT5	293	179
4L T8	293	151
4L HOT5	356	234
6L T8	356	224
4L HOT5	455	234
6L HOT5	455	355
6L T8	455	224
8L T8	455	291
6L HOT5	1,079	355
8L HOT5	1,079	585
(2) 4L HOT5	1,079	468
(2) 6L HOT5	1,079	709
8L T8	1,079	291
10L T8	1,079	366
(2) 6L T8	1,079	447

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU[2]
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF[2]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (2884, 3811, 2886, 2887, 2888, 2889, 2890, 2891, 2892, 3813, 2893, 3814, 2894, 2895, 2896, 2897 = 14 years[1] and 3329, 3330, 3331, 3812, 3332, 3333, 3334 = 15 years)[2]

Deemed Savings

Annual Electric Savings (kWh/year/lamp removed)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Government
T8 4L Replacing 250-399 W HID	3811	532	676	669	462
T5HO 4L Replacing 400-999 W HID	3813	824	1,049	1,038	716
T5HO 6L Replacing 400-999 W HID	3814	375	477	472	326
T8 6L Replacing 400-999 W HID	3812	863	1,098	1,088	750

Summer Peak Savings

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Government
T8 4L Replacing 250-399 W HID	3811	0.11	0.11	0.095	0.091
T5HO 4L Replacing 400-999 W HID	3813	0.17	0.17	0.148	0.141
T5HO 6L Replacing 400-999 W HID	3814	0.077	0.077	0.067	0.064
T8 6L Replacing 400-999 W HID	3812	0.178	0.178	0.155	0.148

Lifecycle Savings (kWh)

New Fixture Type	MMID	Commercial	Industrial	Agriculture	Schools & Government
T8 4L Replacing 250-399 W HID	3811	7,441	9,466	9,373	6,462
T5HO 4L Replacing 400-999 W HID	3813	11,541	14,681	14,536	10,021
T5HO 6L Replacing 400-999 W HID	3814	5,248	6,676	6,610	4,557
T8 6L Replacing 400-999 W HID	3812	12,089	15,379	15,226	10,498

Sources

1. Average of: Cadmus 2013 database;
   2007 GDS residential measure life report: http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf;
   California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com/
   PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual v1.0." Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
2. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." EUL Table. 2014. http://www.deeresources.com/
   Rated ballast life of 70,000 hours. Not rated on bulb life as such capped at 15 years.
3. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual v1.0." Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	10/2016	Removed MMID 2885
03	04/2017	Added MMID 2885
04	01/2019	Removed MMIDs 2884, 3329, 3331, 2886, 2887, 3333, 2888, 2889, 2885, 2890, 3330, 2891, 2892, 3332, 2893, 2894, 3334, 2895, 2896, and 2897

Exterior – Induction, PSMH, CMH, Linear Florescent Fixtures

	Measure Details
Measure Master ID	Induction, PSMH/CMF or Linear Fluorescent, Exterior: Replacing 150-175 Watt HID, 3829 Replacing 250 Watt HID, 3830 Replacing 320 -Watt HID, 3084 Replacing 400 Watt HID, 3832 Replacing 70-100 Watt HID, 3833
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Other
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by fixture
Peak Demand Reduction (kW)	Varies by fixture
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by fixture
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Varies by measure, see Appendix D

Measure Description

Induction, PSMH, CMH, and linear fluorescent lighting fixtures save energy by reducing the light fixture wattage compared to standard metal halide fixtures, without sacrificing illumination quality and safety. These lighting technologies are appropriate for exterior applications.

Description of Baseline Condition

The baseline measure is standard HID lamps between 70 watts and 400 watts, located on exterior poles or high canopies.

Description of Efficient Condition

The efficient measure is induction, PSMH, CMH, and linear fluorescent fixtures between 35 watts and 250 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Wattage of baseline HID fixture
$Watts_{EE}$ = Wattage of efficient induction fixture, PSMH fixture, CMH fixture, or linear fluorescent fixture
1,000 = Kilowatt conversion factor
HOU = Hours of use (= 4,380)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Deemed Savings by Measure

Measure	MMID	Annual Savings (kWh)	Peak Demand Reduction (kW)	Lifecycle Savings (kWh)
Induction, PSMH/CMH, or Linear Fluorescent, Replacing 70-Watt to 100-Watt HID, Exterior	3833	247	0	3,712
Induction, PSMH/CMH, or Linear Fluorescent, Replacing 150-Watt to 175-Watt HID, Exterior	3829	329	0	4,938
Induction, PSMH, CMH, or Linear Fluorescent Replacing 250-Watt HID, Exterior	3830	605	0	9,076
Induction, PSMH, CMH, or Linear Fluorescent Replacing 320-Watt HID, Exterior	3084	556	0	8,344
Induction, PSMH, CMH, or Linear Fluorescent Replacing 400-Watt HID, Exterior	3832	972	0	14,585

Assumptions

The induction wattages shown below include the ballast wattage, which was calculated as 10% of the lamp wattage based on the manufacturer specifications. All exterior replacement calculations use 4,380 hours of annual operation, half the total hours in a year.

70-watt to 100-watt HID exterior replacements are weighted as follows:

- Baseline = 50% 70-watt HID and 50% 100-watt HID (= 111.5 watts)
- Eligible Replacements = 50% linear fluorescent ≤ 60 watts, 25% 35-watt induction, and 25% 55-watt induction (= 55 watts)

150-watt to 175-watt HID exterior replacements are weighted as follows:

- Baseline = 50% 150-watt HID and 50% 175-watt HID (= 194.5 watts)
- Eligible Replacements = 33.33% 100-watt induction, 33.33% 100-watt PSMH or CMH, and 33.33% ≤ 120-watt linear fluorescent (= 119 watts)

250-watt HID exterior replacements are weighted as follows:

- Baseline = 100% 250-watt HID (= 299 watts)
- Eligible Replacements = 14.3% 120-watt to 125-watt induction, 14.3% 150-watt induction, 14.3% 165-watt induction, 14.3% 125-watt PSMH or CMH, 14.3% 140-watt PSMH or CMH, 14.3% 150-watt PSMH or CMH, and 14.3% ≤ 155-watts linear fluorescent (= 161 watts)

320-watt HID exterior replacements are weighted as follows:

- Baseline = 100% 320-watt HID (= 368 watts)
- Eligible Replacements = 16.6% 200-watt induction, 16.6% 225-watt induction, 16.6% 250-watt induction, 16.6% 200-watt PSMH or CMH, 16.6% 210-watt PSMH or CMH, and 16.6% 220-watt PSMH or CMH (= 241 watts)

400-watt HID exterior replacements are weighted as follows:

- Baseline = 100% 400-watt HID (= 463 watts)
- Eligible Replacements = 16.6% 200-watt induction, 16.6% 225-watt induction, 16.6% 250-watt induction, 16.6% 200-watt PSMH or CMH, 16.6% 210-watt PSMH or CMH, and 16.6% 220-watt PSMH or CMH (= 241 watts)

Source

1. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." 2014. http://www.deeresources.com/
   Rated ballast life of 70,000 hours. Not rated on bulb life. Capped at 15 years.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	01/2019	Removed MMIDs 3078, 3081, 3086, and 3087

High Bay – Induction, PSMH, CMH Fixtures

	Measure Details
Measure Master ID	High Bay – Induction, PSMH, CMH Fixtures: ≤ 250 Watt, Replacing 320-400 Watt HID, 3816 ≤ 250 Watt, Replacing 400 Watt HID, 3817 Replacing 250 Watt HID, 3815
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Other
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Varies by measure, see Appendix D

Measure Description

Induction, pulse-start metal halide, and ceramic metal halide lighting fixtures save energy by reducing the light fixture wattage compared to standard metal halide fixtures, without sacrificing illumination quality and safety. These lighting technologies are appropriate for high bay applications.

Description of Baseline Condition

The baseline condition is standard HID lamps between 250 watts and 1,000 watts, located in a parking garage.

Description of Efficient Condition

The efficient condition is induction, pulse-start metal halide, and ceramic metal halide fixtures between 120 watts and 750 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED\ IND} = kWh_{HID} - kWh_{IND}$

$kWh_{SAVED\ PSMH} = kWh_{HID} - kWh_{PSMH}$

$kWh_{SAVED\ CMH} = kWh_{HID} - kWh_{CMH}$

Where:

kWh_{HID} = Annual electricity consumption of standard HID fixture
kWh_{IND} = Annual electricity consumption of induction lighting fixture
kWh_{PSMH} = Annual electricity consumption of pulse start metal halide fixture
kWh_{CMH} = Annual electricity consumption of ceramic metal halide fixture

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = Wattage / 1{,}000 * CF$

$kW_{IND} = kW_{PEAK\ HID} - kW_{PEAK\ IND}$

$kW_{PSMH} = kW_{PEAK\ HID} - kW_{PEAK\ PSMH}$

$kW_{CMH} = kW_{PEAK\ HID} - kW_{PEAK\ CMH}$

Where:

$kW_{PEAK\ HID}$ = Peak demand of existing HID system
$kW_{PEAK\ IND}$ = Peak demand of new induction lighting system
$kW_{PEAK\ PSMH}$ = Peak demand of new pulse start metal halide lighting system
$kW_{PEAK\ CMH}$ = Peak demand of new ceramic metal halide lighting system
HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU[2]
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF[3]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE\ IND} = (kWh_{HID} - kWh_{IND}) * EUL$

$kWh_{LIFECYCLE\ PSMH} = (kWh_{HID} - kWh_{PSMH}) * EUL$

$kWh_{LIFECYCLE\ CMH} = (kWh_{HID} – kWh_{CMH}) * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Average Annual Deemed Savings for High Bay Induction PSMH/CMH Fixtures

Measure	MMID	Commercial 3,730 (0.77)		Schools & Gov 3,239 (0.64)		Industrial 4,745 (0.77)		Agriculture 4,698 (0.67)	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
HB PSMH, CMH, IND Replacing 250 Watt HID	3815	510	0.1053	443	0.0875	649	0.1053	642	0.0916
HB PSMH, CMH, IND (250 Watt or Less) Replacing 400 Watt HID	3817	827	0.1706	718	0.1418	1,052	0.1706	1,042	0.1484
HB PSMH, CMH, IND (250 Watt or Less) Replacing 320-400 Watt HID NC (Based on 320 watt savings)	3816	499	0.1031	433	0.0857	635	0.1031	628	0.0897

Average Lifecycle Deemed Savings for High Bay Induction PSMH/CMH Fixtures

Measure	MMID	Commercial 3,730 (0.77)	Schools & Gov 3,239 (0.64)	Industrial 4,745 (0.77)	Agriculture 4,698 (0.67)
		kWh	kWh	kWh	kWh
HB PSMH, CMH, IND Replacing 250 Watt HID	3815	7,650	6,645	9,735	9,630
HB PSMH, CMH, IND (250 Watt or Less) Replacing 400 Watt HID	3817	12,405	10,770	15,780	15,630
HB PSMH, CMH, IND (250 Watt or Less) Replacing 320-400 Watt HID NC (Based on 320 watt savings)	3816	7,485	6,495	9,525	9,420

Measure Costs for High Bay Induction PSMH/CMH Fixtures

Measure	MMID	Cost ($)
HB PSMH, CMH, IND Replacing 250 Watt HID	3815	$100.00
HB PSMH, CMH, IND (250 Watt or Less) Replacing 400 Watt HID	3817	$240.00
HB PSMH, CMH, IND (250 Watt or Less) Replacing 320-400 Watt HID NC (Based on 320 watt savings)	3816	$290.00

Assumptions

Hours of operation and coincidence factor based on sector. Induction wattage shown includes ballast wattage, which was calculated as 10% of lamp wattage based on the manufacturer specifications. 250-watt HID high bay replacements of ≤ 155 watts weighted as follows:

- Baseline = 100% 250-watt HID
- Eligible Replacements = 16.6% 120-watt to 125-watt induction, 16.6% 150-watt induction, 16.6% 165-watt induction,16.6% 125-watt PSMH or CMH, 16.6% 140-watt PSMH or CMH, and 16.6% 150-watt PSMH or CMH

320-watt HID high bay replacements of ≤ 250 watts weighted as follows:

- Baseline = 100% 320-watt HID
- Eligible Replacements = 16.6% 200-watt induction, 16.6% 225-watt induction, 16.6% 165-watt induction, 16.6% 200-watt PSMH or CMH, 16.6% 210-watt PSMH or CMH, and 16.6% 220-watt PSMH or CMH

400-watt HID high bay replacements of ≤ 365 watts weighted as follows:

- Baseline = 100% 400-watt HID
- Eligible Replacements = 16.6% 250-watt induction, 16.6% 300-watt induction, 16.6% 250-watt PSMH or CMH, 16.6% 270-watt PSMH or CMH, 16.6% 315-watt PSMH or CMH, and 16.6% 320-watt PSMH

1,000-watt HID high bay replacements of ≤ 800 watts weighted as follows:

- Baseline = 100% 1,000-watt HID
- Eligible Replacements = 50% 750-watt induction, and 50% 575-watt PSMH or CMH

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3.2 Lighting Hours of Use in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
3. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3.2 Coincidence Factor for Lighting in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	12/2012	Initial TRM entry
02	09/2015	Updates and revisions
03	01/2019	Removed MMIDs 3075,3076, 3077, 3818, 3090, and 3074

Motors and Drives

Agriculture, VFD, Milk Pump

	Measure Details
Measure Master ID	VFD, Dairy Milk Pump, Agriculture, 3988
Measure Unit	Per milking cow
Measure Type	Prescriptive
Measure Group	Motors & Drives
Measure Category	VFD
Sector(s)	Agriculture
Annual Energy Savings (kWh)	20.7688 kWh
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	311.532 kWh
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$3,004[2]

Measure Description

Milk pumps in dairy milking operations move the milk into a well-water plate cooler before it flows to the mechanical cooling system. The milk flow is usually not consistent as it comes from the cows. Since the load on the milk pump changes as the flow of milk varies during the milking process, quite often milk may either surge or trickle into the well water plate cooler throughout the milking cycles, reducing the effectiveness of heat transfer across the plate cooler heater exchanger fins. By slowing the milk pump flow rate, a greater and more consistent water to milk flow ratio can be achieved, increasing heat transfer between the milk and well water. A VFD or other variable speed drive provides the necessary control of the milk pump for a slower, more consistent and more even flow of milk through the plate cooler. The well water being pumped through the plate cooler to serve as the milk coolant is assumed to be reused for other farm needs after its use in the plate cooler, typically for animal consumption.

Description of Baseline Condition

The baseline condition is a milk pump motor operating at full speed to transfer milk from the receiver jar to the plate cooler without any variable speed milk pump flow control.

Description of Efficient Condition

The efficient condition is to add a VFD to control the milk pump and slow the milk flow through the plate cooler, increasing effectiveness of the heat transfer between the milk and well water. Slowing down milk flow can achieve several additional degrees, up to a maximum of 15°F, of milk cooling out of the existing plate cooler. These few extra degrees of cooling equate to less energy that the refrigeration system compressor will need to cool the milk to its final storage temperature of around 38°F. The output milk temperature from the plate cooler, in conjunction with a VFD on the milk pump, can be within 4°F of well water temperature.[3]

Annual Energy-Savings Algorithm

The prescriptive deemed kWh savings are based on an average per pound of milk per day cooled on a dairy farm as calculated using the hybrid calculations on file with past applications.[2]

$kWh_{SAVED} = \text{lbs of Milk} * C_{P,MILK} * \Delta T_{MILK} * 365 / AEER_{COMPRESSOR} / 1{,}000$

Where:

lbs of Milk = Estimated daily pounds of milk produced by the dairy farm that needs to be cooled through use of a milk pre-cooler (= 68 pounds of milk per cow;[4] with the number of milking cows being user defined)

$C_{P,MILK}$ = Specific heat of milk (= 0.94 Btu/(lb-°F))[5]

ΔT_{MILK} = Temperature difference of the output of plate cooler milk before and after the use of variable speed control on the milk pump to slow milk pump and increase heat removed from milk through the plate cooler prior to mechanical refrigeration. The average plate cooler milk temperature without VFD control is 70°F (see Assumptions). VFD control on the milk pump can help decrease milk temperature in the plate cooler to within around 4°F of the well water temperature.[3] The plate cooler theoretical milk temperature with VFD control is 52.3°F + 4°F = 56.3°F (Final ΔT_{MILK} value= 70°F - 56.3°F = 13.7°F).

365 = Number of milking days per year[7]

$AEER_{COMPRESSOR}$ = Annual energy efficiency ratio of refrigeration compressor (= 15.39 Btu/watt * hr)[8]

1,000 = Conversion factor from watts to kilowatts

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for VFD dairy milk pumps. Through research of refrigeration compressor power demands, no substantial evidence has arisen that any notable kW demand reduction is possible in relation to using a VFD with a milk pre-cooler to pre-cool milk that would otherwise need to be chilled through mechanical refrigeration means.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

- The electric savings value does not account for the potential of electric savings on the milk pump itself due to the VFD usage since milk pumps are typically ≤ 2 hp and savings is deemed minimal compared to savings of the refrigeration compressor. The purpose of installing variable speed control on a milk pump is not aimed at achieving savings from the pump itself. As such, these savings are ignored.
- This measure refers to the use of a VFD to provide milk pump control, however other forms of variable speed drives are also eligible if they adequately reduce the speed of the milk pump to achieve higher well water to milk flow ratios (1:1 to 2:1 or 3:1).
- Assumes an even 50/50 split of farms using scroll versus reciprocating compressors to drive the milk cooling process.[8]
- Milk temperature from the output of a pre-cooler is based on a weighted percentage of single and double pass pre-cooler units. Single pass units roughly drop the milk temperature 25°F while double pass units drop the milk roughly 35°F.[9] Based on past project data analysis related to milk pre-cooler application submittals, the latest Wisconsin trend for new pre-cooler installations is 40% single pass pre-cooler and 60% double pass pre-coolers.[10] The estimated temperature drop for a farm with a pre-cooler = 25°F * 0.4 + 35°F * 0.6 = 31°F.
- Temperature of milk leaving cow is 101°F. Average plate cooler milk temperature without VFD control is 101°F – 31°F = 70°F. The measure savings are based on the assumption that a well water temperature of 52.3°F is used as milk coolant.[6] It is assumed the lowest milk temperature that could be achieve would be 56.3°F (or 4°F higher than well water coolant temperature).[3] The maximum additional cooling for any style of plate cooler in conjunction with a variable speed controlled milk pump would be up to 15°F of additional cooling.[9]
- The user-defined input provided for the number of milking cows is assumed to be the average number of animals being milked throughout the entire year.

Sources

1. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” February 2014. http://www.deeresources.com/
2. Efficiency Vermont. “Technical Reference Use Manual.” p. 24. August 9, 2013. http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf
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4. U.S. Department of Agriculture. “Milk Production Per Cow.” https://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/Dairy/Historical_Data_Series/mkpercow.pdf
5. Hu, Jin. “Determination of Specific Heat of Milk at Different Fat Content Between 1°C and 59°C Using Micro DSC.” Journal of Food Engineering (February 2009): 90(3). p. 395–399.·http://www.researchgate.net/publication/234102534_Determination_of_specific_heat_of_milk_at_different_fat_content_between_1C_and_59C_using_micro_DSC
6. U.S. Department of Energy. “Domestic Hot Water Scheduler.” Average water main temperature of all locations measured in Wisconsin by scheduler, weighted by city populations.
7. Wisconsin Milk Marketing Board. “Did You Know? Website: Milking Every Day.” Accessed December 21, 2015. http://www.dairydoingmore.org/economicimpact/dairyfacts
8. “Dairy Pre-Cooler Supplemental Data.” Compressor Modeling tab created by CESA10 using compressor model data from past projects submitted to Focus on Energy and Compressor Performance Data sheets from Copeland scroll compressors to determine the average of the scroll and reciprocating compressors AEER.
9. Sanford, Scott (University of Wisconsin – Madison). “Energy Efficiency for Dairy Enterprises.” Presentation to Agricultural and Life Sciences Program staff. December 2014. http://farmenergymedia.extension.org/sites/default/files/Dairy%20Energy%20Conservation-2013.pdf
10. “Ag VFD Milk Pump Supplemental Data.” Pre-cooler Measure Analysis tab.
Sample data showing split of single pass to double pass plate coolers installed on Wisconsin dairies of 86 pre-cooler projects entered in SPECTRUM from January 2015 through July 2016.

Revision History

Version Number	Date	Description of Change
01	09/30/2015	Original
02	10/28/2016	Updated measure to be based on number of milking cows. Updated algorithm inputs. Replaced MMID 3797 with MMID 3988.

Agriculture, VFD, Vacuum Pump

	Measure Details
Measure Master ID	VFD, Dairy Vacuum Pump, Agriculture, 3987
Measure Unit	Per milking cow
Measure Type	Prescriptive
Measure Group	Motors & Drives
Measure Category	VFD
Sector(s)	Agriculture
Annual Energy Savings (kWh)	71.162 kWh
Peak Demand Reduction (kW)	0.0001 kW
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	1067.430 kWh
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$4,014.00[2]

Measure Description

Vacuum pumps in dairy milking operations create suction to extract milk from the cow and move the milk to the mechanical cooling system. The vacuum pump is also typically used to flush warm wash water through the milk pipeline to clean it between milkings to prevent bacteria growth. The load on the pump changes between attachments (moving milkers from one cow to the next), as one quarter is emptied and a teat cup drops off, and is affected by how much milk the system is moving at any given time. An alternate way to provide control of motor systems is to use VFDs, which physically slow the pump motors to achieve reduced flow rates at considerable energy savings when the suction load drops in the system. If the total CFM demand of vacuum pump falls below 35% of rated pump speed, the pump motor will start to overheat. Therefore, the pump CFM produced for milking or washing needs will have to be greater than or equal to 35% of rated CFM of the pump.[3] The average amount of milk pumped per day based on sample project data comes out to around 17,868 pounds of milk per day,[5] and the average cow produces 68 pounds of milk per day[5] (these values are used to determine the measure unit value for the average deemed savings).

Description of Baseline Condition

The baseline condition is a vacuum pump motor operating at full speed when in use to handle the demand of the vacuum pump for milking operation as well as the milk pipeline cleaning needs. The only control for the vacuum pump for the baseline condition is a conventional type of vacuum pump regulator that acts to throttle the flow of a vacuum pump to control the suction pressure.

Description of Efficient Condition

The efficient condition is to add a VFD or other variable speed drive to the motor to vary the electric frequency (Hertz) going to the motor, which allows the speed of the motor to be varied. The variable speed drive will be automatically controlled by a vacuum or pressure sensor/transducer that measures the changes in pressure in the milking suction system during milking and wash cycles. A customer can buy a variable speed vacuum pump from a manufacturer that includes the vacuum pump and all variable speed control components in one package ready to install in the dairy milk house. A customer may also retrofit an existing baseline vacuum pump set up by installing an appropriate off the shelf VFD and additional sensor/transducer components, if not already present, to achieve the variable speed control for the pump. Each variable speed vacuum pump setup is different. The VFD controlling the pump should have its control sequence (typically PID control) tuned to meet the appropriate suction needs of the milking operation as part of the equipment installation and commissioning process.

Annual Energy-Savings Algorithm

The prescriptive deemed kWh savings are based on an average per pound of milk per day cooled on a dairy farm as calculated using the hybrid calculations on file with past applications.[2]

$kWh_{SAVED} = kWh_{NO\_VFD} - kWh_{W/VFD}$

kWh_{NO_VFD} = Pump hp * 0.746 * Motor Load / Motor Eff * ($HOURS_{MILK}$ + $HOURS_{WASH}$)

$kWh_{W/VFD} = kW_{MILKING} * HOURS_{MILK} + kW_{WASH} * HOURS_{WASH}$

$kW_{MILKING}$ = (0.05 * (Larger of: (2 CFM/milking unit * MU) **OR %**CFM_{MIN}) + 1.7729[3,4]

kW_{WASH} = (0.05 * 5 CFM/milking unit * # of milking units + 1.7729)[3,4]

Where:

kWh_{NO_VFD} = Baseline condition

$kWh_{W/VFD}$ = Efficient condition

Pump hp = Motor horsepower of the pump (~10 hp,[4] producing around 100 CFM of suction)[3]

Motor Load = Estimated percentage of full load the motor runs at (~90%)

Motor Eff = Based on motor horsepower and NEMA energy-efficient full load motor efficiency ratings (~89.5%)[5]

0.05 = Formula constant[3,4]

2 CFM/milking unit = Formula constant for vacuum pump milking operation[3,4]

MU = Number of milking units needed to be controlled by the vacuum pump, based on an average of SPECTRUM project data (= 15.79)[5]

$\%CFM_{MIN}$ = Minimum speed of 35% that the constant torque vacuum pump needs to keep to prevent from overheating the pump and motor[3] (100 CFM * 35% = 35 CFM)

5 = CFM/milking unit (=formula constant for vacuum pump washing operation)[3,4]

$HOURS_{MILK}$ = Annual milking hours (= 365 days * # of milking's per day (2.45) * Hours per milking (4.92hrs)[5])

$HOURS_{WASH}$ = Annual milking hours (= 365 days * # of milk pipeline washings per day (2.45) * Vacuum pump washing run time (0.75hrs)[5])

The formula above yields an average project savings of approximately 18,700 kWh. Converting that to the prescriptive base unit yields: (18,700 kWh / 17,868 lbs of milk per day = 1.0465 kWh/lb of milk per day * 68 lbs of milk per day per cow[5] = 71.162 kWh/cow).

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = [(Pump hp * 0.746 * Motor Load / Motor Eff) – $kWh_{W/VFD}$ / (Annual milking hours + Annual washing hours)] * CF

Where:

CF = Coincidence factor (~0.45; see note below)

The amount of kW demand reduction is calculated as an average and is only counted for projects that milk at least three times per day (as it is assumed that a dairy farm will be running their vacuum pump during the demand period for one of their milking times every day in this scenario). Based on the sample of project data used for this workpaper, approximately 45% of the sample projects submitted for Focus on Energy VFD vacuum pump incentives milked more than twice a day and are eligible for claiming kW demand reduction. Therefore, a coincidence factor of 0.45 will be used in the savings algorithm above.

Using the defined values stated above and the calculated coincidence factor to complete the savings algorithms, average savings are 1.6596 kW. It is assumed that the same demand power requirements for the vacuum pump are needed during every milking operation time of day. The three or more times per day operations are assumed to have one of their milking times occur during the peak hour of 1:00 p.m. to 4:00 p.m. every day.

The formula and description above yield an average project kW demand reduction of ~1.6596 kW. Converting that to the prescriptive base unit yields: (1.6596 kW / 17,868 lbs of milk per day = ~0.0001 kW/lb of milk per day).

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=15 years)[1]

Assumptions

- This measure assumes that the vacuum pump is large enough to produce the total required suction in CFM needed for all the milking and washing operational needs. It is assumed each horsepower of vacuum pump size equates to ~10 CFM of suction.[3] The variable speed energy savings calculation is based on information presented from Scott Sanford who performed a study of the energy reduction through VFD vacuum pumps on four farms.[3,4]
- It is assumed that the correct sized VFD is installed to control the vacuum pump properly across its operating range.
- Savings based on 365 days per year of milking operations.
- User defined input provided for the '# of milking cows' value is assumed to be the average number of animals being milked throughout the entire year.

Sources

1. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." February 2014. http://www.deeresources.com/
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Revision History

Version Number	Date	Description of Change
01	09/30/2015	Initial TRM entry
02	10/28/2016	Updated to be based on number of milking cows using new sources and replaced MMID 3798 with MMID 3987

Variable Frequency Drive (Variable Torque and Constant Torque)

	Measure Details
Measure Master ID	VFD, Process Fan, 2647, 4581 VFD, Process Pump, 2648, 3835, 4414, 4582 VFD, Constant Torque, 3280, 3836, 4412,4601 VFD, Boiler Draft Fan, 2640,4653 VFD, Cooling Tower Fan, 2641,4654 VFD, Chilled Water Distribution Pump, 2726,4655 VFD, HVAC Fan, 2643,4578 VFD, HVAC Heating Pump, 2644,4579 VFD, Pool Pump Motor, 2646,4580 VFD, Agriculture Primary Use Water System, 4043 VFD, Agriculture Secondary Use Water System, 2639 VFD, Agriculture Secondary Use Water System, Low HOU, 4411 VFD, Irrigation Well Pump, 3776 VFD, Irrigation Well Pump, Low HOU, 4415 VFD, Ventilation/Circulation Fan, 3777 VFD, Ventilation/Circulation Fan, Low HOU, 4413 VFD, Domestic Water Pump, 4757 VSD Vacuum Pump, Variable Torque, 4361 VSD Vacuum Pump, Constant Torque, 4362
Measure Unit	Per motor
Measure Type	Hybrid
Measure Group	Agriculture: (MMIDs 2639, 3776, 3777, 4043, 4411, 4413, and 4415) Boilers & Burners: (MMIDs 2640 and 2644) HVAC: (MMIDs 2641, 2643, and 2726) Domestic Hot Water: (MMID 4757) Pools: (MMID 2646) Process: (MMIDs 2647, 2648, 3280, 3835, 3836, 4361, 4362, 4412, and 4414)
Measure Category	Variable Speed Drive
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0

	Measure Details
Water Savings (gal/yr)	0
Effective Useful Life (years)	15[1]
Incremental Cost	\$210.52 per hp for variable torque measures;[2] \$122.48 per hp for constant torque measures (MMIDs 3280, 3836, 4362)[3]

Measure Description

Fans, pumps, conveyors, and other motor-driven equipment require controls to vary their operation to produce the desired output (such as getting sufficient airflow to cool a building, obtaining hot water for heating, or moving product down a conveyor). Traditionally, flow rates have been reduced by increasing the head and riding the pump (or fan) curve back to a new flow rate (known as throttling control). Alternately, some systems have bypasses that divert a portion of the flow back to the pump or fan inlet to reduce system flow (bypass control). Other systems simply start and stop the motor to meet the given load (on/off control). An alternate way to provide control of motor systems is to use VFDs, which physically slow the motors driving pumps, fans, and other equipment to achieve reduced flow rates at considerable energy savings.

There are three categories of motor applications, outlined below, but only two (variable torque and constant torque) have the potential for energy savings when adding VFDs.[4]

- ***Variable Torque Loads:*** This category consists of centrifugal pumps and fans, regenerative blowers, and a few types of vacuum pumps. For these applications, the motors follow the fan or affinity laws, resulting in the input power varying with the cube of the pump or fan rotational speed. This means that small reductions in flow (such as 20%) can produce large input power savings (50%).
- ***Constant Torque Loads:*** This category consists of equipment where the torque requirement is independent of speed. Examples of constant torque applications include cranes, hoists, conveyors, extruders, mixers, positive displacement pumps, and most types of vacuum pumps. This means that the input power varies linearly with the rotational speed (where a 20% reduction in speed equals a 20% reduction in input power). Most vacuum pumps—including piston, diaphragm, rocking-piston, rotary-vane, and lobed-rotor types—are positive displacement pumps.
- ***Constant Horsepower Loads:*** This category consists of equipment where the torque varies inversely with the speed of the motor. Therefore, the power requirement does not vary, regardless of speed. Examples of constant horsepower loads includes lathes, drilling, and milling equipment. This equipment category does not offer energy savings for installing VFDs[5] and is therefore ineligible for VFD incentives.

Description of Baseline Condition

The baseline condition is a motor for a variable torque or constant torque application operating at full speed and using throttling, bypass, or on/off control to handle variable outputs from the driven device (such as the pump or fan).

Description of Efficient Condition

The efficient condition is adding a VFD to the motor to vary the electric frequency (i.e., Hertz) going to the motor, which will allow the speed of the motor to be varied. For variable torque (pump and fan) applications, the VFD must be automatically controlled by a variable input signal. Constant torque applications have the option to be manually controlled, as these are often used to vary the speed of equipment associated with production in a manufacturing environment.

Annual Energy-Savings Algorithm

Non-HVAC Fan Measures

Energy savings for these measures are custom calculated using spreadsheet tools,[6] which are based on an engineering bulletin[7] and savings calculators from two different VFD manufacturers.[8,9] Energy savings for the HVAC fan measure (MMID 2643) are described in the next section.

For the energy savings analysis, this tool used power curves developed from data obtained by measuring the operating characteristics of various fans and pumps. The curves are representative of typical VFD operation.

Equation used in the software tool:

$$\text{Power at Design GPM [CFM]} = \text{Controlled Horsepower} * \text{Conversion Constant [kW/hp]} * \text{Motor Load at Design GPM [CFM]} / \text{Nameplate Efficiency}$$

Computed for each capacity level:

$$\text{Percentage of Design kW} = A1 + (A2 * \text{Capacity}) + (A3 * (\text{Capacity})^2) + (A4 * (\text{Capacity})^3)$$

$$\text{Percentage of Design kW for VFD} = A1 + (A2 * \text{Capacity}) + (A3 * (\text{Capacity})^2) + (A4 * (\text{Capacity})^3)$$

Where A1, A2, A3, and A4 are variables unique to each “before VFD” control type that allow a quadratic equation to be created to represent the load profile. The table below shows values for A1, A2, A3, and A4.

Equation Variables: Before VFD

Control	A1	A2	A3	A4
Outlet Control Valve	55.21240	0.63700	-0.00190	0.00000
Eddy Current Clutch	16.39683	-0.05647	0.01237	-0.00003
Torque Converter	13.51137	0.34467	0.01269	-0.00007
Bypass Valve	102.00000	0.00000	0.00000	0.00000
VFD Pump	27.44751	-1.00853	0.01762	0.00000
On/Off	100.00000	0.00000	0.00000	0.00000
Inlet Guide Vane, FC Fans	20.00000	0.06808	-0.00128	0.00009
Inlet Guide Vanes	47.26190	0.67944	-0.01554	0.00014
Inlet Damper Box	50.25833	0.71648	-0.01452	0.00013
Outlet Damper, FC Fans	20.41905	0.10983	0.00745	0.00000
Discharge Damper	55.92857	-0.56905	0.02462	-0.00014
Eddy Current Drives	16.39683	-0.05647	0.01237	-0.00003
VFD Fan	5.90000	-0.19567	0.00766	0.00004
Constant Torque VFD	0.00000	1.00000	0.00000	0.00000

HVAC Fan Measure

Energy savings for HVAC fan measures are custom calculated using the same spreadsheet tool as for the other measures,[6] but the algorithm for this measure is different. It relies on data collected by Cadmus from 2014 through 2016.[11]

Cadmus installed 56 meters on HVAC fan VFD motors in the fall of 2014, removing them in the fall of 2015. These meters provided hourly average power consumption for these VFD motors for a year, and their hourly average consumption per motor hp is used as an efficient-case input. Cadmus also installed 66 meters on constant-speed HVAC fans in March of 2015 and removed them in April of 2016. These meters provided monthly average motor consumption per hp for these motors, serving as a baseline.

These two datasets are combined with user-imputed weekly motor run schedules and motor size to calculate baseline and efficient energy consumption, and energy savings. The savings are calculated for every hour of the year and added to produce annual savings.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Expected useful life (= 15 years)[1]

Summer Coincident Peak Savings Algorithm

Non-HVAC Fan Measures

$kW_{SAVED} = kWh_{SAVED} / HOURS * CF$

Where:

HOURS = Annual hours of operation for the system controlled by the VFD (= provided by customer)

CF = Coincidence factor (= varies by VFD use, see table below)

Coincidence Factor by VFD Use

VFD Use	CF	Source
Hot Water Pump	0.0	Heating pumps operate in winter (off peak)
Chilled Water Pump	0.9	DEER model runs are weather normalized for statewide use by population density.
Constant Volume Fan (on/off control)	0.9	
Air Foil/Inlet Guide Vanes	0.9	
Forward Curved Fan with Discharge Damper	0.9	
Forward Curved Inlet Guide Vanes	0.9	
Inlet Guide Vanes (fan type unknown)	0.9	
Cooling Tower Fan	0.9	
Process Pump, Ag Primary/Secondary Water Pumps	0.78	Per Michigan Energy Measures Database[10]
Process Fan	0.78	Assume same CF as other process equipment
Constant Torque (process applications)	0.78	Assume same CF as other process equipment
Pool Pump	0.78	Assume same CF as process equipment
Boiler Draft Fan (HVAC)	0	Does not run in summer
Boiler Draft Fan (process)	0.78	Assume same CF as other process equipment
Ag Field Irrigation Pump	Hybrid	Based on customer feedback on supplemental data sheet. Irrigation happening during peak time: 0-10%=0.00 10-50%=0.33 50-90%=0.66 90-100%=1.00
Ag Ventilation/Circulation Fans	1.0	Assume that the temperature is above 50°F and fans are running during the majority of peak hours
Vacuum Pump	0.95	VSD air compressor CF used as an approximation of VSD vacuum pump CF, per IL and MN TRMs[12,13]
Domestic Water Pump	0.50	Hawaii Technical Reference Manual, PY16 [14]

HVAC Fan Measure

Because the calculation for the HVAC fan measure requires estimates of hour by hour energy savings for the entire year, the coincident peak savings can be directly calculated, rather than through the use of a coincidence factor, according to the following formula:

$kW_{SAVED} = (kWh_{BASE,PEAK} - kWh_{EFF,PEAK})/198$

Where:

$kWh_{BASE,PEAK}$ = Total baseline energy consumption during peak hours

$kWh_{EFF,PEAK}$ = Total VFD energy consumption during peak hours

198 = Total peak period hours[11]

Assumptions

The following rules and requirements apply to the VFD application:

- Variable torque VFDs must be used in conjunction with a process or HVAC fan or pumping application.
- Redundant or back-up units do not qualify.
- Replacement of existing VFDs does not qualify.
- VFD speed (for variable torque applications) must be automatically controlled by differential pressure, flow, temperature, or another variable signal.
- VFD speed (for constant torque applications) may be either automatically or manually controlled.
- VFDs may not be beneficial in pump systems where static head makes up a large portion of the total system head. It is also important that the load on the system vary over time to take advantage of the savings that a VFD can provide. Be sure to understand these aspects of your system and discuss them with the equipment vendor in advance of applying VFD technology.
- Incremental cost are assumed to equal measure installed cost. HVAC and process systems either have equipment described under the Description of Baseline Condition section or have a VFD. Baseline condition equipment is required for operation, so VFD is a replacement technology, not an incremental improvement in efficiency (like for a chiller or boiler).

- The system using the VFD must operate a minimum of 2,000 hours for the commercial, industrial, schools & government, and residential multifamily sectors. A minimum of 1,000 hours is required for the agriculture sector, except for applications with low HOU (MMIDs 4411–4415), where equipment operates between 500 and 1,000 hours annually.
- VFDs used on variable torque vacuum pumps will be processed as "VFD Pump" and "Other Pump" for the load profiles used in the VFD calculation.

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Revision History

Version Number	Date	Description of Change
01	11/21/2013	Added constant torque (conveyor, mixer, positive displacement pump) kilowatt and kilowatt-hour savings for select VFDs
02	10/2017	Added more measure types; added new low-HOU agriculture measures
03	12/2018	Add domestic water pump measure

Other

DEET Behavioral Savings

	Measure Details
Measure Master ID	DEET, Savings Period 1, 3652 DEET, Savings Period 2, 3653 DEET, Savings Period 3, 3654 DEET, Savings Period 4, 3655 DEET, Savings Period 5, 3656 DEET, Savings Period 6, 3657 DEET, Savings Persistence, 3658 DEET, V2.0, Year 1, 4262 DEET, V2.0, Year 2, 4263 DEET, V2.0, Year 3, 4264 DEET, V2.0, Year 4, 4265
Measure Unit	Per building
Measure Type	Hybrid
Measure Group	Other
Measure Category	Whole Building
Sector(s)	Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	4[1]
Incremental Cost ($/unit)	$12,000.00[2]

Measure Description

According to the U.S. Environmental Protection Agency, 30% of a district's total energy may be used inefficiently or unnecessarily.[3] Schools have a considerable opportunity to reduce energy consumption and district energy costs. Recommended behavior changes that will conserve energy include turning off unnecessary lights, shutting down computers, reducing phantom loads, and disseminating regular energy conservation reminders.

Delivery Energy Efficiency Together (DEET) was initially offered in July 2015 as a series of behavioral incentives based on savings measured directly from utility bills in K-12 schools every six months for three years (MMIDs 3652-3658). The amount of kW, kWh, and therm savings incentives is determined by comparing reporting period utility bills to an established baseline (12 months prior to starting the initiative). Program/sector kW, kWh, and therm savings are determined by comparing reporting period consumption to previous year consumption using utility bills.

In September 2017, a new DEET model was released (MMIDs 4262-4265) that only offers kWh and therm savings and incentives. As with the older model, this newer model determines savings by comparing current utility bills to the prior reporting period. However, unlike the older model that determines incentives by comparing current utility bills to a pre-measure baseline, this newer model determines incentives by comparing current utility bills to the prior year consumption (rolling baseline versus static baseline in the initial model). Schools have an option of renewing their enrollment on an annual basis up to three times for a total of four years.

School staff will participate in pre- and post-participation energy behavior surveys and energy awareness campaigns. Points are earned for reducing kWh and therm usage and are redeemed for energy-related prizes such as LED light bulbs and power strips. Periodic reports are provided to schools to illustrate the impact of their energy conservation efforts.

Both models are intended to capture all energy savings with the DEET measures; therefore, participating schools are not eligible for any other Focus on Energy measures while enrolled in DEET.

Description of Baseline Condition

For both models, the baseline condition is a school building that has not completed any measures incented by Focus on Energy within 12 months. In addition, participating buildings must not be planning for major renovations or energy upgrades within three years from the start of the initiative for the original model and within the next year for the new model.

Description of Efficient Condition

DEET participants will use less energy than their baseline by expanding management-driven savings to include occupant behavioral energy savings, sustaining energy reductions, increasing occupancy involvement in energy reduction initiatives, and increasing occupants’ realization of the financial and environmental impact of individual and group energy consumption.

Annual Energy-Savings Algorithm

For the original model, kWh and therm savings are calculated every six months for three years (for a total of six calculation/reporting periods). For the new model, savings are calculated three times each year (three calculation/reporting periods). For both models, measured savings will use the previous year consumption as a baseline.

$kWh_{SAVED} = kWh_{BP} - kWh_{RP}$

$Therm_{SAVED} = Therm_{BP} - Therm_{RP}$

$Therm_{BP} = (Therm_{BPACT}) * (HDD_{30YRAVG} / HDD_{BP})$

$Therm_{RP} = Therm_{NORM} = (Therm_{RPACT}) * (HDD_{30YRAVG} / HDD_{RP})$

Where:

kWh_{BP} = Electrical consumption during baseline period (= varies by building)
kWh_{RP} = Electrical consumption during reporting period (= varies by building)
$Therm_{BP}$ = Natural gas consumption during baseline period (= varies by building)
$Therm_{RP}$ = Natural gas consumption during reporting period (= varies by building)
$Therm_{BPACT}$ = Actual natural gas consumption during baseline period (= varies by building)
$HDD_{30YRAVG}$ = 30-year average heating degree days
HDD_{BP} = Heating degree days during baseline period (= varies by year)
$Therm_{NORM}$ = Natural gas consumption normalized for heating loads (= varies by building)
$Therm_{RPACT}$ = Actual natural gas consumption for reporting period (= directly from utility bill; varies by building)
HDD_{RP} = Heating degree days during reporting period (= varies by year)

Summer Coincident Peak Savings Algorithm

Kilowatt savings are only calculated for the original model. There are no kilowatt savings calculated for the new model due to high variability in use of school facilities over peak periods. For example, a building may host summer school one year and not the next year, resulting in a decrease in demand not related to DEET energy conservation efforts. Kilowatt savings under traditional facility-use conditions are typically insignificant.

There will be no peak savings for periods 1, 3, and 5. For periods 2, 4, and 6, the monthly kilowatts for June, July, and August of the reporting year is averaged and used as the kW_{RP}.

$kW_{SAVED} = kW_{BP} - kW_{RP}$

Where:

kW_{BP} = Average monthly kW usage for baseline year (= average of kW_{JUNE} + kW_{JULY} + kW_{AUG}; varies by building)

kW_{RP} = Average monthly kW usage for reporting year (= average of kW_{JUNE} + kW_{JULY} + kW_{AUG}; varies by building)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 4 years)[1]

Assumptions

The 30-year average heating degree days per month by Wisconsin city[4] are provided in the table below.

30-Year Heating Degree Day Values Per Month by Wisconsin City

Month	Milwaukee	Green Bay	Wausau	Madison	La Crosse	Minocqua	Rice Lake
January	1,443	1,591	1,440	1,561	1,623	1,632	1,623
February	1,211	1,238	1,313	1,272	1,200	1,293	1,455
March	934	1,019	1,278	844	911	1,222	1,125
April	595	630	550	607	514	574	531
May	358	265	460	217	242	321	414
June	126	87	39	105	80	124	84
July	29	38	33	18	10	73	45
August	36	74	54	45	40	97	64
September	116	182	143	233	186	294	185
October	471	560	568	568	522	528	571
November	817	932	844	916	861	969	1,007
December	1,262	1,288	1,261	1,404	1,373	1,665	1,624
Total	**7,398**	**7,903**	**7,982**	**7,791**	**7,561**	**8,793**	**8,726**

The incremental cost of $12,000 per building was based on the following assumptions:

- According to project experience, we assumed that staff will spend approximately 45 minutes per month for DEET initiative activities such as reviewing DEET-related emails and reports, addressing energy topics in staff meetings, and discussing energy with students.
- We assumed an average staff wage of $30 per hour based on working 1,500 hours for the median teacher salary of $45,227 in La Crosse, Wisconsin.[5] (Note that administrators have a higher salary and support staff have a lower salary). The total, at $30 per hour multiplied by 0.75 hours per nine months a year, is $202.50 (rounded to $200).
- We assumed an average of 50 staff per building based on field experience ($200 multiplied by 50 staff/building = $10,000/building).
- Finally, based on rough estimates from general data available to the program, we assumed each building would spend an average of $2,000 in buildings and grounds discretionary funds on small energy projects (such as replacing incandescents and CFLs with LEDs, installing timers and power strips, and adding LED task lighting or vending misers). Since this is the first time an initiative like DEET has been proposed in Wisconsin, we concluded that an incremental cost of $10,000 for staff time and $2,000 for energy projects per building is reasonable and appropriate.

The EUL of four years was based on the following assumptions:

Program Effective Useful Life = Lifetime Savings / First Year Savings

$$\text{Lifetime Savings} = 1^{\text{st}}\text{ Yr Savings} + \sum_{t=2}^{\infty} 1^{\text{st}}\text{ Yr Savings} * (1-\delta)^{t-1} * (1-\alpha)^{t-1}$$

This formula assumes that savings decay indefinitely and at a constant annual rate of (1-δ) * (1-α), with δ being the rate of savings decrease and α being the rate of staff attrition. As this is an infinite series, it converges to a lifetime savings value of:

$$\frac{\text{First Year Savings}}{\delta + \alpha - \delta * \alpha}$$

Therefore, the EUL can be calculated as follows:

$$\text{EUL} = \frac{\text{Lifetime Savings}}{\text{1st Year Savings}} = \frac{\left(\frac{\text{1st Year Savings}}{\delta + \alpha - \delta * \alpha}\right)}{(\text{1st Year Savings})} = \frac{1}{\delta + \alpha - \delta * \alpha}$$

Assuming an annual savings decay rate of 20% and an annual participant attrition rate of 7%, the EUL is four years:

EUL = 1 / (0.20 + 0.07 - 0.20 * 0.07) ≈ 4 Years

Although the decay rate and attrition rate values are based on home energy report studies,[1] they are the best available information to apply to this program. School staff are similar to residential customers in that good energy-related habits will decrease over time at a similar decay rate and staff will move out of their buildings at a similar attrition rate as residential customers moving to new homes.

Sources

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Revision History

Version Number	Date	Description of Change
01	09/01/2015	Initial TRM entry
02	09/14/2017	Updated EUL and added new model measure

Process

Process Exhaust Filtration

	Measure Details
Measure Master ID	Process Exhaust Filtration, 3244
Measure Unit	Per CFM
Measure Type	Hybrid
Measure Group	Process
Measure Category	Filtration
Sector(s)	Commercial, Industrial
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by project
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by project
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1,2,3]
Incremental Cost ($/unit)	$3.95[6]

Measure Description

Process exhaust air filtration systems save energy by reducing the heat load on a make-up air system by recirculating filtered process air instead of bringing in colder outdoor make-up air during the heating season. Energy savings result from the reduced temperature difference through the heat exchanger of the supply air system. The temperature difference between the filtered indoor air and the indoor supply air temperature is much lower than the difference between outdoor air and indoor supply air temperature. This reduction in heat load results in natural gas savings.

Exhaust filtration systems typically use cartridge filters and are frequently found in welding fume exhaust and paint booth exhaust applications. This measure is incented per CFM of make-up air eliminated and savings will be realized in industrial and service facilities. Systems must run a minimum of 2,000 hours annually in order to be eligible.

Description of Baseline Condition

The baseline condition is 100% of process exhaust fumes being evacuated from the space associated with the industrial process, with ventilation provided by 100% outside air with heating provided by a natural gas fired make-up air unit.

Description of Efficient Condition

The efficient condition is a filtration system that reduces or eliminates the need to discharge 100% of process exhaust by filtering and recirculating the air and thereby reducing or eliminating make-up air demand and associated heating energy.

Annual Energy-Savings Algorithm

Btu/°F = CFM * Specific Heat

$\text{Btu}_{\text{SAVED}} = \text{Btu/°F} * \Delta T * \text{HOU}$

$\text{Therm}_{\text{SAVED}} = \text{Btu}_{\text{SAVED}} / (\text{System Efficiency} * 100{,}000)$

Note: Fan energy savings are neglected for this measure, as eliminating the makeup air fan is offset by the increased energy usage of the exhaust fan due to static pressure increases.

Where:

Btu/°F = Energy required to heat volume of make-up air for each additional degree Fahrenheit

CFM = Volumetric flow rate of eliminated make-up air unit (= actual)

Specific Heat = 1.08 Btu/hr/CFM-°F (dry air)

$\text{Btu}_{\text{SAVED}}$ = Total energy required to heat eliminated make-up air

ΔT = Difference between average indoor temperature and average outside winter temperature

HOU = Annual hours requiring exhaust (= actual)

$\text{Therm}_{\text{SAVED}}$ = Natural gas energy required to heat make-up air before eliminated

System Efficiency = Heating efficiency of make-up air system (= actual)

100,000 = Conversion from Btu to therm

Summer Coincident Peak Savings Algorithm

There are no peak savings associated with this measure.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}} = \text{Therm}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (15 years)[1,2,3]

Assumptions

The average inside temperature, 65°F, assumed to equal design temperature. Average outdoor winter temperature of 30.8°F.[5] (Therefore ΔT = 65°F – 30.8°F = 34.2°F).

Sources

1. Using current EULs, rooftop units are very similar to the industrial ventilation system but without a heating or cooling coil. Focus on Energy currently uses a 15 year EUL for rooftop units.
2. Chartered Institution of Building Services Engineers. “Probabilistic Estimation of Service Life.” http://www.cibse.org/knowledge/cibse-technical-symposium-2011/probabilistic-estimation-of-service-life.
   The industrial ventilation system would consist of a fan and a set of filters; fan EUL is 15 to 20 years depending on type and filter EUL is 15 to 20 years depending on type.
3. Wisconsin DOA guideline document for lifecycle costing of state building projects. Page 36 lists 10 to 20 years for rooftop units and 15 to 30 years for fans depending on type.
4. SPECTRUM historical projects (custom projects that implemented comparable measures).
5. Focus on Energy Deemed Savings Manual.
6. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 21 units over 21 projects in 2018.

Revision History

Version Number	Date	Description of Change
01	07/2015	Initial TRM entry
02	12/2018	Updated incremental cost

Pressure Screen Rotor

	Measure Details
Measure Name	Pressure Screen Rotor, 2496
Measure Unit	Per horsepower
Measure Type	Hybrid
Measure Group	Process
Measure Category	Specialty Pulp & Paper
Sector(s)	Industrial
Annual Energy Savings (kWh)	Varies by horsepower
Peak Demand Reduction (kW)	Varies by horsepower
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by horsepower
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[2]
Incremental Cost ($/unit)	$200.77[3]

Measure Description

Paper mills use pressure screens to separate contaminants from the pulp produced from recycled products. A motor is used to spin the rotor at a high velocity, forcing the pulp through narrow slots or apertures that are a barrier to debris, stickies, contaminates, and uncooked or undeveloped bundles of wood fibers (shives). This makes contaminate-free pulp available for further processing.

Pressure screen rotors are an energy-efficient method of removing large contaminants from pulp stock. The new dual element foil design more efficiently removes the contaminants while using less power.

Description of Baseline Condition

The baseline technology for removing contaminants is with a narrow slotted screen.

Description of Efficient Condition

The efficient condition is a pressure screen rotor design.

Annual Energy-Savings Algorithm

There are two methods for estimating savings. The first method relies on pre-retrofit and post-retrofit amp measurements from the participant application; the second method determines deemed savings using an energy savings factor of 30% based on Focus on Energy project history.

Method #1: Custom Approach (Amps Known)

$kWh_{SAVED} = (Amps_{PRE} - Amps_{POST}) * 1.73 * V * PF * Hrs/wk * Weeks$

Method #2: Deemed Approach (Amps Unknown)

$kWh_{SAVED} = hp * LF / Eff * 0.746 * S * Hrs/wk * Weeks$

Where:

$Amps_{PRE}$ = Pre-retrofit pulper amps (= actual; requested in program application or measured)

$Amps_{POST}$ = Post-retrofit pulper amps (= actual; requested in program application or measured)

1.73 = Constant to calculate kWh

V = Voltage of pulper (= actual; requested in program application or reported by customer)

PF = Power factor (= actual reported by customer or deemed 0.75)

Hrs/wk = Hours per week (= actual; requested in program application or reported by customer)

Weeks = Weeks of operation per year (= actual; requested in program application or reported by customer)

hp = Motor horsepower (= actual; reported by customer)

LF = Motor load factor (= actual reported by customer or deemed 65%)

Eff = Estimated motor efficiency (= actual reported by customer or deemed 92%)

0.746 = Conversion from horsepower to watts

S = Deemed savings factor (= 30%)[1]

Summer Coincident Peak Savings Algorithm

Method #1: Custom Approach (Amps Known)

$kW = (Amps_{PRE} - Amps_{POST}) * 1.73 * V * PF$

Method #2: Deemed Approach (Amps Unknown)

$kW = hp * LF / Eff * 0.746 * S$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[2]

Sources

1. Focus on Energy industrial sector project history. 2013.
2. Engineering judgement.
3. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 12 units from 2012 to 2014.

Revision History

Version Number	Date	Description of Change
01	05/2015	Initial TRM entry
02	12/2018	Updated incremental cost

Repulper Rotor

	Measure Details
Measure Name	Repulper Rotor, 2538
Measure Unit	Per horsepower
Measure Type	Hybrid
Measure Group	Process
Measure Category	Specialty Pulp & Paper
Sector(s)	Industrial
Annual Energy Savings (kWh)	Varies by amperage
Peak Demand Reduction (kW)	Varies by amperage
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by amperage
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[3]
Incremental Cost ($/unit)	$271.39[4]

Measure Description

A repulper is a large tank with a mixer, or rotor, on the bottom. Pulping rotors are rebuilt or replaced periodically, providing facility managers with the opportunity to investigate new repulper rotors for their facility. Manufacturers of paper process equipment designed new energy-efficient repulper rotors to help offset rising energy costs, including energy-efficient repulper rotors (HM rotors, new energy efficient repulping blades) replacing conventional HOG-type rotors (existing conventional repulping blades, baseline). HM rotors have a tall, swept-back blade design that provides effective turbulence of the fiber suspension product and maximizes rotor fiber contact while consuming less horsepower than conventional rotors.

Description of Baseline Equipment

The baseline technology is a HOG rotor.

Description of Efficient Equipment

The efficient condition is a HM rotor.

Annual Energy-Saving Algorithm

There are two methods for estimating savings. The first method relies on pre-retrofit and post-retrofit amp measurements as provided in the participant application or obtained; the second method uses deemed savings using an energy savings factor of 23%.[1]

Method #1: Custom Approach (Amps Known)

$kWh_{SAVED} = (Amps_{PRE} - Amps_{POST}) * 1.73 * V * PF * Bwk * t * Weeks$

Method #2: Deemed Approach (Amps Unknown)

$kWh_{SAVED} = hp * LF / Eff * 0.746 * S * Bwk * t * Weeks$

Where:

$Amps_{PRE}$ = Pre-retrofit pulper amps (= actual; from program application or measured)
$Amps_{POST}$ = Post-retrofit pulper amps (= actual; from program application or measured)
1.73 = Constant to calculate kWh
V = Voltage of pulper (= actual; from program application or reported by customer)
PF = Power factor (= actual reported by customer or deemed 0.75)
Bwk = Batches per week (= actual; from program application or reported by customer)
t = Time per pulp batch in minutes (= actual; from program application or reported by customer)
Weeks = Weeks of pulping per year (= actual; from program application or reported by customer)
hp = Motor horsepower (= actual; reported by customer)
LF = Motor load factor (= actual reported by customer or deemed 65%)
Eff = Estimated motor efficiency (=actual reported by customer or deemed 92%)
0.746 = Conversion from horsepower to watts
S = Savings factor (= deemed 23%)[2]

Summer Coincident Peak Savings Algorithm

Method #1: Custom Approach (Amps Known)

$kW = (Amps_{PRE} - Amps_{POST}) * 1.73 * V * PF$

Method #2: Deemed Approach (Amps Unknown)

$kW = hp * LF / Eff * 0.746 * S$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)

Sources

1. Wisconsin Focus on Energy. "Voith High Efficiency HM Rotor Energy Data: A Repulper Rotor Design Case Study." 2005. http://oaktrust.library.tamu.edu/bitstream/handle/1969.1/5580/ESL-IE-05-05-21.pdf?sequence=4&isAllowed=y
2. *Focus on Energy Business Programs - Industrial Sector*. December 16, 2005. Repulper rotor reduces energy costs by 23%.
3. Engineering judgement.
4. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of three units from 2014 to 2016.

Revision History

Version Number	Date	Description of Change
01	05/2015	Initial TRM entry
02	12/2018	Updated incremental cost

High Efficiency Side Entry Agitator

	Measure Details
Measure Master ID	High Efficiency Side Entry Agitator, 4763
Measure Unit	Per agitator motor horsepower
Measure Type	Hybrid
Measure Group	Process
Measure Category	Specialty Pulp and Paper
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by application
Peak Demand Reduction (kW)	Varies by application
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$225.29[2]

Measure Description

In the paper-making process, fiber, filler, and chemical additives are pulped with water (slurried) in a pulper. This slurry, referred to as stock, is pumped to holding tanks that feed process equipment, like refiners and cleaners, en route to the paper machine. These holding tanks must continually be agitated to keep the slurry from settling out. Often times, multiple slurries come together in a single tank and must be mixed into a homogenous slurry before being pumped to the next operation. Side entry agitators are commonly used in the paper industry in stock blending and mixing tanks. Most of them employ marine type impellers, which are essentially boat propellers with the pitch and diameter selected for the specific application.

High-efficiency units are purpose built, replacement impellers designed to replace the typical marine impellers. The pitch and angles on high-efficiency impeller fins allow for improved circulation at lower torque. Only the impeller blades and hub are replaced. The shaft, gearbox, and motor are typically reused.

Description of Baseline Condition

The baseline condition is a typical agitator that uses a marine type impeller, very similar to a boat propeller. This is typically the standard impeller that is installed with the side entry agitator.

Description of Efficient Condition

The efficient condition is an engineered impeller specifically built to replace the standard marine type impeller to reduce energy intensity. Impeller diameter and revolutions per minute are changed specific to the application and tank design.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = HP * 0.746 * LF * Op\ Hours * SF$

Where:

HP = Agitator horsepower (= actual)

0.746 = Conversion factor; 1 hp = 0.746 kW

LF = Load factor; percentage load on the agitator motor over operating hours (= actual)

Op Hours = Agitator operating hours (= actual)

SF = Savings factor (= 15%; see Assumptions)[3]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / Op\ Hours$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Savings vary by application. This is a hybrid measure that uses inputs from the application, which are then entered into the savings algorithm above to generate the kilowatt-hour savings.

Assumptions

The agitator horsepower, load factor, and operating hours are all provided by the end user on the application. These values are known or given. The savings factor is based on manufacturer data[3] and successful customer installation.[4] The manufacturer claims that the typical savings factor with this type of impeller upgrade is 20%; to be conservative with the savings estimate, the savings algorithm above uses 15%.

Sources

1. Engineering judgement. An effective useful life of 15 years is deemed based on consultation with pulp and paper subject matter experts. End of life can occur due to the impeller blades wearing or being damaged by the paper making process. Note that the blades can be changed out individually if needed to maintain the efficient design. Subject matter experts state that 15 to 20 years is a typical EUL.
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. October 2016 through October 2018.
   Weighted average cost of three previous Process, Not Otherwise Specified projects involving this technology is $225.29/hp.
3. GL&V Pulp and Paper Group. "GL&V Agitator Impeller Energy Upgrade Presentation." May 2018. Presentation claims that these impellers are 20% more efficient than typical marine propeller, and details eight motors that were replaced with smaller models after impeller installation.
4. Clean Tech Partners. Wisconsin Focus on Energy Emerging Technologies Program. *Transition of Emerging Technology to Best Practice High Efficiency Side Entry Agitator*. August 2, 2018.
   One customer showed energy savings of 22.2% with this upgrade.

Revision History

Version Number	Date	Description of Change
01	12/4/2018	Initial TRM entry

Spline Rotor Upgrade for Refiners

	Measure Details
Measure Master ID	Spline Rotor Upgrade for Refiners, 4764
Measure Unit	Per refiner horsepower
Measure Type	Hybrid
Measure Group	Process
Measure Category	Specialty Pulp and Paper
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by application
Peak Demand Reduction (kW)	Varies by application
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$127.59[2]

Measure Description

Stock is the fiber slurry sent to a paper machine to make paper. This fiber slurry is forced between the rotor and stator of a refiner, both of which are fitted with removable plates that have patterns of bars and gaps that act to cut or fibrillate the fiber between the bars. Typically, as the bars wear, the dynamics change and greater pressure is required to keep the gap between the rotor and stator the same size using more horsepower to get the same action. With a double disc refiner, the rotor is floating between two stationery plates.

A non-splined rotor operation relies on the linear movement of the entire rotor and shaft assembly to displace and self-center between the stator plates. Inevitably some differences exist on the rotor sides, causing under-refinement on one side of the rotor and over-refinement on the other. When the splined hub is installed, the stock coming from both sides of the rotor is more homogeneous and less energy is required since the refiner is no longer over-refining to achieve the same sheet properties. This problem becomes more pronounced with mechanical condition in the refiner; specifically, as the shaft packing sleeve and motor coupling wear they will become less likely to displace freely.

Description of Baseline Condition

The baseline condition is a typical disc refiner where the rotor and shaft are allowed to move linearly. Essentially, the rotor is connected to a floating shaft and allowed to move side to side between the stators during the refining process. Over time, this can cause uneven refining due to the shaft not floating as well as it should and not remaining properly centered.

Description of Efficient Condition

The efficient condition is upgrading the refiners with spline technology to allow the splined rotor to balance on a splined hub, which is mounted to a non-floating fixed shaft. This improves the rotor centering, which in turn increases the refiner efficiency and performance.[3]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = HP * 0.746 * LF * HOU * SF$

Where:

HP = Refiner horsepower (= actual)

0.746 = Conversion factor for 1 hp (= 0.746 kW)

LF = Load factor; the percentage load on the refiner over operating hours (= actual)

HOU = Refiner operating hours (= actual)

SF = Savings factor (= estimated as 10%; see Assumptions)[3,4,5]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / HOU$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Savings vary by application. This hybrid measure uses inputs from the application that are then entered into the savings algorithm above to generate the kilowatt-hour savings.

Assumptions

The refiner horsepower, load factor, and operating hours are provided by the application end user. These values are known or given.

The savings factor is based on manufacturer data.[3,4,5] Customers typically save in the range of 10% to 15%, with 12% to 14% being more typical as more installations are occurring with this technology. To be conservative with the savings estimate, the savings algorithm above uses 10%.

Sources

1. Engineering judgement. An effective useful life of 15 years is deemed based on consultation with pulp and paper subject matter experts. Refiner life typically lasts longer than 15 years, but they generally require a rebuild in the 15 to 20 year timeframe.
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. December 2015 through July 2018.
   Weighted average cost of six previous process (not otherwise specified) projects involving this technology is $127.59/refiner hp.
3. GL&V Pulp and Paper Group. "Upgrading Your Refiner Will Result in Improved Refining and Power Savings." May 2010.
   Memo claims spline rotors are 10% to 25% more efficient. Two case studies reduce power consumption by 12.5% and 32%.
4. GL&V Pulp and Paper Group. *DD 4600/3600 OEM Upgrades General Equipment Descriptions*. p. 4. 2010.
   Claims estimated energy savings of 15% with this type of refiner.
5. GL&V Pulp and Paper Group. *Power Savings with DD 4600/4500 Upgrade at 90% Motor Load*. 2010.
   Data claiming power savings of 10% to 15% depending on refiner size.

Revision History

Version Number	Date	Description of Change
01	02/2019	Initial TRM entry

Radiant Heater Band for Plastics

	Measure Details
Measure Master ID	Plastics Equipment, Radiant Heater Band Retrofit, 2490
Measure Unit	Per installed kilowatt of existing heater bands
Measure Type	Hybrid
Measure Group	Process
Measure Category	Process Heat
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	Varies
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$267.99 per kilowatt of existing heater bands[2]

Measure Description

This measure is replacing conduction band heaters on plastic forming machine barrels with radiant barrel heaters. Plastic forming machines include injection molding equipment, profile and sheet extrusion equipment, and blow molding equipment. The energy savings comes from two main factors—insulation and heating more quickly.

Description of Baseline Condition

The baseline condition is conduction band heaters on plastic forming machine barrels. These band heaters conduct heat directly to the barrel surface and typically are not insulated.

Description of Efficient Condition

The efficient condition is insulated radiant heaters, installed with an air gap between the heater and the barrel. The insulation makes the immediate work environment more comfortable for the machine operators, and makes the conditions more safe by lowering exposed surface temperatures.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = LF * kW_{EXISTING} * HOU * \% Savings$

Where:

LF = Load factor (= 0.5; see Assumptions)

$kW_{EXISTING}$ = Existing heater kilowatt usage (= user input)

HOU = Hours of use (= user input)

% Savings = Percentage savings (= 15%; see Assumptions)[3]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = LF * kW_{EXISTING} * \% Savings$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

Savings for MMID 2490 (created in 2012) were previously based on the average kilowatt and kilowatt-hour savings per kilowatt of existing heater for 41 projects completed prior to 2012.[4] These were fixed savings per heater of 903 kWh and 0.120 kW. However, that source of data is no longer available.

Two Focus on Energy projects, which had measurement and verification reports completed in 2008, had savings as shown in the table below.

Kilowatt Reduction from Two Projects

Project	Old Heater	New Heater	Difference	% Savings
Project 1	5.672[2]	4.807[2]	0.865	15%
Project 2	37.86[3]	13.59[3]	24.27	64%

However, in Project 2, the barrel temperatures in four of the five zones were 20°F to 35°F lower than the existing condition with the original band heaters, which increased energy savings beyond switching the heater type alone. The values for Project 1 align with industry experience,[5] and these are used for the basis of the 15% savings.

A load factor is also applied to the heater power (kW) to account for cycling on and off—Project 1 had an average kilowatt of approximately 50% of its peak kilowatt value.

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of six units from 2013 to 2016.
3. Wisconsin Focus on Energy (Laube, Dean). *Measurement & Verification – Final Report*. Northern Engraving Corporation. p. 5 and 9. February 2008.
   Used total kilowatt and kilowatt-hour in report divided by the existing heater kilowatt in the report.
4. Wisconsin Focus on Energy. Historical project data, Excel workbook "Radiant Heater Bands-Plasatics1.xlsx." Data for 41 projects.
5. Cadmus (Korn, Dave, and Charles Bicknell). "Review of Work Paper 'Plastics Equipment – Efficient Radiant Heater and Retrofit.'" Memo. May 29, 2012.

Revision History

Version Number	Date	Description of Change
01	10/09/2018	Initial TRM entry

Industrial High Frequency Battery Chargers

	Measure Details
Measure Master ID	Industrial High Frequency Battery Chargers, 4765
Measure Unit	Per kilwatt-hour of battery charger capacity
Measure Type	Hybrid
Measure Group	Process
Measure Category	Other
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$400[1]

Measure Description

Industrial high-frequency battery chargers are used for portable industrial equipment like forklifts, fork trucks, and airport transport equipment in factories, warehouses, and similar facilities. They convert standard AC power to DC power stored in batteries. System inefficiencies occur during charging, charge maintenance, and standby. There are several factors to consider:

- Power Conversion Efficiency – the ratio of energy out of charger to the energy into charger
- Charge Return Factor – the ratio of energy into battery to the energy out of battery
- Maintenance Mode Losses – the power used by charger when connected battery is fully charged
- No Battery Mode Losses – the power used by charger when no battery is connected

High-frequency battery chargers are more efficient than other types of chargers, including ferroresonant, silicon controlled rectifier (SCR), and hybrids of these two technologies. Compared to ferroresonant chargers, high-frequency chargers do not have transformer losses, have better power factor, and have better electrical controls. Compared to SCR chargers, high-frequency chargers have lower switching losses and better power factor.

High-frequency battery chargers have a rated input power of more than 2 kW[2] and may be single phase or three phase. This measure does not apply to vehicle chargers or smaller chargers like those used for golf carts.

Description of Baseline Condition

The baseline condition is a ferroresonant, SCR, or hybrid battery charger, where operating hours are at least 1,000 hours per year.

Description of Efficient Condition

The efficient condition is battery charger that meets the minimum requirements as documented in California's appliance standard for Large Battery Charger Systems (shown in the table below).[2]

Minimum Requirements for Qualifying Large Battery Chargers

Performance Parameter		Requirement
Charge Return Factor	80% Depth of Discharge	≤1.10
	40% Depth of Discharge	≤1.15
Power Conversion Efficiency		≥89%
Power Factor		≥0.9
Maintenance Power Mode (watts)		≤10 + 0.0012 * (Battery watt-hours), in watts
No Battery Mode Power (watts)		≤10 watts

A list of approved products is available online.[3] Operating hours must be at least 1,000 hours per year.

Annual Energy-Savings Algorithm

$$kWh_{SAVED} = kWh_{BASELINE} - kWh_{EE}$$

$$kWh_{BASELINE} = ((CAP * DOD * CHG * CRF_{BASE} / PCE_{BASE}) + (P_{MM,BASE} * HOU_{MM}) + (P_{NBM,BASE} * HOU_{NBM})) / 1{,}000$$

$$kWh_{EE} = ((CAP * DOD * CHG * CRF_{EE} / PCE_{EE}) + (P_{MM,EE} * HOU_{MM,EE}) + (P_{NBM,EE} * HOU_{NBM,EE})) / 1{,}000$$

Where:

CAP = Battery charger capacity in watt-hours (= user input)
DOD = Degree of discharge (= user input; if unknown use 80%)[2]
CHG = Number of charging cycles per year (= user input)
CRF_{BASE} = Baseline charge return factor at degree of discharge (= 1.16; see Assumptions)
PCE_{BASE} = Baseline power conversion efficiency (= 85.1%; see Assumptions)
$P_{MM,BASE}$ = Baseline power in maintenance mode (= 99.1 watts; see Assumptions)
HOU_{MM} = Baseline number of hours per year in maintenance mode (= user input)
$P_{NBM,BASE}$ = Baseline power in no battery mode (= 55.4 watts; see Assumptions)
HOU_{NBM} = Baseline number of hours per year in no battery mode (= user input)

1,000 = Watt to kilowatt conversion factor

CRF_{EE} = Efficient charge return factor at degree of discharge (= user input)

PCE_{EE} = Efficient power conversion efficiency (= user input)

$P_{MM,EE}$ = Efficient power in maintenance mode in watts (= user input)

$P_{NBM,EE}$ = Efficient power in no battery mode in watts (= user input)

Summer Coincident Peak Savings Algorithm

There are no peak demand savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

Savings related to better efficiency in maintenance mode and no battery mode are small relative to savings in charging mode and are neglected.

The baseline values for power conversion efficiency, charge return factor, power in maintenance mode, and power in no battery mode are averages for ferroresonant, SCR, and hybrid chargers. The population fraction of each was derived from Table 1 of a Minnesota study,[5] showing that the general population of industrial battery chargers is 50% ferroresonant, 30% SCR, 5% hybrid, and 10% high frequency. Therefore the baseline splits are assumed to be 50 / (50 + 30 + 5) = 59% for ferroresonant, and so on.

Average Baseline Values[4]

Charger Type	Population Fraction[5]	Power Conversion Efficiency	Charge Return Factor	Maintenance Power (watts)	No Battery Power (watts)
Ferroresonant	59%	85%	1.15	81.7	18.2
SCR	35%	85%	1.18	137.1	125.3
Hybrid	6%	86%	1.12	62.3	14.1
Average		**85.1%**	**1.16**	**99.9**	**55.4**

Sources

1. Pacific Gas & Electric. "Analysis of Standards Options for Battery Charger Systems." EUL: p. 43. Incremental cost: p. 45. Baseline wattages: p. 17. 2010.
   This report is cited in 2019 *Illinois Statewide Technical Reference Manual for Energy Efficiency.* Version 7.0, p. 581. September 28, 2018.
   http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_1-4_Compiled_092818_Final.pdf
2. California Energy Commission. *2016 Appliance Efficiency Regulations*. January 2017. Definition on p. 89. Mininum requirements on p. 230, Table W-1.
   http://www.energy.ca.gov/2017publications/CEC-400-2017-002/CEC-400-2017-002.pdf
3. California Energy Commission.
   https://cacertappliances.energy.ca.gov/Pages/ApplianceSearch.aspx
4. Pacific Gas and Electric Company (Matley, Ryan). *Industrial Battery Charger Energy Savings Opportunities.* Emerging Technologies Program Application Assessment Report #0808, p. 8. May 29, 2009. https://www.etcc-ca.com/reports/forklift-battery-charger
5. Minnesota Department of Commerce, Division of Energy Resources, Conservation Applied Research and Development. *Field Study of Industrial High Frequency Battery Chargers*. September 8, 2017.
   https://www.cards.commerce.state.mn.us/CARDS/security/search.do?documentId=%7b7849AB55-DFC6-4F87-AC80-BD0356BB32D9%7d

Revision History

Version Number	Date	Description of Change
01	10/01/2018	Initial TRM entry

Steam Trap Repair, < 10 psig, Industrial Process Heating

	Measure Details
Measure Name	Steam Trap Repair, < 10 psig, Industrial, 3999
Measure Unit	Per steam trap
Measure Type	Prescriptive
Measure Group	Process
Measure Category	Steam Trap
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	776
Lifecycle Electricity Savings (kWh)	0
Lifecycle Therm Savings (Therms)	4,657
Water Savings (gal/year)	0
Effective Useful Life (years)	6[1]
Incremental Cost ($/unit)	$166.23[2]

Measure Description

Steam distribution systems contain steam traps, which are automatic valves that remove condensate, air, and other non-condensable gases, while preventing or minimizing steam loss. This measure is the repair of failed open and leaking steam traps on industrial process heating steam systems.

Steam traps that fail in the open position allow steam to escape into the condensate lines before the available heat energy can be used for space heating, wasting the energy used to make the steam. By replacing or repairing traps that have failed in the open position, the wasted heating energy can be conserved.

The measure specifications are as follows:

- Boiler must be used for industrial process heating, not space heating
- Repaired traps must be leaking steam, not failed in the closed position or plugged
- The incentive is available once per year per system
- Municipal steam systems do not qualify
- When mass replacing steam traps, 20% of traps replaced will qualify
- System pressure must be < 10 psig

A steam trap survey and repair log must be completed. The information required to calculate savings includes a trap identification tag number, location description, nominal steam pressure, trap type, trap condition (functioning, failed open, or failed closed), and trap orifice diameter. The savings are based on a typical orifice diameter for low-pressure systems of 1/4-inch, based on project experience.

Description of Baseline Condition

The measure baseline is a steam trap that has failed in the open position and is leaking steam into the condensate line in a steam system. The steam from the boiler must be used for process heating and not for space heating applications. It is important to note that the trap must be failed in the open position and not failed in the closed position or plugged.

Description of Efficient Condition

The efficient condition is replacing or repairing traps that have failed in the open position, providing the ability to use steam heat that was previously wasted.

Annual Energy-Savings Algorithm

$\text{Therm}_{SAVED} = 1.9 * K * 60 * (\pi * D^2/4) * \sqrt{([P_{ABS} - \{P_1 - P_2\}] * [P_1 - P_2])} * h_{FG} * HOU * DF / (100{,}000 * eff)$

Where:

1.9 = Constant based on units and fluid flow equation[3]

K = Discharge coefficient (= 0.55)[4]

60 = Conversion from minutes to hours

D = Steam trap orifice diameter (= 1/4-inch)

P_{ABS} = System absolute pressure in pounds per square inch (= 20.7 psia; steam gage pressure at trap inlet (6 psig) + atmospheric pressure at sea level in pounds per square inch (14.7 psi))[5]

P_1 = Steam pressure at trap inlet (= 6 psig)[5]

P_2 = Steam pressure at trap outlet, condensate tank pressure (= 0 psig)

h_{FG} = Latent heat of steam at P_{ABS} (= 959)[6]

HOU = Annual hours of operation the boiler is on and the system is at design pressure (= 7,000)[7]

DF = Derating factor to account for the average percentage of time a trap fails in the open position and actual versus theoretical energy loss (= 32%)[5]

100,000 = Conversion factor from Btu to therms

eff = Boiler efficiency (= 80%)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure, as it does not generate electric savings.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 6 years)[1]

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. SPECTRUM. Pressure-based extrapolation of costs (2013-2014) for MMIDs 2542, 2548, and 2546 (new MMIDs 4001, 4002, 4003).
3. Hornaday, William T. "Steam: Its Generation and Use." Equation 50. Merchant Books, 2007. July 13, 2016. http://www.gutenberg.org/files/22657/22657-h/chapters/flow.html#page_321
   The equation applies to subsonic flow, which occurs when steam flows through an orifice where $P_2 \geq 58\%$ of P_1.
4. Manczyk Energy Consulting. "Estimating the Cost of Steam Loss Through the Orifice of a Steam Trap." http://invenoinc.com/file/Estimating-the-Steam-Loss-through-a-Orifice-of-a-Steam-Trap.pdf
   The discharge coefficient was determined by converging flow rates with the Napier equation at $P_2 = 0.58 * P_1$. The Napier equation is used to determine flow rate through an orifice when $P_2 \leq 0.58 * P_1$. The Napier equation is in fact Equation 49 in source 3, with an added discharge coefficient of 0.6. Matching Equation 50 in source 3 to the Napier formula in the link above, at $P_2 = 0.58 * P_1$, produces this equality: $1.9 * (\pi/4 * D^2) * K * \surd ([P_1 - 0.42 * P_1] * 0.42 * P_1) * 60 = 24.24 * P_1 * D^2$. Note that 60 is inserted to convert lb/min to lb/hr, and that P_1 and P_2 are treated as absolute pressures. Solving this produces K = 0.55.
5. Cadmus. "Focus on Energy Steam Trap Study." 2016.
   In the study, Cadmus determined realized savings from billing data for 35 sites that had applied for steam trap incentives during the 2012 to 2014 program years. This study revealed 6 psig as the weighted average pressure of < 10 psig steam traps surveyed.
   These sites had an overall realization rate of billing data results to calculated savings (using algorithms in this workpaper with site-specific values and the previous derating factor of 50%) of

64%, suggesting that a derating factor of 32% would be more appropriate. Note: the 50% derating factor came from: Enbridge Steam Saver Program. 2005.

6. The Engineering Toolbox. “Properties of Saturated Steam - Imperial Units.” http://www.engineeringtoolbox.com/saturated-steam-properties-d_273.html
7. 7,000 hours is an educated guess value that corresponds to a process running 9.7 months of the year.

Revision History

Version Number	Date	Description of Change
01	01/2017	Initial TRM entry

Steam Trap Repair, ≥ 10 psig, Industrial Process Heating

	Measure Details
Measure Name and ID	Steam Trap Repair, Industrial, 10-49 psig, 4000 50-124 psig, 4001 125-225 psig, 4002 >225 psig, 4003
Measure Unit	Per system psi (absolute)
Measure Type	Prescriptive
Measure Group	Process
Measure Category	Steam Trap
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure, see algorithm below
Life-cycle Electricity Savings (kWh)	0
Life-cycle Natural Gas Savings (therms)	Varies by measure, see algorithm below
Water Savings (gal/year)	0
Effective Useful Life (years)	6[1]
Incremental Cost ($/unit)	Varies by measure, see Incremental Cost table below

Measure Description

Steam distribution systems contain steam traps, which are automatic valves that remove condensate, air, and other non-condensable gases, while preventing or minimizing steam loss. This measure is the repair of failed open and leaking steam traps on industrial process heating steam systems.

Steam traps that fail in the open position allow steam to escape into the condensate lines before the available heat energy can be used for space heating, wasting the energy used to make the steam. By replacing or repairing traps that have failed in the open position, the wasted heating energy can be conserved.

The measure specifications are as follows:

- Boiler must be used for industrial process heating, not for space heating applications
- Repaired traps must be leaking steam, and not be failed in the closed position or plugged
- The incentive is available once per year per system
- Municipal steam systems do not qualify

- When mass replacing steam traps, 20% of traps replaced will qualify
- System pressure must be ≥ 10 psig

A steam trap survey and repair log must be completed. The information required to determine the amount of savings includes a trap identification tag number, location description, nominal steam pressure, trap type, trap condition (functioning, failed open, or failed closed), and trap orifice diameter. The absolute system steam pressure at trap inlet (psia = psig + 14.7) is to be recorded by the implementers and used as savings input.

Description of Baseline Condition

The measure baseline is a steam trap that has failed in the open position and is leaking steam into the condensate line in a high pressure (≥ 10 psig) process heating steam system. The steam from the boiler must be used for process heating and not space heating applications. The boiler is assumed to operate with 80% efficiency. It is important to note that the trap must be failed in the open position and not be failed in the closed position or plugged.

Description of Efficient Condition

The efficient condition is replacing or repairing traps that have failed in the open position, providing the ability to use steam heat that was previously wasted.

Annual Energy-Savings Algorithm

Steam leakage rate follows the Napier equation:[2]

$\text{Therm}_{\text{SAVED}} = 24.24 * P_{\text{ABS}} * D^2 * h_{\text{FG}} * \text{HOU} * \text{DF} / (100{,}000 * \text{eff})$

Where:

24.24 = Constant from Napier equation when units for absolute system pressure are in psia and units of the steam trap diameter are in inches

P_{ABS} = System absolute pressure in pounds per square inch (= steam gauge pressure at trap inlet (as measured by implementers) + atmospheric pressure at sea level in pounds per square inch of 14.7)

D = Steam trap orifice diameter in inches (= varies by measure, and assumed based on system pressure range; see table below)

h_{FG} = Latent heat of vaporization for water at P_{ABS} (= varies by measure; see table below)

DF = Derating factor to account for the average percentage open a trap fails and actual versus theoretical energy loss (= 32%)[3]

HOU = Annual hours of operation the boiler is on and the system is at design pressure (= 7,000)[4]

100,000 = Conversion factor from Btu to therms

eff = Boiler efficiency (= 80%)

The amount of therms saved varies based on the system pressure (the system absolute pressure at trap inlet is to be recorded by implementers).

Orifice diameters are assumed based on system pressure range.

The latent heat of vaporization values (h_{FG}) correspond to the assumed system absolute pressures (P_{ABS}) listed in the table below. Mid-range assumed pressures were used to determine the deemed latent heat of vaporization values for each measure's pressure range. The implementers are to input the absolute system pressure at trap inlet when calculating savings. A simplified algorithm for calculating annual savings uses annual savings multipliers and is as follows:

$$Therm_{SAVED} = \text{System Absolute Pressure} * \text{Annual Savings Multiplier}$$

$$= [\text{System Gauge Pressure} + 14.7] * \text{Annual Savings Multiplier}$$

Diameters, Pressures, Latent Heats, and Savings Multipliers

Measure Name	MMID	Assumed Orifice Diameter[3]	Assumed P_{ABS}s for h_{FG}[3]	Deemed h_{FG} Latent Heat of Steam (Btu/lb)[5]	Annual Savings Multiplier (therms/psia)
Steam Trap Repair, 10-49 psig, Industrial	4000	3/16”	40	933.4	22.3
Steam Trap Repair, 50-124 psig, Industrial	4001	1/8”	102.2	887.5	9.4
Steam Trap Repair, 125-225 psig, Industrial	4002	1/8”	190	846.9	9.0
Steam Trap Repair, >225 psig, Industrial	4003	1/8”	240	827.9	8.8

For example, for MMID 4000 (Steam Trap Repair, 10-49 psig, Industrial), a steam trap repaired on a 25 psig system has an annual savings multiplier of 22.3 and would result in an annual savings of 885.3 therms.

$$Therm_{SAVED} = 24.24 * (25 + 14.7) * 0.1875^2 * 933.4 * 7{,}000 * 32\% / (100{,}000 * 80\%)$$

Or

$$Therm_{SAVED} = (25 + 14.7) * 22.3 = 885.3$$

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure, as it does not generate electric savings.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 6 years)[1]

Incremental Cost

Incremental Costs

Measure Name	MMID	Incremental Cost	Source
Steam Trap Repair, 10-49 psig, Industrial	4000	$276.78	Average of 3 projects for MMID 2542, 2013 – 2014
Steam Trap Repair, 50-124 psig, Industrial	4001	$194.61	Average of 13 projects for MMID 2548, 2013 - 2014. One project with outlier cost excluded.
Steam Trap Repair, 125-225 psig, Industrial	4002	$600.18	Average of 3 projects for MMID 2546, 2013 - 2014
Steam Trap Repair, >225 psig, Industrial	4003	$895.65	Pressure-based extrapolation of costs (2013-14) for MMIDs 2542, 2548, and 2546.

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. "Steam Pressure Reduction: Opportunities and Issues." November 2005. https://energy.gov/eere/amo/downloads/steam-pressure-reduction-opportunities-and-issues
3. Cadmus. "Focus on Energy Steam Trap Study." 2016.
   The derating factor was calculated using study results. The study revealed realized savings from billing data for four sites that had applied for steam trap incentives during the 2012 through 2014 program years. These sites had an overall realization rate of billing data results to calculated savings (using algorithms in this workpaper with site-specific values and the previous derating factor of 50%) of 64%, suggesting that a derating factor of 32% is more appropriate. Note that the 50% derating factor came from: Enbridge Steam Saver Program. 2005.
   The study revealed that a 1/4-inch diameter is typical for steam traps of < 15 psi, and 1/8-inch

diameter is typical for steam traps larger than 15psi. The difference is split for the < 50 psi range (at 3/16-inch).

The median value pressure at inlet is +14.7; this study revealed industrial system pressures across this range.

4. 7,000 hours is an educated guess value that corresponds to a process running 9.7 months of the year.
5. The Engineering Toolbox. "Properties of Saturated Steam – Imperial Units." http://www.engineeringtoolbox.com/saturated-steam-properties-d_273.html
   Latent and total heat in evaporated water - steam - at different gauge pressures and boiling temperatures. User must take the 'Assumed Pabs for hfg' value from the table above and subtract 14.7 psi to correspond to the correct gauge pressure listed in this sources table when looking up corresponding hfg value.

Revision History

Version Number	Date	Description of Change
01	07/2016	Initial TRM entry
02	01/2017	Revised Assumptions and algorithm

Refrigeration

Anti-Sweat Heater Controls

	Measure Details
Measure Master ID	Anti-Sweat Heater Controls: Freezer Case, Low Heat Door, 2197 Freezer Case, No Heat Door, 2198 Freezer Case, Standard Door, 2199 Refrigerated Case, Low Heat or No Heat Door, 2200 Refrigerated Case, Standard Door, 2201
Measure Unit	Per door
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	$85.00[2]

Measure Description

Anti-sweat heater controls sense the humidity outside of refrigeration units and turn off anti-sweat heaters during period of low humidity. Without controls, anti-sweat heaters run continuously whether they are necessary or not. Qualifying controls turn off all heaters, including mullion heaters on cases with no door glass or frame heaters. By controlling all heaters, savings are still possible with no-heat doors. The primary energy savings result from the reduction in electric energy when the heaters are off. Secondary savings result from the reduced cooling load on the refrigeration unit when the heaters are off.

Description of Baseline Condition

The baseline condition is a refrigerated display case with doors, not using anti-sweat heater controls.

Description of Efficient Condition

The efficient condition is a refrigerated display case using anti-sweat heater controls.

Annual Energy-Savings Algorithm

kWh$_{SAVED}$ = Watts$_{BASE}$ * (1 + 1 / COP) / 1,000 * F$_S$ * HOU

Watts$_{BASE}$ = Wattage of door heaters (=132 for MMID 2197, = 54 for MMID 2198, = 191 watts for MMID 2199, = 60.5 for MMID 2200 (see Assumptions), = 109 for MMID 2201)[3]

COP = Coefficient of performance (= 1.4 for MMIDs 2197, 2198, and 2199; = 2.3 for MMIDs 2200 and 2201)[4]

1,000 = Kilowatt conversion factor

F$_S$ = Savings factor (= 46.5% for MMIDs 2197, 2198, and 2199; = 74.2% for MMIDs 2200 and 2201)[5]

HOU = Average annual run hours (= 8,760)

Summer Coincident Peak Savings Algorithm

kW$_{SAVED}$ = Watts$_{BASE}$ * (1 + 1 / COP) / 1,000 * F$_P$

F$_P$ = Coincidence factor (= 10%)[5]

Lifecycle Energy-Savings Algorithm

kWh$_{LIFECYCLE}$ = kWh$_{SAVED}$ * EUL

EUL = Effective useful life (=12 years)[1]

Savings

Deemed Savings for Anti-Sweat Heater Controls

Measure Name	MMID	Watts$_{BASE}$	F$_P$	F$_S$	COP	First Year kWh Savings	Summer Peak kW Savings	EUL	Lifecycle kWh Savings
Freezer Case, Low Heat Door	2197	132	10%	46.5%	1.4	922	0.023	12	11,061
Freezer Case, No Heat Door	2198	54	10%	46.5%	1.4	377	0.009	12	4,525
Freezer Case, Standard Door	2199	191	10%	46.5%	1.4	1,334	0.033	12	16,005
Refrigerated Case, Low Heat or No Heat Door	2200	60.25	10%	74.2%	2.3	562	0.009	12	6,743
Refrigerated Case, Standard Door	2201	109	10%	74.2%	2.3	1,017	0.016	12	12,198

Assumptions

Based on historical program data and discussions with customers, it is assumed that low-heat cooler doors ($\text{Watts}_{\text{BASE}} = 63^3$) make up 75% of the installations, and no-heat cooler doors ($\text{Watts}_{\text{BASE}} = 52^3$) make up 25% of the installations, for the combined measure for anti-sweat heater controls for low-heat and no-heat cooler doors.

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. San Diego Gas & Electric. “Anti-Sweat Heat Controls.” Work Paper WPSDGENRRN0009. Revision 0.
   Cost per linear foot = $34.00, calculated per door assuming 2.5-foot door average.
3. Zero Zone RVZC and RVCC and Hussmann RL and RM specification sheets for reach-in cooler and freezer cases with doors, specification sheets published 2006/2007.
4. U.S. Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Office. “Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration.” DOE Publication ID 6180. Table 3-7. September 2009. http://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf
5. Energize Connecticut. “Connecticut Program Savings Document.” 8th Edition for 2013 Program Year. p. 90 and Appendix 1, p. 253. October 30, 2012. http://www.energizect.com/sites/default/files/2013%20PSD_ProgramSavingsDocumentation-Final110112.pdf
   Report shows 6,500 hours off for coolers, 4,070 hours off for freezers; when divided by 8,760, this produces 74.2% and 46.5%, respectively, with a coincidence factor of 10% for all refrigeration controls.

Revision History

Version Number	Date	Description of Change
01	03/11/2016	Update from Focus on Energy Deemed Savings Manual

Demand Defrost Controls

	Measure Details
Measure Master ID	Demand Defrost Controls, 4758
Measure Unit	Per kilowatt of electric defrost controlled
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	176 (per kilowatt of electric defrost controlled)
Peak Demand Reduction (kW)	0.020 (per kilowatt of electric defrost controlled)
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	1,760 (per kilowatt of electric defrost controlled)
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$619.00 per controller[2]

Measure Description

Evaporator coils in walk-in freezer systems must be intermittently defrosted to prevent the buildup of ice on the coil, which will not allow for proper heat exchange. Coil defrosting is an energy inefficient but necessary process that should only occur when necessary. Defrosting requires an input of heat into a refrigerated space, which increases the energy demand on the system to maintain the desired low temperature, thus lowering the efficiency of the system. Walk-in freezer systems that do not use demand defrost controls engage the defrost process more often and, at times, when not needed.

Demand defrost controls are composed of an array of sensors within the walk-in unit—such as temperature, air pressure, and humidity sensors—along with software to statistically model the process requirements of the system and call for a defrost cycle to engage when needed. Energy is saved in two ways: (1) less energy is required due to fewer defrost cycles, and (2) there is less heat being introduced into the system, thereby decreasing the load required to cool the space after a defrost cycle.

Description of Baseline Condition

The baseline condition is a walk-in freezer system without electronic demand defrost controls to engage the defrost cycle via a timer, which is assumed to cycle on every four hours for 20 minutes per cycle.

Description of Efficient Condition

The efficient condition is a walk-in freezer system with electronic demand defrost controls that engage the defrost cycle only when its array of sensors and statistical modeling deem it necessary.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kW_{DEFROST} * HOU_{BASE} * F_s * [1 + 3.412 / (12 * COP)]$

Where:

$kW_{DEFROST}$ = Wattage of electric defrost (= 1 kW)

HOU_{BASE} = Hours of use for baseline equipment (= 487; see Assumptions)[4]

F_s = Savings factor (= 30%)[3]

3.412/12 = Kilowatt to ton conversion factor (3.412 kW/MBh; 12 MBh/ton)

COP = Coefficient of performance (= 1.4)[5]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (kWh_{SAVED} / HOU)$

Where:

HOU = Hours of freezer use (= 8,760 hours per year)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Assumptions

The unit of measure is per 1 kW of electric defrost system that is to be controlled. This unit of measure was chosen over other units of measure to allow for various sized walk-in freezer systems. The electric defrost load is directly proportional to the size of the walk-in freezer; therefore, the size of the freezer system is accurately incorporated into the savings algorithm.

Baseline hours are assumed to reflect four defrost cycles per day, at 20 minutes per cycle. This is consistent with the typical strategy for preset time cycle control, outlined in a study.[4]

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Grainger, Inc. *Average Cost of Defrost Timer Controls (= $146; average of 23 relevant products).* Baseline cost. Accessed September 2018. https://www.grainger.com/category/defrost-timer-control/

3. Heatcraft Refrigeration Products, LLC. *Cost of Smart Defrost Controls (= $765).* Efficient cost. Accessed September 2018. *https://www.heatcraftrpd.com/PDF/Archived/SDK_CutSheetGen1* Incremental cost= $765-$146=$619.
4. National Renewable Energy Laboratory. *Advanced Energy Retrofit Guide—Grocery Stores.* Appendix F.2.9: Detailed Retrofit Measure Description. p. 168. June 2013. https://www.osti.gov/biblio/1045045
5. Fricke, Brian A., and Sharma, Vishal. Oak Ridge National Laboratory. "Demand Defrost Strategies in Supermarket Refrigeration Systems." October 2011. https://info.ornl.gov/sites/publications/files/pub31296.pdf
6. Navigant Consulting, Inc. "Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration." Table 3-7. U.S. DOE Publication ID 6180. September 2009. https://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf

Revision History

Version Number	Date	Description of Change
01	09/21/2018	Initial TRM entry

Evaporator Fan Control

	Measure Details
Measure Master ID	Cooler Evaporator Fan Control, 2269 Evaporator Fan Control for Reach-in Cooler/Freezer, 4759
Measure Unit	Per motor
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	16[1]
Incremental Cost ($/unit)	$155.00[3]

Measure Description

Walk-in cooler and freezer refrigeration systems typically operate 24 hours per day, 365 days per year. These systems must run when the compressor is running to provide cooling, and they must run when the compressor is not running to provide air circulation, thus preventing the coil from freezing. The only time these fans do not operate is during the defrost cycle.

Significant energy savings can be realized by installing a more efficient evaporator fan motor and control fan system, which regulates the speed of the evaporator fan motor to meet the need during each phase of the refrigeration cycle. These systems save energy in two ways: (1) the evaporator fans consume less energy, and (2) the system results in less heat being introduced to the refrigerated chamber from the evaporator fan motors, which decreases the overall box load, thereby reducing the compressor/condenser on-duty cycle.

Description of Baseline Condition

The baseline condition is a refrigeration system with a shaded pole (SP), permanent split capacitor (PSC), or electronically commutated (ECM) evaporator fan motor in walk-in or reach-in coolers and/or freezers without an evaporator fan controller.

Description of Efficient Condition

The efficient condition is a refrigeration system with a SP, PSC, or ECM evaporator fan motor in walk-in or reach-in coolers and/or freezers with an evaporator fan controller to switch the fan to lower speeds when the temperature of the unit of refrigerant is determined to need lower air movement.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = \sum[Watts_{FULL} – (Watts_{FULL} * (1 – LS) + Watts_{LOW} * LS)] * (1 + 1 / COP) * HOU / 1{,}000$

Where:

$Watts_{FULL}$ = Wattage of the fan motor at normal speed of 1,550 RPM (= varies by motor type; see table below)

LS = Fraction of time fan motor is on low speed setting (= 37%, average of 32% for freezers and 42% for coolers)[3]

$Watts_{LOW}$ = Wattage of the fan motor at low speed of 550 RPM (= varies by motor type; see table below)

COP = Coefficient of performance (= 1.85, average of 1.4 for freezers and 2.3 for coolers)[2]

HOU = Average annual run hours (= 8,517, see Assumptions)[7]

1,000 = Kilowatt conversion factor

Energy Savings for MMID 2269

Motor Nameplate HP[4]	Input Wattage		COP[2]	LS[3]	Savings		Weighted Percentage
	At 1,550 RPM (normal speed)*	At 550 RPM (low speed)*			Annual (kWh)	Coincident Peak (kW)	
SP							
1/47	70.54	8.15	1.85	37%	38.4	0.0045	12.7%
1/25	132.62	15.32	1.85	37%	17.2	0.0020	3.0%
1/20	165.78	19.15	1.85	37%	74.5	0.0088	10.5%
1/15	221.04	25.54	1.85	37%	468.2	0.0550	49.3%
1/8	414.44	47.88	1.85	37%	21.0	0.0025	1.2%
1/3	1,105.19	127.69	1.85	37%	31.5	0.0037	0.7%
PSC							
1/47	26.45	3.06	1.85	37%	1.4	0.0002	1.3%
1/25	49.73	5.75	1.85	37%	0.6	0.0001	0.3%
1/20	62.17	7.18	1.85	37%	2.8	0.0003	1.0%
1/15	82.89	9.58	1.85	37%	17.4	0.0020	4.9%
1/8	155.42	17.96	1.85	37%	0.8	0.0001	0.1%

Motor Nameplate HP[4]	Input Wattage		COP[2]	LS[3]	Savings		Weighted Percentage
	At 1,550 RPM (normal speed)*	At 550 RPM (low speed)*			Annual (kWh)	Coincident Peak (kW)	
1/3	414.44	47.88	1.85	37%	1.2	0.0001	0.1%
ECM							
1/47	22.67	2.62	1.85	37%	2.4	0.0003	2.5%
1/25	42.63	4.93	1.85	37%	1.1	0.0001	0.6%
1/20	53.29	6.16	1.85	37%	4.6	0.0005	2.0%
1/15	71.05	8.21	1.85	37%	29.2	0.0034	9.6%
1/8	133.21	15.39	1.85	37%	1.3	0.0002	0.2%
1/3	355.24	41.04	1.85	37%	2.0	0.0002	0.1%
Total					**715.5**	**0.084**	**100%**

* Motor input wattages are based on the motor nameplate wattage and efficiencies listed in tables below.

Energy Savings for MMID 4759

Motor Nameplate HP[6]	Input Wattage		COP[2]	LS[3]	Savings		Weighted Percentage
	At 1,550 RPM (normal speed)*	At 550 RPM (low speed)*			Annual (kWh)	Coincident Peak (kW)	
SP							
1/83	39.13	4.52	1.85	37%	11.7	0.0014	6.96%
1/38	84.78	9.80	1.85	37%	138.0	0.0162	37.90%
1/20	162.17	18.74	1.85	37%	226.2	0.0266	32.49%
PSC							
1/83	15.00	1.73	1.85	37%	0.4	0.0001	0.69%
1/38	32.50	3.75	1.85	37%	5.2	0.0006	3.75%
1/20	62.17	7.18	1.85	37%	8.6	0.0010	3.21%
ECM							
1/83	12.86	1.49	1.85	37%	0.7	0.0001	1.35%
1/38	27.86	3.22	1.85	37%	8.8	0.0010	7.35%
1/20	53.29	6.16	1.85	37%	14.4	0.0017	6.30%
Total					**414.1**	**0.049**	**100%**

* Motor input wattages are based on the motor nameplate wattage and efficiencies listed in tables below.

Summer Coincident Peak Savings Algorithm

$$kW_{SAVED} = \sum[Watts_{FULL} * (1 - LS) + Watts_{LOW} * (LS)] / 1{,}000 * (1 + 1 / COP)$$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 16 years)[1]

Assumptions

Based on engineering judgement, 15% of motors are assumed to be ECMs, which are poor candidates for the addition of motor controls. The remaining 85% of motors are PSC and SP, and these are assumed to follow the population split seen in historical applications using the existing ECM retrofit measures. This split is 91% SP and 9% PSC. Applying this to the 85% assumed share for SP and PSC motors for this measure produces 77% SP motors and 8% PSC motors. The low speed, 550 RPM, is associated with a 10% load. Using the same methodology for the part load efficiencies with a VFD,[5] the motor efficiencies are 16% for SP, 43% for PSC, and 50% for ECMs.

The motor sizes and their associated weighting for evaporator fans were determined from a review of historical applications using the existing ECM retrofit measures. The historical applications were randomly selected by program to ensure a sampling and review of all motor options. In programs where there were multiple facility (or customer) types available, applications were selected to capture information from the various facility (or customer) types. The applications used to obtain the motor sizes and wattages all contained complete motor information (make and model) for the correct application measure. Multiple location applications were not used in the random selection to ensure that one facility (or customer) type was not favored over the others in the motor sizes and wattages. At least 10% of the total number of applications per program were surveyed, along with the total number of motors surveyed accounting for at least 10% of the motors in each measure category. The quantity and size of each motor, and type of motor replaced, was recorded and used to determine the baseline and proposed wattages, as well as the weighting of each motor size. The table below summarizes the historical application findings and values for efficiencies.

Efficiency Values for MMID 2269

Motor Type	Motor Nameplate HP	Motor Nameplate kW (Motor Nameplate HP * 0.746)	Motor Efficiency		Motor Size Weighting[4]	Motor Type Weighting	
			Full Speed[5]	Low Speed		Historical[4]	Measure
SP	1/47	0.0159	23%	16%	16%	91%	77%
	1/25	0.0298	23%	16%	4%	91%	77%
	1/20	0.0373	23%	16%	14%	91%	77%
	1/15	0.0497	23%	16%	64%	91%	77%

Motor Type	Motor Nameplate HP	Motor Nameplate kW (Motor Nameplate HP * 0.746)	Motor Efficiency		Motor Size Weighting[4]	Motor Type Weighting	
			Full Speed[5]	Low Speed		Historical[4]	Measure
	1/8	0.0933	23%	16%	2%	91%	77%
	1/3	0.2487	23%	16%	1%	91%	77%
PSC	1/47	0.0159	60%	43%	16%	9%	8%
	1/25	0.0298	60%	43%	4%	9%	8%
	1/20	0.0373	60%	43%	14%	9%	8%
	1/15	0.0497	60%	43%	64%	9%	8%
	1/8	0.0933	60%	43%	2%	9%	8%
	1/3	0.2487	60%	43%	1%	9%	8%
ECM	1/47	0.0159	70%	50%	16%	N/A	15%
	1/25	0.0298	70%	50%	4%	N/A	15%
	1/20	0.0373	70%	50%	14%	N/A	15%
	1/15	0.0497	70%	50%	64%	N/A	15%
	1/8	0.0933	70%	50%	2%	N/A	15%
	1/3	0.2487	70%	50%	1%	N/A	15%

Efficiency Values for MMID 4759

Motor Type	Motor Nameplate HP	Motor Nameplate kW (Motor Nameplate HP * 0.746)	Motor Efficiency		Motor Size Weighting[6]	Motor Type Weighting	
			Full Speed[5]	Low Speed		Historical[4]	Measure
SP	1/83	0.0090	23%	16%	9%	91%	77%
	1/38	0.0195	23%	16%	49%	91%	77%
	1/20	0.0373	23%	16%	42%	91%	77%
PSC	1/83	0.0090	60%	43%	9%	9%	8%
	1/38	0.0195	60%	43%	49%	9%	8%
	1/20	0.0373	60%	43%	42%	9%	8%
ECM	1/83	0.0090	70%	50%	9%	N/A	15%
	1/38	0.0195	70%	50%	49%	N/A	15%
	1/20	0.0373	70%	50%	42%	N/A	15%

Controls are assumed to be installed in equal proportions for freezers and coolers due to equal proportions of freezers and coolers with motors throughout refrigerated spaces in retail applications. Evaporator fan motors run constantly to ensure proper airflow and circulation throughout the walk-in to maintain even product temperatures and avoid hot spots in the space. However, during times of defrost, evaporator fans do not run, as heat is being introduced to the system to remove the ice and frost build-up on the evaporator coils. Freezer hours of operation assume four defrost cycles per day at 20 minutes per defrost, producing 8,273 hours. This is consistent with the typical strategy for preset time cycle control, outlined in an Oak Ridge National Laboratory study.[7] As cooler operating temperatures are above freezing, defrost cycles are not required. Overall hours of operation are the average of cooler and freezer case hours of operation: (8,273 + 8,760) / 2 = 8,517.

MMID 4759 motor wattages were categorized into three motor sizes: < 12 watts, 16–23 watts, and > 37 watts,[6] each with an averaged wattage based on the motor sizes of 9 watts, 19.5 watts, and 37 watts, respectively. They also had population splits of 9%, 49%, and 42%, respectively.[4] These output wattages were used to obtain the motor input wattages, based on motor efficiencies.[3] The input wattages were averaged, based on the motor size ratio, to obtain the overall motor input wattages for the savings algorithms.

The low temperature and medium temperature system COPs were derived from the information on Table 3-7 of the U.S. DOE Publication ID 6180.[2] The capacity and power values were calculated to yield the EER and then converted to COP, based on COP = EER / 3.412.

Sources

1. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficiency Resources.” Evaporator Fan Controller for Walk-In Coolers. 2008. http://www.deeresources.com/index.php/deer-versions/deer2008-for-09-11-planning-reporting
2. Navigant Consulting, Inc. “Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration.” U.S. Department of Energy Publication ID 6180. Table 3-7. 2009. https://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf
3. Regional Technical Forum. “Evaporator Fan Controls and Evaporator Fan Uniform Energy Savings Measures Calculations.” 2010. https://nwcouncil.app.box.com/s/pt7getqkjxzmlvm5f87wn3eydvidvjb5
   Cost adjusted from $141 in 2010 dollars to $155 in 2017 dollars based on http://www.usinflationcalculator.com/
4. Focus on Energy historical application data for MMIDs 2308–2311, June 2012 through July 2015.
5. Navigant Consulting Group, Inc. “Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment.” Prepared for U.S. Department of Energy, Building Technologies Office. 2013. https://energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf
   Motor efficiencies are: 23% (average of 15% to 30% for evaporator fans or compressors) for SP

(page 6); 60% (average of 50% to 70%) for PSC (page 5); and 70% for fractional horsepower ECMs (page 16). Part load efficiencies are in Figure 2.6 (page 12).

6. Pacific Gas & Electric Company. "Display Case ECM Motor Retrofit." Workpaper PGE3PREF124. Table 10. 2014.
7. Fricke, Brian A., and Sharma, Vishal. Oak Ridge National Laboratory. "Demand Defrost Strategies in Supermarket Refrigeration Systems." October 2011. https://info.ornl.gov/sites/publications/files/pub31296.pdf

Revision History

Version Number	Date	Description of Change
01	03/2016	Initial TRM entry
02	09/2018	Added measure 4759

Refrigeration Controls, Floating Head Pressure

	Measure Details
Measure Master ID	Refrigeration Controls, Floating Head Pressure, 4360
Measure Unit	Per horsepower
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Controls
Sector(s)	Commercial, Industrial, Schools & Government, Agriculture
Annual Energy Savings (kWh)	639
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	6,390
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$272.25[2]

Measure Description

Reducing the compressor discharge pressure reduces the pressure ratio across the compressor and improves the operating efficiency. Many systems have controls that maintain a minimum condensing pressure to ensure proper operation of all components. By letting the condensing pressure drop down at lower ambient temperatures with head pressure controls, energy savings can be achieved. The typical design target for refrigeration systems for head pressure is the equivalent of approximately 95°F saturated condensing temperature.

Description of Baseline Condition

The baseline condition is a refrigerated system with a set condensing temperature/pressure that is typically around 95°F saturated condensing temperature and 82°F ambient temperature.

Description of Efficient Condition

The efficient condition is a refrigerated system with a condensing temperature allowed to float down at a minimum of 20°F with ambient temperature of at least 75°F.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = \sum [(-0.00239 * DB_{AVE} + 0.1791) * Hours_{BIN\ TEMP}]$

Where:

-0.00239 = Interpolation constant, units of kW / (hp * °F)[3]

DB_{AVE} = Average bin dry bulb temperature in °F, from TRM Appendix B: Common Variables

0.1791 = Interpolation constant, units of kW / hp[3]

$Hours_{BIN\ TEMP}$= Annual hours of Wisconsin Outside Air Temperature, from TRM Appendix B: Common Variables

Summer Coincident Peak Savings Algorithm

No summer coincident peak savings occurs below 75°F, which is assumed to be during non–summer coincident peak hours.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=10 years)[1]

Assumptions

Savings were calculated by adapting savings values from the Vermont Technical Reference Manual[3] to Wisconsin weather. First, per the table below, a distribution of compressor types was assumed so that weighted-average savings for Vermont could be calculated. The various compressor types were assumed to occur at equal weightings (33% each) based on various refrigeration compressor product lines available on the market. It is assumed that these compressor systems will be used for freezers (very low and low temperature) 50% of the time, and for coolers (medium temperature) 50% of the time, due to equal proportions of freezer and cooler refrigerated spaces in retail applications.

The very low temperature (typical for ice cream freezer applications) is assumed to occur 25% of the time for freezer applications and the low temperature (typical for frozen food applications) is assumed to occur 75% of the time for freezer applications. This weighting is due to product storage and facility designs: there is significantly more storage and display area for frozen food than for just ice cream. These weightings combined produce the average savings value of 633 kWh/hp. This represents the average savings for floating head pressure controls in the state of Vermont, using the assumed compressor type population weightings.

Floating Head Savings Values in the State of Vermont, With Assumed Compressor Type Weightings

Compressor Type	kWh/hp Savings based on Evaporator Temperature Range[3]			Compressor Type Weighting	Weighted Average kWh/hp Savings
	Very Low (-35 to -5 SST*)	Low (0 to 30 SST*)	Medium (35 to 55 SST*)		
Standard Reciprocating	695	727	657	33%	633
Discus	607	598	694	33%	
Scroll	669	599	509	33%	
Evaporator Temperature Weighting	12.5%	37.5%	50%	---	

* Saturated suction temperature

This average savings value was adjusted for the state of Wisconsin by interpolating savings as a function of temperature, and applying this to Wisconsin temperature bins. The linear interpolation was based on two points, as shown in the table below.

Temperatures and Savings Used in Linear Interpolation

Temperature	kW/hp	Notes
75°F	0	Floating head pressure controls are assumed to provide no savings above 75°F
43.09°F	0.076257	From Vermont TMY3 temperature bins,[4] 43.09°F is the average temperature in Vermont below 75°F
		0.076257 = 633 / 8,296
		633 is the assumed average savings, in kWh/hp, for floating head pressure controls in Vermont
		From the Vermont TRM TMY3 temperature bins,[4] Vermont has 8,296 hours per year under 75°F

The linear fit produced by interpolating these two points has a slope of -0.00239 and an intercept of 0.1791. This interpolation was then used to determine the energy savings for each weather bin of Wisconsin weather data based on the Outside Air Temperature Bin Analysis located in Appendix B: Common Variables. These savings were summarized, producing savings for Wisconsin of 639 kWh/hp.

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study. Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Regional Technical Forum. “Commercial: Grocery - Floating Head Pressure Controls for Single Compressor Systems.” UES Measure Workbook 1.6. Floating Head Pressure Controls for Single

Compressor Systems measures. December 5, 2016. https://rtf.nwcouncil.org/measure/floating-head-pressure-controls-single-compressor-systems
Average of all operating temperature and refrigeration system design, assuming multiple compressor systems would have the same cost as single compressor systems ($272.25).

3. Efficiency Vermont. "Technical Reference User Manual (TRM): Measure Savings Algorithms and Cost Assumptions." P. 214. February 19, 2010.
4. National Renewable Energy Laboratory. TMY3 weather data. Bin temperature data from Montpelier, Vermont. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html

Revision History

Version Number	Date	Description of Change
01	03/11/2016	Initial TRM entry

ENERGY STAR Commercial Ice Machines

	Measure Details
Measure Master ID	ENERGY STAR Commercial Ice Machine: Ice Making Head, 3906, 4622 Remote Condensing Unit, 3907, 4623 Self-Contained Unit, 3908, 4624
Measure Unit	Per ice machine
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Ice Machine
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	Varies by measure
Effective Useful Life (years)	10[2]
Measure Incremental Cost ($/unit)	$222.00[3]

Measure Description

Commercial ice machines are used in restaurants, hospitals, hotels, schools, offices, and grocery stores. ENERGY STAR-certified Automatic Commercial Ice Makers create energy savings ranging from 8% to 20% depending on size and type.[1]

Description of Baseline Condition

The baseline condition is a commercial ice maker that meets the DOE amended energy conservation standards required as of January 28, 2018.[5]

Description of Efficient Condition

The efficient condition is a new unit that meets the ENERGY STAR V3.0 performance specification that takes effect January 28, 2018.[1] Eligible products must be a commercial ice maker that is air-cooled batch or continuous type, and of ice making head, remote condensing unit, or self-contained design. Water-cooled ice makers, ice and water dispensing systems, and air-cooled remote condensing units that are designed only for connection to remote rack compressors are not eligible for ENERGY STAR qualification.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{BASE} – kWh_{ENERGY\ STAR}$

Where:

kWh_{BASE} = Average annual energy consumption for specific equipment types using the DOE federal standards that took effect January 28, 2018

$kWh_{ENERGY\ STAR}$ = Average annual energy consumption for specific equipment types using the ENERGY STAR Version 3.0 Energy Consumption Rate algorithms with average ice harvest rates by qualifying product data set as of August 14, 2017 (= varies by equipment type; see table below)

The ENERGY STAR V3.0 Energy Consumption Rate is the total energy consumed, stated in kilowatt-hours per one-hundred pounds (kWh/100 lb) of ice, stated in multiples of 0.1. For remote condensing (but not remote compressor) automatic commercial ice makers and remote condensing and remote compressor automatic commercial ice makers, the total energy consumed shall include the energy use of the ice-making mechanism, the compressor, and the remote condenser or condensing unit. The harvest rate (H) is the amount of ice (at 32°F) in pounds produced per 24 hours.

ENERGY STAR Version 3.0 Requirements for Air-Cooled Ice Makers[1]

Equipment Type		Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)	Avg Harvest Rate* (lbs/24 hours, H)	# of Models on ENERGY STAR List	ENERGY STAR Requirement Energy Consumption Rate (kWh/100 lbs ice)
Batch-Type	Ice Making Head	H < 300	243	17	≤ 9.20 - 0.01134 * H
		300 ≤ H < 800	460	73	≤ 6.49 - 0.0023 * H
		800 ≤ H < 1,500	1,081	14	≤ 5.11 - 0.00058 * H
		1,500 ≤ H ≤ 4,000	1,550	3	≤ 4.24
	Remote Condensing Unit	H < 988	758	42	≤ 7.17 - 0.00308 * H
		988 ≤ H ≤ 4,000	1,409	37	≤ 4.13
	Self-Contained Unit	H < 110	65	42	≤ 12.57 - 0.0399 * H
		110 ≤ H < 200	149	28	≤ 10.56 - 0.0215 * H
		200 ≤ H ≤ 4,000	250	18	≤ 6.25
Continuous-Type	Ice Making Head	H < 310	0	0	≤ 7.90 – 0.005409 * H
		310 ≤ H < 820	586	21	≤ 7.08 – 0.002752 * H
		820 ≤ H ≤ 4,000	1,077	14	≤ 4.82
	Remote Condensing Unit	H < 800	669	7	≤ 7.76 – 0.00464 * H
		800 ≤ H ≤ 4,000	1,295	28	≤ 4.05
	Self-Contained Unit	H < 200	92	8	≤ 12.37 – 0.0261 * H
		200 ≤ H < 700	300	15	≤ 8.24 – 0.005429 * H
		700 ≤ H ≤ 4,000	0	0	≤ 4.44

Maximum Consumption and On-Peak Demand Values for ENERGY STAR Version 3.0 Qualifying Ice Makers

Equipment Type	Maximum Annual Consumption (kWh)	On-Peak Demand (kW)
Ice Making Head	11,222.3925	1.2811
Remote Condensing Unit	17,222.2577	1.9660
Self-Contained Unit	4,050.2318	0.4624

DOE Federal Standards – Effective January 28, 2018 (Air-Cooled Models)[5]

Equipment Type		Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)	Avg Harvest Rate, H (lbs/24 hrs)	# of Models on ENERGY STAR List	DOE Requirement Energy Consumption Rate (kWh/100 lbs ice)
Batch-Type	Ice Making Head	H < 300	243	17	≤ 10 - 0.01233 * H
		300 ≤ H < 800	460	73	≤ 7.05 - 0.0025 * H
		800 ≤ H < 1,500	1,081	14	≤ 5.55 - 0.00063 * H
		1,500 ≤ H ≤ 4,000	1,550	3	≤ 4.61
	Remote Condensing Unit (not remote comp)	H < 988	758	42	≤ 7.97 - 0.00342 * H
		988 ≤ H ≤ 4,000	1,409	37	≤ 4.59
	Remote Condensing Unit (remote comp)	H < 930	752	41	≤ 7.97 - 0.00342 * H
		930 ≤ H < 4,000	1,398	38	≤ 4.79
	Self-Contained Unit	H < 110	65	42	≤ 14.79 - 0.0469 * H
		110 ≤ H < 200	149	28	≤ 12.42 - 0.02533 * H
		200 ≤ H ≤ 4,000	250	18	≤ 7.35
Continuous-Type	Ice Making Head	H < 310	0	0	≤ 9.19 - 0.00629 * H
		310 ≤ H < 820	586	21	≤ 8.23 - 0.0032 * H
		820 ≤ H < 4,000	1,077	14	≤ 5.61
	Remote Condensing Unit (not remote comp)	H < 800	669	7	≤ 9.7 - 0.0058 * H
		800 ≤ H < 4,000	1,295	28	≤ 5.06
	Remote Condensing Unit (remote comp)	H < 800	669	7	≤ 9.9 - 0.0058 * H
		800 ≤ H < 4,000	1,295	28	≤ 5.26
	Self-Contained Unit	H < 200	92	8	≤ 14.22 - 0.03 * H
		200 ≤ H < 700	300	15	≤ 9.47 - 0.00624 * H
		700 ≤ H < 4,000	0	0	≤ 5.1

Maximum Consumption and On-Peak Demand Values for DOE Federal Minimum Standards Qualifying Ice Makers

Equipment Type	Maximum Annual Consumption (kWh)	On-Peak Demand (kW)
Ice Making Head	12,467.0957	1.4232
Remote Condensing Unit	20,187.9087	2.3046
Self-Contained Unit	4,730.6305	0.5400

Based on the harvest rate for various ENERGY STAR-qualifying models pulled from the Qualified Products List[1] on August 14, 2017, each qualifying ice machine must meet an energy use limit based on the kilowatt-hours per 100 lbs of ice. The savings are based on the annual energy savings (kWh) when calculating the minimum energy consumption rate for both the ENERGY STAR Version 3.0 specification[4] and the DOE federal minimum standards that went into effect January 28, 2018.

Since the equipment categories for ENERGY STAR and DOE equipment standards do not align perfectly, kWh_{BASE} is the average ice harvest rate from eligible ENERGY STAR-qualifying models, when applying the average rates to the DOE Requirement Energy Consumption Rate formulas within each equipment type (ice making head, remote condensing unit, self-contained unit). $KWh_{ENERGY\ STAR}$ is the average of outputs from the ENERGY STAR Requirement Energy Consumption rate formulas for both the Batch-Type and Continuous Type within each equipment type (ice making head, remote condensing unit, self-contained unit), weighted by the number of ENERGY STAR-certified models within each equipment type.

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (kWh_{BASE} – kWh_{ENERGY\ STAR}) / HOU$

Where:

HOU = Hours of use (=8,760 hours)[3]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[2]

Deemed Savings

Annual and Lifecycle Deemed Savings

Equipment Type	MMID	kW	Annual (kWh)	Lifecycle (kWh)	Annual (Gallons)
Ice Making Head	3906	0.1421	1,245	12,450	4,693
Remote Condensing Unit	3907	0.3385	2,966	29,660	4,581
Self-Contained Unit	3908	0.0777	680	6,800	3,911

Assumptions

For remote condensing units, the ENERGY STAR Version 3.0 performance specification does not differentiate between the two compressor arrangements (with remote compressor/not remote) listed in the DOE federal standards. Therefore, the baseline energy consumption value for remote condensing units is a blended calculation of the harvest rates (and the prevalence of the harvest rates) from the ENERGY STAR data set that factored in both DOE requirements for units with remote compressors and units where the compressor was built into the condensing unit.

Annual water savings will also be affected by the DOE and ENERGY STAR regulations that took place January 28, 2018. Water savings were calculated using the same weighted average process that was used for determining savings (averaging batch and continuous machines together). The values used are taken directly from the ENERGY STAR Certified Commercial Kitchen Equipment Calculator. For batch-type machines, the following values are reported: 6,228 for ice making head, 6,611 for remote condensing unit, and 4,933 for self-contained unit. It is reported that ENERGY STAR-certified continuous-type machines do not save any water in comparison to a standard model.[3]

For incremental measure cost, the ENERGY STAR commercial kitchen savings calculator[3] lists an incremental cost of $0 for batch ice machines and $222 for continuous ice machines. The same weighted average process used for determining savings (averaging batch and continuous machines together) was used to determine the incremental cost for the three different measures.

Sources

1. ENERGY STAR. “Commercial Ice Makers.” Website. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ice_makers
2. Commercial Foodservice Equipment Lifecycle Cost Calculator - Ice Machine. https://fishnick.com/saveenergy/tools/calculators/icemachinecalc.php

3. ENERGY STAR. “Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.” Calculator. 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx
4. “ENERGY STAR Version 3.0 Requirements for Air-Cooled Ice Makers.” https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ice_makers/partners
5. Regulations.gov. “10 CFR Part 431, Docket Number EERE-2010-BT-STD-0037.” https://www.regulations.gov/document?D=EERE-2010-BT-STD-0037-0137

Revision History

Version Number	Date	Description of Change
01	08/05/2016	New measure replacing CEE Tier 2 Ice Machines, removed MMIDs 3414–3424
02	08/16/2017	Updated savings to reflect ENERGY STAR Version 3.0
03	12/2018	Updated incremental cost

ECM Compressor and Condenser/Condensing Unit Fan Motor

	Measure Details
Measure Master ID	ECM Compressor Fan Motor, 2306 ECM Condenser/Condensing Unit Fan Motor, 2307
Measure Unit	Per motor
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Motor
Sector(s)	Commercial, Industrial, Schools & Government, Agriculture
Annual Energy Savings (kWh)	519
Peak Demand Reduction (kW)	0.083
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	8,298
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	16[1]
Incremental Cost ($/unit)	$306.00[2]

Measure Description

Compressor, condenser, and condensing packaged unit fans run when refrigerant is being piped through the system to absorb heat from a space. The fans blow air across the compressor and condenser to cool the equipment and refrigerant. The long-time standard in refrigeration equipment is shaded pole (SP) fan motors, which are highly inefficient and generate excessive heat. Higher-efficiency electronically commutated motors (ECMs) use 75% less energy to run and generate less heat. ECMs or brushless AC fan motors are used in conjunction with air-cooled condensers and/or compressors.

Incentives are available for ECMs replacing SP motors or permanent split capacitor (PSC) motors on existing condenser/packaged condensing unit and compressor fans. This measure does not apply to evaporator fan motors.

Description of Baseline Condition

The baseline condition is a SP or PSC compressor or condenser unit fan motor.

Description of Efficient Condition

The efficient condition is an ECM replacing the SP or PSC motor on a compressor or condenser unit fan.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Input of SP or PSC motor (= 221.0 watts, weighted average; see table below)[3]

$Watts_{EE}$ = Input of ECM (= 137.7 watts, weighted average; see table below)[3]

1,000 = Kilowatt conversion factor

HOU = Average annual run hours (= 6,220)[4]

Motor Input Wattages

	SP 1/20 HP (37.3)*	SP 1/15 HP (49.7)*	PSC 1/10 HP (74.6)*	PSC 1/6 HP (124.3)*	PSC 1/3 HP (267.0)*	Weighted Wattage
Baseline motor efficiency[3]	22.5%	22.5%	60%	60%	60%	N/A
Input wattage of base motor	**165.8**	**221.0**	**124.3**	**207.2**	**414.4**	**221.0**
Efficiency[3] of equivalent ECM	70%	70%	70%	70%	70%	N/A
Input wattage of equivalent ECM	**53.3**	**71.0**	**106.6**	**177.6**	**355.2**	**137.7**
Weighting by motor type	50%		50%		N/A	
Weighting by motor type and size	25%	25%	16.67%	16.67%	16.67%	N/A

* The heading values in parentheses indicate the motor output wattages, which were determined by converting horsepower ratings to watts. Then, the input wattages of the motors was determined based on the efficiencies for fractional refrigeration application motors in the U.S. Department of Energy study.[3]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

EUL = Effective useful life (= 16 years)[1]

Assumptions

It is assumed that any motor greater than or equal to 1/10 horsepower is a PSC motor and any motor less than 1/10 horsepower is a SP motor based on available options for compressor head fan motors, condenser fan motors, and condensing unit fan motors from various refrigeration manufacturers. The occurrence of SP and PSC motors in compressors and condensers/condensing units is 50%/50%. There are two standard refrigeration motor horsepowers less than 1/10 horsepower (1/20 and 1/15), so each size has a weighting factor of 25% (50% occurrence split between two motor sizes). There are three standard refrigeration motor horsepowers greater than or equal to 1/10 horsepower (1/10, 1/6, and 1/3), so each has a weighting of 16.67% (50% occurrence split between three motor sizes).

It is assumed that the replacements will occur in 50% freezer applications and 50% cooler applications due to equal proportions of freezer and cooler display cases and walk-ins throughout refrigerated spaces in retail applications. The compressors, condenser, and condensing units are integral components for refrigerated display cases and walk-ins to maintain proper temperatures, and these units will proportionally match the number of freezer and cooler display cases and walk-ins present in a customer's facility.

The annual hours are based on the compressor duty cycles needed to maintain refrigeration temperatures based on case and walk-in loads. Based on Wisconsin weather conditions, the duty cycle for coolers is 62% and the duty cycle is 80%.[4] These duty cycles for each temperature were then weighted based on the replacement assumption of 50%/50% for coolers and freezers, yielding an average duty cycle of 71% and an average annual run hours of 6,220.

Sources

1. Average of Cadmus database, DEER, 2009 Focus study, 2007 GDS study.
2. Regional Technical Forum. "Commercial: Grocery - Compressor Head Fan Motor Retrofit to ECM." UES Measure Workbook 2.2. June 29, 2016. Cost converted from 2008 dollars to 2017 dollars. https://rtf.nwcouncil.org/measure/compressor-head-fan-motor-retrofit-ecm and http://www.usinflationcalculator.com/
3. U.S. Department of Energy, Building Technologies Office. "Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment." p. 5, 6, 16. 2013. https://energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf
   Motor efficiencies are: 22.5% (average of 15% to 30% for evaporator fans or compressors) for SP, 60% (average of 50% to 70%) for PSC, and 70% for fractional horsepower ECMs.
4. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V 1.0." p. 4–91. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	03/11/2016	Initial TRM entry

ECM Evaporator Fan Motor, Walk-In Cooler/Freezer

	Measure Details
Measure Master ID	ECM Evaporator Fan Motor: Walk-In Cooler, < 1/20 hp, 2308 Walk-In Cooler, 1/20 – 1 hp, 2309 Walk-In Freezer, < 1/20 hp, 2310 Walk-In Freezer, 1/20 – 1 hp, 2311
Measure Unit	Per motor
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Motor
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$260.00[4]

Measure Description

The long-time standard in refrigeration equipment is shaded pole (SP) fan motors, which are highly inefficient and generate excessive heat. Higher-efficiency electronically commuted motors (ECMs) use 75% less energy to run and generate less heat. ECMs or brushless AC fan motors are used in conjunction with walk-in cooler and freezer evaporators.

Incentives are available for ECMs replacing SP motors or permanent split capacitor (PSC) motors on existing walk-in cooler and freezer evaporator fan motors. This measure does not apply to evaporator fan motors in refrigerated display cases.

Description of Baseline Condition

The baseline condition is a SP or PSC walk-in cooler or freezer evaporator fan motor.

Description of Efficient Condition

The efficient condition is an ECM replacing a SP motor or a PSC motor on a walk-in cooler or freezer evaporator.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * (1 + 1 / COP) * HOU$

Where:

$Watts_{BASE}$ = Wattage of the existing SP and PSC fan motor (= weighted average based on historical data, see Deemed Savings table below)[2]

$Watts_{EE}$ = Wattage of the ECM fan motor (= weighted average based on historical data, see Deemed Savings table below)[2]

1,000 = Kilowatt conversion factor

COP = Coefficient of performance (= 2.3 for MMID 2308 and 2309, = 1.4 for MMID 2310 and 2311)[3]

HOU = Average annual run hours (= 8,760 for MMID 2308 and 2309, = 8,273 for MMID 2310 and 2311; see Assumptions)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * (1 + 1 / COP)$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Deemed Savings for ECM Evaporator Fan Motors

Measure Name	MMID	$Watts_{BASE}$[2]	$Watts_{EE}$[2]	COP[3]	Summer Peak kW Savings	First Year kWh Savings	EUL[1]	Life-cycle kWh Savings
Walk-In Cooler, < 1/20 hp	2308	79.38	26.64	2.3	0.07	613	15	9,195
Walk-In Cooler, 1/20 - 1 hp	2309	211.66	71.04	2.3	0.20	1,752	15	26,280
Walk-In Freezer, < 1/20 hp	2310	90.7	30.44	1.4	0.10	827	15	12,405
Walk-In Freezer, 1/20 - 1 hp	2311	244.22	81.97	1.4	0.27	2,234	15	35,385

Assumptions

The wattages are based on a review of historical applications using the existing measures, randomly selected to ensure a sampling of all motor options. For programs with multiple facility (or customer) types available, applications were selected to capture information from the various facility (or customer) types. The applications used to obtain the weighted average motor sizes and wattages all contained complete motor information (make and model) for the correct application measure. Multiple location applications were not used in the random selection to ensure that one facility (or customer) type was not favored over the others in the motor sizes and wattages. At least 10% of the total number of applications per program were surveyed, along with the total number of motors surveyed accounting for at least 10% of the motors in each measure category. The quantity and size of each motor, along with the type of motor the ECM was replacing, was all recorded and used to determine the weighted baseline and proposed wattages. The table below summarizes the historical application findings and values for efficiencies. These values were used to calculate $\text{Watts}_{\text{BASE}}$ and Watts_{EE}.

Efficiency Values for ECM Evaporator Fan Motors

Measure Name	MMID	% of Motors Surveyed[2]	Weighted Output Horsepower [2]	SP Efficiency[5]	SP Weighting [2]	PSC Efficiency[5]	PSC Weighting [2]	ECM Efficiency[5]
Walk-In Cooler, < 1/20 hp	2308	16%	1/40	23%	91%	60%	9%	70%
Walk-In Cooler, 1/20 - 1 hp	2309	19%	1/15	23%	91%	60%	9%	70%
Walk-In Freezer, < 1/20 hp	2310	9%	1/35	23%	91%	60%	9%	70%
Walk-In Freezer, 1/20 - 1 hp	2311	16%	1/13	23%	91%	60%	9%	70%

Evaporator fan motors run constantly to ensure proper airflow and circulation throughout the refrigerated display case to maintain even product temperatures. However, during times of defrost, evaporator fans do not run, as heat is being introduced to the system to remove the ice and frost build-up on the evaporator coils. Freezer hours of operation assume four defrost cycles per day at 20 minutes per defrost. As cooler operating temperatures are above freezing, defrost cycles are not required.

The low temperature and medium temperature system COPs were derived from the information on Table 3-7 of the U.S. DOE Publication ID 6180.[3] The capacity and power values were calculated to yield the EER, then converted to COP, based on COP = EER/3.412.

Sources

1. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” EUL Table. 2014. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx
2. Focus on Energy historical application data, June 2012 through July 2015.
3. U.S. Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Office. “Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration.” DOE Publication ID 6180. Table 3-7. September 2009. https://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf
4. Regional Technical Forum. "Commercial: Grocery - ECMs for Walk-ins." UES Measure Workbook 2.2. June 29, 2016. https://rtf.nwcouncil.org/measure/ecms-walk-ins
   Cost converted from 2008 dollars to 2017 dollars based on http://www.usinflationcalculator.com/
5. United States Department of Energy, Building Technologies Office. “Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment.” p. 5, 6, and 16. 2013. https://energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf
   Motor efficiencies are: 23% (average of 15%-30% for evaporator fans or compressors) for SP; 60% (average of 50% - 70%) for PSC; and 70% for fractional horsepower ECMs.

Revision History

Version Number	Date	Description of Change
01	03/11/2016	Update from Focus on Energy Deemed Savings Manual
02	04/2017	Added MMIDs 4065, 4066, 4067, 4068
03	10/2017	Updated EUL
04	01/2019	Removed MMIDs 4065, 4066, 4067, and 4068

ECM Motor, Cooler/Freezer Case

	Measure Details
Measure Master ID	ECM Motor, Cooler/Freezer Case, 2312
Measure Unit	Per motor
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Motor
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	992
Peak Demand Reduction (kW)	0.116
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	14,880
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$18.88[5]

Measure Description

The long-time standard in refrigeration equipment is shaded pole (SP) fan motors, which are highly inefficient and generate excessive heat. Higher-efficiency electronically commuted motors (ECMs) use 75% less energy to run and generate less heat. ECMs or brushless AC fan motors are used in conjunction with refrigerated display case evaporators.

Incentives are available for ECMs replacing SP motors on existing refrigerated display case evaporator fan motors. This measure does not apply to evaporator fan motors in walk-in coolers and freezers.

Description of Baseline Condition

The baseline condition is a SP refrigerated display case evaporator fan motor.

Description of Efficient Condition

The efficient condition is an ECM replacing a SP motor on a refrigerated display case evaporator.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * (1 + 1 / COP) * HOU$

Where:

$Watts_{BASE}$ = Wattage of the existing SP fan motor (= 112.6 weighted average)[2,3]

$Watts_{EE}$ = Wattage of the ECM fan motor (=37)[2,3]

1,000 = Kilowatt conversion factor

COP = Coefficient of performance (= 1.85, average of 1.4 for freezers and 2.3 for coolers)[4]

HOU = Average annual run hours (= 8,517, see Assumptions)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * (1 + 1 / COP)$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=15 years)[1]

Assumptions

Replacements are assumed to occur in equal proportions for freezers and coolers, based on program experience that equal proportions of freezer and cooler display cases and motors are present throughout refrigerated spaces in retail applications. Evaporator fan motors run constantly to ensure proper airflow and circulation throughout the refrigerated display case to maintain even product temperatures. However, during times of defrost, evaporator fans do not run, as heat is being introduced to the system to remove the ice and frost build-up on the evaporator coils. Freezer hours of operation assume four defrost cycles per day at 20 minutes per defrost. As cooler operating temperatures are above freezing, defrost cycles are not required. Overall hours of operation are the average of cooler and freezer case hours of operation: (8,273 + 8,760) / 2 = 8,517.

The case motor wattages were categorized into three motor sizes: < 12 watts, 16 - 23 watts, and 1/20 hp,[2] each with an averaged wattage based on the motor sizes: 9 watts, 19.5 watts, and 37 watts, respectively. They also had population splits of 9%, 49%, and 42%, respectively. These output wattages were used to obtain the motor input wattages, based on motor efficiencies.[3] The input wattages were averaged, based on the motor size ratio,[2] to obtain the overall baseline and efficient motor input wattages for the savings algorithms.

Sources

1. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” EUL Table. 2005, 2008- High Efficiency Evaporator Fan Motors measure. http://www.deeresources.com/
2. Pacific Gas & Electric Company. “Display Case ECM Motor Retrofit.” Workpaper PGE3PREF124. Table 10. 2014.

3. United States Department of Energy, Building Technologies Office. "Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment." p. 6 and 16. 2013. https://energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf
   Motor efficiencies are: 23% (average of 15% to 30% for evaporator fans for compressors) for SP and 70% for fractional horsepower ECMs.
4. U.S. Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Office. "Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration." DOE Publication ID 6180. Table 3-7. September 2009. http://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf
   The capacity and power values were calculated to yield the EER, then converted to COP, based on COP = EER / 3.412.
5. Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 7,926 units over 135 projects from 2016 to 2018 is $84.88. The base cost of $66 is from RTF current practice for display cases, workbook version 3.3: https://rtf.nwcouncil.org/measure/ecms-display-cases?id=107. The incremental cost is therefore $18.88.

Revision History

Version Number	Date	Description of Change
01	03/11/2016	Update from Focus on Energy Deemed Savings Manual
02	04/2017	Added MMID 4069
03	10/2017	Updated EUL
04	12/2018	Updated incremental cost, removed MMID 4069

Permanent Magnet Synchronous AC Fan Motor - Cooler/Freezer Case

	Measure Details
Measure Master ID	Permanent Magnet Synchronous (PMS) Evaporator Fan Motor, Refrigerated Case, Replacement, 4284, 4652
Measure Unit	Per motor
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Motor
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	1,036
Peak Demand Reduction (kW)	0.122
Annual Therm Savings (Therms)	0
Life-cycle Energy Savings (kWh)	15,540
Life-cycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$92.40[5]

Measure Description

The long-time standard in refrigeration equipment is shaded pole (SP) fan motors, which are highly inefficient and generate excessive heat. Higher-efficiency permanent magnet synchronous (PMS) motors use at least 80% less energy to run and they generate less heat. These motors are used in conjunction with refrigerated display case evaporators.

Incentives are available for PMS motors replacing SP motors on existing refrigerated display case evaporator fan motors. This measure does not apply to evaporator fan motors in walk-in coolers and freezers.

Description of Baseline Condition

The baseline condition is a SP refrigerated display case evaporator fan motor.

Description of Efficient Condition

The efficient condition is a PMS motor/fan assembly replacing an SP motor/fan assembly on a refrigerated display case evaporator.

PMS AC motors directly use grid-supplied AC current without the need to rectify to DC. Synchronous motors are so named because the rotation of the motor’s shaft is synchronized with the frequency of the supplied current. Previously, synchronous motors had been prohibitively expensive for commercial refrigeration evaporator fan applications because of the high cost of the electronic control circuit that is required to bring the synchronous motor up to synchronous speed. The controller for a PMS motor is simpler and lower in cost than previous synchronous motor controllers or electronically commutated motor controllers, making the PMS motors a cost-effective alternative in the commercial refrigeration market. For this application, installation costs are similar to costs for installing electronically commutated motors.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * (1 + 1 / COP) * HOU$

Where:

$Watts_{BASE}$ = Wattage of the existing SP fan motor (= 112.630 watts as a weighted average of three motor size categories, see Assumptions)[2,3]

$Watts_{EE}$ = Wattage of the PMS fan motor (= 33.643 watts)[6,7]

1,000 = Kilowatt conversion factor

COP = Coefficient of performance (= 1.85 averaged, = 1.4 for freezers, and = 2.3 for coolers)[4]

HOU = Average annual run hours (= 8,517, see Assumptions)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * (1 + 1 / COP)$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=15 years)[1]

Assumptions

Replacements are assumed to occur in equal proportions for freezers and coolers, based on program experience that equal proportions of freezer and cooler display cases and motors are present throughout refrigerated spaces in retail applications. Evaporator fan motors run constantly to ensure proper air flow and circulation throughout the refrigerated display case to maintain even product temperatures. However, during times of defrost, evaporator fans do not run, as heat is being introduced to the system to remove the ice and frost build-up on the evaporator coils. Freezer hours of operation assume four defrost cycles per day at 20 minutes per defrost. As cooler operating temperatures are above freezing, defrost cycles are not required. The overall hours of operation are the average of cooler and freezer case hours of operation: (8,273 + 8,760) / 2 = 8,517.

Based on the Pacific Gas and Electric workpaper,[2] the case motor wattages were categorized into three motor sizes: < 12 watts, 16 to 23 watts, and 1/20 HP. Each of these categories had an averaged wattage based on the motor sizes of 9 watts, 19.5 watts, and 37 watts, respectively. They also had population splits of 9%, 49%, and 42%, respectively. These output wattages were used to obtain the motor input wattages, based on motor efficiencies in the Navigant motor study.[3] The input wattages were averaged, based on the motor size ratio study provided in the Pacific Gas and Electric workpaper, to obtain the overall baseline and efficient motor input wattages for the savings algorithms. Motor wattages for the efficient option were obtained from the Wisconsin Focus on Energy.[5]

The low temperature and medium temperature system COPs are derived from the information on Table 3-7 of the U.S. Department of Energy Publication ID 6180.[4] The capacity and power values were calculated to yield the EER then converted to COP, based on COP = EER / 3.412.

PMS motors are expected to have an EUL comparable to electronically commutated motors.

SP motor efficiency is assumed to be 23%. SP evaporator fan motors are small, typically 9 watts to 37 watts. Motors at the low end of this range are about 20% efficient.[6] SP efficiency generally increases with motor size, but is still generally less than 30% in the 37-watt range. Therefore a 23% efficiency is reasonable, and matches the average of a range presented in a U.S. Department of Energy paper.[3]

PMS motor efficiency average is assumed to be 77%.[5,6,7] QM Power's conference presentation noted 75%+ efficiency for 9-watt to 20-watt PMS motors and 78%+ efficiency for 38-watt to 75-watt PMS motors.[7] The Oak Ridge National Laboratory completed a laboratory measurement of 73% for a 12-watt Q Sync motor.[7] Through a direct contact and discussion with Mark Martinez, technical representative at QM Power, he provided a 80% efficiency number for a 45-watt Q Sync motor.[5] Since the market is a mix of smaller and larger motors, a 77% efficiency average is assumed.

Sources

1. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." EUL Table. High Efficiency Evaporator Fan Motors measure. 2005, 2008. http://www.deeresources.com/
2. Pacific Gas & Electric Company. "Display Case ECM Motor Retrofit." Table 10. Workpaper PGE3PREF124. 2014.
3. Navigant Consulting Group, Inc. "Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment." December 2013.

https://energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf

4. Navigant Consulting, Inc. “Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration.” Table 3-7. 2009. U.S. DOE Publication ID 6180. http://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf
5. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 10 units over two projects in 2018.
6. Fricke, B. and B. Becker, Oak Ridge National Laboratory. “Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits.” ORNL/TM-2015/466. 2015. http://info.ornl.gov/sites/publications/files/Pub58600.pdf
7. QM Power. “Q-Sync™ high efficiency fan motors for refrigeration, HVAC and appliance applications.” http://www.arpae-summit.com/paperclip/exhibitor_docs/14AE/QM_Power_192.pdf

Revision History

Version Number	Date	Description of Change
01	05/11/2017	Initial TRM entry
02	09/07/2017	Modified inputs from Business Incentive Program, Aptim, and Cadmus
03	12/2018	Updated incremental cost

Cooler Night Curtains, Open Coolers

	Measure Details
Measure Master ID	Cooler Night Curtains, Open Coolers, 2271
Measure Unit	Per linear foot
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Refrigerated Case Door
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	903
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	4,515
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$44.14[2]

Measure Description

Night curtains are used on open refrigerated cases (open coolers) to reduce heat transfer between the air inside of the case and the air outside of the case. The technology adds a barrier over the open face of the multideck-style case for use during closed hours. When curtains are in use, the heat transfer by convection and radiation is reduced, thereby reducing the cooling load on the refrigeration system.

Description of Baseline Condition

The baseline condition is an open multideck-style refrigerated display case without night curtains.

Description of Efficient Condition

The efficient condition is a permanently installed woven aluminum or perforated plastic night curtain.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Load_{CASE} / 12{,}000) * (12 / 3.412) * COP * PCT_{SAVINGS} * HOU$

Where:

$Load_{CASE}$ = Average refrigeration load without curtains (= 1,733.625 Btuh per linear foot weighted average of 1,727.5 Btuh per linear foot for coolers[3] and 1,850 Btuh per linear foot for freezers)[4]

12,000 = Conversion from Btu to one ton of refrigeration capacity

12/3.412 = Conversion from COP to kW/ton

COP = Coefficient of performance (= 2.255 weighted average of 1.4 for freezers and 2.3 for coolers)[3]

$PCT_{SAVINGS}$ = Percentage of savings (=9%)[5]

HOU = Hours of use (= 8,760)

Summer Coincident Peak Savings Algorithm

There are no peak savings associated with this technology since the night curtains are not used during the peak period. The curtains are used during closed hours.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)[1]

Assumptions

Night curtains are installed on open multideck-style cases; the majority of these cases in the market are cooler cases; however, they are manufactured and used for freezer applications as well. While there are open multideck-style cases for freezers in Wisconsin, they are very rare to find in stores. In order to accurately portray the market, a weighted average of 95% cooler cases and 5% freezer cases, based on historical site audits and discussions with grocery owner and store managers in Wisconsin since 2008.

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf 2
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 2,570 units over 26 projects from 2016 to 2018.
3. Navigant Consulting, Inc. "Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration." U.S. Department of Energy Publication ID 6180. Tables 3-7, 4-2, and 4-4. 2009. http://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf&id=6180
The low temperature and medium temperature system COPs are from Table 3-7. The capacity and power values were calculated to yield the EER, then divided by 3.412 to convert to COP. The open multideck-style cooler case load is based on the case length in the Baseline Case

Description and Thermal Load Breakdown total for Vertical Open Medium Temp cases on Tables 4-2 and 4-4 (20,730 Btuh thermal load for a 12-foot display case = 1,727.5 Btuh per foot).

4. Manufacturer's specification sheet for open multideck style freezer case. Hussmann Excel F6L. November 2010.
5. Southern California Edison. "Display Case Shield Reduces Supermarket Energy Use." https://www.sce.com/NR/rdonlyres/178AB92E-BF6B-4085-A5BC-9C042EAE8C0E/0/BusDisplayCaseSheildsFactSheet.pdf

Revision History

Version Number	Date	Description of Change
01	03/11/2016	Updated based on Focus on Energy Deemed Savings Manual
02	12/2018	Updated incremental cost

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Energy-Efficient Case Doors

	Measure Details
Measure Master ID	Case Door: Freezer, Low Heat, 2234, 4487 Freezer, No Heat, 2235, 4488 Cooler, No Heat, 2236, 4489
Measure Unit	Per door
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Refrigerated Case Doors
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Life-cycle Energy Savings (kWh)	Varies by measure
Life-cycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	Freezer, low heat = $548.67 (MMID 2234); Freezer, no heat = $121.00 (MMID 2235); Cooler, no heat = $208.83 (MMID 2236)[2]

Measure Description

Anti-sweat heaters minimize condensation or sweating on cooler and freezer doors. A standard cooler or freezer case door has three heaters to mitigate condensate build-up so that the product behind the glass can be seen immediately after closing the door. Using low-heat or no-heat doors can reduce the energy consumption of the case by using lower wattage heaters or a reduced number of total heaters per door. The savings results from reduced electric energy consumed by the heaters, and from the reduced cooling load on the refrigeration system.

Description of Baseline Condition

The baseline condition is a cooler or freezer display case with standard energy doors.

Description of Efficient Condition

The efficient condition is a cooler or freezer display case using low-heat or no-heat doors.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = [(Watts_{BASE} – Watts_{EE}) * (1 + 1 / COP)] / 1{,}000 * HOU$

$Watts_{BASE}$ = Wattage of standard door heaters (= 191 for MMIDs 2234 and 2235; = 63 for MMID 2236)[3]

$Watts_{EE}$ = Wattage of door heaters (= 132 for MMID 2234; = 54 for MMID 2235; = 52 for MMID 2236)[3]

COP = Coefficient of performance (= 1.4 for MMIDs 2234 and 2235; = 2.3 for MMID 2236)[4]

1,000 = Kilowatt conversion factor

HOU = Average annual run hours (= 8,760)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = [(Watts_{BASE} – Watts_{EE}) * (1 + 1 / COP)] / 1{,}000$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

EUL = Effective useful life (=11 years)[1]

Deemed Savings

Deemed Savings

Measure Name	MMID	$Watts_{BASE}$	$Watts_{EE}$	COP	First Year kWh Savings	Summer Peak kW Savings	EUL	Lifecycle kWh Savings
Case Door, Freezer, Low Heat	2234	191	132	1.4	886	0.10	11	9,746
Case Door, Freezer, No Heat	2235	191	54	1.4	2,057	0.23	11	22,631
Case Door, Cooler, No Heat	2236	63	52	2.3	138	0.016	11	1,521

Sources

1. Average of 2009 Focus Study.
   California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com/
   Cadmus database March 2013.
2. No heat freezer: Price sheets for Styleline Classic II Plus freezer, and Anthony ELM, ELM 2, and 401 freezers. September 2016. Low heat freezer: Price sheets for Styleline Classic II Plus and Hybridoor freezers, and Anthony 401, 101, and Infinity freezers. September 2016. No heat cooler: Price sheets for Styleline Classic II Plus cooler, and Anthony ELM, ELM 2, 101, 101 No Heat, 401, Infinity, Vista C, and Vista B coolers. September 2016.
3. Zero Zone RVZC and RVCC and Hussmann RL and RM specification sheets for reach-in cooler and freezer cases with doors, specification sheets published 2006/2007.
4. U.S. Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Office. "Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration." DOE Publication ID 6180. Table 3-7. September 2009. http://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf

Revision History

Version Number	Date	Description of Change
01	03/11/2016	Update based on Focus on Energy Deemed Savings Manual

Reach In Refrigerated Case w/ Doors Replacing Open Multi Deck Case

	Measure Details
Measure Master ID	Reach In Refrigerated Case w/ Doors Replacing Open Multi Deck Case, 2509
Measure Unit	Per linear foot
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Refrigerated Case Door
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	976
Peak Demand Reduction (kW)	0.179
Annual Therm Savings (Therms)	113
Lifecycle Energy Savings (kWh)	14,640
Lifecycle Therm Savings (Therms)	1,695
Water Savings (gal/yr)	0
Effective Useful Life (years)	15[8]
Incremental Cost ($/unit)	$550.92[9]

Measure Description

This measure is replacing existing open multi-deck cases with equivalent storage (in cubic feet or linear feet) of reach-in cases with doors. The estimated measure savings are conservative because case replacements use equivalent linear feet, but reach-in cases are designed to hold more cubic feet of product per linear foot (side-to-side measure) than multi-deck cases.

Description of Baseline Condition

The baseline is a 95% to 5% mix of cooler to freezer open multi-deck style cases.

Description of Efficient Condition

The replacement cases must have doors, be tied into a central refrigeration system, and be purchased new. New case upgrades that simply enclose and/or add doors to an existing multi-deck do not qualify for this incentive. New cases must be DOE 2017 Energy Compliant.

Annual Energy-Savings Algorithm

$$\mathrm{kWh}_{\mathrm{SAVED}} = \{(\mathrm{P}_{\mathrm{CE}} - \mathrm{P}_{\mathrm{LE}} - \mathrm{P}_{\mathrm{ME}} - \mathrm{P}_{\mathrm{CE}} \cdot \mathrm{F}_{\mathrm{CR}}) - [\mathrm{P}_{\mathrm{CP}} \cdot (1 - \mathrm{F}_{\mathrm{I}}) - \mathrm{P}_{\mathrm{LP}} - \mathrm{P}_{\mathrm{MP}} - \mathrm{P}_{\mathrm{CP}} \cdot \mathrm{F}_{\mathrm{CR}} \cdot (1 - F_I)]\} \cdot \left[\frac{\mathrm{LF} \cdot \mathrm{HOU}}{3{,}412 \cdot \mathrm{COP}_{\mathrm{REFRIG}}} - \frac{24 \cdot \mathrm{CDD}}{(\mathrm{T}_{\mathrm{S}} - \mathrm{T}_{\mathrm{R}}) \cdot 3{,}412 \cdot \mathrm{COP}_{\mathrm{ROOFTOP}}}\right]$$

$$\text{Therm}_{\text{SAVED}} = \{(P_{CE} - P_{LE} - P_{ME} - P_{CE} \cdot F_{CR}) - [P_{CP} \cdot (1 - F_{I}) - P_{LP} - P_{MP} - P_{CP} \cdot F_{CR} \cdot (1 - F_{I})]\} \cdot \left[\frac{24 \cdot \text{HDD}}{(T_S - T_R) \cdot \text{eff} \cdot 100{,}000}\right]$$

Where:

P_{CE} = Total load of multideck case (= 1,727.5 Btuh per linear foot for coolers;[1] = 1,850 Btuh per linear foot for freezers[2])

P_{LE} = Lighting load of existing case (= 6.7 Btuh per linear foot)[2]

P_{ME} = Motor load of existing case (= 7.3 Btuh per linear foot)[2]

F_{CR} = Amount of case load associated with conduction and radiation (= 13%)[5]

P_{CP} = Total load of new enclosed case (= 332 Btuh per linear foot for coolers; = 528 Btuh per linear foot for freezers)[3]

F_{I} = Amount of case load associated with infiltration reduction (= 68%)[4]

P_{LP} = Lighting load of new case (= 8.2 Btuh per linear foot)[3]

P_{MP} = Motor load of new case (= 2.7 Btuh per linear foot for coolers; = 3.5 Btuh per linear foot for freezers)[3]

LF = Case load factor, the compressor duty cycle needed to maintain case temperatures, deemed (= 62% for coolers; = 80% for freezers)[6]

3,412 = Conversion from kilowatt-hours to Btu

HOU = Average annual operating hours of the case measured in hours per year, deemed (= 8,760)[6]

COP_{REFRIG} = Coefficient of performance of refrigeration system: a measure of the refrigeration system efficiency equal to the ratio of net heat removal to total energy input, deemed (= 2.3 for coolers; = 1.4 for freezers)[1]

24 = Hours per day

CDD = Cooling degree days, the sum of the number of degrees the average daily temperature is greater than a base temperature for a given time period, deemed (= 535)[6]

T_S = Temperature of store, deemed (= 65°F)[6]

T_R = Temperature of refrigerated case that needs to be maintained (= 36.5°F for coolers; = -11°F for freezers)[7]

$COP_{ROOFTOP}$ = Coefficient of performance of rooftop system: a measure of the efficiency of the rooftop system equal to the ratio of net heat removal to total energy input (= 3.2)[7]

HDD = Heating degree days, the sum of the number of degrees the average daily temperature is less than a base temperature for a given time period, deemed (= 7,699)[6]

eff = Heating system efficiency, the average combustion efficiency of the boiler (= 78%)[7]

100,000 = Conversion factor from Btu to therm

Summer Coincident Peak Savings Algorithm

$$kW_{SAVED} = \{(P_{CE} - P_{LE} - P_{ME} - P_{CE} \cdot F_{CR}) - [P_{CP} \cdot (1 - F_I) - P_{LP} - P_{MP} - P_{CP} \cdot F_{CR} \cdot (1 - F_I)]\} \cdot \left[\frac{1}{3{,}412 \cdot COP_{REFRIG}} - \frac{24 \cdot CDD}{(T_S - T_R) \cdot 3{,}412 \cdot COP_{ROOFTOP} \cdot HOU}\right] \cdot CF$$

Where:

CF = Coincidence factor (= 1)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[8]

Assumptions

Refrigerated case temperatures were calculated as the average of the most commonly used settings for cooler and freezer cases: 35°F to 38°F and -14°F to -8°F, respectively.[7]

The majority of open multi-deck style cases in the market are cooler cases; however, open multi-deck style cases are also manufactured and used for freezer applications in Wisconsin (but very rare to find in stores). In order to accurately portray the market, a weighted average of 95% cooler cases and 5% freezer cases is used, based on historical site audits and discussions with grocery owner and store managers in Wisconsin since 2008.

Refrigerated display cases operated 24 hours per day, 7 days per week and are never shut off, as they must maintain proper food product temperatures to avoid product shrink, spoilage, and health code violations. As these cases are constantly on and running, the coincidence factor is set to 1.0 because the case demand reduction will be coincident with the utility peak demand.

The low temperature and medium temperature system COP values are derived from the information on Table 3-7 of the US DOE Publication ID 6180.[1] The capacity and power values were calculated to yield the EER then converted to COP, based on COP = EER/3.412. The open multi-deck style cooler case load is based on the case length in the Baseline Case section, and the thermal load breakdown total for vertical open medium temperature cases on Tables 3-2 and 3-4 (20,730 Btuh thermal load for a 12-foor display case = 1,727.5 Btuh per foot).

The EUL is the DEER[8] value for the “Refrigerator Upgrades (Condenser, Head Pressure, Suction Pressure, Subcooling, Variable Speed Compressors)” measure, which offers the best match in DEER for upgrades to centralized (non self-contained) refrigerated cases. The “Commercial Reach-In Refrigerator / Freezer” measure in DEER, which appears to be similar to this measure, is actually for ENERGY STAR self-contained refrigerators and freezers. Selecting a 15-year EUL for this measure ensures the EUL for the complete case is at least as long as the EUL for the ECMs that go into the case.

Sources

1. Navigant Consulting, Inc. *Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration*. U.S. Department of Energy Publication ID 6180. Tables 3-2, 3-4 and 3-7. 2009. http://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf&id=6180
2. Manufacturer’s specification sheet for open multideck style freezer case. Hussmann Excel F6L. November 2010.
3. Manufacturer’s specification sheet for enclosed reach-in cases. Zero Zone RVCC30 and RVZC30. 2012.
4. Faramarzi, R., B. Coburn, R. Sarhadian, and Rafik. *Performance and Energy Impact of Installing Glass Doors on an Open Vertical Deli/Dairy Display Case.* ASHRAE Transactions: Symposia. 2002.
5. Fricke, Brian, and B. Becker. *Comparison of Vertical Display Cases: Energy and Productivity Impacts of Glass Doors Versis Open Vertical Display Cases*. ASHRAE report RP-1402. 2009.
6. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
7. U.S. Department of Energy Building Technology Program. *Advanced Energy Retrofit Guide: Practical Ways to Improve Energy Performance, Grocery Stores.* National Renewable Energy Laboratory. June 2012. http://www.nrel.gov/docs/fy13osti/54243.pdf

8. California Energy Commission and California Public Utilities Commission. 2008 Database for Energy Efficient Resources (DEER) Version 2008.2.05. www.deeresources.com/files/deer0911planning/downloads/EUL_Summary_10-1-08.xls
9. Historical Focus on Energy project data, 2015-2017.
48 projects, average cost is $550.92 per linear foot.

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	08/2017	Updated COP to remain consistent with other refrigeration workpapers

Retrofit Open Multi-Deck Cases with Doors

	Measure Details
Measure Master ID	Retrofit Open Refrigerated Cases with Doors, 3409
Measure Unit	Per linear foot
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Refrigerated Case Door
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	711
Peak Demand Reduction (kW)	0.131
Annual Therm Savings (Therms)	82
Lifecycle Energy Savings (kWh)	10,665
Lifecycle Therm Savings (Therms)	1,230
Water Savings (gal/yr)	0
Effective Useful Life (years)	15[7]
Incremental Cost ($/unit)	$424.04[8]

Measure Description

Existing open multi-deck style cases can be retrofitted with doors. The doors are designed to fit right onto the open multi-deck style cases with minimal case modification. The measure incentives are based on per-foot of case enclosed.

Description of Baseline Condition

The baseline is a 95% to 5% mix of cooler to freezer open multi-deck style cases.

Description of Efficient Condition

The efficient condition is installing doors on the cooler or freezer multi-deck style cases.

Annual Energy-Savings Algorithm

$$kWh_{SAVED} = [P_C \cdot F_I \cdot (1 - F_{CR})] \cdot \left[\frac{LF \cdot HOU}{3{,}412 \cdot COP_{REFRIG}} - \frac{24 \cdot CDD}{(T_S - T_R) \cdot 3{,}412 \cdot COP_{ROOFTOP}}\right]$$

$$Therm_{SAVED} = [P_C \cdot F_I \cdot (1 - F_{CR})] \cdot \left[\frac{24 \cdot HDD}{(T_S - T_R) \cdot eff \cdot 100{,}000}\right]$$

Where:

P_C = Total case load, the average energy consumption of the refrigerated case (= 1,727.5 Btuh for coolers;[1] = 1,850 Btuh for freezers[2])

F_I = Amount of infiltration reduction, the fraction of the case energy associated with infiltration (= 68%)[3]

F_{CR} = Amount of case load energy associated with conduction and radiation (= 13%)[4]

LF = Case load factor, the compressor duty cycle needed to maintain case temperatures, deemed (= 62% for coolers; = 80% for freezers)[5]

HOU = Average annual operating hours of the cases, deemed (= 8,760)[5]

3,412 = Conversion factor from kilowatt to Btuh

COP_{REFRIG} = Coefficient of performance of refrigeration system, a measure of the refrigeration system efficiency equal to the ratio of net heat removal to the total energy input, deemed (= 2.3 for coolers; = 1.4 for freezers)[1]

24 = Hours per day

CDD = Cooling degree days, the sum of the number of degrees that the average daily temperature is greater than a base temperature for a given time period (the State of Wisconsin uses a base temperature of 65°F, which is a standard value used in the HVAC industry), deemed (= 535)[5]

T_S = Temperature of store, deemed (= 65°F)[5]

T_R = Temperature that the refrigerated case needs to be maintained (= 36.5°F for coolers; = -11°F for freezers)[6]

$COP_{ROOFTOP}$ = Coefficient of performance of rooftop system, a measure of the rooftop system efficiency equal to the ratio of net heat removal to total energy input (= 3.2)[6]

HDD = Heating degree days, the sum of the number of degrees that the average daily temperature is less than a base temperature for a given time period (the State of Wisconsin uses a base temperature of 65°F, which is a standard value used in the HVAC industry), deemed (= 7,699)[5]

eff = Heating system efficiency, the average combustion efficiency of the boiler (= 78%)[6]

100,000 = Conversion factor from Btu to therm

Summary Coincident Peak Savings Algorithm

$$kW_{SAVED} = [P_C \cdot F_I \cdot (1 - F_{CR})] \cdot \left[\frac{1}{3{,}412 \cdot COP_{REFRIG}} - \frac{24 \cdot CDD}{(T_S - T_R) \cdot 3{,}412 \cdot COP_{ROOFTOP}} \cdot \frac{1}{HOU}\right] \cdot CF$$

Where:

CF = Coincidence factor (= 1)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[7]

Assumptions

Refrigerated case temperatures were calculated as the average of the most commonly used settings for cooler and freezer cases: 35°F to 38°F and -14°F to -8°F, respectively.[6]

The majority of open multi-deck style cases in the market are cooler cases; however, open multi-deck style cases are manufactured and used for freezer applications as well. The open multi-deck style cases for freezer cases are present in Wisconsin; however, they are very rare to find in stores. To accurately portray the market, a weighted average of 95% cooler cases and 5% freezer cases was used, based on historical site audits and discussions with grocery owner and store managers in Wisconsin since 2008.

The low temperature and medium temperature system COP values derived from information on Table 3-7 of the U.S. DOE Publication ID 6180.[1] The capacity and power values were calculated to yield the EER then converted to COP, based on COP = EER/3.412. The open multi-deck style cooler case load is based on the case length in the Baseline Case Description and Thermal Load Breakdown total for Vertical Open Medium Temp cases on Tables 3-2 and 3-4 (20,730 Btuh thermal load for a 12-foor display case = 1,727.5 Btuh per foot).

The EUL is the DEER[7] value for the “Refrigerator Upgrades (Condenser, Head Pressure, Suction Pressure, Subcooling, Variable Speed Compressors)” measure, which offers the best match in DEER for upgrades to centralized (non-self-contained) refrigerated cases. The “Commercial Reach-In Refrigerator / Freezer” measure in DEER, which appears to be similar to this measure, is actually for ENERGY STAR self-contained refrigerators and freezers. Selecting a 15-year EUL for this measure ensures that the EUL for the complete case is at least as long as the EUL for the ECMs that go into the case.

Sources

1. Navigant Consulting, Inc. *Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration*. U.S. Department of Energy Publication ID 6180. Tables 3-2, 3-4, and 3-7. 2009. http://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf&id=6180.
2. Manufacturer's specification sheet for open multideck style freezer case. Hussmann Excel F6L. November 2010.
3. Faramarzi, R., B. Coburn, R. Sarhadian, and Rafik. *Performance and Energy Impact of Installing Glass Doors on an Open Vertical Deli/Dairy Display Case*. ASHRAE Transactions: Symposia. 2002.
4. Fricke, Brian, and B. Becker. *Comparison of Vertical Display Cases: Energy and Productivity Impacts of Glass Doors Versus Open Vertical Display Cases*. ASHRAE report RP-1402. 2009.
5. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. U.S. Department of Energy Building Technology Program. *Advanced Energy Retrofit Guide: Practical Ways to Improve Energy Performance, Grocery Stores.* National Renewable Energy Laboratory. June 2012. http://www.nrel.gov/docs/fy13osti/54243.pdf
7. California Energy Commission and California Public Utilities Commission. "2008 Database for Energy Efficient Resources (DEER)." Version 2008.2.05. www.deeresources.com/files/deer0911planning/downloads/EUL_Summary_10-1-08.xls
8. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 1,556 units over 18 projects from 2014 to 2018.

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	08/2017	Updated COP to remain consistent with other refrigeration workpapers

Strip Curtains for Walk-In Freezers and Coolers

	Measure Details
Measure Master ID	Strip Curtains for Walk-In Freezers and Coolers, 3183
Measure Unit	Per linear foot
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Strip Curtain
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	315 per linear foot
Peak Demand Reduction (kW)	0.036 per linear foot
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	1,260 per linear foot
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	4[1]
Incremental Cost ($/unit)	$50.00[4]

Measure Description

Strip curtains reduce the refrigeration load associated with the infiltration of non-refrigerated air into the refrigerated spaces of walk-in coolers or freezers. The most likely areas of application are grocery stores, supermarkets, restaurants, and refrigerated warehouse.

Description of Baseline Condition

The baseline condition is a walk-in cooler or freezer that with no strip curtain or an old, ineffective strip curtain installed.

Description of Efficient Condition

The efficient condition is adding a strip curtain or replacing the ineffective strip curtain on a walk-in cooler or freezer. Strip curtains must be at least 0.06 inches thick. Low temperature strip curtains must be used for low temperature applications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = \Delta kWh/LF * LF$

Where:

LF = Linear feet of door width of installation

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = \Delta kW/LF * LF$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 4 years)[1]

Deemed Savings

The annual deemed savings is calculated based on methods and deemed savings included in the 2013 Pennsylvania TRM.[2] For the Small Business Program, a single deemed measure is developed using the expected mix of program customers and situations.

In order to create the Small Business Program measure mix, the following assumptions based on facility type are assumed (see Assumptions).

- Facility Types
  - Supermarket = 10%
  - Convenience Store = 30%
  - Restaurant = 60%
- Cooler and Freezer Mix
  - Coolers = 75%
  - Freezers = 25%
- Facilities that have existing ineffective strip curtains
  - 25% (75% have no existing strip curtains)

Comparison of Pennsylvania TRM to Focus on Energy Values by Facility Type*

Facility Type	PA TRM 2013 (Source 1)			Focus on Energy		
	Pre-Existing Curtains	Energy Savings (per sq ft)**	Demand Reduction (per sq ft)***	Measure Mix	Weighted Energy Savings (per sq ft)	Weighted Demand Reduction (per sq ft)
Supermarket - Cooler	Yes	37	0.0042	1.88%	0.69	0.00008
	No	108	0.0123	5.63%	6.08	0.00069
	Unknown	108	0.0123	0.00%	0.00	0.00000
Supermarket - Freezer	Yes	119	0.0136	0.63%	0.74	0.00009
	No	349	0.0398	1.88%	6.54	0.00075

Facility Type	PA TRM 2013 (Source 1)			Focus on Energy		
	Pre-Existing Curtains	Energy Savings (per sq ft)**	Demand Reduction (per sq ft)***	Measure Mix	Weighted Energy Savings (per sq ft)	Weighted Demand Reduction (per sq ft)
	Unknown	349	0.0398	0.00%	0.00	0.00000
Convenience Store - Cooler	Yes	5	0.0006	5.63%	0.28	0.00003
	No	20	0.0023	16.88%	3.38	0.00039
	Unknown	11	0.0013	0.00%	0.00	0.00000
Convenience Store - Freezer	Yes	8	0.0009	1.88%	0.15	0.00002
	No	27	0.0031	5.63%	1.52	0.00017
	Unknown	17	0.002	0.00%	0.00	0.00000
Restaurant - Cooler	Yes	8	0.0009	11.25%	0.90	0.00010
	No	30	0.0034	33.75%	10.13	0.00115
	Unknown	18	0.002	0.00%	0.00	0.00000
Restaurant - Freezer	Yes	34	0.0039	3.75%	1.28	0.00015
	No	119	0.0136	11.25%	13.39	0.00153
	Unknown	81	0.0092	0.00%	0.00	0.00000
Refrigerated Warehouse	Yes	254	0.029	0.00%	0.00	0.00000
	No	729	0.0832	0.00%	0.00	0.00000
	Unknown	287	0.0327	0.00%	0.00	0.00000
Focus on Energy Small Business Program Savings Values (per sq ft)					**45.00**	**0.00514**

* Sum values may differ due to rounding.

* The 2013 Pennsylvania TRM uses the Tamm Equation to determine electricity savings: $kWh = 365 * t_{OPEN} * (\eta_{NEW} - \eta_{OLD}) * 20 * CD * A * \{[(T_i - T_r)/T_i] * g * H\}^{0.5} * 60 * (\rho_i * h_i - \rho_r * h_r) / (3{,}413 * COP_{ADJ})$

*** $kW_{SAVED} = kWh_{SAVED} / 8{,}760$

The unit of measurement for strip curtains is per linear foot of doorway width. It is assumed that all walk-in unit doors are 7 feet tall. The table below shows the energy savings per square foot to linear foot comparison for determining deemed savings.

Conversion of Energy Savings

Savings Type	Savings (per sq ft)	Door Height (Ft)	Deemed Value per Linear Foot
Annual Electricity Savings (kWh/year)	45	7	315
Demand Reduction (kW)	0.0051	7	0.036
Annual Natural Gas Savings (therms/year)	0	7	0

Using the EUL, the table below shows updated savings values for strip curtains.

Deemed Annual Savings

Savings Type	Annual Savings	EUL	Lifecycle Savings
Annual Electricity Savings (kWh/year)	315	4	1,260
Annual Natural Gas Savings (therms/year)	0	4	0

Assumptions

The primary cause of air infiltration into walk-in coolers and freezers is the air density difference between two adjacent spaces of different temperatures. The total refrigeration load due to infiltration through the main door into the unit depends on the temperature differential between the refrigerated and non-refrigerated airs, the door area and height, and the duration and frequency of door openings.

The avoided infiltration depends on the barrier efficacy of the newly installed strip curtains, and on the efficacy of the supplanted infiltration barriers, if applicable. The calculation of the refrigeration load due to air infiltration and the energy required to meet that load is rather straightforward, but relies on critical assumptions regarding the aforementioned operating parameters. The calculation for this measure follows the Pennsylvania TRM[1] calculation for Measure 3.17: Strip Curtains for Walk-In Freezers and Coolers. The assumptions in that protocol are based on values that were determined by direct measurement and monitoring of over 100 walk-in units in the 2006-2008 evaluation for the California Public Utility Commission.

Within the TRM calculation, the kW demand reduction is simplistic, but should be noted as a major assumption. The below quote is from Page 259 of the 2013 Pennsylvania TRM;

> “The peak demand reduction is quantified by multiplying savings per square foot by area. The source algorithm is the annual energy savings divided by 8760. This assumption is based on general observation that refrigeration is constant for food storage, even outside of normal operating conditions. This is the most conservative approach in lieu of a more sophisticated model.
>
> $$\Delta kW_{PEAK} = \Delta kWh / 8760$$”

There is no code requiring strip curtains for remodeling walk-in coolers and freezers.

Assumptions for Facility Types and Technology

The assumed levels of facility types within the Small Business Program for Focus on Energy are based on the Program Implementer’s experience between July 2012 and April 2013 (Staples Energy). Although data was not collected on existing walk-in coolers and freezers from the existing customer list, that list was categorized to differentiate restaurants, convenience stores (including liquor stores and florists), and supermarkets (including meat markets and fish markets).

The table below details the number of customers the Program Implementer visited in each category and the estimated number that will have walk-in refrigeration. The customer size in the small business sector indicates the amount of facilities that have walk-in refrigeration, and does not represent the standard mix for the total marketplace.

Percentage of Walk-In Refrigerators by Facility Type

Facility Type	Customer Visits	Percentage with Walk-In Refrigeration	Number with Walk-In Refrigeration	Percentage of Total Facilities
Restaurant	424	33%	139.92	59%
Convenience Store	96	70%	67.2	28%
Supermarket	39	80%	31.2	13%
Total	**559**		**238.32**	**100%**

The calculation uses a slightly more conservative number by reducing the supermarket total to 10% and increasing the convenience store and restaurant totals slightly.

The assumptions for the refrigerator/freezer mix were roughly determined from the same list of customers, broken out by type of facility. The assumptions included determining the numbers of freezers present at the following restaurant types: fast food, Asian cuisine, and fry kitchens. The supermarket freezer components are meat markets, fish markets, and an estimated amount of rural groceries.

Percentage of Walk-In Freezers by Facility Type*

Facility Type	Customer Visits	Number with Walk-In Freezer	Percentage with Walk-In Freezer	Percentage of Total Facilities
Restaurant	424	123	30%	22%
Convenience Store	96	0	0%	0%
Supermarket	39	19	50%	3%
Total	**559**	**142**		**25%**

* Percentages are rounded up

Sources

1. GDS Associates, Inc. The Measure Life Report for Residential and Commercial/Industrial Lighting and HVAC Measures. June 2007.
2. *Pennsylvania Technical Reference Manual*. 2013. http://www.puc.state.pa.us/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx
3. Commercial Facilities Contract Group. *2006-2008 Direct Impact Evaluation.* http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf
4. WESCO Distribution Pricing ($45.00) + Labor ($5.00) = $50.00

Revision History

Version Number	Date	Description of Change
01	04/22/2013	Initial submittal
02	01/2019	Removed MMID 3284

Renewable Energy

Ground Source Heat Pump, Natural Gas and Electric Backup

	Measure Details
Measure Master ID	Ground Source Heat Pump: Electric Back-Up, 2820 Natural Gas Back-Up, 2821
Measure Unit	Per heat pump
Measure Type	Prescriptive
Measure Group	Renewable Energy
Measure Category	Geothermal
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	3,476
Peak Demand Reduction (kW)	0.8277
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	52,140
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Based on actual program data in current year

Measure Description

This measure is installing residential-sized geothermal (ground-source) heat pump systems in non-residential applications. Geothermal heat pump systems use the earth as a source of heating and cooling through the installation of an exterior underground loop working in combination with an interior heat pump unit. The measure provides a centralized heating and cooling system similar to that of a standard air-source heat pump.

Description of Baseline Condition

The baseline condition is an air-source heat pump of 13 SEER and 7.7 HSPF.[4]

Description of Efficient Condition

The efficient condition is a ground-source heat pump of 3.5 COP and 15 EER with either a multi-compressor or a multi-stage compressor as well as an ECM air handler. Additionally, the procedures followed when installing the equipment must conform to the ACCA Standard 5 Quality Installation requirements.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (EFLH_{COOL} * Btu/h_{COOL} * (1 / SEER_{BASE} – 1 / (EER_{EE} * 1.02))) / 1{,}000 + (EFLH_{HEAT} * Btu/h_{HEAT} * (1 / HSPF_{BASE} – 1 / (COP_{EE} * 3.412))) / 1{,}000$

Where:

$EFLH_{COOL}$ = Full-load cooling hours (= 599)[5]

Btu/h_{COOL} = Cooling capacity of equipment (= 40,089 Btu/hour)[3]

$SEER_{BASE}$ = Seasonal energy efficiency ratio of baseline equipment (= 13)[4]

EER_{EE} = Energy efficiency ratio of efficient equipment (= 22.43 kBtu/kWh)[3]

1.02 = Factor to determine SEER based on its EER

1,000 = Kilowatt conversion factor

$EFLH_{HEAT}$ = Full-load heating hours (= 1,466)[6]

Btu/h_{HEAT} = Heating capacity of equipment (= 30,579 Btu/hour)[3]

$HSPF_{BASE}$ = Heating seasonal performance factor of baseline equipment (= 7.7 kBtu/kWh)[4]

COP_{EE} = Coefficient of performance of efficient equipment (= 4.18)[3]

3.412 = Conversion from watts to Btu

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Btu/h_{COOL} * (1 / EER_{BASE} – 1 / EER_{EE})) / 1{,}000 * CF$

Where:

EER_{BASE} = Energy efficiency ratio of baseline equipment (= 12.75)[4]

CF = Coincidence factor (= 0.61)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

This system life expectancy is generally constrained by the heat pump exchanger and compressor equipment. The actual ground loop installation often has a much longer life expectancy.

The runtime differs for nonresidential and residential applications due to internal heat gains, additional ventilation requirements for nonresidential buildings, times of occupancy, and occupancy numbers. Heating run-times from the 2013 Pennsylvania TRM Draft for Commercial HVAC were used and adjusted using EFLH from the U.S. DOE ENERGY STAR Air Source Heat Pump Calculator[5] to account for differences in weather conditions. This resulted in a 42% reduction in hours from ENERGY STAR, or 1,466 hours.

Equivalent Full-Load Heating Hours from Pennsylvania TRM and ENERGY STAR

City	PA TRM (hours)[4]	ENERGY STAR (hours)
Allentown	1,098	2,492
Erie	1,720	2,901
Harrisburg	1,406	2,371
Philadelphia	1,461	2,328
Pittsburgh	1,411	2,380
Scranton	1,501	2,532
Williamsport	1,483	2,502
Average	**1,440**	**2,501**

Equivalent Full-Load Heating Hours from Wisconsin TRM and ENERGY STAR

City	ENERGY STAR (hours)[8]	WI TRM (hours)
Green Bay	2,641	1,521
La Crosse	2,445	1,408
Madison	2,547	1,467
Milwaukee	2,548	1,467
Average	**2,545**	**1,466**

Equivalent Full-Load Heating and Cooling Hours for Average Commercial Building

Building Type	$EFLH_{HEAT}$[6]	$EFLH_{COOL}$[5]
Average Commercial	**1,466**	**599**

The installation of a ground-source heat pump is more likely to happen in the northern part of the state due to the lack of available natural gas. A lower coincidence factor than residential (0.68)[5] and nonresidential (0.80)[5] air conditioning is used to account for the reduced occurrence of operation.

Coincidence Factors by Sector

Sector	Air Conditioner	GSHP
Residential	0.68[5]	0.50[3]
Nonresidential	0.80[7]	0.61

Sources

1. GDS Associates, Inc. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*. June 2007. https://library.cee1.org/system/files/library/8842/CEE_Eval_MeasureLifeStudyLights%2526HVACGDS_1Jun2007.pdf
2. Energy Center of Wisconsin. *Update of Geothermal Analysis.* p. 19–21. August 31, 2009.
3. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” June 2, 2008. http://www.deeresources.com/
   DEER model runs were weather normalized for statewide use by population density.
4. International Energy Conservation Code. Table 503.2.3(1). 2009.
5. See similar measures A/C Split System, ≤ 65 MBh: SEER 14, 2194; SEER 15, 2192; and SEER 16+, 2193.
6. *Pennsylvania Technical Reference Manual*. 2013. Draft for Commercial HVAC.
   Adjusted values using EFLH from the U.S. DOE ENERGY STAR Air Source Heat Pump Calculator to account for differences in weather conditions.

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	10/2017	Updated EUL

Vending and Plug Loads

Engine Block Heater Timer

	Measure Details
Measure Master ID	Timer, Engine Block Heater, 2810
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	Vending & Plug Loads
Measure Category	Controls
Sector(s)	Agriculture
Annual Energy Savings (kWh)	738
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	11,070
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$25.00[2]

Measure Description

Engine block heater timers save energy by reducing the time that engine block heaters operate. Typically, block heaters are plugged in throughout the night. Using timers allows the heater to come on at a preset time during the night, rather than being on throughout the night. Beginning in September 2015, this measure is primarily being used for a Future Farmers of America Fundraiser coordinated by the Agriculture, Schools, and Government Implementer.

Description of Baseline Condition

The baseline measure is an engine block heater in use without a timer.

Description of Efficient Condition

The efficient measure is an engine block heater in use with a timer preset to power the heater on for fewer hours each night.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (P * hours * days * UF)$

Where:

P = Average power consumption of engine block heater (= 1.3 kW)[3]

hours = Reduction in number of hours block heater is used per night (= 9)[3]

days = Number of operating days per year (= 65)[3]
UF = Usage factor (= 0.97)[3]

Summer Coincident Peak Savings Algorithm

There are no peak savings since engine block heaters are not in use during the peak period.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

Inputs for the savings calculation were derived from a survey of 2015 Focus on Energy participants. Between September and November 2015, 115 customers requested 238 timers. During April and May 2016, 109 customers were surveyed via mail (four responses), 61 customers were emailed (six responses), and 31 customers were surveyed via phone (17 responses) for a total of 27 responses. This is a 23% customer response rate representing 65 of the 238 of timers (27%).

The survey revealed an average engine block heater use of 12 hours pre-timer and three hours post-timer. The difference of nine hours is the reduction in hours the block heater is used per night.

The survey also revealed that five timers were given away as gifts, and were omitted from the 'potential in use' data set. Of the remaining 60 timers, two were reported as not in use, resulting in 58 and a usage factor of 0.97.

Sources

1. Gutierrez, Alfredo. *Circulating Block Heater*. Prepared for the California Technical Forum. http://static1.squarespace.com/static/53c96e16e4b003bdba4f4fee/t/556f7c9ee4b0b65c3515c80c/1433369758093/Circulating+Block+Heater+Presentation_ver+2.pdf
   California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com/
2. Implementer research, 2013. Average online cost of Engine Block Heat Timer.
3. 2015 Survey Data (27 customers; 65 timers). See Assumptions.

Revision History

Version Number	Date	Description of Change
01	10/01/2015	Initial release
02	06/01/2016	Updated Assumptions values and source

Vending Machine and Beverage Cooler Controls

	Measure Details
Measure Master ID	Beverage Cooler Controls, 2202 Vending Machine Controls: Occupancy Based, Cold Beverage Machine, 2611 Occupancy Based, Snack Machine, 2612 Sales Based, Cold Beverage Machine, 2613
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	Vending & Plug Loads
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Measure Incremental Cost ($/unit)	Beverage cooler controls = $233.00 (MMID 2202)[1,2] Vending cold beverage machine = $258.00 (MMID 2611)[1,2] Vending snack machine = $224.00 (MMID 2612)[1,2] Vending cold beverage, sales based = $159.00 (MMID 2613)[2,3]

Measure Description

This measure is for the installation of controls to any of the following machines:

- Beverage Cooler: a self-contained, refrigerated cooler with glass front door(s) storing cold beverages in cans or bottles. Lights illuminate products inside plus any signs on the front.
- Beverage Vending Machine: a self-contained, refrigerated vending machine that dispenses cold beverages in cans or bottles. Lights illuminate signs on the front.
- Snack Vending Machine: a non-refrigerated vending machine that dispenses non-perishable food. Lights illuminate products inside plus any signs on the front.

The controls limit the operation of refrigeration systems and turn off lights during unoccupied hours, referred to as sleep mode. Units without controls have lighting and refrigeration operating 24/7, even if the space where the unit is located is not occupied 24/7. The controls periodically power up the unit at regular intervals to maintain product temperature and provide compressor protection. Adding controls can significantly reduce the energy consumption of refrigeration systems (if applicable) and lighting. For occupancy-based measures, units are put into sleep mode when a passive infrared occupancy sensor registers no occupancy for 15 minutes. For sales-based controls, a logic algorithm is used to turn off the compressor based on sales data, but leaves the display lighting and card reader on. ENERGY STAR–qualified cold beverage machines do not qualify for sales-based machines.

Description of Baseline Condition

The baseline condition is a beverage cooler, beverage vending machine, or snack vending machine that does not have controls, such that lights and refrigeration (if applicable) operate continuously 24/7.

Description of Efficient Condition

The efficient condition is a beverage cooler, beverage vending machine, or snack vending machine that has controls to turn off certain lights and limit refrigeration operation (if applicable) during unoccupied periods. The controls are assumed to be installed in locations where the system will be in sleep mode at least six hours per day.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{BASE} * SF$

Where:

kWh_{BASE} = Baseline annual consumption (= 1,546 kWh for beverage cooler; = 1,762 kWh for beverage vending machine; = 175 kWh for snack vending machine; see Assumptions)

SF = Savings factor (= 16.67% for non-sales-based machines; = 15% for sales-based machines; see Assumptions)

Summer Coincident Peak Savings Algorithm

There are no demand savings deemed for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)[1]

Deemed Savings

The calculated savings for each unit type is presented in the table below.

Energy Savings Values

Measure Description	MMID	Annual kWh	Lifecycle kWh
Beverage Cooler Controls	2202	258	1,290
Vending Machine Controls, Occupancy Based, Cold Beverage Machine	2611	294	1,470
Vending Machine Controls, Occupancy Based, Snack Machine	2612	29	145
Vending Machine Controls, Sales Based, Cold Beverage Machine	2613	264	1,320

Assumptions

The baseline energy consumption values for beverage coolers and beverage vending machines are determined by a federal standard.[4] The formulas for the maximum allowed kilowatt-hours per day are presented in the table below.

Baseline Energy Consumption Formulas for Beverage Coolers and Beverage Vending Machines

Machine Type	Maximum Allowed Consumption per Day (kWh)
Beverage Cooler	0.055 * Volume + 2.56
Beverage Vending Machine	0.073 * Volume + 3.16

The Volume in the above formulas is the refrigerated volume of the unit as defined in the federal standard. Using average volumes from ENERGY STAR product data,[5] the maximum allowed consumption per day and per year are presented in the table below.

Baseline Energy Consumption Values for Beverage Coolers and Beverage Vending Machines

Machine Type	Average Volume (cubic feet)	Maximum Allowed Consumption (kWh)	
		Per Day	Per Year
Beverage Cooler	30.5	4.24	1,546
Beverage Vending Machine	22.8	4.83	1,762

The baseline energy consumption for snack vending machines is based on a 20-watt light.[1]

$$kWh_{BASE} = 0.02 \text{ kW} * \text{Hours On per Year}$$
$$= 0.02 \text{ kW} * 8{,}760 \text{ hours/year}$$
$$= 175 \text{ kWh/year}$$

The percentage savings is the percentage of each day the units will be in sleep mode: this workpaper assumes four hours per day.[1]

$$\% \text{ savings} = 100 * 4 \text{ hours} / 24 \text{ hours/day}$$
$$= 16.67\%$$

However, for sales-based controls, the light stays on during the four hours that the refrigeration system is controlled, so the savings factor is decreased such that there are 29 kWh less annual savings (0.02 kW * 4 hours/day * 365 days/year = 29 kWh), for a savings factor of 15%.

The assumed material costs for each unit type is presented in the tables below.

Average Cost for Beverage Cooler Controllers[2]

Model Number	Material Cost
CM150	$169
CM151	$161
CM170	$169
CM171	$161
Average	**$165**

Average Cost for Beverage Vending Machine Controllers[2]

Model Number	Material Cost
VM150	$189
VM151	$181
VM160	$199
VM170	$189
VM171	$181
VM180	$199
VM181	$191
Average	**$190**

Average Cost for Snack Machine Controllers[2]

Model Number	Material Cost
SM150	$160
SM151	$152
SM170	$160
SM171	$152
Average	**$156**

The assumed installation costs for each unit type is presented in the table below. Labor costs are assumed to be one hour at $68 per hour.[1]

Costs for Materials and Installation

Measure Description	MMID	Materials	Labor[1]	Total
Beverage Cooler Controls	2202	$165	$68	$233
Vending Machine Controls				
Occupancy Based, Cold Beverage Machine	2611	$190	$68	$258
Occupancy Based, Snack Machine	2612	$156	$68	$224
Sales Based, Cold Beverage Machine	2613	$91[3]	$68	$159

Sources

1. Pacific Gas & Electric. "PGECOREF111 R5 Vending Machine Controller." Workpaper. (Use Category: "Appliance or Plug Load", PA: "PGE", Other Fields: "Any") Measure life: p. 4. Hours per day off: p. 6. Light wattage: p. 12. Labor cost: p. 16. November 10, 2015. http://deeresources.net/workpapers
2. Website for USA Tech, the manufacturer of CoolerMiser for beverage coolers, VendingMiser for beverage vending machines, and SnackMiser for snack vending machines. Accessed May 2018. https://store.usatech.com/collections/energymiser-products
3. VendingMiserStore.com. Model VM2iQ. Accessed May 2018. https://www.vendingmiserstore.com/product/energymiser-vending-miser-internal-unit-model-vm150?gclid=Cj0KCQjw5-TXBRCHARIsANLixNxtO00k8MlEY1DyQ-WPMOfbvTolGpURNlbleQJMRN4K4tQwNnI8YJlaAsATEALw_wcB
4. Federal regulation: Title 10, Chapter II, Subchapter D, Part 431, Subpart Q, Section 431.296. Accessed May 2018. https://www.ecfr.gov/cgi-bin/text-idx?SID=e039793352d10c6ab6a2f36d45f5960b&mc=true&node=se10.3.431_1296&rgn=div8
5. ENERGY STAR. "Vending Machines Qualifying Product List. Accessed May 2018. https://www.energystar.gov/productfinder/product/certified-vending-machines/results.

Revision History

Version Number	Date	Description of Change
01	05/31/2018	Initial TRM entry

Residential Measures

Through the residential portfolio, Wisconsin Focus on Energy delivers information, incentives, and implementation support to help residential customers in single family homes of one unit and multifamily buildings of four or more units access energy-efficient technologies that help control their electricity and natural gas use. These efficient technologies include, but are not limited to, lighting, heating and cooling systems, home appliances, insulation and air sealing services, and residential renewable energy systems.

Boilers and Burners

Combination Boiler, Natural Gas, AFUE ≥ 0.95

	Measure Details
Measure Master ID	Boiler, 95%+ AFUE, With DHW, Natural Gas, 3559, 3778
Measure Unit	Per combination boiler
Measure Type	Prescriptive
Measure Group	Boilers & Burners
Measure Category	Boiler
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	296
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	5,920
Water Savings (gal/year)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	$2,803.00[2]

Measure Description

Space heating boilers are pressure vessels that transfer heat to water for use in space heating. Boilers either heat water using a heat exchanger that works like an instantaneous water heater or by adding/connecting a separate tank with an internal heat exchanger to the boiler. A combination boiler contains a separate heat exchanger that heats water for domestic hot water use.

Qualifying combination boilers must be whole-house units used for both space conditioning (boiler) and hot water heating with one appliance and energy source. Only participants who have a natural gas account with a participating natural gas utility are eligible for this rebate.

Description of Baseline Condition

The baseline condition is a boiler with the federal minimum of 82% AFUE[2] and a residential, natural gas-fueled, 0.575 EF storage water heater.[3] New federal efficiency standards that took effect in April 2015 raised the minimum EF for baseline units from 0.575 to 0.600. The criteria date was rounded to January 1, 2016 since the code took affect mid-year 2015.

Description of Efficient Condition

The efficient condition is a combination boiler unit with boiler AFUE of 95% or greater. The combination boiler must have a sealed combustion unit and be capable of modulating the firing rate. Measures that do not qualify for this incentive include boilers with a storage tank and redundant or backup boilers.

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}} = \text{Therm}_{\text{SAVED - BOILER}} + \text{Therm}_{\text{SAVED – WH}}$

$\text{Therm}_{\text{SAVED - BOILER}} = \text{BC} * \text{EFLH}\ (1 – \text{EFF}_{\text{BASE}} / \text{EFF}_{\text{EE}}) / 100$

$\text{Therm}_{\text{SAVED – WH}} = ((\text{GPD} * 365 * 8.33 * 1 * \Delta T_w)/100{,}000) * ((1/\text{RE}_{\text{BASE}}) – (1/\text{E}_{\text{C,EE}})) + ((\text{UA}_{\text{BASE}} / \text{RE}_{\text{BASE}}) – (\text{UA}_{\text{EE}} / \text{E}_{\text{C,EE}})) * (\Delta T_s * 8{,}760)/100{,}000$

Where:

BC = Boiler capacity (= 110 MBtu/hour)[3]

EFLH = Equivalent full-load hours (= 1,158)[4]

EFF_{BASE} = Baseline AFUE (= 82%)[5]

EFF_{EE} = Efficient AFUE (= 95%)

100 = Conversion

GPD = Gallons of hot water used by the home (= 42.75 per day)[6,11]

365 = Days per year

8.33 = Density of water (lb/gal)

1 = Specific heat of water (Btu/lb °F)

ΔT_w = Average difference between cold water inlet temperature (52.3°F) and hot water delivery temperature (125°F) (= 72.7°F)[7]

100,000 = Conversion from Btu to therm

RE_{BASE} = Recovery efficiency of the baseline tank type water heater (= 76%)[8]

$\text{E}_{\text{C,EE}}$ = Combustion efficiency of combination boiler used to provide DHW (= 95%)[9]

UA_{BASE} = Overall heat loss coefficient of baseline tank-type water heater (= 14.0 Btu/hr-°F) [10]

UA_{EE} = Overall heat loss coefficient of combination boiler (=0 Btu/hr-°F)

ΔT_S = Temperature difference between stored hot water (125°F) and ambient indoor temperature (65°F) (= 60°F)

8,760 = Hours per year

Summer Coincident Peak Savings Algorithm

There is no peak demand reduction for this measure.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}} = \text{Therm}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (= 20 years)[1]

Assumptions

Because the efficiency of a residential water heater is measured in EF, the true thermal efficiency and overall heat loss coefficient (UA_{BASE}) is not available. A TE of 76% and a UA_{BASE} of 14 is assumed.

The overall heat loss of the combination heater is assumed to be 0 Btu/hr-°F due to the minimal amount of domestic hot water stored within the unit. The average difference of 60°F assumes pipe and ambient air temperatures of 125°F and 65°F, respectively.

Gallons per day are calculated by fitting a polynomial equation to data from Table 3 of the Florida Solar Energy Center study.[6] An average value of 2.43 occupants per home was used for Wisconsin, based on U.S. Census data.[11] The fitted equation is GPD = -0.0089 * x2 + 16.277 * x + 3.25, where x is the average number of occupants per home.

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Navigant Consulting. A Report on Costs in Six Northeast & Mid-Atlantic Markets. p. A-10. NEEP Regional Evaluation, Measurement & Verification Forum, 2011. Mid-sized (126 MBh) Residential Combination Heat/Hot Water Incremental Cost 95 CAE is $2,803.00.
3. Average input capacity of boilers under 300 MBh in the 2013 SPECTRUM Database.
4. Cadmus. Focus on Evaluated Energy Deemed Savings Changes. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf Residential boilers are assumed to have sizing practices similar to furnaces, and therefore have the same EFLH.
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6. Florida Solar Energy Center. *Estimating Daily Domestic Hot-Water Use in North American Homes*. June 30, 2015. http://www.fsec.ucf.edu/en/publications/pdf/FSEC-PF-464-15.pdf
7. Public Service Commission of Wisconsin. Request for Proposals. Issued for Mass Markets Portfolio Residential Energy Efficiency Program Implementation. July 26, 2011.
8. Air-Conditioning, Heating, and Refrigeration Institute. "RWH Search." http://www.ahridirectory.org/ahridirectory/pages/rwh/defaultSearch.aspx. Most common RE for non-heat pump water heaters.
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10. United States Department of Energy. Technical Support Document: Energy Efficiency Standards for Consumer Products, Residential Water Heaters, Including Regulatory Impact Analysis. 2000.
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Revision History

Version Number	Date	Description of Change
01	11/03/2014	Original
02	12/17/2014	Changed ΔT_S to match residential indirect, provided Assumptions for value used in calculation, and provided justification for UA_{EE} value
03	12/2018	Updated gallons per day calculation and EFLH values

Hot Water Boiler, 95%+ AFUE

	Measure Details
Measure Master ID	Hot Water Boiler, 95%+ AFUE, 1983, 3780
Measure Unit	Per boiler
Measure Type	Prescriptive
Measure Group	Boilers & Burners
Measure Category	Boiler
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	202
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	4,040
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	$3,105.00[4]

Measure Description

Space heating boilers are pressure vessels that transfer heat to water for use primarily in space heating applications. Boilers either heat water using a heat exchanger that works like an instantaneous water heater, or by the addition of a separate tank with an internal heat exchanger that is connected to the boiler.

High-efficiency space heating boilers are applicable to any residential boiler used for space heating. They are not applicable to boilers used for process end uses, DHW, pools, or spas. The space heating boiler qualifications are listed in the table below.

Qualifications for Space Heating Boilers

Type	Input Rating	Required Efficiency
95% Efficient Boiler	≤ 300 MBh	AFUE ≥ 95%

Description of Baseline Condition

The baseline equipment is a hot water boiler with 82% AFUE.[2]

Description of Efficient Condition

Energy-efficient space heating boilers often feature high-efficiency and/or low-Nox burners, and typically have features such as forced air burners, relatively large heat exchange surfaces, and/or use heat recovery from stack gases.

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}} = \text{BC} * \text{EFLH} * (\text{EFF}_{\text{EE}} / \text{EFF}_{\text{BASELINE}} - 1)$

Where:

BC = Boiler capacity (= 110 MBtu/hour)[5]
EFLH = Equivalent full-load hours (= 1,158)[3]
$\text{EFF}_{\text{BASELINE}}$ = AFUE of baseline measure (= 82%)
EFF_{EE} = AFUE of efficient measure (= 95%)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}} = \text{Therm}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (= 20 years)[1]

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Energy Efficiency and Renewable Energy Office. *Annual Fuel Utilization Efficiency.* Section 10 CFR 430.23(n)(2). http://www.regulations.gov/#!documentDetail;D=EERE-2006-STD-0102-0009.

   Cadmus. *Focus on Energy Evaluated Deemed Savings Changes.* November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf Residential boilers are assumed to have sizing practices similar to furnaces, and therefore have the same EFLH.
3. In 2013, Program Implementer surveyed 40 Trade Allies and took the average reported cost for an 82% boiler and subtracted that amount from the average reported cost for a 95% boiler.
4. Average input capacity of boilers under 300 MBh in the 2013 SPECTRUM database.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	01/2015	MMIDs 1982 and 1978 deactivated and removed
03	12/2018	Updated EFLH and savings algorithm

Natural Gas Boiler, ≥ 90% AFUE

	Measure Details
Measure Master ID	Boiler, ≥ 90% AFUE, Natural Gas, 2747
Measure Unit	Per MBh
Measure Type	Custom
Measure Group	Boilers & Burners
Measure Category	Boiler
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	1.84
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	36.8
Water Savings (gal/year)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	$50.82/MBh[4]

Measure Description

High efficiency sealed combustion, condensing, and modulating boilers operate by taking advantage of condensing to lower energy consumption. Condensing boilers are designed to capture the latent heat of condensation in the form of water vapor in the exhaust stream. Capturing this latent heat produces high efficiency levels. For a boiler to operate in condensing mode, its return water temperature should be kept below 120°F. In order to capture as much latent heat as possible, condensing boilers are made from stainless steel or other corrosion resistant materials. Chimney liners must be installed for boilers that are replacing a naturally drafting unit that was vented through the same flue as a water heater. Flue closure protocols must be followed when the chimney that will used by the replacement unit was not in use for the previous equipment.

Description of Baseline Condition

The baseline equipment is an 82% AFUE boiler.[2]

Description of Efficient Condition

The efficient equipment is an 85% to 90%+ AFUE boiler[3] that is capable of modulating the firing rate, has integrated input/output reset control, and is used for space heating. Industrial process or DHW applications do not qualify. Redundant or backup boilers do not qualify.

Annual Energy-Savings Algorithm

These savings are per MBh of input boiler capacity.

$Therm_{SAVED} = BC * EFLH * (EFF_{EE} / EFF_{BASELINE} - 1) / 100$

Where:

BC = Boiler capacity in MBh (=1)
EFLH = Equivalent full-load hours (= 1,890)[3]
$EFF_{BASELINE}$ = AFUE of baseline measure (=82%)
EFF_{EE} = AFUE of efficient measure (=85-90%)
100 = Conversion factor from MBtu to therms

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 20 years)[1]

Assumptions

The boiler baseline efficiency is based on the EISA requirements of 82%.

Sources

1. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” June 2, 2008. http://www.deeresources.com/
2. Energy Efficiency and Renewable Energy Office. *Annual Fuel Utilization Efficiency*. Section 10 CFR 430.23(n)(2). http://www.regulations.gov/#!documentDetail;D=EERE-2006-STD-0102-0009.
3. Full load hours for all residential natural gas measures estimate from: Pigg and Nevius. *Electricity Use by New Furnaces.* 2000. http://www.ecw.org/sites/d3efault/files/230-1.pdf
4. Illinois Technical Reference Manual. p. 141. 2013. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	01/2015	Savings changed from per unit to per MBh

Boiler Tune-Up, Single Family

	Measure Details
Measure Master ID	Boiler Tune-Up, Single Family, 4659
Measure Unit	Per tune-up
Measure Type	Prescriptive
Measure Group	Boilers & Burners
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	37
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	74
Water Savings (gal/yr)	0
Effective Useful Life (years)	2[1]
Incremental Cost ($/unit)	$150.00[2]

Measure Description

This measure is for a residential boiler that provides space heating. The boiler tune-up will improve efficiency by cleaning burners, the combustion chamber, and burner nozzles. The tune-up also includes adjusting airflow if needed and ensuring proper temperature rise, and may also include adjustments to the burner and natural gas inputs. The tune-up includes a check of venting, safety controls, and combustion air intake. Combustion efficiency is to be measured before and after the tune-up using an electronic flue gas analyzer.

Description of Baseline Condition

The baseline measure is an 82% AFUE boiler.

Description of Efficient Condition

The efficient condition is a boiler tuned up to nameplate efficiency by a technician. The maximum boiler size for measure eligibility is 300,000 Btu per hour. The incentive is available once in a 24-month period. The incentives are only available for space heating equipment.

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}} = \text{BOF} * \text{CAP} * \text{SF} * \text{HDD} * 24 / [(\text{T}_{\text{INDOOR}} - \text{T}_{\text{OUTDOOR}}) * \text{AFUE}_{\text{PRE}} * 100]$

Where:

BOF = Boiler oversize factor (= 77%, deemed)
CAP = Size of the boiler being tuned (= 108 MBh)[3]
SF = Savings factor (= 1.6%, deemed)[4]
HDD = Heating degree days (= 7,699)[4]
T_{INDOOR} = Indoor design temperature (= 65°F)[4]
$\text{T}_{\text{OUTDOOR}}$ = Outdoor design temperature (= -15°F)[4]
AFUE_{PRE} = AFUE of boiler prior to tune-up (= 82%)[5]
100 = Conversion factor from MBh to therm

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}} = \text{Therm}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (= 2 years)[1]

Sources

1. Illinois Energy Efficiency Statewide Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 6.0*. Volume 3. p. 148. February 8, 2017. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_3_Res_020817_Final.pdf
   Value for furnace tune-up used.
2. CLEAResult. Informal survey of four Wisconsin Trade Allies. December 2017.
3. Focus on Energy. *SPECTRUM Focus Prescriptive Database*.
   Program data collected from 2015 through 2017 shows that the average capacity of 110 delivered boilers is 108 MBh.

4. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Program: Deemed Savings Manual V1.0." Updated March 22, 2010. p. 4-11 (saving factor). https://focusonenergycom/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf.
5. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation ACES: Default Deemed Savings Review." Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Energy Efficiency and Renewable Energy Office. "2008-07-28 Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Furnaces and Boilers; Final rule; technical amendment." Federal standard for residential boilers. Effective August 27, 2008. https://www.regulations.gov/document?D=EERE-2006-STD-0102-0009

Revision History

Version Number	Date	Description of Change
01	05/2018	Initial TRM entry

Building Shell

Air Sealing

	Measure Details
Measure Master ID	Air Sealing, 2745
Measure Unit	Per CFM leakage
Measure Type	Custom
Measure Group	Building Shell
Measure Category	Air Sealing
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	Varies by heating and cooling system
Peak Demand Reduction (kW)	Varies by heating and cooling system
Annual Therm Savings (Therms)	Varies by heating system
Lifecycle Energy Savings (kWh)	Varies by heating and cooling system
Lifecycle Therm Savings (Therms)	Varies by heating system
Water Savings (gal/year)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	Varies by project

Measure Description

Air sealing is the sealing of cracks, gaps, or other penetrations that allow unwanted outside air to enter or exit conditioned spaces. Air sealing reduces the load on heating and cooling equipment and can increase comfort. Typical areas to seal are attics, basements, crawlspaces, and around doors and windows. Blower door tests may be required to estimate the CFM of leaks before and after air sealing is performed. Savings are determined either by pre- and post-blower door testing or pre- and post-billing analysis.

Description of Baseline Condition

The baseline condition is no air sealing.

Description of Efficient Condition

The efficient condition is air sealing of cracks, gaps, or other penetrations that allow unwanted outside air to enter or exit conditioned spaces.

Annual Energy-Savings Algorithm

The savings algorithm is derived from an article in the ASHRAE Journal.[2]

$kWh_{SAVED} = kWh_{SAVED\ COOL} + kWh_{SAVED\ HEAT}$

For systems with cooling installed:

$kWh_{SAVED\ COOL} = [\{((CFM50_{PRE} – CFM50_{POST})) / N_{COOL}) * 60 * 24 * CDD * 0.018\} / (1{,}000 * Cool_{EFF})] * LM$

For systems with electric heat:

$kWh_{SAVED\ HEAT} = [((CFM50_{PRE} – CFM50_{POST}) / N_{HEAT}) * 60 * 24 * HDD * 0.018] / (3{,}412 * Heat_{EFF})$

For systems with natural gas heat:

$Therm_{SAVED} = [((CFM50_{PRE} – CFM50_{POST}) / N_{HEAT}) * 60 * 24 * HDD * 0.018] / (100{,}000 * Heat_{EFF})$

Where:

$CFM50_{PRE}$ = Blower door test result before air sealing is performed
$CFM50_{POST}$ = Blower door test result after air sealing is performed
N_{COOL} = Conversion factor for CFM from 50 Pascal to natural conditions (= 18.5 assuming normal shielding)
60 = Constant to convert minutes to hours
24 = Hours per day
CDD = Cooling degree days (= 565; see table below)
0.018 = Specific heat capacity of air in Btu/cubic feet – °F
1,000 = Kilowatt conversion factor
$Cool_{EFF}$ = Cooling system efficiency, Btu/W - hr (= 10 SEER if manufactured before 2006; = 13 SEER if manufactured in 2006 or later)
LM = Latent multiplier to convert the calculated sensible cooling savings to a value representing sensible and latent cooling loads (= 6.6 as an average in Chicago and Minneapolis)[2]
N_{HEAT} = Conversion factor for CFM from 50 Pascal to natural conditions, assuming normal shielding (= 18.5 if one story; = 16.5 if 1.5 stories; = 15.0 if two stories; = 14.1 if 2.5 stories; = 13.3 if three stories)[3]
HDD = Heating degree days (= 7,616; see table below)

Cooling Degree Days and Heating Degree Days by Location

Location	HDD[4]	CDD[4]
Milwaukee	7,276	548
Green Bay	7,725	516
Wausau	7,805	654
Madison	7,599	630
La Crosse	7,397	729
Minocqua	8,616	423
Rice Lake	8,552	438
Statewide Weighted	**7,616**	**565**

3,412 = Conversion factor from kWh to Btu

$Heat_{EFF}$ = Heating system efficiency (fraction of heat output per unit of energy input expressed as a decimal)

100,000 = Conversion factor from Btu to therms

For systems with electric heat, $Heat_{EFF} = HSPF/3.412$

- Heat pumps manufactured before 2006, $Heat_{EFF} = 6.8/3.412 = 1.99$
- Heat pumps manufactured in 2006 or later, $Heat_{EFF} = 7.7/3.412 = 2.26$
- Electric resistance, $Heat_{EFF} = 1.0$

Installed AFUE for systems with natural gas heat:

- $Heat_{EFF} = 0.92$ for condensing systems; see Assumptions
- $Heat_{EFF} = 0.80$ for non-condensing systems; see Assumptions

Summer Coincident Peak Savings Algorithm

For systems with central air conditioning:

$$kW_{SAVED} = (kWh_{SAVED\ COOL} / EFLH_{COOL}) * CF$$

Where:

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 410; see table below)

CF = Coincidence factor (= 0.66)[6]

Supporting Inputs for Load Hours in Several Wisconsin Cities

Location	$EFLH_{COOL}$[5]	Weighting by Participant
Green Bay	344	22%
La Crosse	323	3%
Madison	395	18%
Milwaukee	457	48%
Wisconsin Average	380	9%
Overall	**410**	

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 20 years)[1]

Assumptions

Ninety-two multifamily sites were visited as part of the 2016 *Potential Study*,[7] and the heating AFUE (for natural gas furnaces or boilers) was recorded at many of these sites.

Of these, 17 sites had known central noncondensing AFUE values, with an average AFUE of 80.81%. Eight sites had known in-unit noncondensing AFUE values, with an average of 79.79%. Of the 92 sites visited, 58.7% had central heating and 41.3% had in-unit heating. Therefore, the average AFUE for natural gas heating in multifamily sites is 80%.

Also from this sample, six sites had known central condensing AFUE values, with an average of 91.67%. Seven sites had known in-unit condensing AFUE values, with an average of 92.21%. These groups combine, using the central versus in-unit weighting outlined above, for an average condensing multifamily AFUE of 92%.

Sources

1. GDS Associates. *Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures*. 2007. http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf
2. Harriman et al. "Dehumidification and Cooling Loads from Ventilation Air." ASHRAE Journal. Added the latent and sensible loads to determine the total (using averages from Chicago and Minneapolis to represent Wisconsin), then divided by the sensible load.

3. Lawrence Berkeley National Laboratory. *Building Performance Institute Building Analyst Technical Standards.* http://www.bpi.org/tools_downloads.aspx?selectedTypeID=1&selectedID=2
4. ASHRAE Estimation of Degree-Days: Fundamentals, Chapter 14. Calculated from TMY3 weather files of the seven Wisconsin locations using statewide weighted values calculated from 2010 U.S. Census data for Wisconsin.
5. *Illinois Statewide Technical Reference Manual.* Used average EFLH and CDD and applied to Wisconsin CDD.
6. Opinion Dynamics Corporation. *Delaware Technical Resource Manual.* April 30, 2012. http://www.dnrec.delaware.gov/energy/information/otherinfo/Documents/EM-and-V-guidance-documents/DELAWARE_TRM_August%202012.pdf
7. Cadmus. *2016 Potential Study for Focus on Energy.* Data maintained by Cadmus and Wisconsin PSC.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	05/2018	Updated based on Potential Study data

Air Sealing without Blower Door Test

	Measure Details
Measure Master ID	Air Sealing, Natural Gas Heat with Cooling, 4749 Air Sealing, Natural Gas Heat without Cooling, 4750 Air Sealing, Electric Heat with Cooling, 4751 Air Sealing, Electric Heat without Cooling, 4752
Measure Unit	Per conditioned square foot
Measure Type	Hybrid
Measure Group	Building Shell
Measure Category	Air Sealing
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$0.27[2]

Measure Description

Sealing air leaks in multifamily buildings reduces air infiltration by at least 10%. Sealing should be of the whole building, not just individual units, and should include caulking or spray foaming wall and roof penetrations, weatherstripping around doors and windows, and caulking other cracks as needed.

Description of Baseline Condition

The baseline condition is a multifamily building in its original condition.

Description of Efficient Condition

The efficient condition is a multifamily building with air leaks sealed sufficiently to reduce air infiltration by at least 10%.

Annual Energy-Savings Algorithm

Savings for air sealing are calculated when the corresponding systems are present. If not present, the respective savings values are considered zero. Savings are the sum of iterations over the full range of temperatures (-30°F to 100°F), for heating or cooling, broken into five-degree intervals. The total savings account for the distribution of the number of hours for each temperature interval.

$kWh_{SAVED} = kWh_{SAVED\_COOL} + kWh_{SAVED\_HEAT}$

$kWh_{SAVED\_COOL} = [60 * 0.075 * V * (H_{OUT} – H_{IN}) / (1{,}000 * EER)] * HOU_{COOL} * SF$

(This should be summed for each temperature bin above the outside temperature when the cooling system is “on.”)

$kWh_{SAVED\_HEAT} = [1.08 * V * (T_{HEAT} – T_{OUT}) / (COP * 3{,}412)] * HOU_{HEAT} * SF$

(This should be summed for each temperature bin below the outside temperature when the heating system is “on.” It equals zero if there is no electric heat.)

Where:

60 = Units conversion from minutes to hours

0.075 = Air density in lb/ft^3

V = Volume rate of infiltration air in CFM

= $ACH * A_{FLOOR} * HT_{CEILING} / 60$

Where:

ACH = Baseline air infiltration rate in air changes per hour (= 0.2 for buildings built in 2015 or later, = 1.0 during heating season for buildings built in 2014 or earlier, = 0.5 during cooling season for buildings built in 2014 or earlier; see Assumptions)[3]

A_{FLOOR} = Floor area of conditioned space in square feet (= user input)

$HT_{CEILING}$ = Average ceiling height in feet (= user input)

H_{OUT} = Enthalpy of outside air during the cooling season, in Btu/lb (= varies, from weather data)

H_{IN} = Enthalpy of inside air during the cooling season, in Btu/lb (= 28.3, see Assumptions)

1,000 = Conversion from Btu/h to MBh

EER = Efficiency of cooling equipment in Btu/watt (= user input)

HOU_{COOL} = Number of hours per year the outside temperature is above T_{COOL} + ΔT_{COOL} (= varies, from weather data)

Where:

T_{COOL} = Thermostat setpoint during cooling season (= 75°F, see Assumptions)

ΔT_{COOL} = Degrees above cooling thermostat setpoint (T_{COOL}) that cooling equipment is off (= 5°F, see Assumptions)

SF = Savings fraction (= 0.10, see Assumptions)

1.08 = Sensible heat constant in Btu/hr-CFM-°F

T_{HEAT} = Thermostat setpoint during heating season (= 65°F, see Assumptions)

T_{OUT} = Temperature of outside air during the heating season in °F (= from weather data)

COP = Coefficient of performance in watts of heat transferred per watt of electrical input (= 1.0 for electric resistance heat, = user input for heat pumps). If heat pump provides HSPF as efficiency, COP = HSPF / 3.412

3,412 = Conversion from Btu/h to kW

HOU_{HEAT} = Number of hours per year the outside temperature is below T_{HEAT} + ΔT_{HEAT} (= varies, from weather data)

Where:

ΔT_{HEAT} = Degrees below the heating thermostat setpoint (T_{HEAT}) that the heating equipment is off (= 10°F, see Assumptions)

$Therms_{SAVED} = [1.08 * V * (T_{HEAT} – T_{OUT}) / (Eff_{HEAT} * 100{,}000)] * HOU_{HEAT} * SF$

(This should be summed for each temperature below the outside temperature when the heating system is “on.” It equals zero if there is no natural gas heat.)

Where:

Eff_{HEAT} = Thermal efficiency of heating equipment, fraction (= user input)

100,000 = Conversion from Btu to therms

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = CF * kWh_{SAVED\_COOL} / HOU_{COOL}$

Where:

CF = Coincidence factor (= 0.68)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

The indoor enthalpy during the cooling season is 28.3 Btu/lb, which corresponds to 75°F and 50% relative humidity.

Thermostat setpoints are assumed to be 75°F for cooling and 65°F for heating; these averages account for setbacks for nighttime and unoccupied periods. The cooling system is enabled when the outside temperature is at least 5°F warmer than the thermostat cooling setpoint of 75°F. The heating system is enabled when the outside temperature is 10°F cooler than than the thermostat heating setpoint of 65°F. Between the temperatures of 55°F (= 65°F - 10°F) and 80°F (= 75°F + 5°F), both the heating and cooling systems are off.

The enthalpy for each temperature bin shown in the table is identical to those for MMID 2314. Values are population weighted from TMY3 weather files.

Temperature Intervals and Corresponding Enthalpies

Temperature Range	Range Midpoint	Enthalpy (Btu/lb)[7]
95°F to 100°F	97.5°F	42.118
90°F to 95°F	92.5°F	40.566
85°F to 90°F	87.5°F	39.454
80°F to 85°F	82.5°F	35.131
75°F to 80°F	77.5°F	32.397
70°F to 75°F	72.5°F	30.686
65°F to 70°F	67.5°F	28.335
60°F to 65°F	62.5°F	25.217
55°F to 60°F	57.5°F	21.965
50°F to 55°F	52.5°F	19.174
45°F to 50°F	47.5°F	17.107
40°F to 45°F	42.5°F	15.063
35°F to 40°F	37.5°F	12.954
30°F to 35°F	32.5°F	10.992
25°F to 30°F	27.5°F	9.132
20°F to 25°F	22.5°F	7.610
15°F to 20°F	17.5°F	5.871
10°F to 15°F	12.5°F	4.039
5°F to 10°F	7.5°F	2.526
0°F to 5°F	2.5°F	1.301
-5°F to 0°F	-2.5°F	0.075
-10°F to -5°F	-7.5°F	-1.387
-15°F to -10°F	-12.5°F	-2.521

Temperature Range	Range Midpoint	Enthalpy (Btu/lb)[7]
-20°F to -15°F	-17.5°F	-3.901
-25°F to -20°F	-22.5°F	-4.858
-30°F to -25°F	-27.5°F	-6.222

Temperature bin hours, population weighted for the state of Wisconsin, are listed in the table below.

Bin Hours[7]

Temperature Range	Green Bay	LaCrosse	Madison	Milwaukee	Average	Weighted Average
95°F to 100°F	0	7	0	5	3	**3**
90°F to 95°F	22	46	25	16	27	**21**
85°F to 90°F	62	121	86	59	82	**68**
80°F to 85°F	275	355	339	225	299	**267**
75°F to 80°F	398	445	486	400	432	**419**
70°F to 75°F	445	489	447	497	470	**474**
65°F to 70°F	675	762	723	692	713	**698**
60°F to 65°F	871	746	770	936	831	**877**
55°F to 60°F	647	583	605	545	595	**584**
50°F to 55°F	543	615	597	679	609	**626**
45°F to 50°F	404	444	491	471	453	**457**
40°F to 45°F	579	597	510	723	602	**638**
35°F to 40°F	777	826	905	883	848	**859**
30°F to 35°F	820	719	741	720	750	**748**
25°F to 30°F	507	425	396	423	438	**438**
20°F to 25°F	579	457	439	531	502	**520**
15°F to 20°F	443	319	353	390	376	**392**
10°F to 15°F	265	227	212	228	233	**234**
5°F to 10°F	178	208	164	125	169	**150**
0°F to 5°F	90	110	105	88	98	**93**
-5°F to 0°F	81	106	157	61	101	**88**
-10°F to -5°F	83	109	105	57	89	**76**
-15°F to -10°F	9	23	70	6	27	**21**
-20°F to -15°F	7	9	21	0	9	**6**
-25°F to -20°F	0	6	9	0	4	**2**
-30°F to -25°F	0	6	4	0	3	**1**

Four cities, shown in the table below, account for 91% of the population. The hours used for the remaining 9% of the population are the average of the four cities.

Population Weighting Percentages

Location	Weighting by Location
Green Bay	22%
Lacrosse	3%
Madison	18%
Milwaukee	48%
Average	**9%**

ACH Baseline and Reduction

Because of generally large site-to-site variation, calculating savings for air sealing measures normally requires performing a blower door test to measure the ACH value at 50 pascals of pressure difference. However, this is difficult to perform for multifamily sites—if performed on a single unit, the reading will reflect air leakage from adjacent units in addition to air leakage from the exterior. To perform on the entire building usually requires large and difficult coordination of residents.

This measure does not require a blower door test, instead employing prescriptive values for the baseline ACH and ACH reduction factor. These are conservative values selected based on several sources of data and subsequent reasoning. These data are presented in the table below.

Data for Baseline and Reduction in ACH

Data Source	Data Count	Baseline ACH		Average ACH Reduction %
		Summer	Winter	
2006 Lawrence Berkely National Laboratory study for the California Energy Commision[3]	24 units in four buildings	0.77	1.44	N/A
2014 and 2016 Focus on Energy data (SPECTRUM)	Seven buildings or units	0.56	1.00	55%
2008 Focus on Energy data (local)	344 units in 19 buildings	0.3		23%

In addition, the New York Technical Reference Manual[8] assumes (with no reference) baseline ACH values of 0.5 in summer and 1.0 in winter and an ACH reduction of 15%.

Based on these data and benchmarking, conservative values of an ACH of 1.0 in winter and 0.5 in summer and a reduction of 10% are assumed for older buildings. Actual ACH reduction is likely to vary greatly and the average value may be higher than this, but a deemed quantity for a highly variable value should be very conservative. In the future if enough blower door tests are performed for this measure, or if a billing analysis can be performed, these numbers will be revisited.

For new construction, defined as 2015 or later, the infiltration rate is determined by using the factor from ENERGY STAR[5] to convert from the infiltration rate at a pressure of 50 pascals (ACH50) to neutral pressure. For the zone where Wisconsin is located (Zone 2), this factor ranges from 11.7 for an exposed three-story building to 22.2 for a well-shielded one-story building. A moderate value of 15 is used. Dividing the code value of 3.0 ACH50[6] by 15 gives 0.2 ACH at neutral pressure.

Incremental Cost

Several sources were examined for the incremental cost.[2,9,10] The source chosen[2] was the most conservative (highest) and local to Wisconsin.

Sources

1. GDS Associates. *Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures*. 2007. http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf
2. Energy House LLC. Personal communication with Doug McFee on April 10, 2019 suggests $0.27 per square foot.
3. Lawrence Berkely National Laboratory. Public Interest Energy Research Program. *Indoor-Outdoor Air Leakage of Apartments and Commercial Buildings.* Figure 10 (p. 31). December 2006. https://www.energy.ca.gov/2006publications/CEC-500-2006-111/CEC-500-2006-111.PDF
4. Cadmus. “Focus on Energy Evaluated Deemed Savings Changes.” November 14, 2014 https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
5. ENERGY STAR Home Sealing Specification. Table 4 (p. 5). October 16, 2001. (https://www.energystar.gov/ia/home_improvement/home_sealing/ES_HS_Spec_v1_0b.pdf)
6. International Code Council. 2015 International Energy Conservation Code. Section R402.4.1.2 https://codes.iccsafe.org/content/IECC2015/chapter-4-re-residential-energy-efficiency
7. National Solar Radiation Data Base, 1991- 2005 Update: Typical Meteorological Year 3. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html
8. New York State Joint Utilities. *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs. Version 6*. p. 45 and 498. http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/72c23decff52920a85257f1100671bdd/$FILE/TRM%20Version%206%20-%20January%202019.pdf

9. Fixr. Home Air Sealing Cost. Accessed April 2019. https://www.fixr.com/costs/air-leaks-sealing. $350 - $600 for a 2,500 square foot home ($0.14 to $0.24 per square foot).
10. Steven Winter Associates. *Measure Guideline: Sealing Attics in Multifamily Buildings*. https://www.nrel.gov/docs/fy12osti/54720.pdf
$0.10 to $0.25 listed for air sealing and insulation.

Revision History

Version Number	Date	Description of Change
01	04/30/2019	Initial TRM entry

Attic Insulation, Multifamily

	Measure Details
Measure Master ID	Insulation, Attic: Natural Gas Heat with Cooling: Existing Insulation ≤ R-11, 3707 Existing Insulation R-12 to R-19, 3709 New Construction to R-49, 4824 Natural Gas Heat without Cooling: Existing Insulation R-12 to R-19, 3710 Existing Insulation ≤ R-11, 3708 New Construction to R-49, 4379 Electric Heat with Cooling: Existing Insulation ≤ R-11, 3711 Existing Insulation R-12 to R-19, 3713 New Construction to R-49, 4380 Electric Heat without Cooling: Existing Insulation ≤ R-11, 3712 Existing Insulation R-12 to R-19, 3714 New Construction to R-49, 4381
Measure Unit	Per square foot of roof (over conditioned space)
Measure Type	Prescriptive
Measure Group	Building Shell
Measure Category	Insulation
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/yr)	0
Effective Useful Life (years)	25[1]
Incremental Cost ($/unit)	Existing Insulation ≤ R-11 = $1.36 (MMIDs 3707, 3708, 3711, and 3712); Existing Insulation R-12 to R-19 = $1.04 (MMIDs 3709, 3710, 3713, and 3714); New Construction to R-49 = $0.85 (MMIDs 4824, 4379, 4380, and 4381)[2]

Measure Description

This measure is installing additional attic insulation in an existing or new construction multifamily residence, assumed to be heated with either natural gas or electricity and may be electrically cooled.

For existing buildings, an additional requirement of this measure is that the existing space have less than or equal to R-11 insulation or R-12 to R-19 excluding assembly section, and be insulated to a minimum of R-38. This specific measure detail was determined through additional analysis and calculations in reference to the Illinois TRM attic insulation methodologies.[3] A framing factor was not included in the calculation, as attic insulation is typically deep enough to completely cover the framing, making the framing impacts negligible. Attics with an existing R-value greater than R-19 and attics with an efficient condition of significantly greater than R-38 will be treated as custom measures.

For retrofits or new construction, heating systems other than electric resistance or a natural gas furnace or boiler will be treated as custom measures.

Description of Baseline Condition

For existing buildings, there are two tiers of baseline condition for this measure incentive: Tier 1 is an attic insulated to R-11 or less and Tier 2 is an attic insulated to between R-12 and R-19.

For new construction, the baseline is an attic insulated to R-38.

Description of Efficient Condition

For existing buildings, the efficient condition is an attic insulated to R-38 or greater.

For new construction, the efficient condition is an attic insulated to R-49 to match ENERGY STAR residential insulation recommendations.[10]

Annual Energy-Savings Algorithm

The following equations are used when the corresponding systems are present. If not present, the respective savings values are considered zero.

$$Therms_{SAVED} = [(1 / R_{BASE} – 1 / R_{EE}) * HDD * 24 * Area] / (100,000 * AFUE)$$

$$kWh_{SAVED} = kWh_{SAVED\_HEAT} + kWh_{SAVED\_COOL}$$

$$kWh_{SAVED\_HEAT} = [(1 / R_{BASE} – 1 / R_{EE}) * HDD * 24 * Area] / (1,000 * HSPF)$$

$$kWh_{SAVED\_COOL} = [(1 / R_{BASE} – 1 / R_{EE}) * CDD * 24 * Area] / (1,000 * SEER)$$

Where:

R_{BASE} = Existing R-value of attic (= R-11 or R-19 for existing buildings, = R-38 for new construction)

R_{EE} = Proposed R-value of attic after retrofit (= R-38 for existing buildings, = R-49 for new construction)

HDD = Heating degree days (= 7,616; see table below)

24 = Hours per day

Area = Attic area to be insulated (in square feet)

100,000 = Conversion from Btu to therms

AFUE = Natural gas heating system efficiency (= 84%)[6]

1,000 = Kilowatt conversion factor

HSPF = Electric heating system efficiency (= 3.412 for electric resistance heat, the number of Btus in a watt-hour)

CDD = Cooling degree days (= 565; see table below)

SEER = Cooling system efficiency (= 13)[4,5]

Cooling and Heating Degree Days by City

Location	HDD[7]	CDD[7]
Milwaukee	7,276	548
Green Bay	7,725	516
Wausau	7,805	654
Madison	7,599	630
La Cross	7,397	729
Minocqua	8,616	423
Rice Lake	8,552	438
Statewide Weighted	**7,616**	**565**

Summer Coincident Peak Savings Algorithm[8]

$kW_{SAVED} = (kWh_{SAVED\_COOL} / EFLH_{COOL}) * CF$

Where:

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 410)[9]

CF = Coincidence factor (= 0.68)[9]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therms_{LIFECYCLE} = Therms_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 25 years)[1]

Deemed Savings

Deemed Natural Gas and Electricity Savings per Square Foot of Attic Insulation

Measure	MMID	Annual kWh	Annual Therms	Peak kW	Lifecycle kWh	Lifecycle Therms
Natural Gas Heat with Cooling						
Existing Insulation ≤ R-11	3707	0.0674	0.1406	0.0001	1.685	3.5150
Existing Insulation R-12 to R-19	3709	0.0274	0.0573	0.0001	0.685	1.4325
New Construction to R-49	4824	0.0062	0.0129	0	0.155	0.3225
Natural Gas Heat without Cooling						
Existing Insulation ≤ R-11	3708	--	0.1406	--	--	3.5150
Existing Insulation R-12 to R-19	3710	--	0.0573	--	--	1.4325
New Construction to R-49	4379	--	0.0129	--	--	0.3225
Electric Heat with Cooling						
Existing Insulation ≤ R-11	3711	3.5280	--	0.0001	88.185	--
Existing Insulation R-12 to R-19	3713	1.4370	--	0.0001	35.935	--
New Construction to R-49	4380	0.3226	--	0	8.055	--
Electric Heat without Cooling						
Existing Insulation ≤ R-11	3712	3.4600	--	--	86.500	--
Existing Insulation R-12 to R-19	3714	1.4100	--	--	35.250	--
New Construction to R-49	4381	0.3165	--	--	7.900	--

Assumptions

The summer coincident peak savings algorithm is derived from the Illinois TRM.[8]

The incremental costs for attic insulation are based on matching the measures listed above with the measures from DEER 2008, as shown in the following table.

Measure Details from Database for Energy Efficient Resources

Insulation Improvement	MMIDs	DEER 2008 Measure	DEER Cost ($/Sq Ft)		
			Material	Labor	Total
Retrofit R-11 to R-38 (R-27 improvement)	3707, 3708, 3711, 3712	Ceiling - Add R-30 batts	$0.75	$0.61	$1.36
Retrofit R-19 to R-38 (R-19 improvement)	3709, 3710, 3713, 3714	Ceiling - Add R-19 batts	$0.51	$0.53	$1.04
New Construction R-38 to R-49 (R-11 improvement)	4824, 4379, 4380, 4381	Ceiling - Add R-11 batts	$0.40	$0.45	$0.85

Sources

1. GDS Associates. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*. Table 1, Ventilation. June 2007. http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf
2. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." Revised Measure Cost Summary. June 2, 2008. http://www.deeresources.com/index.php/deer-versions/deer2008-for-09-11-planning-reporting
3. Illinois Energy Efficiency Statewide Advisory Group. *Illinois Statewide Technical Reference Manual*. Section 5.6.4 Wall and Ceiling/Attic Insulation. June 1, 2015. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_4/2-13-15_Final/Updated/Illinois_Statewide_TRM_Effective_060115_Final_02-24-15_Clean.pdf
4. Appliance Standards Awareness Project. "Central Air Conditioners and Heat Pumps." Accessed January 2018. http://www.appliance-standards.org/product/central-air-conditioners-and-heat-pumps
5. International Energy Conservation Code. Table 503.2.3(1). 2009.
6. Cadmus. *2016 Potential Study for Focus on Energy.*
   Data maintained by Cadmus and Wisconsin PSC. Residential site visits from the summer of 2016 revealed that the average AFUE of multifamily natural gas heat is 84%. Twenty-three sites had an average central natural gas heating AFUE of 83.6% while 15 sites had an in-unit natural gas heating AFUE of 85.6%, and sites had a 58.7%/41.3% split of central/in-unit heating.
7. ASHRAE Estimation of Degree-Days: Fundamentals, Chapter 14.
   Calculated from TMY3 weather files of the seven Wisconsin locations using statewide weighted values calculated from 2010 U.S. Census data for Wisconsin.

8. Illinois Energy Efficiency Statewide Advisory Group. *Illinois Statewide Technical Reference Manual.* Section 5.6.1 Air Sealing. June 1, 2015. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_4/2-13-15_Final/Updated/Illinois_Statewide_TRM_Effective_060115_Final_02-24-15_Clean.pdf
9. Cadmus. "Focus on Energy Evaluated Deemed Savings Changes." November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
10. ENERGY STAR website. Accessed November 1, 2018. www.energystar.gov/index.cfm?c=home_sealing.hm_improvement_insulation_table

Revision History

Version Number	Date	Description of Change
01	01/2016	Initial TRM entry
02	11/2017	Updated to add measures for new construction
03	11/2018	Changed new construction attic insulation from R-50 to R-49

Wall Insulation, Multifamily

	Measure Details
Measure Master ID	Insulation, Wall: NG Heat with Cooling, 3703 NG Heat without Cooling, 3704 Electric Heat with Cooling, 3705 Electric Heat without Cooling, 3706
Measure Unit	Per square foot of exterior wall
Measure Type	Prescriptive
Measure Group	Building Shell
Measure Category	Insulation
Sector(s)	Residential– multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/yr)	0
Effective Useful Life (years)	25[1]
Incremental Cost ($/year)	$1.86 for retrofit measures; $0.82 for new construction measures[2]

Measure Description

This measure is installing insulation to above-grade exterior walls in an existing or new construction multifamily residence. This measure includes any increase in R-value due to installed insulation, including but is not limited to fiberglass batts, spray foam, loose fill cellulose, metalized polymers, or other material that meets local and state building codes. Sill boxes are considered part of the exterior wall. A combination of insulation materials may be used, provided they meet the required efficient condition (for example, 2x4 construction will likely not meet R-20 with just cavity insulation and will likely require continuous insulation also).

Buildings with existing exterior wall insulation greater than R-5, exterior walls with an efficient condition of significantly greater than R-20, and application in buildings with heating systems other than electric resistance or a natural gas furnace or boiler will still be treated as custom.

For new construction projects, buildings with heating systems other than electric resistance or natural gas furnace or boiler will still be treated as custom.

Description of Baseline Condition

For existing buildings, the baseline condition is minimal wall insulation such that the existing R-value is at or less than R-5.

For new construction buildings, the baseline condition is R-20 wall insulation.

Description of Efficient Condition

For existing buildings, the efficient condition is exterior wall insulation that complies with International Energy Conservation Code 2009.[3] IECC 2009 lists R-21 exterior wall insulation for climate zone 7 (roughly the northern quarter of the state) and R-20 for climate zone 6 (remainder of the state). R-20 was selected to provide one common value statewide.

The use of R-13 cavity insulation plus R-5 insulated sheathing is considered equal to R-20 for climate zone 6 by IECC 2009. Since most of Wisconsin is in this climate zone, this is an acceptable alternative.

IECC 2009 provides an alternate compliance path which allows for a non-fenestration U-factor of 0.057 or less to be used instead of the R-20 or R-21 insulation to allow for alternative exterior wall construction types.[4] This is also an acceptable alternative.

For new construction buildings, the efficient condition is R-25 wall insulation.

Annual Energy-Savings Algorithm

$$\text{Therms}_{\text{SAVED}} = [(1 / \text{R}_{\text{BASE}} - 1 / \text{R}_{\text{EE}}) * \text{Area} * (1 - \text{FramingF})] * 24 * \text{HDD} / (100{,}000 * \text{AFUE})$$

$$\text{kWh}_{\text{SAVED}} = \text{kWh}_{\text{SAVED\_HEAT}} + \text{kWh}_{\text{SAVED\_COOL}}$$

$$\text{kWh}_{\text{SAVED\_HEAT}} = [(1 / \text{R}_{\text{BASE}} – 1 / \text{R}_{\text{EE}}) * \text{Area} * (1 – \text{FramingF})] * 24 * \text{HDD} / (1{,}000 * \text{HSPF})$$

$$\text{kWh}_{\text{SAVED\_COOL}} = [(1 / \text{R}_{\text{BASE}} - 1 / \text{R}_{\text{EE}}) * \text{Area} * (1 - \text{FramingF})] * 24 * \text{CDD} / (1{,}000 * \text{SEER})$$

Where:

R_{BASE} = Existing condition insulation R-value (= R-5 for existing buildings, = R-20 for new construction)

R_{EE} = Efficient condition insulation R-value (= R-20 for existing buildings, = R-25 for new construction)

Area = Wall area to be insulated in square feet

FramingF = Adjustment to account for area of framing (= 25%)[4]

HDD = Heating degree days (= 7,616; see table below)

AFUE = Natural gas heating system efficiency (= 84%)[5]

HSPF = Electric heating system efficiency (= 3.412 for electric resistance heat)

CDD = Cooling degree days (= 565; see table below)

SEER = Cooling system efficiency (= 13)[6,7]

Heating and Cooling Degree Days by Location

Location	HDD[8]	CDD[8]
Milwaukee	7,276	548
Green Bay	7,725	516
Wausau	7,805	654
Madison	7,599	630
La Cross	7,397	729
Minocqua	8,616	423
Rice Lake	8,552	438
Statewide Weighted	**7,616**	**565**

Summer Coincident Peak Savings Algorithm

The following algorithm is from Illinois TRM.[4]

$kW_{SAVED} = (kWh_{SAVED\_COOL} / EFLH_{COOL}) * CF$

Where:

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 410)[9]

CF = Coincidence factor (= 0.68)[9]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therms_{LIFECYCLE} = Therms_{SAVED} * EUL$

Where:

EUL = Effective useful life (=25 years)[1]

Deemed Savings

Deemed Savings for Wall Insulation

Measure	MMID	Annual kWh	Annual Therms	Peak kW	Lifecycle kWh	Lifecycle Therms
Residential - Multifamily						
NG Heat with Cooling	3703	0.117	0.245	0.0002	2.93	6.12
NG Heat without Cooling	3704	-	0.245	-	-	6.12
Electric Heat with Cooling	3705	6.144	-	0.0002	153.60	-
Electric Heat without Cooling	3706	6.027	-	-	150.70	-
NC-Residential - Multifamily						
NG Heat with Cooling	3703	0.008	0.016	0.0001	0.20	0.41
NG Heat without Cooling	3704	-	0.016	-	-	0.41
Electric Heat with Cooling	3705	0.410	-	0.0001	10.24	-
Electric Heat without Cooling	3706	0.402	-	-	10.04	-

Assumptions

The incremental costs for wall insulation are based on matching the measures listed above with the measures from DEER 2008 shown in the following table.

Measure Values from Database for Energy Efficient Resources

	Insulation Improvement	DEER 2008 Measure	DEER Material Cost ($/Sq Ft)		
			Material	Labor	Total
Retrofit	Retrofit R-5 to R-20	Wall 2x6 R-19 Batts + R-5 Rigid	$0.92	$0.94	$1.86
New Construction	Increase R-20 to R-25	Wall 2x6 R-19 Batts + R-5 Rigid, less cost for Wall 2x6 R-19 Insulation-Batts (to obtain R-5 Rigid cost)	$0.41	$0.41	$0.82

Sources

1. GDS Associates. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*. Table 1, Ventilation. June 2007. http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf
2. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” Revised Measure Cost Summary. June 2, 2008. http://www.deeresources.com/index.php/deer-versions/deer2008-for-09-11-planning-reporting

3. *International Energy Conservation Code*. Chapter 4 – Residential Energy Efficiency, Tables 402.1.1 and 402.1.3. 2009.
4. Illinois Energy Efficiency Statewide Advisory Group. *Illinois Statewide Technical Reference Manual*. Section 5.6.4 Wall and Ceiling/Attic Insulation. Section 5.6.1 Air Sealing. June 1, 2015. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_4/2-13-15_Final/Updated/Illinois_Statewide_TRM_Effective_060115_Final_02-24-15_Clean.pdf
5. Cadmus. *2016 Potential Study for Focus on Energy.*
   Data maintained by Cadmus and Wisconsin PSC. Residential site visits from the summer of 2016 reveal that the average AFUE of multifamily natural gas heat is 84%. Twenty-three sites had an average central natural gas heating AFUE of 83.6% while 15 sites had an in-unit natural gas heating AFUE of 85.6%, and sites had a 58.7%/41.3% split of central/in-unit heating.
6. Appliance Standards Awareness Project. “Central Air Conditioners and Heat Pumps.” Accessed January 2018. http://www.appliance-standards.org/product/central-air-conditioners-and-heat-pumps
7. *International Energy Conservation Code*. Table 503.2.3(1). 2009.
8. *ASHRAE Estimation of Degree-Days: Fundamentals*. Chapter 14.
   Calculated from TMY3 weather files of the seven Wisconsin locations using statewide weighted values calculated from 2010 U.S. Census data for Wisconsin; 2010 US Census data for Wisconsin (statewide weighted values).
9. Cadmus. “Focus on Energy Evaluated Deemed Savings Changes.” November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

Revision History

Version Number	Date	Description of Change
01	01/2016	Initial TRM entry
02	11/2017	Added measures for new construction

Domestic Hot Water

Kitchen/Bathroom Aerators and Showerheads

	Measure Details
Measure Master ID	Faucet Aerator, Kitchen: 1.5 GPM, Electric, 4384 1.5 GPM, NG, 4385 1.0 GPM, Electric, 4386 1.0 GPM, NG, 4387 0.5 GPM, Electric, 4388 0.5 GPM, NG, 4389 0.5/1.0/1.5 Variable GPM, Electric, 4390 0.5/1.0/1.5 Variable GPM, NG, 4391 Pack Based, 1.5 GPM, 3862 Faucet Aerator, Bath: 1.5 GPM, Electric, 4392 1.5 GPM, NG, 4393 1.0 GPM, Electric, 4394 1.0 GPM, NG, 4395 0.5 GPM, Electric, 4396 0.5 GPM, NG, 4397 Pack Based, 1.0 GPM, 3863 Showerhead: 1.5 GPM, Shower, Electric, 4398 1.5 GPM, Shower, NG, 4399 1.25 GPM, Shower, Electric, 4400 1.25 GPM, Shower, NG, 4401 Handheld, 1.5 GPM, Pack-based 4274 Upgraded, 1.5 GPM, Pack-based 4273
Measure Unit	Per aerator
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Aeration
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Variable
Peak Demand Reduction (kW)	Variable
Annual Therm Savings (Therms)	Variable

	Measure Details
Lifecycle Electricity Savings (kWh)	Variable
Lifecycle Therm Savings (Therms)	Variable
Water Savings (gal/year)	Variable
Effective Useful Life (years)	10[1]
Measure Incremental Cost ($/unit)	Prescriptive faucet aerators= $6.54 (MMIDs 4384–4397)[2] Prescriptive showerheads = $3.11 (MMIDs 4398–4401)[3] Pack-based 1.5 GPM kitchen faucet = $1.26 (MMID 3862)[4] Pack-based 1.0 GPM bathroom faucet = $0.48 (MMID 3863)[4] Pack-based handheld showerhead = $5.41 (MMID 4273)[4] Pack-based upgraded showerhead = $10.69 (MMID 4274)[4]

Measure Description

This measure is installing low-flow kitchen or bathroom aerators or low-flow showerheads in existing buildings or new construction. Pack-based and upstream measures reduce both natural gas and electric consumption, based on building stock splits derived from the *2016 Focus on Energy Potential Study*.[7] All measures also reduce total water consumption.

Description of Baseline Condition

The baseline equipment is a kitchen or bathroom aerator at 2.2 GPM or a showerhead at 2.5 GPM.

Description of Efficient Condition

The efficient condition is a kitchen aerator at 0.5, 1.0, or 1.5 GPM; a variable kitchen aerator that can be changed by the user to 0.5, 1.0, or 1.5 GPM; a bathroom aerator at 0.5, 1.0, or 1.5 GPM; or a showerhead at 1.25 or 1.5 GPM.

Annual Energy-Savings Algorithm

$$\text{kWh}_{\text{SAVED}} = \text{Gallons}_{\text{SAVED}} * 8.33 * C * (T_{\text{POINT OF USE}} - T_{\text{ENTERING}}) / (\text{EF}_{\text{ELECTRIC}} * 3{,}412)$$

$$\text{Therm}_{\text{SAVED}} = \text{Gallons}_{\text{SAVED}} * 8.33 * C * (T_{\text{POINT OF USE}} - T_{\text{ENTERING}}) / (\text{EF}_{\text{GAS}} * 100{,}000)$$

Aerators

$$\text{Gallon}_{\text{SAVED}} = (\text{GPM}_{\text{EXISTING}} - \text{GPM}_{\text{NEW}}) * (\text{PH} / \text{FH}) * \text{FLU} * 365 * \text{IR} * \text{DF}$$

Showerheads

$$\text{Gallon}_{\text{SAVED}} = (\text{GPM}_{\text{EXISTING}} - \text{GPM}_{\text{NEW}}) * (\text{PH} * \text{SPD} / \text{FH}) * \text{SLU} * 365 * \text{IR} * \text{DF}$$

Where:

$Gallons_{SAVED}$ = First-year water savings in gallons

8.33 = Density of water, lbs/gallon

C = Specific heat of water (= 1 Btu/lb °F)

$T_{POINT\ OF\ USE}$ = Temperature of water at point of use (= 93°F for kitchen aerators; = 86°F for bathroom aerators; = 101°F for showerheads)[5]

$T_{ENTERING}$ = Temperature of water entering water heater (= 52.3°F)[6]

$EF_{ELECTRIC}$ = Energy factor of electric water heater (= 94% for single family,[7] = 92% for multifamily,[7] see Assumptions)

3,412 = Conversion from Btu to kWh

EF_{GAS} = Energy factor of natural gas water heater (= 61% for single family;[7] = 75% for multifamily,[7] see Assumptions)

100,000 = Conversion from Btu to therm

$GPM_{EXISTING}$ = Baseline flow rate (= 2.2 GPM for kitchen and bathroom aerators; = 2.5 GPM for showerheads)[8]

GPM_{NEW} = Efficient flow rate (= 0.5, 1.0, or 1.5 GPM for kitchen and bathroom aerators; = 1.25 or 1.5 GPM for showerheads)

PH = Persons per house (= 2.52 for single family homes, = 1.93 for multifamily units)[9]

FH = Fixtures per house (for single family homes = 1.0 for kitchen aerators, = 2.04 for bathroom aerators, and = 1.5 for showerheads; for multifamily units = 1.0 for kitchen aerators, = 1.43 for bathroom aerators, and = 1.0 for showerheads)[5]

FLU = Fixture length of use in minutes per person per day (= 4.5 for kitchen aerators; = 1.6 for bathroom aerators)[5]

365 = Conversion from days to years

IR = Installation rate (= 1.0 for prescriptive aerators, = 1.0 for prescriptive showerheads, = 0.54 for pack-based aerators,[10, 11] and = 0.65 for pack-based showerheads)[11, 12]

DF = Drain factor (=0.75 for kitchen aerators, = 0.90 for bathroom aerators; see Assumptions)

SPD = Showers per person per day (= 0.6)[5]

SLU = Shower length of use (= 7.8 minutes per shower)[5]

Summer Coincident Peak Savings Algorithm

Aerators

$kW_{SAVED} = kWh_{SAVED} * CF / (PH * LU * 365 / 60 / FH)$

$CF = \%Peak_{AERATOR} * LU / 180$

Showerheads

$kW_{SAVED} = kWh_{SAVED} * CF / (PH * SPD * SLU * 365 / 60 / FH)$

$CF = \%Peak_{SHOWER} * SLU * SPD / 180$

Where:

kWh_{SAVED} = Calculated savings per faucet

CF = Coincidence factor (= 0.0033 for kitchen aerators, = 0.0012 for bathroom aerators, = 0.0023 for showerheads)

60 = Conversion from minutes to hours

$\%Peak_{AERATOR}$ = Amount of time faucet aerator is used during peak period (= 13%)[13]

180 = Number of minutes during peak period

$\%Peak_{SHOWER}$ = Amount of time shower is used during peak period (= 9%)[13]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Deemed Savings, Prescriptive Multifamily

Description	MMID	Water Saved (Gallons)	kW Saved	kWh Saved		Therms Saved	
				Annual	Lifecycle	Annual	Lifecycle
Kitchen, Electric							
0.5/1.0/1.5 Variable GPM	4390	2,853	0.0190	308	3,080	0	0
0.5 GPM	4388	4,042	0.0269	437	4,370	0	0
1.0 GPM	4386	2,853	0.0190	308	3,080	0	0
1.5 GPM	4384	1,664	0.0111	180	1,800	0	0

Description	MMID	Water Saved (Gallons)	kW Saved	kWh Saved		Therms Saved	
				Annual	Lifecycle	Annual	Lifecycle
Kitchen, Gas							
0.5/1.0/1.5 Variable GPM	4391	2,853	0	0	0	13	130
0.5 GPM	4389	4,042	0	0	0	18	180
1.0 GPM	4387	2,853	0	0	0	13	130
1.5 GPM	4385	1,664	0	0	0	8	80
Bathroom, Electric							
0.5 GPM	4396	1,206	0.0095	108	1,080	0	0
1.0 GPM	4394	851	0.0067	76	760	0	0
1.5 GPM	4392	497	0.0039	44	440	0	0
Bathroom, Gas							
0.5 GPM	4397	1,206	0	0	0	5	50
1.0 GPM	4395	851	0	0	0	3	30
1.5 GPM	4393	497	0	0	0	2	20
Shower, Electric							
1.25 GPM	4400	4,121	0.0227	533	5,330	0	0
1.5 GPM	4398	3,297	0.0181	426	4,260	0	0
Shower, Gas							
1.25 GPM	4401	4,121	0	0	0	22	220
1.5 GPM	4399	3,297	0	0	0	18	180

Deemed Savings, Pack Based

Description	MMID	Sector	Water Savings (Gallons)	kW Saved	kWh Saved		Therms Saved	
					Annual	Lifecycle	Annual	Lifecycle
Faucet Aerator, Pack Based								
1.5 GPM, Kitchen	3862	SF	1,173	0.0012	25	250	5	50
		MF	1,173	0.0008	14	140	3	30
1.0 GPM, Bathroom	3863	SF	421	0.0007	7	70	1	10
		MF	421	0.0005	6	60	1	10
Showerhead, Pack Based								
Handheld, 1.5 GPM	4274	SF	1,865	0.0023	47	470	9	90
		MF	2,143	0.0017	39	390	10	100
Upgraded, 1.5 GPM	4273	SF	1,865	0.0023	47	470	9	90
		MF	2,143	0.0017	39	390	10	100

Assumptions

The variable kitchen aerator can be changed by the user to 0.5, 1.0, or 1.5 GPM depending on the flow needed for the task. It assumed that equal time would be spent at each flow rate, meaning the average GPM would be the average of 0.5, 1.0, and 1.5, or 1.0 GPM.

For pack-based measures, 54% is the average installation rate for aerators,[10, 11] while 65% is the average installation rate for showerheads.[11, 12] These installation rates were applied to account for some water measures not actually being installed.

The peak percentage values of 9% and 13% for showerheads and aerators, respectively, were determined from Figure 2 of a study conducted by Aquacraft, Inc.[13] The peak values are from the 1 p.m. to 4 p.m. time period.

Two programs have independently applied drain factors. First, the Illinois TRM[14] uses values of 75% for kitchen usage and 90% for bathroom usage. These values were agreed to by the Illinois Technical Advisory Group, as no studies of drain factor are known. Second, the Ontario Energy Board[15] uses values of 50% for bathrooms and 70% for kitchens, citing a study from 2008. Because the citation used by the Ontario Energy Board to produce these numbers cannot be found, and because the Illinois TRM values are more recent and for a region that likely more closely reflects Wisconsin, the Illinois TRM values are used.

Energy Factors

Based on six units observed as part of the *2016 Potential Study,*[7] the average EF for single family electric water heaters is 94%. Based on 40 units observed from the same study, the average EF for single family natural gas water heaters is 61%.

Ninety-two multifamily sites were visited as part of the *2016 Potential Study.*[7] Of these, three sites with central electric DHW and recorded EF show an average EF of 91%, and 13 sites with in-unit DHW and recorded EF show an average EF of 93%. Overall, 70% of sites had central DHW, so the weighted average electric EF is 92%. Similarly, nine sites with central natural gas domestic hot water and recorded EF show an average EF of 82%. Two sites with in-unit natural gas DHW and recorded EF show an average EF of 59%. Therefore, the average natural gas EF is 75%.

Pack-Based Fuel Splits

Pack-based measures claim both natural gas and electric savings. For single family homes, these are weighted at 73% and 20%, respectively, based on water heater data from 104 sites audited as part of the *2016 Potential Study*[7] (7% of single family homes had propane water heaters).

Ninety-two multifamily sites were visited as part of the *2016 Potential Study*[7] and the water heater fuel type was recorded at many of these sites. Of these, 27 sites had known central water heater fuel types, with 15% being electric and 85% being natural gas. Twenty-three sites had known in-unit water heater fuel types, with 13% being electric and 87% being natural gas. Of the 92 sites visited, 70% had central water heaters and 30% had in-unit water heaters. Therefore, 86% of multifamily sites had natural gas hot water and 14% had electric hot water.

Sources

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3. $5.00 = WESCO Distribution Pricing ($3.11) + Labor ($1.89). Only included $3.11 in materials.
4. Cost for pack-based measures is the cost to the program, which is equal to the incentive. Incremental cost data was updated on May 22, 2018 for calendar year 2018, and is scheduled to be reviewed by no later than January 2019.
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Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	01/2015	Added measures/flow rates
03	11/2016	Added measures/flow rates
04	12/2017	Added measures/flow rates and updated per *Potential Study* results
05	04/2018	Added multifamily savings for pack-based measures
06	09/2018	Added drain factors, per 2018 Deemed Savings memo

DHW Temperature Turndown, Pack-Based

	Measure Details
Measure Master ID	DHW Temperature Turn Down, Pack Based, Blended Natural Gas & Electric, 4271
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Controls
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	1.51
Peak Demand Reduction (kW)	0.0002
Annual Therm Savings (Therms)	0.62
Lifecycle Energy Savings (kWh)	22.5
Lifecycle Therm Savings (Therms)	9.0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$0.84[9]

Measure Description

Homeowners receive a kit including a card to measure the DHW temperature, and are responsible for turning the water heater temperature down to 120°F.

There are two main effects of hot water storage temperature on energy use. The primary effect is due to standby loss, which increases with hot water temperature. The secondary effect is that hotter stored water affects hot water end uses. This happens in two ways:

1. For batch appliances, such as most clothes washers, more energy is used for hot and warm wash cycles because a fixed number of gallons is drawn for each load. For mixed end uses (showers, sinks, bathtubs), when the stored water is hotter, less of it is mixed with cold water to achieve the target use temperature. Since most hot water use is mixed temperature, a modest change in the hot water temperature (of 10°F to 20°F) has a relatively small impact on the energy required to heat the delivered hot water.
2. The reduction in standby loss also affects internal gains. For electric hot water, the reduction in internal gains from a temperature turn down results in slightly smaller cooling load; assuming that most water heaters in Wisconsin are in basements, and that basements have little or no direct air conditioning, this effect can be ignored. Heating effects are ignored for electric water heaters, assuming a predominance of natural gas heat; however, it should be accounted for at an appropriate efficiency in residences with a heat pump or electric resistance heat.

Description of Baseline Condition

The baseline condition is a residential hot water heater with a temperature setpoint of 125°F.

Description of Efficient Condition

The efficient condition is a residential water heater with a temperature setpoint of 120°F.

Annual Energy-Savings Algorithm

Electric Measures

$kWh_{SAVED} = [(HW_{BASE} + SB_{BASE}) – (HW_{EFF} + SB_{EFF})] * 365 * (1 / 3{,}412) * BR_{ELEC} * IR$

$$HW = \frac{GPD * C_P * (T_{WH}\text{-}T_{ENTERING})}{RE_{ELEC}} * \left[1 - \frac{UA_{ELEC} * (T_{WH}\text{-}T_{ROOM})}{Input_{ELEC}}\right]$$

$SB = UA_{ELEC} * 24 * (T_{WH} – T_{ROOM})$

$$UA_{ELEC} = \left(\frac{1}{EF_{ELEC}} - \frac{1}{RE_{ELEC}}\right) \Big/ \left[67.5 * \left(\frac{24}{Q_{OUT}} - \frac{1}{RE_{ELEC} * Input_{ELEC}}\right)\right]$$

Where:

HW = Hot water energy use

SB = Standby energy use

365 = Number of days per year

3,412 = Conversion from Btu to kWh

BR_{ELEC} = Electric blended rate (= 20%)[5]

IR = Installation rate (= 16%, see Assumptions)

GPD = Gallons of hot water use per day (= 32.8 for baseline measure; = 34.8 for efficient measure, see Assumptions)

C_P = Heat capacity of water (= 8.33 Btu/gallon/°F)

T_{WH} = Temperature in tank (= 125°F for baseline; = 120°F for efficient)

$T_{ENTERING}$ = Cold water mains temperature (= 52.3°F)[2]

RE_{ELEC} = Water heater recovery efficiency (= 0.98)[3]

UA_{ELEC} = Electric water heater equivalent heat loss factor (= 1.24 Btu/hr-°F)

T_{ROOM} = Ambient temperature surrounding tank (= 65°F, see Assumptions)

$Input_{ELEC}$ = Firing rate (= 15,354 Btu/hr, see Assumptions)[4]

24 = Number of hours per day

EF_{ELEC} = Energy factor (= 0.94)[5]

67.5 = Temperature difference during 24-hour test (see Assumptions)[4]

Q_{OUT} = Energy content of water drawn from water heater during 24-hour test (= 41,094 Btu/day, see Assumptions)[4]

Therm Measures

$Therm_{SAVED} = [(HW_{BASE} + SB_{BASE}) – (HW_{EFF} + SB_{EFF})] * 365 * 1 / 100{,}000 * BR_{GAS} * IR$

$HW = GPD * C_P * (T_{WH} – T_{ENTERING}) * 1 / RE_{GAS} * [1 – UA_{GAS} * (T_{WH} – T_{ROOM}/Input_{GAS})]$

$SB = UA_{GAS} * 24 * (T_{WH} – T_{ROOM})$

$$UA_{GAS} = \left(\frac{1}{EF_{GAS}} - \frac{1}{RE_{GAS}}\right) \Big/ \left[67.5 * \left(\frac{24}{Q_{OUT}} - \frac{1}{RE_{GAS} * Input_{GAS}}\right)\right]$$

Where:

BR_{GAS} = Natural gas blended rate (= 73%)

RE_{GAS} = Water heater recovery efficiency (= 0.76)[3]

UA_{GAS} = Water heater equivalent heat loss factor (= 8.72 Btu/hr-°F)

$Input_{GAS}$ = Firing rate (= 38,000 Btu/hr; see Assumptions)[4]

EF_{GAS} = Energy factor (= 0.61)[5]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (kWh_{SAVED} / 8{,}760) * CF$

Where:

8,760 = Number of hours in one year

CF = Coincidence factor (= 1)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

This pack-based measure is applied to a mix of electric and natural gas water heaters. This mix was derived from the 2016 Focus on Energy Potential Study[5] and is 73% natural gas, 20% electric, and 7% propane water heaters.

Participant survey results from the Focus on Energy 2017 Simple Energy Efficiency program evaluation revealed an installation rate of 16% for this measure. Of the 570 respondents, 325 (57%) said they had used the card to check their water temperature, and 94 (16%) said they had actually reduced their water temperature as a result of using the card.

The gallons per day assumptions were as follows:

- Gallons per day were calculated by fitting a polynomial equation to data from Table 3 of the Florida Solar Energy Center study.[6] An average value of 2.43 occupants per home was used for Wisconsin, based on U.S. Census data.[7] The fitted equation is $GPD = -0.0089 * x^2 + 16.277 * x + 3.25$, where "x" is the average number of occupants per home. With x at 2.43, GPD is 42.8.
- Hot water use is broken into two components. Unmixed use, primarily for clothes washers and dishwashers, is direct draw from the water heater and does not vary with stored hot water temperature. Mixed use, for showers and sinks, is delivered to the fixture at 105°F, so the total draw from the water heater varies with stored water temperature. Table 3 from the Florida Solar Energy Center study[6] also displays washer use as a function of household size. A fitted equation of $GPD = 0.0071 * x^2 + 1.2729 * x + 3.42$ produces an unmixed GPD of 6.6 gallons, and therefore a mixed GPD of 36.2 gallons.
- As the setpoint temperature goes down, the hot water consumption at the tank goes up. As the stored temperature is reduced, more hot and less cold must be mixed to reach the target of 105°F at the showerhead or sink. Therefore, the water heater draw is given as:
  - $GPD_{BASE} = 6.6 + 36.2 * (105 - 52.3) / (125 - 52.3) = 32.8$ GPD
  - $GPD_{EFF} = 6.6 + 36.2 * (105 - 52.3) / (120 - 52.3) = 34.8$ GPD

The home is assumed to be maintained at 65°F.

Derivation of heat loss factor (UA) comes from the U.S. Department of Energy test procedures for consumer and commercial water heaters.[8]

Some algorithm inputs are derived from the Home Energy Saver engineering documentation, from the Lawrence Berkeley National Laboratory website.[4] These values include:

- $Input_{ELEC}$ is from the “User Inputs to the Water Heater Model” heading. This page shows that the rated input for electric water heaters is 4.5 kW, which is the equivalent of 15,354 Btu/hr.
- $Input_{GAS}$ is from the same page, which shows 38,000 Btu/hr.
- Q_{OUT} can be found under the “Standby Heat Loss Coefficient” heading, which shows that 41,094 Btu/day is drawn during the standard test.
- Also under the “Standby Heat Loss Coefficient” heading, a temperature difference of 67.5°F is used. This reflects a test hot water temperature of 135°F and a room temperature of 67.5°F.

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The average energy factor of six electric water heaters at single-family sites is 0.94.
The average energy factor of 40 natural gas water heaters at single-family sites is 0.76.
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9. 2018 cost of measure to pack-based program implementer.

Revision History

Version Number	Date	Description of Change
01	01/01/2012	Initial TRM entry
02	03/09/2013	Updated to new template and added lifecycle savings
03	04/22/2013	Revised and added comments
04	12/15/2013	Added multifamily sector and larger DHW heater savings
05	10/16/2016	Removed MMIDs 2125 and 2131
06	03/19/2018	Added pack-based MMID

Pipe Insulation, Pack Based

	Measure Details
Measure Master ID	Insulation, DHW Pipe, Pack-based, 4272
Measure Unit	Per kit
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Insulation
Sector(s)	Residential- multifamily, Residential- single family
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$2.43[2]

Measure Description

Pipes are often uninsulated because the original insulation was damaged, the original insulation was removed (for example, as part of an asbestos abatement program) and never replaced, or the new pipe was installed but the insulation job was not completed. Insulating pipes reduces heat losses to unheated building areas and decreases problems with overheating in areas with uninsulated pipe.

This workpaper documents pipe insulation that is sent directly to customers via a Focus on Energy pack, in which customers install the pipe insulation on their own. While multifamily prescriptive insulation measures (MMIDs 3689–3692, 3699–3702, and 3755–3758) must be installed in unconditioned spaces, these pack-based measures may or may not be installed in conditioned spaces, such as when a water heater and its nearby piping are in a finished section of a home. In these cases, HVAC interactive factors must be considered.

Description of Baseline Condition

The baseline condition is piping for a space heating hot water system, steam loop system, or domestic hot water system with no insulation. Domestic hot water piping is assumed to be copper and space heating piping is assumed to be either copper or steel.

Description of Efficient Condition

Pack-based kits include a 15-foot long, 2-inch wide roll of R-2 foam insulation[3] for use with domestic hot water systems only. Each roll can insulate approximately nine linear feet of pipe.

Annual Energy-Savings Algorithm

Electric Savings

$kWh_{SAVED} = (kWh_{UNCOND} * \%Uncond + kWh_{COND} * \%Cond) * ISR$

$kWh_{UNCOND} = Insul * Length * HOU / (EF_{ELEC} * 3{,}412) * f_{ELEC}$

$kWh_{COND} = kWh_{UNCOND} – kWh_{HEAT} + kWh_{COOL}$

Where:

kWh_{UNCOND} = Kilowatt-hours saved for insulation installed in unconditioned space, averaged across HVAC system splits (= 72.8 kWh for single family, = 52.1 kWh for multifamily; calculated values)

%Uncond = Fraction of insulation installed in unconditioned space (= 19% for single family,[4] = 0% for multifamily; see Assumptions)

kWh_{COND} = Kilowatt-hours saved for insulation installed in conditioned space, averaged across HVAC system splits (= 88.6 kWh for single family, = 21.3 kWh for multifamily; calculated values)

%Cond = Fraction of insulation installed in conditioned space (= 81% for single family, = 100% for multifamily; see Assumptions)[4]

ISR = Installation rate for insulation (= 40% for single family,[5] = 6% for multifamily; see Assumptions)

Insul = Hot water heat loss prevented by installing pipe insulation (= 14.81 Btuh/ft; see Assumptions)[6]

Length = Length of pipe covered by wrap (= 9 feet)

HOU = Hours of use (= 8,760)

EF_{ELEC} = Energy factor of electric water heater (= 94% for single family, = 92% for multifamily)[4]

3,412 = Conversion factor for kilowatt-hours per Btu

f_{ELEC} = Fraction of sites receiving insulation packs with electric hot water heating (= 20% for single family, = 14% for multifamily)[4]

kWh_{HEAT} = Heating kilowatt-hours reduced by pipe heat losses in conditioned space for an average pack (= 4.10 kWh for single family, = 35.96 kWh for multifamily; see Assumptions)

kWh_{COOL} = Cooling kilowatt-hours increased by pipe heat losses in conditioned space for an average pack (= 19.85 kWh for single family, = 5.21 kWh for multifamily; see Assumptions)

Natural Gas Savings

$Therms_{SAVED} = (Therms_{UNCOND} * \%Uncond + Therms_{COND} * \%Cond) * ISR$

$Thms_{UNCOND} = Insul * Length * HOU / (EF_{GAS} * 100{,}000) * f_{GAS}$

$Therms_{COND} = Therms_{UNCOND} – Therms_{HEAT}$

Where:

$Therms_{UNCOND}$ = Therms saved for insulation installed in unconditioned space, averaged across HVAC system splits (= 14.0 therms for single family, = 13.4 therms for multifamily; calculated values)

$Therms_{COND}$ = Therms saved for insulation installed in conditioned space, averaged across HVAC system splits (= 8.6 therms for single family, = 8.1 therms for multifamily; calculated values)

EF_{GAS} = Energy factor of natural gas water heater (= 61% for single family, = 75% for multifamily)[4]

100,000 = Conversion factor for Btu per therm

f_{GAS} = Fraction of sites receiving insulation packs with natural gas hot water heating (= 73% for single family, = 86% for multifamily)[4]

$Therms_{HEAT}$ = Heating therms reduced by pipe heat losses in conditioned space for an average pack (= 5.41 therms for single family, = 5.313 therms for multifamily; see Assumptions)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (kW_{UNCOND} * \%Uncond + kW_{COND} * \%Cond) * ISR$

$kW_{UNCOND} = kWh_{UNCOND} / 8{,}760$

$kW_{COND} = kW_{UNCOND} + kW_{COOL}$

$kW_{COOL} = kWh_{COOL} * CF / (8{,}760 * \%Cool)$

Where:

CF = Coincidence factor (= 0.66)[7]

%Cool = Portion of constant pipe heat loss that goes to increasing cooling needed (= 27%; see Assumptions)

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Deemed Savings for Natural Gas and Electricity, per Kit (Blended Pack-Based)

Measure	Sector	Annual kW	Annual kWh	Annual therms	Lifecycle kWh	Lifecycle therms	Incremental Cost
Insulation, DHW Pipe, Pack-Based	Residential-single family	0.0051	34.2	3.8	513.0	57.0	$2.43
Insulation, DHW Pipe, Pack-Based,	Residential-multifamily	0.0004	1.3	0.5	19.5	7.5	$2.43

Assumptions

The heat loss per foot of pipe insulation installed was calculated using CheCalc[6] and the following assumptions:

- Pipe diameters of 0.5-inch and 0.75-inches were modeled, and the average results of the two were used
- Hot water temperature = 125°F

- Ambient temperature = 75°F
- Wind = 0
- Insulation is elastomeric
- Surface emissivity = 0.04 (aluminum, new, bright)
- Thickness = 0.125 inches

The resulting loss factor for bare pipe was 26.01 Btuh/ft, and the resulting loss factor for insulated pipe was 11.2 Btuh/ft, for a difference of 14.81 Btuh/ft.

Savings calculations assume that for insulation installed in an unconditioned space, the energy savings comes completely from the pipe losses and resultant extra consumption at the water heater. For insulation installed in a conditioned space, these energy savings are still in place, but heat loss in the winter produces decreased heating requirements (which reduces overall savings) and heat loss in the summer produces increased cooling requirements (which increases overall savings). Savings for installing in both unconditioned and conditioned spaces is calculated, and the final savings is a weighted average of these two.

For installations in a conditioned space, it is assumed that 49% of pipe heat losses go toward reducing heating requirements, and 27% go toward increasing cooling requirements.[8] Therefore, the total therms of heating reduced per pack installed in a conditioned space is Insul * Length * HOU * 49% / 100,000 = 5.721 therms, and the total therms of cooling increased per pack installed in a conditioned space is Insul * Length * HOU * 27% / 100,000 = 3.153 therms.

Single Family Assumptions

The 2016 Focus on Energy Potential Study[4] revealed that 19% of single family water heaters were installed in unconditioned spaces. It is assumed that 19% of delivered pipe insulation will also be installed in unconditioned spaces, and 81% will be installed in conditioned spaces.

The value for heating therms reduced (5.721) is combined with HVAC system population splits and efficiencies shown in the table below to produce single family kWh_{HEAT} and $\text{Therms}_{\text{HEAT}}$, which are the population-averaged reduced heating needs for a pack of insulation installed.

For example, the “Input Therms Reduced” for homes with a natural gas furnace is (5.721 / 91.4%), or 6.260 therms. This means that since the average home with a natural gas furnace is assumed to have a furnace that is 91.4% efficient and the heating requirements for the home are assumed to be reduced by 5.721 therms per year when insulation is installed in conditioned space, the therm consumption of the home is assumed to be reduced by 6.26 therms.

A similar calculation is conducted for homes with a boiler, producing a reduced therm consumption of 6.977 for those homes. These two values are combined with the HVAC system population fractions to produce the average input therms reduced for an installed pack, which is ($Therms_{HEAT}$ = 82% * 6.260 + 4% * 6.977), or 5.412 therms. Similar algorithms are also applied to produce the "Input kWh Reduced."

Weighted Average Heating Input Reduced, Single Family

Primary Heating System	Population Fraction*	Average Efficiency	Average Efficiency Source	Input Therms Reduced**	Input kWh Reduced**
Natural gas furnace	82%	91.4%	Potential Study[4]	6.260	0.000
Propane furnace	7%	N/A	N/A	0.000	0.000
Wood stove	5%	N/A	N/A	0.000	0.000
Natural gas boiler	4%	82%	Federal standard	6.977	0.000
Electric baseboard	2%	3.412 HSPF	Conversion	0.000	167.680
Heat pump	1%	7.7 HSPF	Federal standard	0.000	74.300
Weighted Average Heating Input Reduced***				**5.412**	**4.100**

* This data comes from the 2016 Focus on Energy Potential Study.[4]
** These represent kWh_{HEAT} and $Therms_{HEAT}$ divided by the system efficiency.
*** This represents the sum of the population fraction and input heating reduced.

Similarly, the value for cooling therms increased is combined with HVAC system population splits and efficiencies shown in the table below to produce kWh_{COOL}. For instance, the assumed value for the "Input kWh Increased" for homes with a central air conditioner is (3.153 therms) * (100 Btu per them) / (12.1 Btu / kWh) = 26.05 kWh. A similar calculation is conducted for heat pumps, and their assumed values for the "Input kWh Increased" are combined with population splits to produce kWh_{COOL} = 75% * 26.05 + 1% * 30.091 = 19.85 kWh.

Note that it is assumed that room air conditioners are not installed in the same room as the pipe insulation, so heat losses through the piping do not contribute to increased cooling needs.

Weighted Average Cooling Input Increased, Single Family

Primary Cooling System	Population Fraction*	Average Efficiency	Average Efficiency Source	Input kWh Increased**
Central air conditioner	75%	12.1 SEER	Potential Study[4]	26.050
Room air conditioner	19%	10.2 SEER	Potential Study[4]	0.000
Heat pump	1%	8.4 SEER	Federal standard	30.091
Weighted Average Heating Input Reduced***				**19.850**

* This data comes from the 2016 Focus on Energy Potential Study.[4]
** This represent kWh_{HEAT} and $Therms_{HEAT}$ divided by the system efficiency.
*** This represents the sum of the population fraction and input heating reduced.

Multifamily Assumptions

Multifamily packs are delivered directly to residents, and not to building owners or managers. Therefore, savings are reliant on participants having access to the piping around their hot water heater. Potential study data indicates that 30% of multifamily water heaters are in-unit. It is deemed that half of these residents do not have access to the piping around their water heater. It is also assumed that 40% of these participants would install the insulation (similar to the single family ISR). Therefore, the multifamily installation rate is deemed to be 30% * 50% * 40% = 6%. It is assumed that 100% of this insulation is installed in conditioned space.

The value for heating therms reduced, combined with HVAC system population splits and efficiencies shown in the tables below, produces the multifamily kWh_{HEAT}, $Therms_{HEAT}$, and kWh_{COOL}, which are the population-averaged reduced heating needs and increased cooling needs for a pack of insulation installed. Note that the multifamily value for kWh_{HEAT} of 35.956 is significantly higher than the single family value; this is because of the higher population fraction for electric heat at multifamily sites.

Weighted Average Heating Input Reduced, Multifamily

Primary Heating System	Population Fraction*	Average Efficiency	Average Efficiency Source	Input Therms Reduced**	Input kWh Reduced**
Natural gas furnace	24%	84%	Potential Study[4]	6.811	0.000
Natural gas boiler	54%	84%	Federal standard	6.811	0.000
Electric baseboard	21%	3.412 HSPF	Conversion	0.000	167.680
Heat pump	1%	7.7 HSPF	Federal standard	0.000	74.300
Weighted Average Heating Input Reduced* **				**5.313**	**35.956**

* This data comes from the 2016 Focus on Energy Potential Study.[4]

** These represent kWh_{HEAT} and $Therms_{HEAT}$ divided by the system efficiency.

*** This represents the sum of the population fraction and input heating reduced.

Weighted Average Cooling Input Increased, Multifamily

Primary Cooling System	Population Fraction*	Average Efficiency	Average Efficiency Source	Input kWh Increased**
Central air conditioner	75%	12.1 SEER	Potential Study[4]	26.050
Room air conditioner	19%	10.2 SEER	Potential Study[4]	0.000
Heat pump	1%	8.4 SEER	Federal standard	30.091
Weighted Average Heating Input Reduced* **				**5.412**

* This data comes from the 2016 Focus on Energy Potential Study.[4]

** This represent kWh_{HEAT} and $Therms_{HEAT}$ divided by the system efficiency.

*** This represents the sum of the population fraction and input heating reduced.

Note that data for HVAC system splits and efficiencies was sometimes sparse for multifamily sites—the average natural gas and electric hot water efficiencies are based on data obtained from just 11 and 16 units. However, savings for multifamily packs is largely driven by the installation rate, followed by the electric and natural gas hot water fuel splits (based on a 50-site sample). Hot water and HVAC efficiencies play a relatively minor role in savings amount.

Sources

1. GDS Associates. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*. Table 1, Pipe Wrap. 2007. https://library.cee1.org/system/files/library/8842/CEE_Eval_MeasureLifeStudyLights%2526HVACGDS_1Jun2007.pdf
2. Incremental cost for pack-based measures is equivalent to the cost to the program, which is equivalent to the incentive rebate offering.
3. Grainger. "FROST KING Foam and Foil Pipe Insulation Wrap." Accessed March 2018. https://www.grainger.com/product/FROST-KING-1-8-x-2-x-15-ft-Foam-and-Foil-48H494
4. Cadmus. *2016 Potential Study for Focus on Energy.* Data maintained by Cadmus and Wisconsin Public Service Commission.
   Data includes information 120 single family sites and 92 multifamily units.
5. Cadmus. *Focus on Energy Calendar Year 2017 Evaluation Report*. Volume II. May 22, 2018. Table 158. https://focusonenergy.com/sites/default/files/WI%20FOE%20CY%202017%20Volume%20II%20FINAL.pdf
6. CheCalc. "Insulation Heat Loss Calculation." Accessed March 2018. https://checalc.com/calc/inshoriz.html
7. Opinion Dynamics Corporation. *Delaware Technical Reference Manual.* April 30, 2012. http://www.dnrec.delaware.gov/energy/information/otherinfo/Documents/EM-and-V-guidance-documents/DELAWARE_TRM_August%202012.pdf
8. Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 5.0. Volume 3: Residential Measures*. p. 168. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Final/IL-TRM_Effective_060116_v5.0_Vol_3_Res_021116_Final.pdf
   For the waste heat cooling savings factor, REM Rate determined the percentage of lighting savings that result in reduced cooling loads (27%) and increased heating loads (49%). Lighting is used as a proxy for hot water heating since load shapes suggest that their seasonal usage patterns are similar.

Revision History

Version Number	Date	Description of Change
01	08/2018	Initial TRM entry

Pipe Insulation, Multifamily

	Measure Details
Measure Master ID	Insulation, Piping: Hot Water Space Heating: 0.5” and 0.75” Pipe, NG, 3685; Elec, 3689 1” and 1.25” Pipe, NG, 3686; Elec, 3690 1.5” and 2” Pipe, NG, 3687; Elec, 3691 3” and 4” Pipe, NG, 3688; Elec, 3692 Steam Space Heating: 0.5” and 0.75” Pipe, NG, 3751; Elec, 3755 1” and 1.25” Pipe, NG, 3752; Elec, 3756 1.5” and 2” Pipe, NG, 3753; Elec, 3757 3” and 4” Pipe, NG, 3754; Elec, 3758 Domestic Hot Water: 0.5” and 0.75” Pipe, NG, 3695; Elec, 3699 1” and 1.25” Pipe, NG, 3696; Elec, 3700 1.5” and 2” Pipe, NG, 3697; Elec, 3701 3” and 4” Pipe, NG, 3698; Elec, 3702
Measure Unit	Per linear foot of piping
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Insulation
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/yr)	0
Effective Useful Life (years)	15[1]
Incremental Cost	Varies by measure[2]

Measure Description

Pipes are often uninsulated because the original insulation was damaged or removed, the original insulation was removed as part of an asbestos abatement program and never replaced, or the new pipe was installed but the insulation job was not completed. Insulating pipes reduces heat losses to unheated building areas and decreases problems with overheating in areas with uninsulated pipe. Piping is in an unconditioned space, likely a basement or mechanical room.

Description of Baseline Condition

The baseline condition is piping for a space heating hot water system, steam loop system, or domestic hot water system with no insulation. Domestic hot water piping is assumed to be copper, while space heating piping is assumed to be either copper or steel.

Description of Efficient Condition

The efficient condition is piping insulated with fiberglass insulation, K-value 0.27 Btu-in/hr-ft^2-°F, which is approximately R-5 for 1.5-inch thickness, R-3.5 for 1.0-inch thickness, and R-2 for 0.5-inch thickness. Foam insulation, K-value 0.30 Btu-in/hr-ft^2-°F, is also acceptable for domestic hot water systems. There are also specific requirements by system type:

- Hot water space heating systems must have 1.0-inch thick insulation for 3-inch and smaller pipe
- Hot water space heating systems must have 1.5-inch thick insulation for greater than 3-inch pipe
- Steam space heating systems must have 1.5-inch thick insulation
- Domestic hot water systems must have at least 0.5-inch thick insulation for less than 2-inch pipe
- Domestic hot water systems must have at least 1.0-inch thick insulation for 2-inch and larger pipe

Annual Energy-Savings Algorithm

$kWh_{SAVED} = Insul_{SAVINGS} * Length * HOU / (TE * 3{,}412)$

$Therms_{SAVED} = Insul_{SAVINGS} * Length * HOU / (TE * 100{,}000)$

Where:

$Insul_{SAVINGS}$ = Energy savings through insulating nominal pipe sizes (see Insulation Savings Space Heating tables)

Length = Length of insulated pipe in feet (= 1 foot)

HOU = Annual hours of operation (= 4,000 for space heat; = 8,760 for domestic hot water; see Assumptions)

TE = Thermal efficiency (= 0.75 for natural gas; = 0.92 for electric)[3]

3,412 = Conversion from Btu to kilowatt-hours

100,000 = Conversion from Btu to therms

Insulation Savings Space Heating Hot Water Pipe[4]

Pipe Outside Diameter (in)	Insulation Thickness (in)	Copper Pipe	Steel Pipe	Heat Loss, Btu/hour-linear foot		
				Bare Pipe	Insulated Pipe	$Insul_{SAVINGS}$
0.5	1.0	50.0%	50.0%	60.36	11.94	48.42
0.75	1.0	50.0%	50.0%	73.18	14.37	58.81
1	1.0	50.0%	50.0%	89.13	14.92	74.21
1.25	1.0	50.0%	50.0%	109.65	19.21	90.44
1.5	1.0	50.0%	50.0%	123.85	19.44	104.41
2	1.0	50.0%	50.0%	151.60	22.73	128.87
3	1.0	50.0%	50.0%	216.55	30.94	185.61
4	1.5	50.0%	50.0%	273.70	28.03	245.67

Insulation Savings Space Heating Steam Pipe[4]

Pipe Outside Diameter (in)	Insulation Thickness (in)	Copper Pipe	Steel Pipe	Heat Loss, Btu/hour-linear foot		
				Bare Pipe	Insulated Pipe	$Insul_{SAVINGS}$
0.5	1.5	50.0%	50.0%	93.65	14.49	79.16
0.75	1.5	50.0%	50.0%	113.65	16.79	96.86
1	1.5	50.0%	50.0%	138.60	18.24	120.37
1.25	1.5	50.0%	50.0%	170.75	20.37	150.39
1.5	1.5	50.0%	50.0%	192.90	23.06	169.84
2	1.5	50.0%	50.0%	236.40	26.33	210.07
3	1.5	50.0%	50.0%	338.15	34.81	303.34
4	1.5	50.0%	50.0%	427.70	41.96	385.75

Insulation Savings Domestic Hot Water Pipe[4]

Pipe Outside Diameter (in)	0.5 Inch Insulation	1.0 Inch Insulation	Heat Loss, Btu/hour-linear foot		
			Bare Pipe	Insulated Pipe	$Insul_{SAVINGS}$
0.5	50.0%	50.0%	25.56	8.07	17.50
0.75	50.0%	50.0%	30.88	9.37	21.52
1	50.0%	50.0%	37.48	10.43	27.05
1.25	50.0%	50.0%	45.96	13.08	32.88
1.5	50.0%	50.0%	51.81	14.09	37.72
2	0.0%	100.0%	63.27	12.78	50.49
3	0.0%	100.0%	90.04	17.35	72.69
4	0.0%	100.0%	113.60	20.75	92.85

Summer Coincident Peak Savings Algorithm

To be consistent with single-family residential pipe insulation measures, domestic hot water piping insulation does not have demand savings. Heating hot water and steam piping are only in use during the winter and therefore also have no demand savings.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

The following Deemed Savings tables list the natural gas and electricity deemed savings per linear foot of insulation for the direct install measures.

Deemed Savings, Natural Gas, Per Linear Foot

Measure	MMID	Measure Group	Annual kWh	Annual therms	Lifecycle kWh	Lifecycle therms	Incremental Cost
Hot Water Space Heat							
0.5” and 0.75” Pipe	3685	Space Heating	--	2.86	--	42.9	$9.40
1” and 1.25” Pipe	3686		--	4.39	--	65.9	$9.40
1.5” and 2” Pipe	3687		--	6.22	--	93.3	$9.40
3” and 4” Pipe	3688		--	11.50	--	172.5	$10.53
Steam Space Heat							
0.5” and 0.75” Pipe	3751	Space Heating	--	4.69	--	70.4	$11.65
1” and 1.25” Pipe	3752		--	7.22	--	108.3	$11.65
1.5” and 2” Pipe	3753		--	10.13	--	152.0	$11.65
3” and 4” Pipe	3754		--	18.38	--	275.6	$11.65
Domestic Hot Water							
0.5” and 0.75” Pipe	3695	Domestic Hot Water	--	2.28	--	34.2	$7.15
1” and 1.25” Pipe	3696		--	3.50	--	52.5	$7.15
1.5” and 2” Pipe	3697		--	5.15	--	77.3	$8.28
3” and 4” Pipe	3698		--	9.67	--	145.0	$9.40

Deemed Savings, Electricity, Per Linear Foot

Measure	MMID	Measure Group	Annual kWh	Annual therms	Lifecycle kWh	Lifecycle therms	Incremental Cost[2]
Hot Water Space Heat							
0.5” and 0.75” Pipe	3689	Space Heating	66.9	-	1,003	-	$9.40
1” and 1.25” Pipe	3690		102.7	-	1,540	-	$9.40
1.5” and 2” Pipe	3691		145.5	-	2,182	-	$9.40
3” and 4” Pipe	3692		268.9	-	4,034	-	$10.53
Steam Space Heat							
0.5” and 0.75” Pipe	3755	Space Heating	109.8	-	1,646	-	$11.65
1” and 1.25” Pipe	3756		168.8	-	2,533	-	$11.65
1.5” and 2” Pipe	3757		236.9	-	3,554	-	$11.65
3” and 4” Pipe	3758		429.7	-	6,446	-	$11.65
Domestic Hot Water							
0.5” and 0.75” Pipe	3699	Domestic Hot Water	53.3	-	799	-	$7.15
1” and 1.25” Pipe	3700		81.8	-	1,228	-	$7.15
1.5” and 2” Pipe	3701		120.5	-	1,807	-	$8.28
3” and 4” Pipe	3702		226.1	-	3,391	-	$9.40

Assumptions

For each pair of pipe diameters, the calculations are based on the average insulation savings.

The pipe insulation is being applied to multifamily central heating system supply and return pipes and multifamily domestic hot water piping.

- The heating season is November 1 to April 15, which is 166 days. The 166 days multiplied by 24 hours per day is 3,984 hours, which was rounded to 4,000 to be consistent with the business measure for steam pipe insulation (MMID 2430 in the October 2015 Wisconsin TRM).
- Space heating boiler supplies 180°F hot water, or 5-psi steam.
- Water heater supplies 125°F hot water (consistent with the hot water supply temperature for MMID 2760, domestic hot water plant replacement).
- Piping is in a basement or mechanical room that is unconditioned (assumption for MMID 2128, direct install domestic hot water piping insulation).
- Both copper and steel pipe are used for space heating, so space heating savings assume that 50% of pipe is copper and 50% is steel. All domestic hot water piping is assumed to be copper.

- For smaller pipe sizes that are only required to have 0.5-inch insulation, many installations may elect to use up to 1-inch insulation. Therefore, a 50/50 split of 0.5-inch and 1-inch insulation was assumed in the energy savings calculations.
- Incremental costs[2] are \$7.15 per foot for 0.5-inch thick insulation, \$9.40/ft for 1.0-inch thick insulation, and \$11.65/ft for 1.5-inch thick insulation. When two different insulation thicknesses are used within a single measure (such as for MMIDs 3688, 3697, 3692, and 3701), the corresponding incremental costs are weighted 50/50 to determine the average.

Sources

1. GDS Associates. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*. Table 1, Pipe Wrap. 2007. https://library.cee1.org/system/files/library/8842/CEE_Eval_MeasureLifeStudyLights%2526HVACGDS_1Jun2007.pdf
2. Illinois Energy Efficiency Statewide Advisory Group. *Illinois Statewide Technical Reference Manual*. Section 4.4.14, Pipe Insulation. June 1, 2015. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_4/2-13-15_Final/Updated/Illinois_Statewide_TRM_Effective_060115_Final_02-24-15_Clean.pdf
   This Illinois TRM lists costs for 1-inch and 2-inch pipe insulation, interpolated to determine the cost of 0.5-inch and 1.5-inch pipe insulation.
3. Cadmus. *2016 Potential Study for Focus on Energy*.
   Data maintained by Cadmus and Wisconsin PSC. Natural gas thermal efficiency based on 11 units at multifamily sites; electric thermal efficiency based on 16 units at multifamily sites.
4. Savings calculated using 3E Plus software developed by North American Insulation Manufacturers Association. www.pipeinsulation.org

Revision History

Version Number	Date	Description of Change
01	01/2016	Initial TRM entry
02	09/2018	Updated efficiencies

Domestic Hot Water Plant Replacement

	Measure Details
Measure Master ID	DHW Plant Replacement, 2760
Measure Unit	Per MBh
Measure Type	Hybrid
Measure Group	Domestic Hot Water
Measure Category	Other
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies
Water Savings (gal/year)	0
Effective Useful Life	15[1]
Incremental Cost ($/unit)	$4.53[2]

Measure Description

This measure is upgrading an entire DHW plant in a building with central DHW.

Commercial water heaters with greater than 75,000 Btu/hour have a thermal efficiency (TE) rating, which typically varies from around 80% for standard efficiency natural gas water heaters to 90% or greater for condensing water heaters.

Description of Baseline Condition

The baseline condition is a DHW plant with TE of 80%.

Description of Efficient Condition

The efficient condition is installing a new water heater, which must be:

- A stand-alone condensing water heater ≥ 90% TE, or
- An indirect storage tank connected to a ≥ 90% AFUE boiler(s).

Fuel switching is not included in this measure. The additional requirements are:

- Building must have a central DHW system.
- Entire DHW system must be replaced: single water heater replacement in a multiple water heater system do not qualify.
- For new construction projects, the total combined water heating capacity must be < 1,000,000 Btu/hr.

Annual Energy-Savings Algorithm

$Therm_{SAVED} = Therm_{BASE} - Therm_{EE}$

$Therm_{BASE} = [(GPD * N_{APTS} * 8.33 * C_P * \Delta T * 365) / (\eta_{BASE} * 100{,}000)] + [(Q_{LOSS\text{-}BASE} * N_{WH} * 24 * 365) / (100{,}000)]$

$Therm_{EE} = [(GPD * N_{APTS} * 8.33 * C_P * \Delta T * 365) / (\eta_{EE} * 100{,}000)] + [(Q_{LOSS\text{-}EE} * N_{WH} * 24 * 365) / (100{,}000)]$

Where:

GPD = Gallons per day (= 34.14, see Assumptions)[3,8]
N_{APTS} = Total number of dwelling units served by system (= user input)
8.33 = Conversion from gallons to pounds
C_P = Specific heat of water at constant pressure (= 1.0 Btu/lb-°F)
ΔT = Hot water setpoint of 125°F minus inlet water temperature of 52.3°F (= 72.7°F)[4]
365 = Number of days per year
η_{BASE} = Baseline TE (= 80%)[5]
100,000 = Conversion from Btu to therm
$Q_{LOSS\text{-}BASE}$ = Baseline standby heat loss (= 1,233 Btu/hour)[6]
N_{WH} = Total number of DWH tanks (= user input)
24 = Number of hours per day
η_{EE} = Efficient TE (= user input, must be at least 90%)
$Q_{LOSS\text{-}EE}$ = Efficient standby heat loss (= user input; if not known, use 929 Btu/hour)[7]

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

Gallons per day are calculated by fitting a polynomial equation to data from Table 3 of the Florida Solar Energy Center study.[3] An average value of 1.9 occupants per home was used for Wisconsin, based on 2009 RECS data.[8] The fitted equation is GPD = $-0.0089 * x^2 + 16.277 * x + 3.25$, where ‘x’ is the average number of occupants per home.

Sources

1. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” Commercial Water Heater measures in EUL Table. 2014. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx
2. Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 213 water heaters over 118 projects from 2016 to 2018 is $31.39/MBh. August 2018 online lookups of 43 baseline and 29 efficient boiler models on www.grainger.com and www.supplyhouse.com allow for a linear fit of cost to MBh for baseline and efficient models. This fit was applied to the spead of water heater sizes in Focus program data, revealing an efficient cost 14.4% higher than the baseline cost. Therefore the incremental cost is 14.4% * $31.39 = $4.53/MBh.
3. Florida Solar Energy Center. *Estimating Daily Domestic Hot-Water Use in North American Homes.* June 30, 2015. http://www.fsec.ucf.edu/en/publications/pdf/FSEC-PF-464-15.pdf
4. United States Department of Energy. *DHW Scheduler.*
   Average water main temperature of all locations measured in Wisconsin by scheduler, weighted by city populations. The water heater setpoint is assumed to be 125°F. Wisconsin building code 704.06 requires landlords to set water heaters to 125°F: https://docs.legis.wisconsin.gov/statutes/statutes/704/06. Water heater setpoints typically range from 120°F to 140°F, because temperatures below 120°F are susceptible to Legionella bacteria (which lead to Legionnaires Disease) and heaters set to temperatures above 140°F can quickly scald users: http://www.nrel.gov/docs/fy12osti/55074.pdf. Most TRMs assume water heater setpoints of 120°F, 125°F, or 130°F, though most of these are unsourced engineering assumptions.

5. International Code Council. *2015 International Energy Conservation Code*. Table C404.2 (for natural gas storage water heaters > 75,000 Btu/hr). https://codes.iccsafe.org/public/document/IECC2015
6. Federal standard for natural gas storage water heater with 80-gallon storage and 199 kBtu/hour heat input.
7. Average standby loss of AHRI-certified natural gas storage water heaters with TE > 94%, storage volume between 80 and 100 gallons, and heat input less than 200 kBtu/hour.
8. U.S. Energy Information Administration. *Residential Energy Consumption Survey*. 2009. https://www.eia.gov/consumption/residential/index.php

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	08/2016	Updated to remove reference to Building America tool and to reflect new state building code requirements
03	10/2018	Adjusted units to be per MBh, adjusted GPD value, adjusted cost

Natural Gas Storage Water Heater, 0.67 EF

	Measure Details
Measure Master ID	Water Heater, NG, EF of 0.67 or Greater, 1985
Measure Unit	Per water heater
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Water Heater
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	16.45
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	213.91
Water Savings (gal/year)	0
Effective Useful Life (years)	13[1]
Incremental Cost ($/unit)	$400.00[2]

Measure Description

This measure is residential-sized, tank-type storage, domestic water heaters (small storage water heaters), defined as equipment with an input rating $\leq$75,000 Btuh and a storage volume from 20 to 100 gallons. There is a program incentive for participants who install a small storage water heater that has an efficiency rating $\geq$0.67 Energy Factor (EF).

Description of Baseline Condition

The base case is a residential, natural gas–fueled storage water heater with an EF of 0.60.[3]

Description of Efficient Condition

The efficient condition is upgrading from the 0.60 EF minimum code to a higher efficiency 0.67 EF natural gas storage-type water heater.

Annual Energy-Savings Algorithm

$$\text{Therm}_{\text{SAVED}} = ((\text{GPD} * 365 * 8.33 * C_{\text{P,WATER}} * \Delta T_{\text{W}}) / 100{,}000) * ((1 / \text{EF}_{\text{BASE}}) - (1 / \text{EF}_{\text{EE}}))$$

Where:

GPD = Average daily hot water consumption (= 42.8 gallons per day)[5]

365 = Days per year

8.33 = Density of water (pounds per gallon)

$C_{\text{P,WATER}}$ = Specific heat of water (= 1 Btu/lb °F)

ΔT_W = Average difference between the cold water inlet temperatures (52.3°F) and the hot water delivery temperature (125°F) (= 72.7°F)[4]

100,000 = Conversion factor from Btu to therm

EF_{BASE} = Energy factor of the baseline water heater (= 0.60)

EF_{EE} = Energy factor of the efficient water heater (= 0.67)

Summer Coincident Peak Savings Algorithm

Natural gas–fired storage water heaters consume no electrical energy; therefore, they have no impact on demand reduction.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 13 years)[1]

Assumptions

The federal standard baseline is calculated by the equation: EF = 0.675 - (0.0015 * tank_size). The water tank size is assumed to be 50 gallons, producing a baseline energy factor of 0.60.

Gallons per day are calculated by interpolating within Table 3 of the Florida Solar Energy Center study.[5] An average value of 2.43 occupants per home was used for Wisconsin, based on US Census data.[6]

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study.” Final Report. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. U.S. Department of Energy. *Water Heater Market Profile*. p. 15. September 2009. https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/Water_Heater_Market_Profile_Sept2009.pdf
3. U.S. Department of Energy. Federal standard for residential water heaters. Effective April 1, 2015. https://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf
4. Public Service Commission of Wisconsin. *Request for Proposals*. Issued for Mass Markets Portfolio Residential Energy Efficiency Program Implementation. July 26, 2011.

5. Florida Solar Energy Center. *Estimating Daily Domestic Hot-Water Use in North American Homes*. June 30, 2015. http://www.fsec.ucf.edu/en/publications/pdf/FSEC-PF-464-15.pdf
6. United States Census Bureau. *2010 Demographic Profiles*. Accessed May 15, 2017.

Revision History

Version Number	Date	Description of Change
01	01/01/2012	Initial TRM entry
02	10/30/2014	Updated therm based off 72.7°F for the change in temperature
03	04/27/2017	Updated therms based on new federal baseline and other figures

Condensing Water Heater, NG, 90%+

	Measure Details
Measure Master ID	Condensing Water Heater, NG, 90%+, 1986 Condensing Water Heater, NG, 90%+, Claim Only, 3584
Measure Unit	Per water heater
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Water Heater
Sector(s)	Residential- multifamily, Residential- single family
Annual Energy Savings (kWh)	-50
Peak Demand Reduction (kW)	-0.0050
Annual Therm Savings (Therms)	Single family = 35; Multifamily = 24
Lifecycle Energy Savings (kWh)	Single family = -650; Multifamily = -650
Lifecycle Therm Savings (Therms)	Single family = 455; Multifamily = 312
Water Savings (gal/yr)	0
Effective Useful Life (years)	13 (see Assumptions)
Incremental Cost ($/unit)	$685.00[3]

Measure Description

This measure is installing high-efficiency, commercial-sized condensing tank-type water heaters. These heaters are used for whole-house domestic water heating in the single family residential sector and in large, single multifamily units or multiple smaller multifamily units. Commercial-sized water heaters have a minimum input rating of 75,000 Btuh and have a thermal efficiency rating of 80%. While these appliances have a commercial rating, they are often installed in residential homes.

The rebate is for customers who install condensing water heaters with a thermal efficiency rating of at least 90% in a single family residential home or multifamily unit.

Description of Baseline Condition

The base case is a residential, natural gas–fueled storage water heater with an energy factor of 0.6 (see Assumptions).

Description of Efficient Condition

The efficient condition is upgrading from the code-standard minimum natural gas storage residential water heater to a higher 90% thermal efficiency commercial natural gas storage-type water heater. Natural gas storage water heaters are used to supply domestic hot water.

Annual Energy-Savings Algorithm

Because the efficiency of traditional natural gas storage water heaters is measured using an energy factor and the efficiency of condensing water heaters is measured using the thermal efficiency, different algorithms are used to calculate the baseline energy use and efficient energy use.

$\text{Therm}_{\text{SAVED}} = \text{Therm}_{\text{BASELINE}} - \text{Therm}_{\text{MEASURE}}$

Baseline Energy Usage[5]

$\text{Therm}_{\text{BASELINE}} = [\text{GPD} * 8.33 * C_P * (T_{\text{TANK}} - T_{\text{INLET}}) / \text{EF}] * (365 / 100{,}000)$

Where:

GPD = Gallons of hot water used by the home per day (= 34.14 for multifamily; = 42.75 for single family, see Assumptions)[6]

8.33 = Density of water (lb/gal)

C_P = Specific heat of water (= 1 Btu/lb-°F)

T_{TANK} = Water heater thermostat setpoint temperature (= 125°F)[7]

T_{INLET} = Inlet water temperature (= 52.3°F)[8]

EF = Energy factor (= 0.6 for 50-gallon water heater)[4]

365 = Number of days per year

100,000 = Conversion factor from Btu to therms

Efficient Energy Usage

While residential storage water heater efficiency is measured by the energy factor, which includes standby losses, commercial-sized storage water heater efficiency is measured by thermal efficiency. While the efficiency equation for thermal efficiency is similar to the equation for energy factor, it only measures the amount of energy used to heat the water consumed, and not the amount of energy needed for standby losses. The total energy usage a water heater consumes can be defined as:

$\text{Therm}_{\text{MEASURE}} = Q_{\text{USAGE}} + Q_{\text{STANDBY}}$

$Q_{\text{USAGE}} = [\text{GPD} * 8.33 * C_P * (T_{\text{TANK}} - T_{\text{INLET}}) / \text{TE}] * (365 / 100{,}000)$

$Q_{\text{STANDBY}} = \text{UA} * (T_{\text{TANK}} - T_{\text{AMB}}) * [24 - ((Q_{\text{USAGE}} / (\text{RE} * P_{\text{ON}}))] * (365 / 100{,}000)$

Where:

TE = Thermal efficiency of measure (= 0.90)

UA = Standby heat loss coefficient (= 3.319 Btu/hr-°F)

T_{AMB} = Ambient temperature (= 65°F)[5]

24 = Number of hours per day

RE = Recovery efficiency (= 0.90, assume thermal efficiency as a proxy)

P_{ON} = Rated input power (= 76,000 Btu/hour, conservative)[5]

Electrical Energy Savings

Condensing water heaters must be power vented to qualify for a program incentive. Power-vented equipment includes an electrical fan to exhaust flue gases, which therefore has a negative electrical impact.

Summer Coincident Peak Savings Algorithm

The estimated electrical peak impact of power-vented equipment is -0.0050 kW.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 13 years; see Assumptions)

Assumptions

The average water heater as measured by the 2016 *Focus on Energy Potential Study* is 42.8 gallons. Following federal standards,[9] this size indicates a baseline uniform energy factor of 0.576 for medium-draw water heaters and of 0.636 for high-draw water heaters. An average baseline of 0.6 was used.

Gallons per day were calculated by fitting a polynomial equation to data from Table 3 of the Florida Solar Energy Center study.[6] For single family sites, an average value of 2.43 occupants per home was used for Wisconsin, based on U.S. Census data.[10] For multifamily sites, an average value of 1.9 people per home was used for Wisconsin multifamily and 2.36 people per home was used for Wisconsin single family, based on RECS 2009 data.[11] The fitted equation is $GPD = -0.0089 * x^2 + 16.277 * x + 3.25$, where x is the average number of occupants per home.

The home is assumed to be maintained at 65°F. Ambient temperature in the U.S. Department of Energy test standard is 67.5°F ± 2.5°F.[3]

The EUL is a consensus average based on values from several sources. ENERGY STAR[1] cites 13 years for high-efficiency water heaters, referring to an unavailable 2004 source, as well as 15 years for condensing water heaters, although this is unsourced. DEER[2] previously used 15 years but in 2008 reduced this to 11 years. The Illinois TRM[3] uses 13 years, citing a reference that is no longer available. Thirteen years was selected as the consensus value.

Sources

1. ENERGY STAR. *ENERGY STAR Residential Water Heaters: Final Criteria Analysis*. April 1, 2008. https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/WaterHeaterAnalysis_Final.pdf
2. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." EUL Table. 2008. http://www.deeresources.com/files/deer0911planning/downloads/EUL_Summary_10-1-08.xls
3. Illinois Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 6.0, Volume 3: Residential Measures*. p. 170. February 8, 2017. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_3_Res_020817_Final.pdf
4. 2010-04-16 Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters; Final rule. Table I.1. https://www.regulations.gov/document?D=EERE-2006-STD-0129-0005
5. Pacific Gas and Electric Company. *Applied Technology Services Performance Testing and Analysis Unit ATS Report #: 491-08.5, PY2008 Emerging Technologies Program*. 2008. Formula: p. 9. Ambient temperature: p. 11. http://www.etcc-ca.com/sites/default/files/OLD/images/stories/reswhtestreport1.pdf.
6. Florida Solar Energy Center. *Estimating Daily Domestic Hot-Water Use in North American Homes*. June 30, 2015. http://www.fsec.ucf.edu/en/publications/pdf/FSEC-PF-464-15.pdf
7. Wisconsin State Legislature. *Chapter 704. Landlord and Tenant*. Section 704.06. https://docs.legis.wisconsin.gov/statutes/statutes/704/06
   Water heater setpoints typically range between 120°F and 140°F because temperatures below 120°F are susceptible to Legionella bacteria and heaters set to temperatures above 140°F can quickly scald users: http://www.nrel.gov/docs/fy12osti/55074.pdf
8. U.S. Department of Energy. *DHW Scheduler*.
   The average water main temperature is for all locations measured in Wisconsin, weighted by city population.
9. Electronic Code of Federal Regulations. Accessed October 2018. https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8

10. U.S. Census. "Demographic Profile for Wisconsin." 2010. https://www.census.gov/newsroom/releases/archives/2010_census/cb11-cn137.html
11. U.S. Energy Information Administration. *Residential Energy Consumption Survey (RECS)*. http://www.eia.gov/consumption/residential/data/2009

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	12/2015	Sector added
03	11/2018	Updated GPD, added multifamily sector

Tankless Water Heater, NG, EF ≥ 0.90

	Measure Details
Measure Master ID	Tankless Water Heater, NG, EF ≥ 0.90, 4836
Measure Unit	Per water heater
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Water Heater
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	-50
Peak Demand Reduction (kW)	-0.0050
Annual Therm Savings (Therms)	52
Lifecycle Energy Savings (kWh)	-1,000
Lifecycle Therm Savings (Therms)	1,040
Water Savings (gal/yr)	0
Effective Useful Life (years)	20[1]
Incremental Cost	$605.00[2]

Measure Description

This measure is installing an ENERGY STAR–qualified, tankless water heater with an energy factor (EF) of at least 0.90. In addition, qualifying tankless water heaters must be whole-house units used for domestic water heating, and must be natural gas fueled.

Residential tankless water heaters are defined as equipment having a nominal input between 50,000 Btuh and 200,000 Btuh and a rated storage volume of at least two gallons.

Description of Baseline Condition

The base case is a residential, natural gas–fueled storage water heater with an EF of 0.60.[3]

Description of Efficient Condition

The efficient condition is upgrading from the 0.60 EF minimum code to a 0.90 EF natural gas tankless water heater.

Annual Energy-Savings Algorithm

$$\text{Therms}_{\text{SAVED}} = \{[\text{GPD} * 365 * 8.33 * C_{\text{P,WATER}} * (T_{\text{TANK}} - T_{\text{INLET}})] / 100{,}000\} * (1 / \text{EF}_{\text{BASE}} - 1 / \text{EF}_{\text{EE}})$$

Where:

GPD = Average daily hot water consumption (= 42.75 gallons)[4,5]

365 = Days per year

8.33 = Density of water (pounds per gallon)

$C_{P,WATER}$ = Specific heat of water (= 1 Btu/lb °F)

T_{TANK} = Water heater thermostat setpoint temperature (= 125°F)[6]

T_{INLET} = Inlet water temperature (52.3°F)[7]

100,000 = Conversion factor from Btu to therm

EF_{BASE} = Energy factor of the baseline water heater (= 0.60)

EF_{EE} = Energy factor of the efficient water heater (= 0.90)

Electrical Energy Savings

Condensing water heaters must be power vented to qualify for a program incentive. Power-vented equipment includes a range from an electrical fan to exhaust flue gases, and therefore has a negative electrical impact. As shown in the RFP TRC calculator,[8] the estimated electrical impact of power-vented equipment is 50 kWh and 0.005 kW per year.

Summer Coincident Peak Savings Algorithm

The estimated electrical peak impact of power-vented equipment is -0.0050 kW.[8]

Lifecycle Energy-Savings Algorithm

$Therms_{LIFECYCLE} = Therms_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 20 years)[1]

Assumptions

The average water heater size as measured by the 2016 Focus on Energy Potential Study is 42.8 gallons. Following federal standards,[3] this size indicates a baseline uniform energy factor of 0.576 for medium-draw water heaters and of 0.636 for high-draw water heaters. An average baseline of 0.6 is used.

Gallons per day are calculated by fitting a polynomial equation to data from Table 3 of the Florida Solar Energy Center study.[4] An average value of 2.43 occupants per home was used for Wisconsin, based on U.S. Census data.[5] The fitted equation is $GPD = -0.0089 * x^2 + 16.277 * x + 3.25$, where "x" is the average number of occupants per home.

Sources

1. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” EUL Table. 2014. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx
2. Ohio Technical Reference Manual. p. 123. 2010. http://s3.amazonaws.com/zanran_storage/amppartners.org/ContentPages/2464316647.pdf
   Tankless DHW EF > 0.82 incremental cost is $605.00 per water heater.
3. “Electronic Code of Federal Regulations. Accessed October 2018. https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8
4. Florida Solar Energy Center. *Estimating Daily Domestic Hot-Water Use in North American Homes*. June 30, 2015. http://www.fsec.ucf.edu/en/publications/pdf/FSEC-PF-464-15.pdf
5. U.S. Census. “Demographic Profile for Wisconsin.” 2010. https://www.census.gov/newsroom/releases/archives/2010_census/cb11-cn137.html
6. Wisconsin State Legislature. *Chapter 704. Landlord and Tenant*. Section 704.06. https://docs.legis.wisconsin.gov/statutes/statutes/704/06
   Water heater setpoints typically range between 120°F and 140°F because temperatures below 120°F are susceptible to Legionella bacteria and heaters set to temperatures above 140°F can quickly scald users: http://www.nrel.gov/docs/fy12osti/55074.pdf
7. U.S. Department of Energy. “Domestic Hot Water Scheduler.” Average water main temperature of all locations measured in Wisconsin by scheduler, weighted by city populations.
8. Public Service Commission of Wisconsin. *Request for Proposals*. Issued for Mass Markets Portfolio Residential Energy Efficiency Program Implementation. July 26, 2011.
9. Cadmus. *2016 Potential Study for Focus on Energy.*
   Data maintained by Cadmus and Wisconsin PSC. Residential site visits from the summer of 2016, with data for 63 single family water heaters, reveal an average water heater size of 42.8 gallons.

Revision History

Version Number	Date	Description of Change
01	08/28/2018	Initial TRM entry

Water Heater, ≥ 0.82 EF, Tankless, Residential, Natural Gas

	Measure Details
Measure Master ID	Water Heater, ≥ 0.82 EF, Tankless, Residential, Natural Gas, 2652
Measure Unit	Per water heater
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Water Heater
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	34
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	680
Water Savings (gal/year)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	$605.00[6]

Measure Description

This measure is installing an ENERGY STAR–qualified, small tankless water heater with an EF of 0.82 or greater and an input rating less than or equal to 75,000 Btu/hour. In addition, qualifying tankless water heaters must be whole-house units used for domestic water heating and must be natural gas fueled.

Residential tankless water heaters are defined as equipment having a nominal input between 50,000 Btu/hour and 200,000 Btu/hour and a rated storage volume of 2 gallons or less.

Description of Baseline Condition

The base case is a residential, natural gas–fueled storage water heater with an EF of 0.60.

Description of Efficient Condition

Qualifying tankless water heaters must meet the qualifications listed in the table below.

Qualification Requirements for Tankless Water Heaters

Sector	Input Rating	EF
Multifamily and Single Family	≥ 50,000 Btu/hour, ≤ 200,000 Btu/hour	≥ 0.82

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}} = \{[\text{GPD} * 365 * 8.33 * C_{\text{P,WATER}} * (T_{\text{TANK}} - T_{\text{INLET}})] / 100{,}000\} * (1 / \text{EF}_{\text{BASE}} - 1 / \text{EF}_{\text{EE}})$

Where:

GPD = Gallons of hot water used in the home per day (= 34.14 for multifamily, = 42.75 for single family)[4]

365 = Days per year

8.33 = Density of water, lbs/gal

$C_{\text{P,WATER}}$ = Specific heat of water (= 1 Btu/lb-°F)

T_{TANK} = Water heater temperature setpoint (= 125°F)[2]

T_{INLET} = Temperature of water entering water heater (= 52.3°F)[3]

100,000 = Conversion from Btu to therms

EF_{BASE} = Baseline energy factor (= 0.600; see Assumptions)[5]

EF_{EE} = Efficient energy factor (= 0.820)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}} = \text{Therm}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (= 20 years)[1]

Assumptions

The average water heater size as measured by the 2016 *Focus on Energy Potential Study* is 42.8 gallons. Following federal standards,[5] this size indicates a baseline uniform energy factor of 0.576 for medium-draw water heaters and of 0.636 for high-draw water heaters. An average baseline of 0.6 is used.

Sources

1. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” EUL Table. 2014. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx
2. The water heater setpoint is assumed to be 125°F, as Wisconsin building code 704.06 requires landlords to set water heaters to 125°F: https://docs.legis.wisconsin.gov/statutes/statutes

/704/06. Water heater setpoints typically range between 120°F and 140°F because temperatures below 120°F are susceptible to Legionella bacteria (which lead to Legionnaires Disease) and heaters set to temperatures above 140°F can quickly scald users: http://www.nrel.gov/docs/fy12osti/55074.pdf. Most TRMs assume water heater setpoints of 120°F, 125°F, or 130°F, though most of these are unsourced engineering assumptions. (Residential water heater setpoint resources include: Connecticut 2012 TRM PSD: 130°F for natural gas domestic water heater and 125°F for tank wrap, heat pump water heater, and temperature reduction; Mid-Atlantic TRM v3.0: 130°F for tank wrap and pipe insulation; Illinois TRM v2.0: 125°F for pipe insulation, natural gas water heater, heat pump water heater, and tank wrap and 120°F for temperature reduction; and Indiana TRM v1.0: 130°F for pipe insulation.)

3. United States Department of Energy. *DHW Scheduler*.
   Average water main temperature for all Wisconsin locations as measured by scheduler and weighted by city population.
4. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes-DRAFT*. Appendix A: Non-Evaluation Findings, Gallons Per Day Value Adjustment. September 2018.
5. "Electronic Code of Federal Regulations." Accessed October 2018. www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8
6. *Ohio Technical Reference Manual*. p. 123. 2010.
   http://s3.amazonaws.com/zanran_storage/amppartners.org/ContentPages/2464316647.pdf
   Tankless DHW EF > 0.82 incremental cost is $605.00 per water heater.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	10/2018	Revised inputs for multifamily measure

Heat Pump Water Heater

	Measure Details
Measure Master ID	Heat Pump Water Heater, 4108
Measure Unit	Per water heater
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Water Heater
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	1,660.36
Peak Demand Reduction (kW)	0.079
Annual Therm Savings (Therms)	-23.44
Lifecycle Energy Savings (kWh)	21,584.65
Lifecycle Therm Savings (Therms)	-304.73
Water Savings (gal/year)	0
Effective Useful Life (years)	13[1]
Incremental Cost ($/unit)	$1,000.00[12]

Measure Description

This measure is the installation of a heat pump domestic hot water heater in place of a standard electric water heater in a residential home. The associated measure characteristics are presented based on a natural gas heated home with electric water heating.

Description of Baseline Condition

The baseline condition is a heat pump with an energy factor of 0.945. The deemed measure algorithms and associated savings for the heat pump water heater are based on the *Illinois Statewide Technical Reference Manual* Section 5.4.3 Heat Pump Water Heaters[2] (except where noted).

Description of Efficient Condition

The efficient condition is a heat pump water heater that is ENERGY STAR certified.

Annual Energy-Savings Algorithm

The associated electric and natural gas energy savings are calculated based on the following algorithms:

$kWh_{SAVED} = (((1/EF_{BASE} - 1/EF_{EFF}) * GPD * 365 * 8.33 * \Delta T * C_{P,WATER}) / 3{,}412) + kWh_{COOL}$

kWh_{COOL} = Cooling savings from conversion of heat in home to water heat = $(([((GPD * 365 * 8.33 * \Delta T * C_{P,WATER}) / 3{,}412) - ((GPD * 365 * 8.33 * \Delta T * C_{P,WATER}) / 3{,}412) / EF_{EFF}] * LF * 27\%) / COP_{COOL}) * LM$

$\text{Therm}_{\text{SAVED}}$ = Heating increase from conversion of heat in home to water heat = $-([((GPD * 365 * 8.33 * \Delta T * C_{P,WATER}) / 3{,}412) - (((GPD * 365 * 8.33 * \Delta T * C_{P,WATER}) / 3{,}412) / EF_{EFF})] * LF * 49\% * 0.03412) / EFF_{HEAT}$

Where:

EF_{BASE} = Baseline energy factor (= 0.945)[3]

EF_{EFF} = Efficient energy factor (= 2.0)[4]

GPD = Gallons per day (= 42.75)[5,6]

365 = Number of days per year

8.33 = Specific weight of water (lb/gallon)

ΔT = Average difference between the cold water inlet temperatures (52.3°F)[7] and the hot water delivery temperature (125°F)[8] (= 72.7°F)

$C_{P,WATER}$ = Specific heat of water (= 1.0 Btu/(lb * °F))

3,412 = Btu to kWh conversion factor

LF = Location factor (= 0.81)[9]

27% = Reduction of waste heat resulting in cooling savings[2]

COP_{COOL} = Coefficient of performance of cooling system (= 3.52)[10]

LM = Latent multiplier (= 1.33)[11]

49% = Reduction of waste heat resulting in heating increase[2]

0.03412 = kWh to therms conversion factor

EFF_{HEAT} = Efficiency of heating system (= 80%)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / \text{Hours} * CF$

Where:

Hours = 2,533[2]

CF = Coincidence factor (= 0.12)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$\text{Therm}_{LIFECYCLE} = \text{Therm}_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 13 years)[1]

Assumptions

The incremental measure cost of the heat pump water heater equipment was determined as $1,000 based on calculations from the Illinois TRM.[2] This is relatively high for an emerging technology, but will decrease over time with the appropriate market uptake and increased consumer awareness.

Baseline efficiency was derived from federal standard for electric storage water heaters as[3]: EF = 0.960 – (0.0003 x volume), where volume is assumed to be 50 gallons.

Gallons per day are calculated by fitting a polynomial equation to data from Table 3 of the Florida Solar Energy Center study.[5] An average value of 2.43 occupants per home was used for Wisconsin, based on US Census data.[6] The fitted equation is $GPD = -0.0089 * x^2 + 16.277 * x + 3.25$, where "x" is the average number of occupants per home.

A heating system efficiency of 80% is assumed.

Sources

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2. Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 5.0. Volume 3: Residential Measures*. p. 168. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Final/IL-TRM_Effective_060116_v5.0_Vol_3_Res_021116_Final.pdf
   Waste heat cooling savings factor: REM Rate determined percentage (27%) of lighting savings that result in reduced cooling loads (lighting is used as a proxy for hot water heating since load shapes suggest their seasonal usage patterns are similar)
   Waste heat heating increase factor: REM Rate determined percentage (49%) of lighting savings that result in increased heating loads (lighting is used as a proxy for hot water heating since load shapes suggest their seasonal usage patterns are similar)
   Hours: Full load hours assumption based on Efficiency Vermont analysis of Itron eShapes
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4. ENERGY STAR. "Water Heater Key Product Criteria." Accessed May 5, 2017. https://www.energystar.gov/products/water_heaters/residential_water_heaters_key_product_criteria
5. Florida Solar Energy Center. *Estimating Daily Domestic Hot-Water Use in North American Homes.* June 30, 2015. http://www.fsec.ucf.edu/en/publications/pdf/FSEC-PF-464-15.pdf
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   Water heater setpoints typically range between 120°F and 140°F because temperatures below 120°F are susceptible to Legionella bacteria and heaters set to temperatures above 140°F can quickly scald users: http://www.nrel.gov/docs/fy12osti/55074.pdf
9. Cadmus. *2016 Potential Study for Focus on Energy.*
   Data maintained by Cadmus and Wisconsin PSC. Residential site visits from the summer of 2016 reveal that 81% of water heaters are installed in conditioned spaces in single family homes.
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    Sensible heat ratio of 0.75 for typical split system from page 10.
12. Northeast Energy Efficiency Partnerships. *Incremental Cost Study Phase Three Final Report*. May 28, 2014. http://www.neep.org/incremental-cost-study-phase-3

Revision History

Version Number	Date	Description of Change
01	11/06/2012	Original
02	12/07/2016	Update to new formatting
03	01/26/2017	Made corrections to some values and references

Water Heater, Indirect

	Measure Details
Measure Master ID	Water Heater: Indirect, 95% or greater, 1988, 3784 Indirect, Claim Only, 3585
Measure Unit	Per water heater
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Water Heater
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	88
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	1,320
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Varies by measure, see Appendix D[2]

Measure Description

Indirect water heaters are applicable to any indirectly fueled water heater, and must be paired with a high-efficiency boiler. In addition, qualifying indirect water heaters must be whole-house units or used for domestic water heating.

Unlike other water heaters, indirect water heaters use a boiler as the heat source. The water heater may also have a direct energy source for non-heating seasons when the boiler is shut off and thus not able to meet the water heating demands.[3]

Description of Baseline Condition

The base case is a residential, gas-fueled, storage water heater with an EF of 0.575.[4] New federal efficiency standards that took effect in April 2015 raised the minimum EF for baseline units from 0.575 to 0.600. The criteria date was rounded to January 1, 2016 since the code takes affect mid-year 2015.

Description of Efficient Condition

Indirect water heaters must be connected to a boiler with an AFUE of 95% or greater.

Annual Energy-Savings Algorithm

$$Therm_{SAVED} = ((GPD * 365 * 8.33 * 1 * \Delta T_{w})/100{,}000) * ((1/RE_{BASE}) - (1/E_{C,EE})) + ((UA_{BASE} / RE_{BASE}) - (UA_{EE} / E_{C,EE})) * (\Delta T_{s} * 8{,}760)/100{,}000$$

Where:

GPD = Average daily hot water consumption (= 42.75 gallons per day)[5,10]

365 = Days per year

8.33 = Density of water (lb/gallon)

1 = Specific heat of water (Btu/lb °F)

ΔT_{w} = Average difference between the cold water inlet temperatures (52.3°F) and the hot water delivery temperature (125°F) (= 72.7°F)[6]

100,000 = Conversion factor (Btu/therm)

RE_{BASE} = Recovery efficiency of the baseline tank type water heater (= 76%)[6]

$E_{C,EE}$ = Combustion efficiency of energy-efficient boiler used to heat indirect water heater (= 95%)[7]

UA_{BASE} = Overall heat loss coefficient of base tank type water heater (= 14.0 Btu/hr-°F)[8]

UA_{EE} = Overall heat loss coefficient of indirect water heater storage tank (= 6.1 Btu/hr-°F; see table below)[9]

Typical Values for UA_{EE}

Volume (gal)	H (bare tank) inches	Diameter (bare tank) inches	Insulation	UA (Btu/hr-°F)
40	44	17	1 in foam	4.1
			2 in foam	2.1
80	44	24	1 in foam	6.1
			2 in foam	3.1
120	65	24	1 in foam	8.4
			2 in foam	5.4

ΔT_{S} = Temperature difference between the stored hot water temperature (125°F) and the ambient indoor temperature (65°F) (= 60°F)

8,760 = Conversion factor (hours/year)

Summer Coincident Peak Savings Algorithm

Indirect water heaters consume no electrical energy; therefore, they have no impact on demand reduction.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}} = \text{Therm}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (15 years)[1]

Assumptions

Because the efficiency of residential water heater is measured in EF, the true EF and UA_{BASE} is not available. A thermal efficiency of 76% and a UA_{BASE} of 14 is assumed. The average difference of 60°F assumes pipe and ambient air temperatures of 125°F and 65°F, respectively.

Gallons per day were calculated by fitting a polynomial equation to data from Table 3 of the Florida Solar Energy Center study.[5] An average value of 2.43 occupants per home was used for Wisconsin, based on US Census data.[10] The fitted equation is GPD = -0.0089 * x2 + 16.277 * x + 3.25, where x is the average number of occupants per home.

Sources

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2. New York Statewide Residential Gas High Efficiency Heating Equipment Programs: Evaluation of 2009-2011 Programs. Average of mean and median costs using both approaches, in Table 1-4. http://www.coned.com/energyefficiency/PDF/EEPS%20CY1%20NY%20HEHE%20Evaluation%20Report%20FINAL%20APPROVED%202014-08-21.pdf
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7. Assumed the combustion efficiency is a proxy for AFUE, with program minimum of 95% AFUE.

8. United States Department of Energy. Technical Support Document: Energy Efficiency Standards for Consumer Products, Residential Water Heaters, Including Regulatory Impact Analysis. 2000.
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10. U.S. Census Bureau. "Demographic Profile for Wisconsin." May 12, 2011. https://www.census.gov/newsroom/releases/archives/2010_census/cb11-cn137.html

Revision History

Version Number	Date	Description of Change
01	01/01/2012	Initial TRM entry
02	10/30/2014	Updated therms based on 72.7°F temperature
03	12/2018	Updated gallons per day calculation

HVAC

Room Air Conditioner, ENERGY STAR

	Measure Details
Measure Master ID	Room Air Conditioner, ENERGY STAR, 4035
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Air Conditioner
Sector(s)	Residential- upstream
Annual Energy Savings (kWh)	40
Peak Demand Reduction (kW)	0.0223
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	360
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	9[1]
Incremental Cost ($/unit)	$114.00[1]
Important Comments	Measure under Retail Product Platform (RPP) Pilot

Measure Description

A room air conditioner is a factory-encased air conditioner that is designed (1) as a unit for mounting in a window, through a wall, or as a console, and (2) for delivery without ducts of conditioned air to an enclosed space. This measure consists of ENERGY STAR-certified room air conditioner units that meet the ENERGY STAR Version 4.0 requirements.[2] ENERGY STAR-certified units are 15% more efficient than non-qualified models.

Description of Baseline Condition

The baseline condition is a non-ENERGY STAR-certified standard room air conditioner. The resulting energy usage is the (market-weighted) average energy consumption across product classes and the (simple) average energy consumption across operating hours associated with the Wisconsin cities of Green Bay, La Crosse, Madison, and Milwaukee.[4]

Description of Efficient Condition

The efficient condition is ENERGY STAR-certified room air conditioners that meet ENERGY STAR Version 4.0 requirements.[2] The resulting energy usage is the (market-weighted) average across product classes and the (simple) average across operating hours associated with the Wisconsin cities of Green Bay, La Crosse, Madison, and Milwaukee.[1]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = UEC_{BASE} - UEC_{EE}$

Where:

UEC_{BASE} = Annual unit energy consumption of baseline unit (= 442.11 kWh)[1,2]

UEC_{EE} = Annual unit energy consumption of measure unit (= 401.79 kWh)[1]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (kWh_{SAVED} / Hours) * CF$

Where:

Hours = Hours of operation per year (= 543)[3]

CF = Coincidence factor (= 0.3)[3]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 9 years)[1]

Sources

1. ENERGY STAR. *Retail Products Platform: Product Analysis for Room Air Conditioners.* Effective May 11, 2016. https://drive.google.com/open?id=0B9Fd3ckbKJp5OEpWSHg1eksyZ1U.
Lifetime based on Appliance Magazine - Market Research. "The U.S. Appliance Industry: Market Value, Life Expectancy & Replacement Picture 2013." December 2013.
Incremental costs are based on the Room Air Conditioner TSD Life-Cycle Cost and Payback Analysis "2011-04-18_TSD_Chapter_8_Life-Cycle_Cost_and_Payback_Period_Analyses.pdf". To calculate an average incremental cost, a weighted average was created based on the market share of each product subtype. http://www.regulations.gov/#!documentDetail;D=EERE-2007-BT-STD-0010-0053
Baseline energy consumption is based on the federal standard for room air conditioners. Accessed November 21, 2016. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=52&action=viewlive
It is calculated by taking a market share weighted average of the unit energy consumption of all product subtypes listed in the ENERGY STAR specification. It is assumed that the room air

conditioner is in operation for 543 hours per year, an average of the hours for the four Wisconsin cities listed in the Analysis workbook. This value was used to replace the national value of 750 hours per year used for the various types of AC in the workbook.
Efficient energy consumption is based on the ENERGY STAR Version 4.0 standard for Room Air Conditioners.[2] The efficient condition energy consumption is calculated by taking a market share weighted average of the unit energy consumption of all product subtypes listed in the ENERGY STAR specification. It is assumed that the room air conditioner is in operation for 543 hours per year, an average of the hours for the four Wisconsin cities listed in the Analysis workbook. This value was used to replace the national value of 750 hours per year used for the various types of AC in the workbook.

2. ENERGY STAR. *Program Requirements for Room Air Conditioners – Eligibility Criteria.* Version 4.0. Accessed November 17, 2016. www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.0%20Room%20Air%20Conditioners%20Program%20Requirements.pdf
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Revision History

Version Number	Date	Description of Change
01	06/24/2016	Initial TRM entry

Communicating Thermostats

	Measure Details
Measure Master ID	Communicating Thermostat, Existing Natural Gas Boiler, 4298 Communicating Thermostat, Existing Natural Gas Furnace, 4299 Communicating Thermostat, Existing Air-Source Heat Pump, 4300
Measure Unit	Per thermostat
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Varies by existing heating system
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by existing heating system
Lifecycle Energy Savings (kWh)	Varies by existing heating system
Lifecycle Therm Savings (Therms)	Varies by existing heating system
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$90.89[2]

Measure Description

Standard programmable thermostats require customers to adjust temperature setpoints at different times of the day to allow for some energy savings during unoccupied periods. Communicating thermostats provide this base level of functionality and can be programmed remotely through Wi-Fi.

Description of Baseline Condition

The baseline condition is a manual or standard programmable thermostat installed in a home with an existing natural gas furnace, natural gas boiler, or air-source heat pump (ASHP).

Description of Efficient Condition

The efficient condition is a communicating thermostat installed in a home to replace the existing thermostat. To qualify as communicating, the thermostat must be Wi-Fi capable (with the Wi-Fi connection established by the customer), but not certified as an ENERGY STAR Connected Thermostat, and not included as a qualifying smart thermostat for the smart thermostat measure prior to 2018.

Annual Energy-Savings Algorithm

$$\text{Therm}_{\text{SAVED}} = (0.75 * \text{CONS}_{\text{THERM,BA}} + 0.25 * \text{CONS}_{\text{THERM,CALC}}) * \text{ESF}_{\text{THERM}} * \text{P}_{\text{MF,AREA}}$$

$$\text{CONS}_{\text{THERM,CALC}} = \text{HOURS}_{\text{HEATING}} * \text{CAP}_{\text{GAS}} / (\text{AFUE} * 100)$$

$kWh_{SAVED} = kWh_{SAVED\ COOLING} + kWh_{SAVED\ HEATING}$

$kWh_{SAVED\ COOLING} = (0.75 * CONS_{KWh,COOL,BA} * P_{MF,AC} + 0.25 * CONS_{KWh,COOL,CALC}) * ESF_{KWh,COOLING}$

$CONS_{KWh,COOL,CALC} = EFLH_{COOL} * CAP_{COOL} * AC\% / SEER$

$kWh_{SAVED\ HEATING} = (0.75 * CONS_{KWh,HEAT,BA} + 0.25 * CONS_{KWh,HEAT,CALC}) * ESF_{KWh,HEATING}$

$CONS_{KWh,HEAT,CALC} = EFLH_{HEAT,KWh} * CAP_{ASHP,HEAT} / (HSPF * 3.412)$

Where:

$CONS_{THERM,BA}$ = Annual therms consumed by smart thermostat participants before smart thermostat installation, as determined by Cadmus billing analysis (= 653 therms for furnace; = 1,050 therms for boiler; = 0 therms for ASHP)

$CONS_{THERM,CALC}$ = Annual therms consumed by communicating thermostat participants before communicating thermostat installation (= 896 therms for furnace; = 1,375 therms for boiler; = 0 therms for ASHP, see Assumptions)

ESF_{THERM} = Heating energy savings fraction for communicating thermostats (= 2.8% for furnace; = 3.0% for boiler; = 0% for ASHP)

$P_{MF,AREA}$ = Scale factor for multifamily home size (= 100.0% for single family; =52.9% for multifamily,[5] see Assumptions)

$HOURS_{HEATING}$ = Annual home heating hours (= 1,158 hours for furnace[3] or boiler;[4] = 0 hours for ASHP)

CAP_{GAS} = Natural gas heating system capacity (= 70.7 MBtu/hour for furnace;[5] = 110 MBtu/hour for boiler[6])

AFUE = AFUE of system (= 91.4% for furnace;[5] = 80% for boiler)

100 = Conversion from therms to MBtu

$CONS_{KWh,COOL,BA}$ = Annual cooling kilowatt-hours consumed by smart thermostat participants before smart thermostat installation, as determined by Cadmus billing analysis (= 1,584 kWh for furnace, boiler, and ASHP)

$P_{MF,AC}$ = Scale factor for multifamily homes with natural gas furnaces and central air conditioners (= 100.0% for single family and multifamily with boiler and ASHP; = 112.6% for multifamily with natural gas furnace,[5] see Assumptions)

$CONS_{KWh,COOL,CALC}$ = Annual cooling kilowatt-hours consumed by communicating thermostat participants before communicating thermostat installation (= 729 kWh for furnace and boiler; = 867 kWh for ASHP, see Assumptions)

$ESF_{KWh,COOLING}$ = Kilowatt-hour energy savings fraction for cooling for communicating thermostats (= 12.4%)

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 410 for furnace, boilers, and ASHP)[3]

CAP_{COOL} = Cooling system capacity (= 25.6 MBtu/hour)[5]

AC% = Fraction of participants with an air conditioner (= 84% for furnace and boiler;[5] = 100% for ASHP)

SEER = Seasonal energy efficiency rating (= 12.1)[5]

$CONS_{KWh,HEAT,BA}$ = Annual heating kilowatt-hours consumed by smart thermostat participants before smart thermostat installation (= 808 kWh for furnace; = 0 kWh for boiler; = 962 kWh for ASHP, see Assumptions)

$CONS_{KWh,HEAT,CALC}$ = Annual heating kilowatt-hours consumed by communicating thermostat participants before communicating thermostat installation (= 0 kWh for furnace and boiler; = 2,902 kWh for ASHP, see Assumptions)

$ESF_{KWh,HEATING}$ = Kilowatt-hour energy savings fraction for heating for communicating thermostats (= 8.6% for furnace; = 0% for boiler; = 7.3% for ASHP)

$EFLH_{HEAT,KWh}$ = Equivalent full-load heating hours (= 1,890 for ASHP;[7] = 0 for furnace and boiler)

$CAP_{ASHP,HEAT}$ = ASHP heating capacity (= 37.2 MBtu/hour)

HSPF = Heating seasonal performance factor (= 7.1)

3.412 = Conversion from Btu to watts

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure. It is assumed that only a small minority of participants have regular behavioral patterns that would produce demand reduction. These patterns entail not being at home during the peak period and not already setting the temperature back during that time.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Annual and Lifecycle Savings by Communicating Thermostat Measure

Method of Home Heating	MMID	Sector	Peak kW	Annual kWh	Lifecycle kWh	Annual therms	Lifecycle therms
Natural Gas Boiler	4298	SF	0	170	1,700	36	360
		MF	0	90	900	19	190
Natural Gas Furnace	4299	SF	0	223	2,230	20	200
		MF	0	128	1,280	11	110
Air-Source Heat Pump	4300	SF	0	280	2,800	0	0
		MF	0	148	1,480	0	0

Assumptions

Because manual and programmable thermostats often last for decades, measure cost and savings assume a technology-based upgrade as opposed to end-of-life replacement, so the baseline condition would have continued with existing equipment.

The GDS Associates document[1] cited for EUL is also used by the Illinois TRM for programmable thermostats.

For the 2016 Focus evaluation, Cadmus conducted a billing analysis to examine savings for participants who installed smart thermostats as part of MMIDs 3609, 3610, and 3611 (updated to MMIDs 4301, 4302, and 4303). The 2016 *Focus on Energy Evaluation Report*[9] discusses these findings, and results from that billing analysis are analyzed further in the updated workpaper for these MMIDs. This study did not examine communicating thermostats, but it did reveal that smart thermostat participants had lower pre-install heating consumption and higher pre-install cooling consumption than the TRM calculations had predicted. This indicates that the sample for the billing analysis—participants who installed smart thermostats—systematically differs from the Wisconsin general population. These differences may apply to participants who install communicating thermostats as well. Therefore, the pre-install consumption values are a weighted average, based 25% on the previous TRM calculations and assumptions and based

75% on the billing analysis results for consumption. For details on savings calculations for smart thermostats, refer to measures 3609, 3610, and 3611.

Values for energy savings factors for communicating thermostats were derived by extrapolating data from the Minnesota TRM.[8] This TRM finds a heating and cooling energy savings factor of 5.4% for communicating thermostats, and a heating and cooling energy savings factor of 8.9% for smart thermostats. Therefore, this TRM shows that energy savings factors for communicating thermostats are 60.7% of those for smart thermostats. That ratio was applied to the energy savings factors for communicating thermostats in this workpaper, using the energy savings factors for smart thermostats found from the 2016 Cadmus billing analysis. Details are shown in the table below.

Energy Savings Factors for Communicating Thermostats

Parameter	Thermostat Type	Furnace	Boiler	ASHP
ESF_{THERM}	Smart	4.6%	5.0%	N/A
	Communicating	2.8%	3.0%	N/A
$ESF_{KWh,COOL}$	Smart	20.5%	20.5%	20.5%
	Communicating	12.4%	12.4%	12.4%
$ESF_{KWh,HEAT}$	Smart	14.2%	N/A	12.0%
	Communicating	8.6%	N/A	7.3%

The capacity of residential heat pumps installed in Wisconsin is assumed to be 3.1 tons, based on an analysis of 75 ASHPs installed between 2013 and 2015 in Focus on Energy residential programs. At 12,000 Btu/hour/ton, the assumed average capacity is 37.2 MBtu/hour.

The default efficiency levels are based on existing heating and cooling equipment efficiencies of 80% AFUE boilers and HSPF 7.1 ASHPs. Current baselines for boilers and ASHPs assume 82% AFUE and HSPF 7.7, respectively, based on current installation standards in Wisconsin (and assuming that the average customer in Wisconsin is slightly below the baseline due to some homes still using older equipment). Updated values for average furnace capacity and AFUE, cooling capacity and SEER, and fraction of homes with a central air conditioner installed were updated based on data from the 2016 Focus on Energy potential study.[5]

Supporting inputs for cooling load hours (furnaces and ASHPs) in several Wisconsin cities are shown in the table below.

Supporting Inputs for Equivalent Full-Load Cooling Hours by City

Location	$EFLH_{COOL}$ (furnace, boiler, and ASHP)[3,7]	$EFLH_{HEAT}$ (ASHP)[7]	Weighting by Participant[3]
Green Bay	344	1,852	22%
Lacrosse	323	1,966	3%
Madison	395	1,934	18%
Milwaukee	457	1,883	48%
Wisconsin Average	380	1,909	9%
Weighted Average	**410**	**1,890**	**100%**

The billing analysis that serves as the basis for smart thermostat savings examined thermostats installed in single family residences. Multifamily residences are assumed to have the same energy savings fractions, but consumptions scale due to two factors:

- First, all multifamily heating and cooling consumptions scale based on residence size. Data from the Wisconsin Focus on Energy potential study[5] indicate that the average single family home has 1,652 sq ft of finished space, while the average multifamily unit has 874 sq ft of finished space. Therefore, all consumption values for multifamily homes incorporate an area scaling factor of $P_{MF,AREA}$ equal to 874 divided by 1,652 (52.9%). This applies to factors derived from the billing analysis and from calculations.
- Second, billing analysis derived multifamily cooling consumption for natural gas furnace sites is also scaled. The average natural gas furnace cooling consumption observed in the billing analysis is directly dependent on the fraction of those homes that have central air conditioners. That fraction, while not specifically known for the billing analysis sample, may be different for multifamily sites receiving smart thermostats. The potential study[5] sample may be different from the billing analysis sample, but its data can be used here. The potential study data shows that 85.5% of multifamily sites with natural gas furnaces also have central air conditioners, and that this fraction for single family sites is 75.9%. Therefore, for multifamily sites with natural gas furnaces, there is an assumed cooling consumption scaling factor of $P_{MF,AC}$ equal to 85.5 divided by 75.9 (112.6%).

Sources

1. GDS Associates. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*. Table 1, HVAC Controls. June 2007. http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf Used programmable thermostat EUL as the closest proxy for communicating thermostats.
2. Average cost of communicating thermostats. Online retail research conducted February 2017. Minus the cost of a manual thermostat, which is $39.11 based on online lookups from July 2018.

3. Cadmus. *Focus on Evaluated Energy Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
4. Ibid. Residential boilers are assumed to have sizing practices similar to furnaces, and therefore have the same EFLH.
5. *SPECTRUM Focus Prescriptive Database*. 2013.
   Average input capacity of boilers under 300 MBtu/hour.
6. *Illinois Statewide Technical Reference Manual*.
   Calculated using an average from Illinois TRM, applied to Wisconsin cooling degree days.
7. Minnesota Department of Commerce, Division of Energy Resources. *State of Minnesota Technical Reference Manual for Energy Conservation Improvement Programs, Version 2.0*. April 2016. http://mn.gov/commerce-stat/pdfs/mn-trm-v2.0-041616.pdf
8. Cadmus. *Focus on Energy Calendar Year 2016 Evaluation Report, Volume II*. May 19, 2017. https://focusonenergy.com/sites/default/files/WI%20FOE%20CY%202016%20Volume%20II%20-%20%28Low%20Res%29.pdf

Revision History

Version Number	Date	Description of Change
01	06/2017	Initial TRM entry
02	12/2018	Updated incremental cost and boiler EFLH

Smart Thermostats

	Measure Details
Measure Master ID	Smart Thermostat, Existing Natural Gas Boiler, 4301, 4666 Smart Thermostat, Existing Natural Gas Furnace, 4302, 4667 Smart Thermostat, Existing Air-Source Heat Pump, 4303, 4668
Measure Unit	Per thermostat
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Varies by existing heating system
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by existing heating system
Lifecycle Energy Savings (kWh)	Varies by existing heating system
Lifecycle Therm Savings (Therms)	Varies by existing heating system
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$173.89[2]

Measure Description

Standard programmable thermostats (PTs), when running a program, automatically change temperature setpoints according to a schedule. Typical 5/2 PT schedules include weekday setbacks during working hours as well as daily setbacks during sleep hours. When used, these setbacks result in more energy-efficient temperatures during unoccupied and overnight periods to enable energy savings. However, research has suggested that many PTs are kept in permanent-hold,[6] which effectively eliminates savings from automatic setbacks: "...90% of respondents reported that they rarely or never adjusted the thermostat to set a weekend or weekday program. Photographs of thermostats were collected in one online survey, which revealed that about 20% of the thermostats displayed the wrong time and that about 50% of the respondents set their programmable thermostats on 'long-term hold' (or its equivalent)."

Some consumers, however, may manually setback their manual or programmable thermostat to achieve savings even when kept in permanent hold.

Compared to PTs, smart thermostats provide enhanced functionality that can include:

- More simple use and programming, both on the thermostat and remotely via smartphone apps and web portals
- Occupancy sensing that enables energy savings from automatic setbacks during unoccupied periods (occupancy sensing may use sensors in the thermostat or capability to track the resident's location through a smartphone app)
- Learning capability or automatic schedule generation or modification (such thermostats are capable of dynamically adjusting or constructing a program schedule based on actual occupancy patterns, eliminating the need for programming)
- Intelligent control of HVAC equipment, including minimizing energy expended for recovery from setback, intelligent control of two-stage HVAC sources, and minimizing the use of inefficient electric-resistance heat (which is associated with most heat-pumps)
- Use of outside temperature and other weather data to better ensure comfort and minimize energy use
- Encourage the use of more energy-efficient set temperatures, such as a leaf icon that appears when the set temperature is moved in the direction of less energy use
- Algorithms that make frequent, subtle set temperature changes to save energy

Description of Baseline Condition

The baseline condition is a manual or standard programmable thermostat installed in a home with an existing natural gas furnace, natural gas boiler, or air-source heat pump (ASHP).

Description of Efficient Condition

The efficient condition is a smart thermostat installed in a home to replace an existing manual or programmable thermostat. To qualify as smart, the thermostat must be certified as an ENERGY STAR Connected Thermostat, or have been included as a qualifying smart thermostat for this measure prior to 2018.

Annual Energy-Savings Algorithm

$Therm_{SAVED} = CONS_{THERM} * ESF_{THERM} * P_{MF,AREA}$

$kWh_{SAVED} = (CONS_{kWh,COOL} * P_{MF,AC} * ESF_{kWh,COOL} + CONS_{kWh,HEAT} * ESF_{kWh,HEAT}) * P_{MF,AREA}$

Where:

$CONS_{THERM}$ = Annual therms consumed by smart thermostat participants before smart thermostat installation (= 653 therms for furnace; = 1,050 therms for boiler; = 0 therms for ASHP)

ESF_{THERM} = Therm energy savings fraction (= 4.6% for furnace; = 5.0% for boiler; = 0% for ASHP)

$P_{MF,AREA}$ = Scale factor for multifamily home size (= 100.0% for single family; =52.9% for multifamily, see the Assumptions section)[7]

$CONS_{kWh,COOL}$ = Annual cooling kilowatt-hours consumed by smart thermostat participants before smart thermostat installation (= 1,584 kWh for furnace, boiler, and ASHP)

$P_{MF,AC}$ = Scale factor for multifamily homes with natural gas furnaces and central air conditioners (= 100.0% for single family and multifamily with boiler and ASHP; = 112.6% for multifamily with natural gas furnace, see the Assumptions section)[7]

$ESF_{kWh,COOL}$ = Kilowatt-hour energy savings fraction for cooling (= 20.5% for furnace, boiler, and ASHP)

$CONS_{kWh,HEAT}$ = Annual heating kilowatt-hours consumed by smart thermostat participants before smart thermostat installation (= 808 kWh for furnace; = 0 kWh for boiler; = 962 kWh for ASHP)

$ESF_{kWh,HEAT}$ = Kilowatt-hour energy savings fraction for heating (= 14.2% for furnace; = 0% for boiler; = 12% for ASHP)[3]

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure. It is assumed that only a small minority of participants have regular behavioral patterns that would produce demand reduction, such as not being at home during the peak period and not already setting the temperature back during that time.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Annual and Lifecycle Savings by Measure

Measure	MMID	Sector	Peak kW	Annual kWh	Lifecycle kWh	Annual therms	Lifecycle therms
Smart Thermostat, Home Heated by Natural Gas Boiler	4301	SF	0	325	3,250	53	530
		MF	0	172	1,720	28	280
Smart Thermostat, Home Heated by Natural Gas Furnace	4302	SF	0	439	4,390	30	300
		MF	0	254	2,540	16	160
Smart Thermostat, Home Heated by Air Source Heat Pump	4303	SF	0	440	4,400	-	-
		MF	0	233	2,330	-	-

Assumptions

For the CY2016 Focus evaluation, Cadmus conducted a billing analysis to examine savings for participants who installed smart thermostats as part of MMIDs 3609, 3610, and 3611 (former versions of measures 4301, 4302, 4303). There were 2,427 natural gas customers and 2,110 electric customers for this analysis. Following a Princeton Scorekeeping Method (PRISM) modeling approach, the analysis filtered weather-sensitive electric and natural gas consumption from total electric and natural gas usage, and determined smart thermostat savings as a percentage of this consumption.

The 2016 Focus on Energy Evaluation Report[4] discusses these findings, but does not break them into components for heating and cooling, or for furnace, boiler, and ASHP smart thermostat measures: that analysis is discussed below.

Therm Savings

Of the 2,427 natural gas customers, 2,329 had a natural gas furnace. Based on the billing data for these participants, their baseline natural gas consumption averages 653 therms, and the savings fraction from installing a smart thermostat for these participants is 4.6% (30 therms).

There were 93 participants with a natural gas boiler. Their average baseline natural gas consumption is 1,050 therms, and the savings fraction for these participants is 5.0%. The relative precision for all these values is ≤ 9%.

Electric Savings

Furnaces

Of the 2,110 electric customers, 2,089 had an electric furnace installed. Many of these homes also had air conditioner installed: the sample represents an average split of homes with and without air conditioning where smart thermostats were installed.

The average baseline electric consumption for participant houses with an electric furnace is 2,392 kWh. This consisted of 1,584 kWh in the cooling season and 808 kWh in the heating season. Heating season consumption may be from furnace motors and participant homes with electric space heating.

The analysis revealed savings factors of 20.5% for cooling season consumption and 14.2% for heating season consumption, with an overall electric savings factor of 18.4%. Relative precision values for heating and cooling consumption and cooling savings are ±8%, and relative precision for heating savings is ±24%.

Boilers

Electric data for boilers is limited, since the billing analysis only examined electric data for three homes. While the results are imprecise due to the small sample (at ±55% to ±75% precision), cooling consumption and savings were observed for these homes, which indicates many had air conditioner installed and controlled by their thermostat. Therefore, the cooling consumption and savings for participants with an electric furnace is applied to the smart thermostat with boiler measure.

Air-Source Heat Pumps

The billing analysis examined data for 18 homes with an ASHP. Cooling consumption and savings values for these homes were generally imprecise, with precision around ±35%. Therefore, the cooling consumption and savings values for furnaces was used, knowing that these values generally reflect homes with an air conditioner.

Previously, the ASHP heating consumption value was 2,902 kWh, based on the heat pump providing all heat during winter. However, the billing analysis revealed an ASHP heating consumption of value of 962 kWh. This value is also imprecise, at ±60%, but still indicates that ASHPs are not generally providing all a participant's home winter heating needs. Therefore, the value of 962 kWh is used for baseline ASHP heating consumption. The ASHP heating savings value is extremely imprecise, so a value of 12% is obtained and used from a different study.[3]

All the above values were for the average participant in each of the three measures, and represent an average split of system AFUE and SEER values, houses with and without air conditioning, space heating, manual and programmable thermostats, and other variables.

Scaling for Multifamily

The billing analysis that serves as the basis for this study examined thermostats installed in single family residences. Multifamily residences are assumed to have the same energy savings fractions, but consumptions scale due to two factors.

First, all multifamily heating and cooling consumptions scale based on residence size. Data from the Wisconsin Focus on Energy Potential Study[7] indicate that the average single family home has 1,652 sq ft of finished space, while the average multifamily unit has 874 sq ft of finished space. Therefore, all consumption values for multifamily homes incorporate an area scaling factor of $P_{MF,AREA}$ equal to 874 divided by 1,652 (52.9%).

Second, multifamily cooling consumption for natural gas furnace sites is also scaled. The average natural gas furnace cooling consumption observed in the billing analysis is directly dependent on the fraction of those homes that have central air conditioners. That fraction, while not specifically known for the billing analysis sample, may be different for multifamily sites receiving smart thermostats. The Potential Study sample may be different from the billing analysis sample, but its data can be used here. The Potential Study data shows that 85.5% of multifamily sites with natural gas furnaces also have central air conditioners, and that this fraction for single family sites is 75.9%. Therefore for multifamily sites with natural gas furnaces, there is an assumed cooling consumption scaling factor of $P_{MF,AC}$ equal to 85.5 divided by 75.9 (112.6%).

Sources

1. GDS Associates. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*. Table 1, HVAC Controls. June 2007. http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf
   Used programmable thermostat EUL as the closest proxy for smart thermostats.
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. July 2017 to December 2017. Average actual measure cost of 2,585 smart thermostat measures incented by Focus on Energy is $213.00 (MMIDs 3609, 3610, and 3611), minus $39.11 for the cost of a manual thermostat, based on online lookups from July 2018.
3. Apex Analytics. *Nest Thermostat Heat Pump Control Pilot Evaluation*. Prepared for Energy Trust of Oregon. October 10, 2014. https://nest.com/downloads/press/documents/energy-trust-of-oregon-pilot-evaluation-whitepaper.pdf

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5. Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 5.0. Volume 3: Residential Measures*. February 11, 2016. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Final/IL-TRM_Effective_060116_v5.0_Vol_3_Res_021116_Final.pdf
6. Meier, Alan, C. Aragon, T Peffer, D. Perry, and M. Pritoni. *Usability of Residential Thermostats: Preliminary Investigations*. October 2011. http://www.sciencedirect.com/science/article/pii/S0360132311000874
7. Cadmus. *2016 Potential Study for Focus on Energy*. Data maintained by Cadmus and Wisconsin PSC. Data includes information 103 single family sites and 92 multifamily units.

Revision History

Version Number	Date	Description of Change
01	03/2015	Initial TRM entry
02	06/2017	Updated based on Cadmus billing analysis
03	11/2017	Updated to include multifamily savings
04	12/2018	Updated incremental cost

Smart Thermostat, installed with home heating measure

	Measure Details
Measure Master ID	Smart Thermostat, Installed with: 95% AFUE NG Furnace, 3612 96% AFUE NG Furnace, 4054 97% AFUE NG Furnace, 4055 98% AFUE NG Furnace, 4056 95% AFUE NG Boiler, 3613 Furnace and A/C, 3614 Air Source Heat Pump, 3615
Measure Unit	Per Thermostat
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	Varies by heating system installed
Peak Demand Reduction (kW)	Varies by heating system installed
Annual Therm Savings (Therms)	Varies by heating system installed
Life-cycle Energy Savings (kWh)	Varies by heating system installed
Life-cycle Therm Savings (Therms)	Varies by heating system installed
Water Savings (gal/yr)	0
Effective Useful Life (years)	10[1]
Measure Incremental Cost ($/unit)	$173.89[2]

Measure Description

Standard programmable thermostats require customers to adjust temperature setpoints at different times of the day, changing temperatures during unoccupied periods to allow for some energy savings. Communicating thermostats provide this base level of functionality but can be programmed remotely through Wi-Fi.

Smart thermostats provide enhanced functionality that can include:

- Easier use and programming, both on the thermostat and remotely via smartphone apps and web portals.
- Occupancy sensing that enables energy savings from automatic setbacks during unoccupied periods. Occupancy sensing may use sensors in the thermostat or capability to track the residents' location through a smartphone app.

- Learning capability or automatic schedule generation/modification. Such thermostats are capable of dynamically adjusting and/or constructing a program schedule based on actual occupancy patterns, eliminating the need for programming.
- Intelligent control of HVAC equipment, including minimizing the energy expended for recovery from setback, having intelligent control of two-stage HVAC sources, and minimizing the use of inefficient electric-resistance heat associated with most heat pumps.
- Use of outside temperature and other weather data to better ensure comfort and minimize energy use.
- Encourage use of more energy-efficient set temperatures (for example, an icon of a leaf appears when the set temperature is moved in the direction of less energy use).
- Algorithms that make frequent subtle temperature changes in order to save energy.

The savings calculations for these measures are based on the deemed savings values for the smart thermostat and communicating thermostat workpapers (MMIDs 4301 – 4303 and 4298 – 4300). Savings for those measures are based on a billing analysis that examined weather-normalized gas and electric consumption at sites, before and after receiving a smart thermostat. For the measures in this workpaper, the calculated savings for MMIDs 4301 – 4303 and 4298 – 4300 are modified based on the known efficiencies of the HVAC units that the thermostats are being installed with, which are different from the average efficiencies of sites from the billing analysis. The combined furnace and AC measure is also modified based on the assumed fraction of billing analysis sites with ACs.

Description of Baseline Condition

The baseline condition is a manual or programmable thermostat installed in a home with new, program qualified, natural gas furnace, natural gas boiler, furnace/AC combo, or air source heat pump.

See Assumptions section for detail on weighted average applied to savings to account for combination of manual and programmable thermostats that comprise the baseline population in Wisconsin.

Description of Efficient Condition

The efficient condition is a smart thermostat installed in a home to replace an existing manual or programmable thermostat. To qualify as smart, the thermostat must be certified as an ENERGY STAR Connected Thermostat, or otherwise meet the following criteria:

- Must be Wi-Fi capable
- Must be capable of internet connection
- Must feature occupancy sensing, via geolocation and/or motion sensing
- The above features must be built-in and not require add-on devices or services

- The application and connectivity service must be free after thermostat purchase
- Thermostat default behavior must be to set back temperature when house is unoccupied

Annual Energy-Savings Algorithm

$Therm_{SAVED} = CONS_{THERM} (AFUE_{BILL} / AFUE_{MEAS}) * ESF_{THERM}$

Furnace and Boiler Measures$kWh_{SAVED} = CONS_{kWh,COOL} * ESF_{kWh,COOL} + CONS_{kWh,HEAT} * ESF_{kWh,HEAT}$

Furnace + AC Measure

$kWh_{SAVED} = CONS_{kWh,COOL} / AC\%_{BILL} * (SEER_{BILL} / SEER_{MEAS}) * ESF_{kWh,COOL} + CONS_{kWh,HEAT} * ESF_{kWh,HEAT}$

Air Source Heat Pump Measure

$kWh_{SAVED} = CONS_{kWh,COOL} / AC\%_{BILL} * (SEER_{BILL} / SEER_{MEAS}) * ESF_{kWh,COOL} + CONS_{kWh,HEAT} * (HSPF_{BILL} / HSPF_{MEAS}) * ESF_{kWh,HEAT}$

Where:

$CONS_{THERM}$ = Annual therms consumed by smart thermostat billing analysis participants before smart thermostat installation (= 653 therms for furnace; = 1,050 therms for boiler; = 0 therms for ASHP)

$AFUE_{BILL}$ = Deemed average AFUE of billing analysis sample (= 92.8% for furnace measures; = 80% for boiler measures, see Assumptions)

$AFUE_{MEAS}$ = AFUE of installed furnace (see table below)

ESF_{THERM} = Therm energy savings fraction (= 4.6% for furnace; = 5.0% for boiler; = 0% for ASHP)

$CONS_{kWh,COOL}$ = Annual cooling kilowatt-hours consumed by smart thermostat billing analysis participants before smart thermostat installation (= 1,584 kWh for furnace, boiler, and ASHP)

$ESF_{kWh,COOL}$ = Kilowatt-hour energy savings fraction for cooling (= 20.5% for furnace, boiler, and ASHP)

$CONS_{kWh,HEAT}$ = Annual heating kilowatt-hours consumed by smart thermostat billing analysis participants before smart thermostat installation (= 808 kWh for furnace; = 0 kWh for boiler; = 962 kWh for ASHP)

$ESF_{kWh,HEAT}$ = Kilowatt-hour energy savings fraction for heating (= 14.2% for furnace; = 0% for boiler; = 12% for ASHP)[3]

$AC\%_{BILL}$ = Deemed fraction of billing analysis sample with air conditioning (= 92.5%, see Assumptions)

$SEER_{BILL}$ = Deemed average SEER of billing analysis sample (= 13.9, see Assumptions)

$SEER_{MEAS}$ = SEER of installed air conditioner (= 16)

$HSPF_{BILL}$ = Deemed average HSPF of billing analysis sample (= 7.7, see Assumptions)

$HSPF_{MEAS}$ = HSPF of installed air source heat pump (= 8.4)

Deemed Installed Furnace AFUE Across Measures

Measure	MMID	Deemed Installed Furnace AFUE
Smart Thermostat, Installed with 95% AFUE NG Furnace	3612	95%
Smart Thermostat, Installed with 96% AFUE NG Furnace	4054	96%
Smart Thermostat, Installed with 97% AFUE NG Furnace	4055	97%
Smart Thermostat, Installed with 98% AFUE NG Furnace	4056	98%
Smart Thermostat, Installed with 95% AFUE NG Boiler	3613	95%
Smart Thermostat, Installed with Furnace and A/C	3614	95%

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure. It is assumed that only a small minority of participants have regular behavioral patterns that would produce demand reduction. These patterns entail not being at home during the peak period and not already setting the temperature back during that time.

Life-cycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Deemed Savings

Measure	MMID	Peak kW	Annual kWh	Lifecycle kWh	Annual therms	Lifecycle therms
Smart Thermostat, Installed With:						
95% AFUE NG Furnace	3612	0	439	4,390	29	290
96% AFUE NG Furnace	4054	0	439	4,390	29	290
97% AFUE NG Furnace	4055	0	439	4,390	29	290
98% AFUE NG Furnace	4056	0	439	4,390	28	280
95% AFUE NG Boiler	3613	0	325	3,250	44	440
Furnace and A/C	3614	0	420	4,200	29	290
Air Source Heat Pump	3615	0	411	4,100	0	0

Assumptions

For more context on the background of the smart and communicating thermostats averaged in this workpaper, including savings formulas, assumptions, and citations, see the workpapers for measures 4301, 4302, and 4303 (smart) and for measures 4298, 4299, and 4300 (communicating).

It is assumed that furnace sites participating in the billing analysis had an average furnace $AFUE_{BILL}$ of 92.8%. This reflects the average market value AFUE, as calculated as part of the 2017 Standard Market Practice analysis in the 2017 Focus on Energy Evaluation Report.[3] This value was chosen over the stock value of 91.4%, recorded as part of the 2016 Focus on Energy Potential Study,[4] because it was assumed that smart thermostat participants generally have more efficient furnaces than the average WI site.

Pre-install consumption was scaled based on the difference between $AFUE_{BILL}$ and $AFUE_{MEAS}$—because the furnaces are more efficient, consumption without the thermostat would have been less than the pre-thermostat consumption recorded as part of the billing analysis.

A related normalization is performed regarding the fraction of billing analysis furnace sites with and without air conditioners. The average cooling kWh consumption of all such sites is 653 kWh. But the average consumption of those sites with an air conditioner is higher. For instance, if 80% of billing analysis furnace sites had air conditioners it could be assumed that the average site with an air conditioner consumed 653 / 80% = 816 kWh for its cooling needs, and this should be the pre-thermostat consumption for the furnace and AC combination measure.

This fraction likely lies between two known values. The first one is the 84.0% value recorded by the 2016 Focus on Energy Potential Study,[4] which reflects the average value for all WI single family sites. The second one is the 92.5% value that reflects the fraction of sites receiving a furnace-only measure that also have an air conditioner.[5] It is assumed that sites receiving a smart thermostat are more likely to have an air conditioner than general building stock, and that the fraction of billing analysis furnace sites with air conditioners is 92.5%. Therefore the pre-thermstat consumption for sites with a furnace and AC combo measure is 653 / 92.5% = 705.9 kWh.

It is also assumed that billing analysis furnace sites and sites installing a smart thermostat along with their furnace-only measure have the same air conditioner fraction.

The assumed SEER of sites from the billing analysis, $SEER_{BILL}$, is 13.9. Like $AFUE_{BILL}$, this reflects the 2017 Standard Market Practice analysis in the 2017 Focus on Energy Evaluation Report[3] and was chosen over the stock baseline of 12.1.[4]

Air source heat pump base HSPF is assumed to be 7.7, matching the value assumed by the air source heat pump measure (MMID 2992).

Sources

1. GDS Associates. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*. Table 1, HVAC Controls. June 2007. http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf
   Used programmable thermostat EUL as the closest proxy for smart thermostats.
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. July 2017 to December 2017. Average actual measure cost of smart thermostat measures incented by Focus on Energy is $213.00 (MMIDs 3609, 3610, and 3611). Minus the cost of a manual thermostat, which is $39.11 based on online lookups from July 2018.
3. Cadmus. *Focus on Energy Calendar Year 2017 Evaluation Report*. Volume II. May 22, 2018. https://focusonenergy.com/sites/default/files/WI%20FOE%20CY%202017%20Volume%20II%20FINAL.pdf
4. Cadmus. *2016 Potential Study for Focus on Energy.*
   Data maintained by Cadmus and Wisconsin PSC.
   Based on site visit data from 103 single family homes in Wisconsin.
5. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

Revision History

Version Number	Date	Description of Change
01	9/2018	Initial TRM entry

Smart and Communicating Thermostats, Pack Based

	Measure Details
Measure Master ID	Smart Thermostat, Premium, Pack-Based, 4304 Smart Thermostat, Value, Pack-Based, 4436 Communicating Thermostat, Pack-Based, 4305
Measure Unit	Per thermostat
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/yr)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	Smart, Premium = $222.20 (MMID 4304); Smart, Value = $135.04 (MMID 4436); Communicating = $115.21 (MMID 4305)[2]

Measure Description

Standard programmable thermostats require customers to adjust temperature setpoints at different times of the day, manually changing temperatures during unoccupied periods to allow for some energy savings. Communicating thermostats provide this base level of functionality but can be programmed remotely through Wi-Fi.

Smart thermostats provide enhanced functionality that can include several features:

- Easier use and programming, both on the thermostat and remotely via smartphone apps and web portals.
- Occupancy sensing that enables energy savings from automatic setbacks during unoccupied periods. Occupancy sensing may use sensors in the thermostat or capability to track the resident’s location through a smartphone app.
- Learning capability or automatic schedule generation and modification. Such thermostats are capable of dynamically adjusting and/or constructing a program schedule based on actual occupancy patterns, eliminating the need for programming.

- Intelligent control of HVAC equipment, including minimizing the energy expended for recovery from setback, having intelligent control of two-stage HVAC sources, and minimizing the use of inefficient electric-resistance heat associated with most heat pumps.
- Use of outside temperature and other weather data to better ensure comfort and minimize energy use.
- Encourage use of more energy-efficient set temperatures (for example, an icon of a leaf appears when the set temperature is moved in the direction of less energy use).
- Algorithms that make frequent, subtle temperature changes in order to save energy.

The savings calculations for these measures are based on the deemed savings values for the smart thermostat and communicating thermostat workpapers (MMIDs 4301–4303 and 4298–4300). An installation rate and a ratio of heating systems were applied to combine the savings from those measures to produce savings for pack-based measures.

Description of Baseline Condition

The baseline condition is a manual or standard programmable thermostat installed in a home with an existing natural gas furnace, natural gas boiler, or air-source heat pump (ASHP).

See the Assumptions for detail on weighted averages applied to savings to account for the combination of manual and programmable thermostats in the baseline Wisconsin population.

Description of Efficient Condition

The efficient condition is a communicating or smart thermostat, provided in a Focus on Energy kit, installed in a home to replace the existing thermostat.

To qualify as *smart*, the thermostat must be certified as an ENERGY STAR Connected Thermostat or have been included as a qualifying smart thermostat for this measure prior to 2018.

To qualify as *communicating*, the thermostat must be Wi-Fi capable (with the Wi-Fi connection established by the customer), but not certified as an ENERGY STAR Connected Thermostat, and not included as a qualifying smart thermostat for the smart thermostat measure prior to 2018.

Annual Energy-Savings Algorithm

$$\text{Therm}_{SAVED,COMM} = [(\text{Annual Therm}_{BOIL,COMM} * \text{Boiler}_{RATIO}) + (\text{Annual Therm}_{FURN,COMMT} * \text{Furnace}_{RATIO}) + (\text{Annual Therm}_{HP,COMM} * \text{ASHP}_{RATIO})] * \text{IR}$$

$$\text{Therm}_{SAVED,SMART} = [(\text{Annual Therm}_{BOIL,SMART} * \text{Boiler}_{RATIO}) + (\text{Annual Therm}_{FURN,SMART} * \text{Furnace}_{RATIO}) + (\text{Annual Therm}_{HP,SMART} * \text{ASHP}_{RATIO})] * \text{IR}$$

$kWh_{SAVED,COMM} = [(Annual\ kWh_{BOIL,COMM} * Boiler_{RATIO}) + (Annual\ kWh_{FURN,COMMT} * Furnace_{RATIO}) + (Annual\ kWh_{HP,COMM} * ASHP_{RATIO})] * IR$

$kWh_{SAVED,SMART} = [(Annual\ kWh_{BOIL,SMART} * Boiler_{RATIO}) + (Annual\ kWh_{FURN,SMART} * Furnace_{RATIO}) + (Annual\ kWh_{HP,SMART} * ASHP_{RATIO})] * IR$

Where:

Annual Therm = Annual therm savings by thermostat type and heating system (= varies by measure; see table below)

$Boiler_{RATIO}$ = Percentage of homes in Wisconsin with a natural gas boiler (= 3.4%; see table below and Assumptions)

$Furnace_{RATIO}$ = Percentage of homes in Wisconsin with a natural gas furnace (= 95%; see table below and Assumptions)

$ASHP_{RATIO}$ = Percentage of homes in Wisconsin with an ASHP (= 1.6%; see table below and Assumptions)

Heating Type Ratios

Heating Type	Percentage of Wisconsin Homes
Natural Gas Boiler	3.4%
Natural Gas Furnace	95.0%
Air-Source Heat Pump	1.6%

IR = Installation rate (= 100%; see Assumptions)

Annual kWh = Annual kilowatt-hour savings by thermostat type and heating system (= varies by measure; see table below)

Annual and Lifecycle Savings by Heating System

Measure	MMID	Sector	Peak kW	Annual kWh	Lifecycle kWh	Annual therm	Lifecycle therm
Communicating Thermostat, Home Heated by							
Natural Gas Boiler	4305	Single family	0	170	1,700	34	340
		Multifamily	0	90	900	18	180
Natural Gas Furnace		Single family	0	223	2,230	20	200
		Multifamily	0	128	1,280	11	110
Air-Source Heat Pump		Single family	0	280	2,800	0	0
		Multifamily	0	148	1,480	0	0
Smart Thermostat, Home Heated by							
Natural Gas Boiler	4304, 4436	Single family	0	325	3,250	53	530
		Multifamily	0	172	1,720	28	280
Natural Gas Furnace		Single family	0	439	4,390	30	300
		Multifamily	0	254	2,540	16	160
Air-Source Heat Pump		Single family	0	440	4,400	0	0
		Multifamily	0	233	2,330	0	0

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure. It is assumed that only a small minority of participants have regular behavioral patterns that would produce demand reduction. These patterns entail not being at home during the peak period and not already setting the temperature back during that time.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Proportional Savings for Pack-Based Measures

Measure	MMID	Sector	Peak kW	Annual kWh	Lifecycle kWh	Annual therms	Lifecycle therms
Communicating Thermostat, Pack-Based	4305	Single family	0	222	2,200	20	200
		Multifamily	0	127	1,270	11	110
Smart Thermostat, Pack-Based	4304, 4436	Single family	0	435	4,350	30	300
		Multifamily	0	251	2,510	16	160

Assumptions

For more background of the smart and communicating thermostats averaged in this workpaper, including savings formulas, assumptions, and citations, see the workpapers for measures 4301, 4302, and 4303 (smart) and for measures 4298, 4299, and 4300 (communicating).

To calculate the percentage of Wisconsin homes with natural gas boilers, natural gas furnaces, and ASHPs, every smart thermostat application measure in SPECTRUM (MMID 3609 for natural gas boilers, 3610 for natural gas furnaces, and 3611 for ASHPs) from 2015 to 2017 was examined. Proportions from this set of data were used in the Heating Type Ratios table.

It is assumed that kits featuring a smart or communicating thermostat will have a 100% installation rate.

Without data on HVAC system types for multifamily sites installing smart thermostats, single family heating type ratios were used.

Incremental cost was calculated using the average cost to the implementers, plus any copays required of the customer. Communicating thermostat packs do not have copays and the incremental costs reflect the implementer cost of $115.21 per thermostat.

There are two types of smart thermostats. *Value* smart thermostats, such as the Nest E, have a basic look and are made of standard materials, providing all the functionality of a smart thermostat at a lower cost. The incremental cost is equal to the entire product cost of $135.04.*Premium* smart thermostats, such as the standard Nest, are made with high-quality, more expensive materials. The incremental cost is $222.20, which includes both the $120 customer copay and the $102.20 incentive provided by the program.

Sources

1. GDS Associates. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*. Table 1, HVAC Controls. 2007. http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf
   Used programmable thermostat effective useful life as the closest proxy for smart thermostats.
2. Energy Federation, Inc. December 2017.
   Incremental cost is the average incentive cost to the implementer providing the pack, plus the customer copay for higher-end smart thermostat models. The cost for a communicating thermostat is $115.21. The implementer cost for premium smart thermostats is $102.20, with customers opting for a $120 copay. The implementer cost for value smart thermostats is $135.04.

Revision History

Version Number	Date	Description of Change
01	12/2017	Initial TRM entry
02	04/2018	Added multifamily sector

Gas Furnaces

	Measure Details
Measure Master ID	LP or Oil Furnace with ECM: 90%+ AFUE (Existing), 3679 Tier 2, 90%+ AFUE (Existing), 3781 Natural Gas Furnace, Tier 2, 95% AFUE, 3783 Natural Gas Furnace with ECM: 95%+ AFUE (Existing), 1981 Tier 2, 95%+ AFUE (Existing), 3782 96%+ AFUE, 3868 Tier 2, 96%+ AFUE, 3870 97%+ AFUE, 3440 Tier 2, 97%+ AFUE, 3871 98%+ AFUE, 3869 Tier 2, 98%+ AFUE, 3872
Measure Unit	Per furnace
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Furnace
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	416 (excluding non-ECM)
Peak Demand Reduction (kW)	0.0792 (excluding non-ECM)
Annual Therm Savings (Therms)	Varies by AFUE and fuel type
Lifecycle Energy Savings (kWh)	8,320 (excluding non-ECM)
Lifecycle Therm Savings (Therms)	Varies by AFUE and fuel type
Water Savings (gal/year)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	Varies by measure, see Appendix D

Measure Description

Conventional gas furnaces produce by-products, such as water vapor and carbon dioxide, which are usually vented out through a chimney along with a considerable amount of heat. This occurs not only when the furnace is in use, but also when it is turned off. Newer designs increase energy efficiency by reducing the amount of heat that escapes and by extracting heat from the flue gas before it is vented. These furnaces use much less energy than conventional furnaces.

Description of Baseline Condition

The current federal furnace standard is a 78% AFUE without an electronically commutated motor (ECM). However, data on furnace sales in Wisconsin indicate a higher market baseline for natural gas furnaces. Non-income eligible measures (Tier 1) use a 92.8% AFUE furnace without an ECM as the baseline, based on sales and audit data indicating that this was the average AFUE of units sold in Wisconsin in 2015.[2] Income eligible measures (Tier 2) maintain an 80% AFUE baseline, the lowest AFUE for which sales were present in the sales data, due to income restraints for participating consumers. The measure characteristics were previously based on a 90% AFUE furnace without an ECM for Tier 1 and a 78% AFUE furnace without an ECM for Tier 2 from 2011 through 2014.

Description of Efficient Condition

The efficient furnace condition varies by measure-specific requirements; the measure master name largely explains the efficient condition for each measure. For all measures, the efficient condition pertains to a furnace installed in a residential application.

Annual Energy-Savings Algorithm

$$\text{Therms}_{\text{SAVED}} = \text{CAP} * \text{hours}_{\text{HEATING}} * (\text{AFUE}_{\text{EE}} / \text{AFUE}_{\text{BASE}} - 1) * (1/100)$$

$$\text{kWh}_{\text{SAVED}} = \text{kWh}_{\text{SAVED COOLING}} + \text{kWh}_{\text{SAVED HEATING}} + \text{kWh}_{\text{SAVED CIRC}}$$

$$\text{kWh}_{\text{SAVED COOLING}} = \text{tons} * \text{EFLH}_{\text{COOLING}} * 12\ \text{kBtu/ton} * (1/\text{SEER}_{\text{BASE}} - 1/\text{SEER}_{\text{ECM}}) * \text{AC\%}$$

$$\text{kWh}_{\text{SAVED HEATING}} = \text{hours}_{\text{HEATING}} * \Delta\text{kW}_{\text{HEAT}}$$

$$\text{kWh}_{\text{SAVED CIRC}} = \text{hours}_{\text{CIRC}} * \Delta\text{kW}_{\text{CIRC}}$$

Where:

CAP = Rated input heating capacity (= 72 MBtu/hour)[3]

$\text{AFUE}_{\text{BASE}}$ = Baseline AFUE (= 80% for Tier 2 and 92.8% for Tier 1)

AFUE_{EE} = Efficient AFUE (= 95%, 96%, 97%, or 98%)

tons = Cooling capacity in tons (= 2.425)[4]

$\text{EFLH}_{\text{COOLING}}$ = Effective full-load cooling hours (= 410 average; varies by location; see table below)

Effective Full-Load Cooling Hours by Location

Location	$EFLH_{COOLING}$	Weighting by Participant
Green Bay	344	22%
Lacrosse	323	3%
Madison	395	18%
Milwaukee	457	48%
Wisconsin Average	380	9%
Overall	**410**	

$SEER_{BASE}$ = Baseline SEER (= 12)[4]

$SEER_{ECM}$ = SEER of unit with ECM (= 13)[4]

AC% = % of non-A/C furnace measures that also had an A/C installed (= 92.5%)[4]

$hours_{HEATING}$ = Hours of heating operation (= 1,158 hours)[4]

ΔkW_{HEAT} = Heating demand (= 0.116 kW)[4]

$hours_{CIRC}$ = Annual hours on circulate setting (= 1,020 hours)[4]

ΔkW_{CIRC} = Demand on circulate setting (= 0.207 kW)[4]

Summer Coincident Peak Savings Algorithm

Peak electrical energy savings for the ECM changed based on the Focus on Energy ECM Study[4] and is deemed as 0.0792 kW/unit.

$kW_{SAVED} = tons * 12\ kBtu/ton * (1/EER_{BASE} - 1/EER_{ECM}) * CF * AC\%$

Where:

EER_{BASE} = Baseline SEER (= 10.5)[4]

EER_{ECM} = EER of unit with ECM (= 11)[4]

CF = Coincidence factor (= 68%)[4]

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=20 years)[1]

Assumptions

The incremental costs for 95% and 97% AFUE furnaces was established in previous workpapers, based on a combination of installation data and surveys with participating trade allies regarding cost differences between 95% and 97% AFUE furnaces and 92% AFUE furnaces. Incremental cost for 96% AFUE furnaces was calculated as the average between the 95% and 97% AGUE costs. Incremental cost for 98% AFUE furnaces was derived by adding the same cost increment to the 97% cost as was between 95%, 96%, and 97% AFUE furnaces.

Incremental costs for Tier 1 units come from a 2018 effort,[5] while those for Tier 2 units come from a 2014 effort.[6]

Deemed Savings

Deemed Savings for Tier 1 and Tier 2 Measures

Measure	MMID	kW	Annual kWh	Lifecycle kWh	Annual therms	Lifecycle therms	Inc. Cost
Tier 1							
LP or Oil Furnace w/ECM, 90%+ AFUE (Existing)	3679	0.0792	416	8,320	0	0	$215.91
Natural Gas Furnace w/ECM, 95%+ AFUE (Existing)	1981	0.0792	416	8,320	20	400	$388.72
Natural Gas Furnace w/ECM, 96%+ AFUE	3868	0.0792	416	8,320	29	580	$899.86
Natural Gas Furnace w/ECM, 97%+ AFUE	3440	0.0792	416	8,320	38	760	$1,538.08
Natural Gas Furnace w/ECM, 98%+ AFUE	3869	0.0792	416	8,320	47	940	$2,219.37
Tier 2							
LP or Oil Furnace w/ECM, Tier 2, 90%+ AFUE (Existing)	3781	0.0792	416	8,320	0	0	$432.00
Natural Gas Furnace, Tier 2, 95% AFUE	3783	0	0	0	156	3,120	$1,194.00
Natural Gas Furnace w/ECM, Tier 2, 95%+ AFUE (Existing)	3782	0.0792	416	8,320	156	3,120	$1,565.00
Natural Gas Furnace w/ECM, Tier 2, 96%+ AFUE	3870	0.0792	416	8,320	167	3,340	$2,007.50
Natural Gas Furnace w/ECM, Tier 2, 97%+ AFUE	3871	0.0792	416	8,320	177	3,540	$2,450.00
Natural Gas Furnace w/ECM, Tier 2, 98%+ AFUE	3872	0.0792	416	8,320	188	3,760	$2,892.50

Sources

1. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." EUL Table. 2014. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx
2. Cadmus. *Focus on Energy Calendar Year 2013 Baseline Market Study.* May 14, 2014. https://focusonenergy.com/sites/default/files/Appendix%20B%20-%20FOC_XC_Deemed_WriteUp_12122013%20(2).pdf
3. Focus on Energy. *SPECTRUM Focus Prescriptive Database.* Average furnace size of 13,000 furnaces. 2012.
4. Focus on Energy. *Deemed Savings Report.* October 27, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
5. CLEAResult. Survey of trade allies. Summer 2018.
6. Wisconsin Public Service Commission. *Incremental Cost Database*. December 2014.

Revision History

Version Number	Date	Description of Change
01	03/05/2012	Original
02	11/05/2012	Updated memo
03	02/20/2013	Review and updates for new formatting
04	08/15/2014	New format, changes from 2014 Baseline Study and ECM Study
05	09/29/2014	Final results from the 2014 ECM study
06	10/29/2014	Final edits/additions from 2014 Cadmus ECM study and Deemed Savings Report
07	04/28/2016	Addition of 96%, 97%, 98% AFUE measures
08	04/24/2017	Fixed discrepancies in kW, LC kWh, and EUL
09	10/2017	Updated EUL
10	12/2018	Updated savings algorithm
11	5/2019	Updated costs for Tier 1 measures

Joint Furnace & Central AC with ECM

	Measure Details
Measure Master ID	Furnace and A/C, ECM, 95%+ AFUE, ≥ 16 SEER, 2990 Furnace and A/C, Tier 2, ECM, 95% + AFUE, ≥ 16 SEER, 3779
Measure Unit	Per system
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Other
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	518
Peak Demand Reduction (kW)	0.277
Annual Therm Savings (Therms)	Varies by baseline
Lifecycle Energy Savings (kWh)	11,028
Lifecycle Therm Savings (Therms)	Varies by baseline
Water Savings (gal/yr)	0
Effective Useful Life (years)	20 (Furnace),[1] 24 (AC)[2]
Incremental Cost ($/unit)	Tier 1 Standard Track = $1,451.66 (MMID 2990); Tier 2 Income-Qualified Track = $2,238.73 (MMID 3779)[3]

Measure Description

This measure is the joint delivery of a high-efficiency furnace with an ECM and a central air conditioner.

Description of Baseline Condition

The baseline condition for Tier 1 measures is a 92.8% AFUE[4] natural gas furnace without an ECM and a 13 SEER central air conditioner, and the baseline condition for Tier 2 measures is an 80% AFUE natural gas furnace without an ECM and a 13 SEER central air conditioner.

Description of Efficient Condition

The efficient condition is a 95% AFUE natural gas furnace with an ECM and a 16 SEER central air conditioner.

Annual Energy-Savings Algorithm

$$\text{Therm}_{\text{SAVED}} = \text{CAP} * \text{hours}_{\text{HEATING}} * (\text{AFUE}_{\text{EE}} / \text{AFUE}_{\text{BASE}} – 1) /100$$

$$\text{kWh}_{\text{SAVED}} = \text{kWh}_{\text{SAVED COOLING}} + \text{kWh}_{\text{SAVED HEATING}} + \text{kWh}_{\text{SAVED CIRC}}$$

$$\text{kWh}_{\text{SAVED COOLING}} = \text{tons} * \text{EFLH}_{\text{COOLING}} * 12\ \text{kBtu/ton} * (1/\text{SEER}_{\text{BASE}} – 1/\text{SEER}_{\text{ECM}})$$

$$\text{kWh}_{\text{SAVED HEATING}} = \text{hours}_{\text{HEATING}} * \Delta\text{kW}_{\text{HEAT}}$$

$kWh_{SAVED\ CIRC} = hours_{CIRC} * \Delta kW_{CIRC}$

Where:

CAP = Heating capacity (= 72 MBtu/hour)[5]

$hours_{HEATING}$ = Hours of heating operation (= 1,158)[6]

$AFUE_{EE}$ = Efficient AFUE (= 96.5%; see Assumptions)[4]

$AFUE_{BASE}$ = Baseline AFUE (= 92.8% for Tier 1, = 80% for Tier 2; see Assumptions)[4]

100 = Conversion from MBtu to therms

$kWh_{SAVED\ COOLING}$ = Kilowatt-hours saved from air conditioner with ECM (= 172.08)

$kWh_{SAVED\ HEATING}$ = Kilowatt-hours saved in heating mode, deemed (= 134.33)

$kWh_{SAVED\ CIRC}$ = Kilowatt-hours saved in circulation mode, deemed (= 211.14)

tons = Cooling capacity in tons (= 2.425)[7]

$EFLH_{COOLING}$ = Effective full-load cooling hours (= 410 average; varies by location, see table below)[6]

Equivalent Full-Load Cooling Hours by Location

Location	$EFLH_{COOL}$	Weighting by Participant
Green Bay	344	22%
La Crosse	323	3%
Madison	395	18%
Milwaukee	457	48%
Wisconsin Average	380	9%
Overall	**410**	

$SEER_{BASE}$ = Federal minimum seasonal energy efficiency ratio (= 13)

$SEER_{ECM}$ = Efficient measure seasonal energy efficiency ratio (= 16)

ΔkW_{HEAT} = Average power saved in heating mode (= 0.116 kW)[6]

$hours_{CIRC}$ = Annual hours on circulate setting (= 1,020)[6]

ΔkW_{CIRC} = Average power saved in circulation mode (= 0.207 kW)[6]

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = tons * 12 kBtu/ton * ($1/EER_{BASE} – 1/EER_{ECM}$) * CF

Where:

EER_{BASE} = Baseline energy efficiency ratio (= 11.0)[6]
EER_{ECM} = Efficient measure energy efficiency ratio (= 13)[6]
CF = Coincidence factor (= 68%)[6]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = ($kWh_{SAVED\ HEATING}$ + $kWh_{SAVED\ CIRC}$) * EUL_{FURN} + $kWh_{SAVED\ COOLING}$ * EUL_{AC}

$Therm_{LIFECYCLE}$ = $Therm_{SAVED}$ * EUL_{FURN}

Where:

EUL_{FURN} = Furnace effective useful life (= 20 years)[1]
EUL_{AC} = Air conditioner effective useful life (= 24 years)[2]

Deemed Savings

Deemed Savings by Measure

Measure	MMID	Annual kWh Savings	kW Reduction	Lifecycle kWh	Annual therms	Lifecycle therms
Tier 1 Standard Track	2990	518	0.277	11,039	33	660
Tier 2 Income-Qualified Track	3779	518	0.277	11,039	172	3,440

Assumptions

The effective useful life for this measure was examined during the 2017 program year. The EUL for natural gas furnaces was adjusted during the 2017 analysis from 23 years down to 20 years, citing the DEER database. This change is supported by region-specific data from EERE.[1] The furnace-associated savings of this measure assume 20 years to maintain consistency with EERE estimates as well as with other furnace measures in the Wisconsin TRM. While the previous 23-year assumption for a central air conditioner was reduced to 18 years based on the DEER database, recent region-specific EERE data from the U.S. DOE[2] suggest a 24-year lifetime for central air conditioner installations in cold climates including Wisconsin due to reduced cooling hours and associated run time compared to other regions.

The current federal furnace standard is an 80% AFUE furnace without an ECM. However, Tier 1 furnaces in Wisconsin use a baseline of 92.8% AFUE furnace without an ECM based on sales and audit data indicating that this was the average AFUE of units sold in Wisconsin in 2017.[4] Tier 2 furnaces maintain the 80% AFUE baseline, the lowest AFUE present in the sales data, due to income restraints for participating consumers.

All residential furnace measures, and these furnace and air conditioner combo measures, have net savings that reflect a market baseline and delivered capacities and efficiencies, calculated as part of the Standard Market Practice analysis.[4] The standalone furnace measures (MMIDs 1981, 3440, 3781–3783, and 3868–3872) are granted a market baseline and split out into separate AFUE tiers in order to bring their gross savings closer to net set savings for program planning purposes. These furnace and air conditioner combo measures also use a market baseline for that reason, but rather than being split into different AFUE tiers, the actual delivered AFUE of 96.5% from the Standard Market Practice analysis is used for gross savings.

Electrical energy savings for the ECM were established in a State of Wisconsin Department of Administration Division of Energy *Impact Assessment Report*, and later revised in a 2009 *Impact Assessment Report*, to be 733 kWh/furnace.[8] Upon receiving feedback from Cadmus, the ECM electric savings were adjusted down to 500 kWh/furnace in 2012. The ECM savings were revised in 2014 to 415 kWh per furnace for the 2015 program year.[6]

AHRI ratings reveal that 76% of 16 SEER combinations have an EER rating of 13 or higher. This is consistent with federal tax credits given to 13 EER/16 SEER equipment in 2006, 2007, and 2009 through 2013.

AHRI combination ratings reveal that an EER rating is approximately two less than SEER rating.[8] This is very close to the U.S. DOE guideline of EER = -0.02 * SEER^2 + 1.12 * SEER (http://www.nrel.gov/docs/fy11osti/49246.pdf), obtained using an equation first proposed in: Wassmer, M. *A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations.* Master's Thesis, University of Colorado at Boulder. 2003.

Sources

1. U.S. Department of Energy. "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces." Appendix 8G. 2016. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=59&action=viewlive#current_standards
2. U.S. Department of Energy. "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Central Air Conditioners and Heat Pumps." Table 9.5.2. 2016. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=48&action=viewlive

3. Incremental costs based on a fall 2014 review of residential prescriptive trade allies. Costs are different for the two tiers because the measures use different baselines.
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8. *Focus on Energy Evaluation, ECM Furnace Impact Assessment Report: Final Report.* January 12, 2009. https://focusonenergy.com/sites/default/files/emcfurnaceimpactassessment_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry

Single Package Vertical HVAC Unit

	Measure Details
Measure Master ID	Single Package Vertical HVAC Unit: ≥ 90%+ Thermal Efficiency, Natural Gas, 3694 ≥ 90%+ Thermal Efficiency, ≥ 10.0 EER Cooling, Natural Gas, 3693
Measure Unit	Per furnace
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Furnace
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	23[1]
Incremental Cost ($/unit)	$550.00[2]

Measure Description

Conventional natural gas furnaces produce by-products, such as water vapor and carbon dioxide, which are usually vented out through a chimney along with a considerable amount of heat. This occurs not only when the furnace is in use, but also when it is turned off. Newer designs increase energy efficiency by reducing the amount of heat that escapes and by extracting heat from the flue gas before it is vented. These furnaces use much less energy than conventional furnaces.

Description of Baseline Condition

The current federal furnace standard is 78% AFUE without an ECM. Single package vertical units rated by AHRI generally have a thermal efficiency rating of 80% or 82%.[3] Roughly equal quantities of 80% and 82% units are available,[3] so a baseline of 81% thermal efficiency is used. A review of specification sheets for the 80% to 82% efficient models indicated they are only available with standard permanent split capacitor motor (PSC). Per ASHRAE Standard 90.1-2007, the minimum cooling efficiency for new single package vertical units is 9.0 EER.[5]

Description of Efficient Condition

The efficient condition is a single package vertical furnace with a thermal efficiency of 90% or higher and a multi-speed ECM motor installed in a multifamily building and used for space heating only.

Additional savings for qualified cooling efficiency requires a single package vertical unit with an EER of 10.0 or higher.

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}} = \text{CAP} * \text{Hours}_{\text{HEATING}} * (\eta_{\text{EE}} / \eta_{\text{BASE}} - 1) * (1/100)$

$\text{kWh}_{\text{SAVED}} = \text{kWh}_{\text{SAVED HEATING}} + \text{kWh}_{\text{SAVED CIRC}} + \text{kWh}_{\text{SAVED COOLING}}$

$\text{kWh}_{\text{SAVED HEATING}}$ (applies to all systems as ECM savings from heating season) = $\text{Hours}_{\text{HEATING}} * \Delta\text{kW}_{\text{HEAT}}$

$\text{kWh}_{\text{SAVED CIRC}}$ (applies to all systems as ECM savings from cooling season, since AHRI data indicates that all listed natural gas single package vertical units have cooling) = $\text{Hours}_{\text{CIRC}} * \Delta\text{kW}_{\text{CIRC}}$

$\text{kWh}_{\text{SAVED COOLING}}$ (applies if the system meets the requirement for high-efficiency cooling) = $\text{Tons} * \text{EFLH}_{\text{COOL}} * \text{Cooling}_{\text{QUALIFIES}} * 12\ \text{kBtu/ton} * (1/\text{EER}_{\text{BASE}} – 1/\text{EER}_{\text{ECM}})$

Where:

CAP = Rated input heating capacity (= 40.4 MBtu/hr)[3]

$\text{Hours}_{\text{HEATING}}$ = Heating hours (= 1,158)[4]

η_{BASE} = Baseline efficiency (= 81% thermal efficiency)[3]

η_{EE} = Energy efficient unit efficiency (= 90% thermal efficiency)[3]

100 = Conversion factor from therm to MBtu

$\Delta\text{kW}_{\text{HEAT}}$ = Heating demand (=0.116 kW)[4]

$\text{Hours}_{\text{CIRC}}$ = Annual hours on circulate setting (= 1,020)[4]

$\Delta\text{kW}_{\text{CIRC}}$ = Demand on circulate setting (= 0.207 kW)[4]

Tons = Cooling capacity (= 1.548 tons)[3]

$\text{EFLH}_{\text{COOL}}$ = Equivalent full-load cooling hours (= 410)[4]

$\text{Cooling}_{\text{QUALIFIES}}$ = Binary variable indicating whether the efficient unit meets the minimum qualifying EER of 10.0 (1 = yes; 0 = no)

12 kBtu/ton = Conversion factor from EER to kW/ton

EER_{BASE} = Energy efficiency rating of efficient unit (= 9.0)[5]

EER_{ECM} = Energy efficiency rating of efficient unit (= 10.7)[3]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED\ COOLING}$ = Tons * 12 kBtu/ton * ($1/EER_{BASE} - 1/EER_{ECM}$) * CF

Where:

CF = Coincidence factor (= 68%)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

$Therm_{LIFECYCLE}$ = $Therm_{SAVED}$ * EUL

Where:

EUL = Effective useful life (=23 years)[1]

Deemed Savings

Deemed Savings for Single Package Vertical HVAC Units

	≥ 90%+ Thermal Efficiency, Natural Gas, 3694	≥ 90%+ Thermal Efficiency, ≥ 10.0 EER Cooling, Natural Gas, 3693
Annual Energy Savings (kWh)	345	480
Peak Demand Reduction (kW)	0	0.223
Annual Therm Savings (Therms)	52	52
Lifecycle Energy Savings (kWh)	7,946	11,038
Lifecycle Therm Savings (Therms)	1,196	1,196

Sources

1. Energy Center of Wisconsin. Energy Efficiency and Customer-Sited Renewable Energy: Achievable Potential in Wisconsin 2006-2015, Volume II. Technical Appendix. p. 192. November 2005. https://seventhwave.org/publications/energy-efficiency-and-customer-sited-renewable-energy-achievable-potential-wisconsin
2. MESP program manager discussion with vendor of single package vertical units early 2015. Vendor noted an incremental cost of $500.00 to $600.00 to upgrade from an 80% to 90% efficient unit. Used $550.00 as the midpoint of this range.
3. Air Conditioning, Heating, and Refrigeration Institute. “Single Package Vertical Systems – AC” category under Commercial, filtered to thermal efficiency > 0 (eliminate cooling only and electric heat models). Accessed September 8, 2015. https://www.ahridirectory.org/ahridirectory/pages/home.aspx

4. Cadmus. “Focus on Energy Evaluated Deemed Savings Changes.” November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
5. ASHRAE Standard 90.1-2007, Table 6.8.1D for SPVAC (single package vertical air conditioning).

Revision History

Version Number	Date	Description of Change
01	10/08/2015	Initial entry
02	01/11/2016	Revised per Cadmus comments
03	01/21/2016	Revised per PSC comments
04	12/2018	Updated savings algorithm

Ductless Mini-Split Heat Pump

	Measure Details
Measure Master ID	Ductless Mini-Split, Replacing Electric Resistance and CAC, 3874 Ductless Mini-Split, Replacing Electric Resistance and CAC, Tier 2, 3891 Ductless Mini-Split, Replacing Electric Resistance and Room AC, 3875 Ductless Mini-Split, Replacing Electric Resistance and Room AC, Tier 2, 3892 Ductless Mini-Split, Replacing Electric Furnace and CAC, 3876 Ductless Mini-Split, Replacing Electric Furnace and CAC, Tier 2, 3893 Ductless Mini-Split, Replacing Electric Resistance and No AC, 3877 Ductless Mini-Split, Replacing Electric Resistance and No AC, Tier 2, 3894
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Other
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	Varies by baseline measure
Peak Demand Reduction (kW)	Varies by baseline measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by baseline measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	18[1]
Incremental Cost	$3,450.00[2]

Measure Description

This measure is a residential-sized ductless mini-split heat pump (DHP) with an output capacity of ≤ 65,000 Btu per hour.[3] This workpaper documents the energy savings for DHPs with energy efficiency performance of 18 SEER and 9.0 HSPF or greater with inverter technology.

Description of Baseline Condition

In the baseline condition, a DHP system could be installed as the primary heating or cooling system for a home or as a secondary heating or cooling system for a single room. Qualifying baseline scenarios involve electric heat (baseboard, furnace) and cooling (central AC, room AC) conditions. Measure characteristics assume an all-electric heated and cooled home.

Description of Efficient Condition

A survey of the Wisconsin market conducted by Tetra Tech[4] indicated that the efficient condition for DHPs is 18 SEER and 9.0 HSPF or greater with inverter technology. Savings are dependent on the existing electric heating and cooling system types, as well as the SEER, EER, and HSPF of efficient unit from nameplate information.

Annual Energy-Savings Algorithm

$kWh = kWh_{HEATING} + kWh_{COOLING}$

$kWh_{HEATING} = (CAP_{EE} * HOU_{HEATING\text{-}EE} * (DLF_{BASE} / HSPF_{BASE} - 1 / HSPF_{EE}) / 1{,}000$

$kWh_{COOLING} = (CAP_{EE} * HOU_{COOLING\text{-}EE} * (DLF_{BASE} / SEER_{BASE} - 1 / SEER_{EE}) / 1{,}000$

$kWh_{COOLING\text{-}BASE\ NO\text{-}AC} = (CAP_{EE} * HOU_{COOLING\text{-}EE} * (0 – 1 / SEER_{EE})$

Where:

CAP_{EE} = Capacity of efficient equipment (= 15,600 Btu/hour)

$HOU_{HEATING\text{-}EE}$ = Hours of use for efficient equipment heating (= 1,940)[5]

DLF_{BASE} = Duct leakage factor of baseline equipment that accounts for the percentage of energy lost to duct leakage and conduction for ducted systems (= see table below)[3]

Duct Leakage Factor of Baseline Equipment

Existing HVAC Type	DLF
Central AC	1.15
Electric Furnace	1.15
Electric Resistance (baseboard, space heaters)	1.00
Room AC	1.00

$HSPF_{BASE}$ = Baseline heating seasonal performance factor (= 3.412 for electric baseboard, = 3.242 for electric furnace)[3]

$HSPF_{EE}$ = Efficient measure heating seasonal performance factor (= 9.0)

1,000 = Kilowatt conversion factor

$HOU_{COOLING\text{-}EE}$ = Hours of use for efficient equipment cooling (= 369)[6]

$SEER_{BASE}$ = Baseline seasonal energy efficiency ratio (= 13.0 for CAC, = 11.3 for room AC)[3]

$SEER_{EE}$ = Efficient measure seasonal energy efficiency ratio (= 18)

Summer Coincident Peak Savings Algorithm

$kW = CAP * (1 / EER_{BASE} – 1 / EER_{EE}) / 1{,}000 * CF$

$kW_{BASE\ NO\text{-}AC} = CAP * (0 – 1 / EER_{EE}) / 1{,}000 * CF$

Where:

EER_{BASE} = Energy efficiency ratio of baseline unit (= 9.8 for room AC, = 11.0 for CAC)[3]
EER_{EE} = Energy efficiency ratio of efficient unit (= 12.5)
CF = Coincidence factor (= 0.68)[6]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 18 years)[1]

Deemed Savings

Annual and Lifecycle Kilowatt-Hour Savings for Ductless Mini-Split Heat Pumps

Type of Savings (kWh)	Ductless Mini-Split, Replacing . . .			
	Electric Resistance and CAC (3874, 3891)	Electric Resistance and Room AC (3875, 3892)	Electric Furnace and CAC (3876, 3893)	Electric Resistance and No AC (3877, 3894)
Annual	5,699	5,699	7,565	5,190
Lifecycle	102,582	102,582	136,170	93,420

Annual Kilowatt Savings for Ductless Mini-Split Heat Pumps

Type of Savings (kW)	Ductless Mini-Split, Replacing . . .			
	Electric Resistance and CAC (3874, 3891)	Electric Resistance and Room AC (3875, 3892)	Electric Furnace and CAC (3876, 3893)	Electric Resistance and No AC (3877, 3894)
Annual	0.2760	0.5575	0.2760	-2.0237

Assumptions

The capacity of residential heat pumps is assumed to be 1.3 tons for equipment installed in the Wisconsin market, based on SPECTRUM data of 62 Focus on Energy installations in 2011. At 12,000 Btu/hour per ton, the assumed average capacity is therefore 15,600 Btu/hour.

No ENERGY STAR criteria are set for DHPs, and air-source heat pump ENERGY STAR levels are insufficient to adequately push the market for this technology. Therefore, efficiency levels were selected that yield strong savings calculations while also serving to push the market to higher efficiency levels. A 20 SEER/9 HSPF combination was initially selected because it is met by roughly 30% of available models according to the AHRI database, but the SEER was raised to 25 based on a more realistic assessment of installations in Northeast markets. The revision of the SEER requirement to 18 is based on Wisconsin-specific market data obtained from EERD research conducted by Tetra Tech (2016)[4] and corroborated by trade ally surveys.

No EER level is set in the program requirements, but 12.5 was selected based on models in the market that match the other two criteria.

Full-load cooling hours were reduced 10% from the 410 hours found in the *Wisconsin Deemed Savings Review*, leading to 369 hours, based on assessment of assumed EFLH for DHPs in other states.

For the constant of capacity-time-hours in the algorithm, the assumption is that a DHP is replacing a certain Btu output from the baseline equipment, so the key difference in calculating savings is just the difference in efficiency between baseline and efficient cases. To that end, while the constant is shown as "capacity times hours of use" only for the DHP, that total Btu output also represents the baseline equipment Btu output load being replaced or supplemented by the DHP, so the algorithm can multiply that single constant by both efficiency levels in the parenthetical statement.

Sources

1. GDS Associates. *Measure Life Report, Residential and Commercial/Industrial HVAC Measures*. June 2007. http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf
   Table A-2, "Residential Heating and Cooling," gives 18 years as a median measure life found from multiple heat pump sources.
2. Swift, Joseph R. and R. Meyer. *Ductless Heat Pumps for Residential Customers in Connecticut*. Table 5 (p. 2-302). 2010. http://aceee.org/files/proceedings/2010/data/papers/1960.pdf
   Also used in 2016 Illinois TRM. Adjusted for average Wisconsin equipment capacity of 15,600 Btu/hour. Calculation derived from table data yields equation: $IMC = 0.125 * CAP_{EE} + 1{,}500$.
3. Pennsylvania Public Utility Commission. *Technical Reference Manual*. June 2016. Section 2.2.3, p. 51. http://www.puc.pa.gov/pcdocs/1350348.docx
4. Tetra Tech. *Ductless Mini-Split Heat Pump Market Assessment and Savings Review Report*. December 30, 2016. https://www.focusonenergy.com/sites/default/files/research/Focus%20EERD%20DMSHP%20Final%20Report_30Dec2016.pdf

5. Hours of use calculated by comparing TMY average weather data from four Wisconsin cities (Green Bay, La Crosse, Madison, Milwaukee) to aggregate meter data collected by Cadmus from 70 cold-climate DHPs in Vermont, and evaluated against Vermont run-time variance to determine hours of use at various external temperatures. The four specific Wisconsin cities were chosen per other Wisconsin TRM workpapers to best represent the whole state.
6. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

Revision History

Version Number	Date	Description of Change
01	05/2016	Initial entry

Residential Air Conditioning Tune Up - Coil Cleaning and Filter Replacement

	Measure Details
Measure Master ID	Residential AC Tune-Up, 4838
Measure Unit	Per air conditioner or air-source heat pump
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Air Conditioner – Residential
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	78.80
Peak Demand Reduction (kW)	0.1492
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	157.59
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	2[1]
Incremental Cost ($/unit)	$122.48[1]

Measure Description

This measure is for cleaning the condensing coil and replacing the filter on a central air conditioning or heat pump unit in a residence. This increases the operating efficiency of the unit. There are several service requirements:

- Clean condensing coil
- Check/replace filter
- Check line loads
- Measure temperature drop
- Maintain condenser fan and motor
- Verify thermostat operation is in accordance with manufacturer recommendations
- Confirm proper operation of the system

Description of Baseline Condition

The baseline condition is an air conditioner or air-source heat pump system that has not been maintained in the last two years.

Description of Efficient Condition

The efficient equipment is an air conditioner or air-source heat pump that has had a coil cleaning and filter changed as part of a tune up.

Annual Energy-Savings Algorithm

kWh_{SAVED} = CAP * 12 * EFLH / [SEER * (1 - SF)] * SF

Where:

CAP = Unit capacity (= 2.425 tons)[2]
12 = Conversion from tons to kBtuh
EFLH = Effective full load cooling hours (= 410)[2]
SEER = Seasonal energy efficiency ratio (= 12.1)[3]
SF = Savings factor (= 7.4%)[4]

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = CAP * 12 * EFLH / [EER * (1 - SF)] * SF * CF

Where:

EER = Energy efficiency ratio (= 10.6)[5]
CF = Coincidence factor (= 0.68)[2]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

Where:

EUL = Effective useful life (= 2 years)[1]

Assumptions

Only the savings from cleaning the condenser coil are used even though an additional adjustment (filter change) is completed—the study referenced[4] does not clarify the additive effects of these two adjustments.

Sources

1. Average cost based on responses from 12 residential HVAC contractors in Wisconsin. Costs ranged from $98 to $150. January 2019.
2. Wisconsin Focus on Energy. *Deemed Savings Report*. October 27, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
3. Cadmus. Findings from the 2016 potential study audit. Based on site visit data from 103 single family homes and 92 units at 88 multifamily sites in Wisconsin.

4. Seventhwave. *Improving Installation and Maintenance Practices for Minnesota Residential Furnaces, Air Conditioners and Heat Pumps*. Table 11. September 30, 2016. https://www.cards.commerce.state.mn.us/CARDS/security/search.do?documentId=%7B881DD1B7-1FE4-495A-9FC0-F74A54B99CB6%7D
5. Wassmer, M. "A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations." Masters Thesis, University of Colorado at Boulder. 2003.

Revision History

Version Number	Date	Description of Change
01	12/17/2018	Initial TRM entry

Furnace Tune-Up, Single Family

	Measure Details
Measure Master ID	Furnace Tune-Up, Single Family, 4660
Measure Unit	Per tune-up
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	14
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	28
Water Savings (gal/yr)	0
Effective Useful Life (years)	2[1]
Measure Incremental Cost ($/unit)	$150[2]

Measure Description

A tune-up of a residential furnace that provides space heating will improve efficiency. The tune-up involves cleaning the burners, combustion chamber, and burner nozzles; adjusting airflow if needed; and ensuring proper temperature rise. The tune-up may also include adjustments to the burner and gas inputs. The tune-up includes a check of venting, safety controls, and combustion air intake. Combustion efficiency is to be measured before and after tune-up using an electronic flue gas analyzer.

Description of Baseline Condition

The baseline measure is a 91% AFUE furnace, operating at a lower efficiency from lack of maintenance.

Description of Efficient Condition

The efficient condition is a furnace that is tuned up to nameplate efficiency by a technician. The incentive is available once in a 24-month period.

Annual Energy-Savings Algorithm

$$\text{Therm}_{SAVED} = CAP * SF * EFLH_{HEAT} / (AFUE_{PRE} * 100)$$

Where:

CAP = Size of the boiler being tuned (= 70.7 MBh)[3]

SF = Savings factor (= 1.6%)[4]

$EFLH_{HEAT}$ = Equivalent full-load hours (= 1,158)[5]

$AFUE_{PRE}$ = AFUE of boiler prior to tune-up (= 91%)[3]

100 = Conversion factor from MBh to therm

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therms_{LIFECYCLE} = Therms_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 2 years)[1]

Sources

1. Illinois Energy Efficiency Statewide Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 6.0*. Volume 3. p. 148. February 8, 2017. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_3_Res_020817_Final.pdf
2. CLEAResult. Informal survey of four Wisconsin Trade Allies. December 2017.
3. Cadmus. 2016 potential study audit.
   Based on site visit data from 103 single family homes in Wisconsin.
4. PA Consulting Group Inc. "Wisconsin Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0." p. 4-11. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Cadmus. *Focus on Evaluated Energy Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

Revision History

Version Number	Date	Description of Change
01	05/2018	Initial TRM entry

Laundry

ENERGY STAR Multifamily Common Area Clothes Washers

	Measure Details
Measure Master ID	Clothes Washer, Common Area, ENERGY STAR, Electric, 2756 Clothes Washer, Common Area, ENERGY STAR, Natural Gas, 2757
Measure Unit	Per clothes washer
Measure Type	Prescriptive
Measure Group	Laundry
Measure Category	Clothes Washer
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	Varies by fuel source
Peak Demand Reduction (kW)	Varies by fuel source
Annual Therm Savings (Therms)	Varies by fuel source
Lifecycle Energy Savings (kWh)	Varies by fuel source
Lifecycle Therm Savings (Therms)	Varies by fuel source
Water Savings (gal/year)	13,978
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$325.40[4]

Measure Description

ENERGY STAR is a standard for energy-efficient consumer appliances. This standard increases savings for clothes washers in multifamily buildings, which are derived from factors such as hot water fuel, dryer type, and location (in-unit or common area).

This measure describes clothes washers in common areas. For washers installed in individual units of a multifamily building, see the residential single-family clothes washer measure.

Description of Baseline Condition

The baseline condition is a non-ENERGY STAR commercial clothes washer.

Description of Efficient Condition

The efficient condition is an ENERGY STAR commercial clothes washer.

Annual Energy-Savings Algorithm

Clothes Washer with Electric DHW

$kWh_{SAVED} = [\Delta kWh(EG) * \%EG + \Delta kWh(EE) * \%EE + \Delta kWh(EnD) * \%EnD] * Cycles/year$

$\text{Therm}_{\text{SAVED}} = [\Delta\text{Therm(EG)} * \%\text{EG}] * \text{Cycles/year}$

Clothes Washer with Natural Gas DHW

$\text{kWh}_{\text{SAVED}} = [\Delta\text{kWh(GE)} * \%\text{GE} + \Delta\text{kWh(GG)} * \%\text{GG} + \Delta\text{kWh(GnD)} * \%\text{GnD}] * \text{Cycles/year}$

$\text{Therm}_{\text{SAVED}} = [\Delta\text{Therm(GG)} * \%\text{GG} + \Delta\text{Therm(GE)} * \%\text{GE} + \Delta\text{Therm(GnD)} * \%\text{GnD}] * \text{Cycles/year}$

Where:

Mix of dryers for clothes washers with electric DHW[2]

EG = Electric DHW and natural gas dryer (= 8.0%)
EE = Electric DHW and electric dryer (= 92.0%)
EnD = Electric DHW with no dryer (= 0.0%)
Cycles/year = Wash cycles per year (= 1,241)[2]

Mix of dryers for clothes washers with natural gas DHW[2]

GG = Natural gas DHW and natural gas dryer (= 26.5%)
GE = Natural gas DHW and electric dryer (= 74.5%)
Gnd = Natural gas DHW with no dryer (=0.0%)
Cycles/year = Wash cycles per year (= 1,241)[2]

Electric and natural gas savings for mixes of dryer and DHW types[2]

ΔkWh(GE) = Electric savings per cycle in kWh (= 1.45)
ΔkWh(EG) = Electric savings per cycle in kWh (= 0.25)
ΔkWh(EE) = Electric savings per cycle in kWh (= 1.70)
ΔkWh(EnD) = Electric savings per cycle in kWh (=1.70)
ΔTherm(GG) = Natural gas savings per cycle in therms (= 0.066)
ΔTherm(GE) = Natural gas savings per cycle in therms (= 0.011)
ΔTherm(EG) = Natural gas savings per cycle in therms (= 0.055)
ΔTherm(GnD) = Natural gas Savings per cycle in therms (= 0.011)

Summer Coincident Peak Savings Algorithm

$\text{kW}_{\text{SAVED}} = \text{kWh}_{\text{SAVED}} / (\text{Cycles/year} * \text{Hours/cycle}) * \text{CF}$

Where:

Hours/cycle = 1 (estimated)
CF = Coincidence factor (= 0.045)[2]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Deemed Savings by Measure

	CAE (MMID 2756)	CAG (MMID 2757)
Annual Deemed Electricity Savings (kWh)	1,971	1,331
Deemed Summer Peak Electricity Demand Reduction (kW)	0.071	0.048
Lifecycle Deemed Electricity Energy Savings (kWh)	21,681	14,641
Annual Deemed Natural Gas Energy Savings (therms)	5.3	31.9
Lifecycle Deemed Natural Gas Energy Savings (Therms)	58	351
Annual Demand Water Savings (gallons)	13,978	13,978
Lifecycle Deemed Water Savings (gallons)	195,692	195,692

Sources

1. Energy Savings Potential and RD&D Opportunities for Commercial Building Appliances: U.S. Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Program, Navigant Consulting, Inc. 2009. http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/commercial_appliances_report_12-09.pdf
2. California Public Utilities District. *Res Retro HIM Evaluation Report*. Weighted by quantity of each efficiency level from MESP SPECTRUM.
3. RECs Database - Wisconsin Multifamily unit counts.
4. Illinois Technical Reference Manual. p. 141. 2013. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry

Electric Clothes Dryer, ENERGY STAR

	Measure Details
Measure Master ID	Electric Clothes Dryer, ENERGY STAR, 4038
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	Laundry
Measure Category	Dryer
Sector(s)	Residential- upstream
Annual Energy Savings (kWh)	160
Peak Demand Reduction (kW)	0.0170
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	1,920
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	$224.91[1]

Measure Description

An electric clothes dryer is a cabinet-like appliance designed to dry fabrics in a tumble-type drum with forced air circulation. The heat source is electricity and the drum and blower(s) are driven by an electric motor or motors. This measure consists of ENERGY STAR-certified electric clothes dryer units that meet the ENERGY STAR Version 1.0 requirements.[1]

Description of Baseline Condition

The baseline condition is non-ENERGY STAR-certified electric clothes dryer units with a combined energy factor (CEF) of 3.11 lbs/kWh according to a modified 2015 Federal Standard.[2]

Description of Efficient Condition

The efficient condition is standard-sized (equal to or larger than 4.4 cubic feet) ventless or vented electric ENERGY STAR-certified clothes dryer units that meet ENERGY STAR Version 1.0 requirements of CEF of 3.93 lbs/kWh.[1]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = UEC_{BASE} - UEC_{EE}$

Where:

UEC_{BASE} = Annual unit energy consumption of baseline unit (= 768.92 kWh)[1]

UEC_{EE} = Annual unit energy consumption of measure unit (= 608.49 kWh)[1]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (kWh_{SAVED} / Hours) * CF$

Where:

Hours = Assumed annual run hours of clothes dryer (= 283; Ncycles * 1 Hour)

CF = Coincidence factor (= 2.9%)[3]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 12 years)[1]

Sources

1. ENERGY STAR. “Retail Products Platform: Product Analysis for Clothes Dryers.” RPP Product Analysis_5-25-16.xlsx. Updated May 11, 2016. https://drive.google.com/open?id=0B9Fd3ckbKJp5OEpWSHg1eksyZ1U
ENERGY STAR assumes 12 years based on: Appliance Magazine. “U.S Appliance Industry: Market Value, Life Expectancy & Replacement Picture.”
ENERGY STAR assumes $224.91 Ventless or Vented Electric, Standard Clothes Dryer; this is based on: the Dryer TSD Life-Cycle Cost and Payback Analysis "2011-04-18_TSD_Chapter_8_Life-Cycle_Cost_and_Payback_Period_Analyses.pdf" 8.2.9 Vented Dryer, Electric, Standard: Consumer Product Costs, Installation Costs, and Total Installed Costs in 2014.
2. U.S. Department of Energy. “10 CFR Part 431. Docket Number EERE–2014-BT-STD-0058. Energy Conservation Program: Energy Conservation Standards for Residential Clothes Dryers.” Table II-6. March 23, 2015. Accessed November 16, 2016. http://energy.gov/sites/prod/files/2015/03/f20/Clothes%20Dryer%20Standards_RFI.pdf
3. Prepared by Shelter Analytics; Facilitated and Managed by Northeast Energy Efficiency Partnership. “Mid-Atlantic Technical Reference Manual Version 4.0.” Clothes washer measure, p. 184. June 2014. http://www.neep.org/sites/default/files/resources/Mid_Atlantic_TRM_V4_FINAL.pdf

Revision History

Version Number	Date	Description of Change
01	06/24/2016	Initial TRM entry

Natural Gas Clothes Dryer, ENERGY STAR

	Measure Details
Measure Master ID	Natural Gas Clothes Dryer, ENERGY STAR, 4039
Measure Unit	Per dryer
Measure Type	Prescriptive
Measure Group	Laundry
Measure Category	Dryer
Sector(s)	Residential- upstream
Annual Energy Savings (kWh)	8
Peak Demand Reduction (kW)	0.0008
Annual Therm Savings (Therms)	5
Lifecycle Energy Savings (kWh)	96
Lifecycle Therm Savings (Therms)	60
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	$270.16[1]

Measure Description

A natural gas clothes dryer is a cabinet-like appliance designed to dry fabrics in a tumble-type drum with forced air circulation. The heat source is a natural gas and the drum and blower(s) are driven by an electric motor(s). This measure consists of ENERGY STAR-certified natural gas clothes dryer units that meet the ENERGY STAR Version 1.0 requirements.[2]

Description of Baseline Condition

The baseline condition is non-ENERGY STAR-certified, vented, natural gas clothes dryers that meet the 2015 federal standard combined energy factor (CEF) of 2.84 lbs/kWh.[1]

Description of Efficient Condition

The efficient condition is ENERGY STAR-certified, vented, natural gas clothes dryers that meet the ENERGY STAR Version 1.0 requirements of CEF of 3.48 lbs/kWh.[2]

Annual Energy-Savings Algorithm

$Therm_{SAVED} = UEC_{BASE} - UEC_{EE}$

$kWh_{SAVED} = UEC_{BASE} - UEC_{EE}$

Where:

UEC_{BASE} = Annual unit energy consumption of baseline unit (42.1 kWh/year, 27.2 therm/year)[1]

UEC_{EE} = Annual unit energy consumption of measure unit (34.36 kWh/year, 22.2 therm/year)[1]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (\Delta kWh/Hours) * CF$

Where:

ΔkWh = Annual unit energy savings (= 7.74 kWh, rounded to 8 kWh)

Hours = Annual hours of use (= 283)[1]

CF = Coincidence factor (= 2.9%)[3]

Lifecycle Energy-Savings Algorithm

$Therm_{LIEFCYCLE} = Therm_{SAVED} * EUL$

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 12 years)[1]

Sources

1. ENERGY STAR. “Retail Products Platform: Product Analysis for Clothes Dryers.” Updated May 11, 2016. https://drive.google.com/open?id=0B9Fd3ckbKJp5OEpWSHg1eksyZ1U
   ENERGY STAR assumes 12 years based on: Appliances Magazine. “U.S Appliance Industry: Market Value, Life Expectancy & Replacement Picture.”
   ENERGY STAR assumes $270.16 Ventless or Vented Gas, Standard Clothes Dryer; this is based on: the Dryer TSD Life-Cycle Cost and Payback Analysis "2011-04-18_TSD_Chapter_8_Life-Cycle_Cost_and_Payback_Period_Analyses.pdf" Table 8.2.12 Vented Dryer, Gas, Standard: Consumer Product Costs, Installation Costs, and Total Installed Costs in 2014.
   The workbook cites a CEF of 2.84 as the 2015 Federal Standard.
   Baseline energy consumption is based on a modified 2015 Federal Standard (10 CFR Part 431,

discussed in Subpart B, Appendix D2). Calculations assume 283 cycles per year and an 8.45 lb load for standard sized dryers (≥ 4.4 cubic foot capacity).

2. ENERGY STAR. “Product Specifications & Partner Commitments Search.” https://www.energystar.gov/products/spec/clothes_dryers_specification_version_1_0_pdf
3. Prepared by Shelter Analytics; Facilitated and Managed by Northeast Energy Efficiency Partnership. “Mid-Atlantic Technical Reference Manual Version 4.0.” Clothes washer measure, p. 184. June 2014. http://www.neep.org/sites/default/files/resources/Mid_Atlantic_TRM_V4_FINAL.pdf

Revision History

Version Number	Date	Description of Change
01	06/24/2016	Initial TRM entry

Lighting

Interior Lighting Controls, CALP

	Measure Details
Measure Master ID	Lighting Controls, Interior, CALP, 3969
Measure Unit	Per watt controlled
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Controls
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	3
Peak Demand Reduction (kW)	0.0003
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	24
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	8[1]
Incremental Cost ($/unit)	$0.92[2]

Measure Description

Interior lighting controls (also known as occupancy sensors) reduce energy consumption by reducing the operating hours for lighting equipment in low occupancy areas, such as hallways, storage rooms, and restrooms. Occupancy sensors automatically turn lights off a preset time after people leave a space, and turn lights on automatically when movement is detected. Occupancy sensors feature a delay adjustment that determines the time that lights are on after no occupancy is detected, as well as a sensitivity adjustment that determines the magnitude of the signal required to trigger the occupied status.

The two primary technologies used for occupancy sensors are passive infrared (PIR) and ultrasonic. PIR sensors determine occupancy by detecting the difference in heat between a body and the background. Ultrasonic sensors detect people using volumetric detectors and broadcast sounds above the range of human hearing, then measure the time it takes the waves to return.

Description of Baseline Condition

The baseline condition is no occupancy sensor, with lighting fixtures being controlled by manual wall switches.

Description of Efficient Condition

The efficient condition is a hard-wired, fixture-, wall-, or ceiling-mounted occupancy sensor, where lighting fixtures are controlled by the sensors based on detected occupancy.

Annual Energy-Savings Algorithm

kWh_{SAVED} = Watts / 1,000 * SF * HOU

Where:

Watts = Controlled lighting wattage (provided for each project)
1,000 = Kilowatt conversion factor
SF = Savings factor, deemed (= 41%)[3]
HOU = Hours of use (= 6,614)[4]

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = Watts * SF /1,000 * CF

Where:

CF = Coincidence factor (= 0.77)[3]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

Where:

EUL = Effective useful life (= 8 years)[1]

Deemed Savings

Annual Savings (per watt controlled)

Measure	MMID	Multifamily	
		kWh	kW
Lighting Controls, Interior, CALP	3969	3	0.0003

Lifecycle Savings (per watt controlled)

Measure	MMID	Multifamily
Lighting Controls, Interior, CALP	3969	24

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." Appendix B. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Average incremental costs from 2016 CALP LED SPECTRUM measure master IDs 3605, 3606, 3201 and 3202, converted to dollars per watt.
   3605: Similar to MMID 2474. WESCO Distribution Pricing ($70.00) + Labor ($25.00) = $95.00
   3606: Similar to MMID 2474. WESCO Distribution Pricing ($70.00) + Labor ($25.00) = $95.00
   3201: WESCO Distribution Pricing ($18.75) + Labor ($16.25) = $35.00 for Wall Mount. WESCO Distribution Pricing, 2013 + Labor = $120.00 for Ceiling Mount. $77.50 is the average.
   3202: WESCO Distribution Pricing ($18.75) + Labor ($16.25) = $35.00 for Wall Mount. WESCO Distribution Pricing, 2013 + Labor = $120.00 for Ceiling Mount. $77.50 is the average.
3. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Updated March 22, 2010. Table 4-161. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. Historical Focus on Energy project data, January 1, 2015 through November 15, 2016. Weighted average of 12-hour versus 24-hour fixture replacements under MMIDs 3199, 3197, 3198, 3735, 3603, 3604, 3200, 3196 and 3195. Forty-nine percent of replaced fixtures operated 12 hours or more and 51% operated 24 hours
5. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs; see Table 4-1 showing multifamily housing (in unit) CF of 65% to 83%.

Revision History

Version Number	Date	Description of Change
01	11/15/2016	Initial TRM entry

CFL, Reflector, 15 Watt, Retail Store Markdown

	Measure Details
Measure Master ID	CFL, Reflector, 15 Watt, Retail Store Markdown, 3552
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Fluorescent, Compact (CFL)
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	39
Peak Demand Reduction (kW)	0.0045
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	312
Lifecycle Therm Savings (Therms)	0
Effective Useful Life (years)	8[1]
Incremental Cost ($/unit)	$2.80[2]

Measure Description

This measure is installing an ENERGY STAR–certified CFL reflector that was purchased through a retail outlet to replace an incandescent bulb. Savings are based on a time-of-sale purchase for installation in a residential location.

Description of Baseline Condition

The baseline is an incandescent or halogen reflector lamp.

Description of Efficient Condition

The efficient equipment is a standard screw-based 15-watt ENERGY STAR–certified CFL reflector. The actual wattage of the installed bulb is used to calculate savings for the evaluation.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = \Delta Watts * HOU / 1{,}000$

Where:

ΔWatts = Change in wattage, calculated by subtracting the efficient bulb wattage from the baseline wattage determined from its lumen bin (= 39)[3]

HOU = Hours of use (= 996 [(2.20 * 93.4% + 10.2 * 6.6%) * 365 days/year]; see Assumptions)

1,000 = Kilowatt conversion factor

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= 0.1162 [0.0699 * 93.4% + 0.77 * 6.6%]; see Assumptions)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 8 years)[1]

Assumptions

Hours of use is a weighted average of single-family residential, multifamily, and commercial use. The weighting for these variables are shown in the table below.

Cross-Sector Sales Hours of Use and Coincidence Factor Weightings

Sector	Weighting	HOU per Day[3]	CF[3]
Residential	**93.4%**	**2.20**	**0.0699**
Multifamily	25.3%	2.01	0.0550
Single Family	74.7%	2.27	0.0075
Commercial	**6.6%**	**10.20**	**0.7700**

Sources

1. EUL based on similar measure; CFL, reflector replacing incandescent.
2. Online research. ENERGY STAR®. March 2016.
   Lowes. Website. Accessed March 2016. www.lowes.com
   Home Depot. Website. Accessed March 2016. www.homedepot.com
   1000 Bulbs. Website. Accessed March 2016. www.1000bulbs.com
3. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. September 12, 2016. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2016_v1%207.pdf

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	05/2018	Updated based on 2016 Deemed Savings report

CFL, Standard Bulb, Retail Store Markdown

	Measure Details
Measure Master ID	CFL, Standard Bulb, Retail Store Markdown: 310–749 Lumens, 3548 750–1,049 Lumens, 3549 1,050–1,489 Lumens, 3550 1,490–2,600 Lumens, 3551
Measure Unit	Per bulb
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Fluorescent, Compact (CFL)
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Varies by light output
Peak Demand Reduction (kW)	Varies by light output
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by light output
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	8[1]
Incremental Cost	Varies by measure, see Appendix D

Measure Description

This measure is installing an ENERGY STAR–certified standard screw-in CFL purchased through a retail outlet in place of an incandescent or halogen screw-in bulb. Assumptions are based on a time-of-sale purchase for installation in a residential location.

Description of Baseline Condition

The baseline equipment is an incandescent light bulb (standard or EISA compliant halogen). The baseline wattage is determined using the lumens equivalence method in conjunction with the lumen output of the efficient bulb.

Description of Efficient Condition

The efficient measure is a standard ENERGY STAR–certified CFL. Typical values are used in this workpaper, but the actual wattage of the installed bulb is used to calculate savings for the evaluation.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = \Delta Watts * HOU / 1{,}000$

Where:

ΔWatts = Change in wattage, calculated by subtracting the efficient bulb wattage from the baseline wattage determined from its lumen bin (= varies by lumen bin; see table below)

HOU = Hours of use (= 996 [(2.20 * 93.4% + 10.2 * 6.6%) * 365 days/year]; see Assumptions)

1,000 = Kilowatt conversion factor

Wattage Reduction by Lumen Bin

Measure Name	MMID	Evaluated Gross ΔWatts
CFL, Standard Bulb, Retail Store Markdown, 310-749 Lumens	3548	19
CFL, Standard Bulb, Retail Store Markdown, 750-1,049 Lumens	3549	31
CFL, Standard Bulb, Retail Store Markdown, 1,050-1,489 Lumens	3550	34
CFL, Standard Bulb, Retail Store Markdown, 1,490-2,600 Lumens	3551	50

Summer Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= 0.1162 [0.0699 * 93.4% + 0.77 * 6.6%]; see Assumptions)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 8 years)[1]

Deemed Savings

Deemed Savings by Measure

MMID	Annual kWh_{SAVED}	kW_{SAVED}	Lifecycle kWh_{SAVED}
3548	19	0.0022	152
3549	31	0.0036	248
3550	34	0.0040	272
3551	50	0.0058	400

Assumptions

The hours of use and coincidence factor were calculated using the cross-sector sales weighting shown in the table below.

Cross-Sector Sales Hours of Use and Coincidence Factor Weightings

Sector	Weighting	HOU per Day[4]	CF[4]
Residential	**93.4%**	**2.20**	**0.0699**
Multifamily	25.3%	2.01	0.0550
Single Family	74.7%	2.27	0.0075
Commercial	**6.6%**	**10.20**	**0.7700**

Delta watts values are derived from the 2016 Focus on Energy program evaluation, using the Uniform Methods Project[5] as described in the 2016 Deemed Savings report.[4]

The incremental costs by lumen bin for CFL standard bulb are:[3]

- 310–749 lumens = $1.21
- 750–1,049 lumens = $0.37
- 1,050–1,489 lumens = $0.38
- 1,490–2,600 lumens = $1.03

Sources

1. Similar measure MMID 2959, CFL Retail Store Markdown.
2. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
3. Light bulb sales data obtained by Cadmus for California from 2010 through 2012. Note that the CFL average lamp costs include incented lamps.

4. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. September 12, 2016. https://focusonenergy.com/sites/default/files/2016%20Deemed%20Savings%20Review.pdf
5. National Renewable Energy Laboratory. *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures*. Chapter 21. February 2015. http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	05/2018	Updated based on 2016 Deemed Savings report

8-Foot Linear Fluorescent T8 Replacement System Parking Garage

	Measure Details
Measure Master ID	T8 2-Lamp, 4-Foot, HPT8 or RWT8: Replacing T12HO 1-Lamp, 8-Foot, BF > 1.00, Parking Garage, 3148 T8 4-Lamp, 4-Foot, HPT8 or RWT8: Replacing T12HO 2-Lamp, 8-Foot, 0.78 < BF < 1.00, Parking Garage, 3152 Replacing T12HO 2-Lamp, 8-Foot, BF ≤ 0.78, Parking Garage, 3153
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Fluorescent, Linear
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Varies by measure, see Appendix D

Measure Description

This measure is high performance and reduced wattage 4-foot linear fluorescent lighting fixtures that use low ballast factors, high wattage lamps, or reduced wattage lamps are an energy-efficient alternative to 8-foot standard wattage T12, T12HO, and T12VHO linear fluorescent fixtures commonly found in parking garages within multifamily buildings. These products can be installed on a two-to-one basis to replace 1-lamp or 2-lamp T12 luminaires without sacrificing lighting quality.

Description of Baseline Condition

For existing building parking garages, the baseline measure is 8-foot, 1-lamp or 2-lamp, standard T12, T12HO, and T12VHO linear fluorescent fixtures.

Description of Efficient Condition

The efficient measure is 2-lamp or 4-lamp, 4-foot, high performance T8 fixtures with normal and low ballast factor, and reduced wattage, 25-watt and 28-watt T8s with high, normal, and low ballast factors.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{8' T12} - kWh_{HP/RW}$

Where:

$kWh_{8' T12}$ = Annual electricity consumption of an 8-foot, T12, T12HO, or T12VHO lamp linear fluorescent fixture

$kWh_{HP/RW}$ = Annual electricity consumption of a 4-foot linear fluorescent high performance or reduced wattage fixture

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = Wattage / 1{,}000 * CF$

Where:

Wattage = Wattage used

1,000 = Kilowatt conversion factor

CF = Coincidence factor (= 1.0) [3]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Annual Deemed Savings for 8-Foot Linear Fluorescent T8 Replacement System Parking Garage

Measure	MMID	Existing Building	
		kWh	kW
T8 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO 1-Lamp, 8-Foot, BF > 1.00, Parking Garage	3148	473	0.0541
T8 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO 2-Lamp, 8-Foot, 0.78 < BF < 1.00, Parking Garage	3152	1,083	0.1236
T8 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO 2-Lamp, 8-Foot, BF ≤ 0.78, Parking Garage	3153	1,191	0.136

Lifecycle Deemed Savings for 8-Foot Linear Fluorescent T8 Replacement System Parking Garage

Measure	MMID	Existing Building (kWh)
T8 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO 1-Lamp, 8-Foot, BF > 1.00, Parking Garage	3148	7,095
T8 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO 2-Lamp, 8-Foot, 0.78 < BF < 1.00, Parking Garage	3152	16,245
T8 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO 2-Lamp, 8-Foot, BF ≤ 0.78, Parking Garage	3153	17,865

Measure Costs for 8-Foot Linear Fluorescent T8 Replacement System Parking Garage[2]

Measure	MMID	Existing Building Cost
T8 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO 1-Lamp, 8-Foot, BF > 1.00, Parking Garage	3148	$41.00
T8 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO 2-Lamp, 8-Foot, 0.78 < BF < 1.00, Parking Garage	3152	$66.00
T8 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO 2-Lamp, 8-Foot, BF ≤ 0.78, Parking Garage	3153	$66.00

Sources

1. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” June 2, 2008. http://www.deeresources.com/
2. Michigan Master Measure Database. 2011 baselines. Updated May 26, 2011.
3. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. Tetra Tech. “ACES Deemed Savings Desk Review.” November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	12/31/2012	Initial TRM entry
02	01/2019	Removed MMIDs 3144—3147, 3149—3151, and 3154-3156

Linear Fluorescent, 2-Lamp, 4-Foot, RWT8 Replacements, 24 Hours, CALP

	Measure Details
Measure Master ID	Linear Fluorescent, 2-Lamp, 4-Foot, RWT8 Replacements, 24 Hours, CALP, 3195
Measure Unit	Per fixture (lamps and ballast)
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Fluorescent, Linear
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	307.00
Peak Demand Reduction (kW)	0.035
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by installation year
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$34.97[2]

Measure Description

Reduced wattage (RW) 4-foot linear fluorescent lighting fixtures that use low ballast factors are an energy-efficient alternative to standard 40-watt or 34-watt linear T12 fluorescent products commonly found in multifamily buildings. These products can be installed on a one-for-one basis to replace 2-lamp T12 luminaires that are “on” 24 hours per day without sacrificing lighting quality.

Description of Baseline Condition

The baseline equipment for existing buildings is a standard 2-lamp T12 fixture.

Description of Efficient Condition

The efficient equipment is a reduced wattage, 2-lamp, 28-watt T8 with a low ballast factor.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{2L\ 4'\ T12} - kWh_{HP/RW}$

Where:

$kWh_{2L\ 4'\ T12}$ = Annual electricity consumption of 2-lamp T12 luminaire

$kWh_{HP/RW}$ = Annual electricity consumption of a 4-foot, linear fluorescent, high performance or low wattage fixture

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = Wattage / 1,000 * CF

Where:

Wattage = Wattage per fixtures
1,000 = Kilowatt conversion factor
CF = Coincidence factor (= 1.0)[3]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Annual Deemed Savings for 4-Foot RWT8 Linear Fluorescents

Measure	Existing Building
Low Watt T8 System: 28-Watt, 2-Lamp, 4-Foot Ballast & Lamps ≤ 0.78	307 kWh 0.035 kW

Lifecycle Deemed Savings for 4-Foot RWT8 Linear Fluorescents*

Measure	Installation Year			
	2013	2014	2015	2016 and Beyond
Multifamily Common Area 4-Foot 2-Lamp T12 to T8	2,706.8 kWh 0.0350 kW	2,549.2 kWh 0.0350 kW	2,391.5 kWh 0.0350 kW	2,233.8 kWh 0.0170 kW

* kWh savings for products replacing T12 lamps calculated using the following methodology:

- Installed in 2013: receive three years T12 savings and 12 years EISA compliant T8 baseline savings.
- Installed in 2014: receive two years T12 savings and 13 years EISA compliant T8 baseline savings.
- Installed in 2015: receive one year T12 savings and 14 years EISA compliant T8 baseline savings.
- Installed in 2016: receive no T12 savings and 15 years of EISA compliant T8 baseline savings.

Measure Costs for 4-Foot RWT8 Linear Fluorescents

Measure	Existing Building Cost
Low Watt T8 System: 28-Watt, 2-Lamp, 4-Foot Ballast & Lamps ≤ 0.78	$110.90

Assumptions

Annual operating hours: 8,760. 2-lamp T12 fixtures used to generate baseline usage. For 2-lamp reduced wattage with low ballast factor, 28-watt, T8 lamps were used to calculate the new measure average annual energy savings.

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Actual cost from 2015-16 program data, 30 applications.
3. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	06/20/2013	Initial TRM entry

Linear Fluorescent, 2-Lamp, 4-Foot, RWT8 Replacements, 12 Hours, CALP

	Measure Details
Measure Master ID	Linear Fluorescent, 2-Lamp, 4-Foot, RWT8 Replacements, 12 Hours, CALP, 3196
Measure Unit	Per fixture (lamps and ballast)
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Fluorescent, Linear
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	153.00
Peak Demand Reduction (kW)	0.0270
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by installation year
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$9.80[2]

Measure Description

Reduced wattage 4-foot linear fluorescent lighting fixtures that use low ballast factors are an energy-efficient alternative to standard 40-watt or 34-watt linear T12 fluorescent products commonly found in multifamily buildings. These products can be installed on a one-for-one basis to replace 2-lamp T12 luminaires without sacrificing lighting quality.

Description of Baseline Condition

The baseline equipment for existing buildings is a standard 2-lamp T12 fixture.

Description of Efficient Condition

The efficient equipment is a reduced wattage, 2-lamp, 28-watt T8 with a low ballast factor.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{2L\ 4'\ T12} - kWh_{HP/RW}$

Where:

$kWh_{2L\ 4'\ T12}$ = Annual electricity consumption of 2-lamp T12 luminaire

$kWh_{HP/RW}$ = Annual electricity consumption of a 4-foot, linear fluorescent, high performance or low wattage fixture

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = Wattage / 1,000 * CF

Where:

Wattage = Wattage per fixtures
1,000 = Kilowatt conversion factor
CF = Coincidence factor (= 0.77)[3]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Annual Deemed Savings for 4-Foot RWT8 Linear Fluorescents

Measure	Existing Building
Low Watt T8 System: 28-Watt, 2-Lamp, 4-Foot Ballast & Lamps ≤ 0.78	153 kWh 0.0270 kW

Lifecycle Deemed Savings for 4-Foot RWT8 Linear Fluorescents*

Measure	Installation Year			
	2013	2014	2015	2016 and Beyond
Multifamily Common Area 4-Foot 2-Lamp T12 to T8	1,353.4 kWh 0.0270 kW	1,274.6 kWh 0.0270 kW	1,195.7 kWh 0.0270 kW	1,116.9 kWh 0.0131 kW

* kWh savings for products replacing T12 lamps calculated using the following methodology:

- Installed in 2013: receive three years T12 savings and 12 years EISA compliant T8 baseline savings.
- Installed in 2014: receive two years T12 savings and 13 years EISA compliant T8 baseline savings.
- Installed in 2015: receive one year T12 savings and 14 years EISA compliant T8 baseline savings.
- Installed in 2016: receive no T12 savings and 15 years of EISA compliant T8 baseline savings.

Measure Costs for 4-Foot RWT8 Linear Fluorescents

Measure	Existing Building Cost
Low Watt T8 System: 28-Watt, 2-Lamp, 4-Foot Ballast & Lamps ≤ 0.78	$110.90

Assumptions

The annual operating hours were assumed to be 4,380.

The baseline usage was generated using 2-lamp T12 fixtures.

For 2-lamp reduced wattage with low ballast factor, 28-watt, T8 lamps were used to calculate the new measure average annual energy savings.

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. 2014 Focus on Energy Program Data; verified with average price of lamps on 1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013. Assumes T8 and CEE ballast as baseline.
3. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	06/20/2013	Initial TRM entry

Reduced Wattage 8-Foot T8 Lamps Replacing 8-Foot Standard T8 Lamps

	Measure Details
Measure Master ID	Reduced Wattage 8-Foot T8 Lamps Replacing 8-Foot Standard T8 Lamps, 2665
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Fluorescent, Linear
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	Varies by wattage
Peak Demand Reduction (kW)	Varies by wattage
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by wattage
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$4.33[4]

Measure Description

Reduced wattage 8-foot standard wattage T8 lamps save energy by reducing the total input wattage of the luminaires where installed. Reduced wattage 8-foot T8 lamps can be installed in place of existing 59-watt 8-foot T8 lamps where the tasks that take place in the space do not require the light level provided by the existing lamps.

Description of Baseline Condition

The baseline equipment is standard 59-watt 8-foot T8 lamps.

Description of Efficient Condition

The efficient equipment is 49-watt, 50-watt, 51-watt, or 54-watt 8-foot T8 lamps.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{59wattT8} - kWh_{RWLamp}$

Where:

$kWh_{59wattT8}$ = Annual electricity consumption of standard 59-watt 8-foot T8 lamp

kWh_{RWLamp} = Annual electricity consumption of reduced wattage 8-foot T8 lamp

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = Wattage / 1,000 * CF

Where:

Wattage = Wattage of installed fixture; (= ballast factor * lamp wattage)
1,000 = Kilowatt conversion factor
CF = Coincidence factor (= 0.77)[3]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = ($kWh_{59wattT8}$ - kWh_{RWLamp}) * EUL

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

An average of 25% each of 49-watt, 50-watt, 51-watt, and 54-watt 8-foot T8 lamps was used to generate the new measure wattage.

Sources

1. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” February 4, 2014. http://www.deeresources.com/
Rated ballast life of 70,000 hours. Not rated on bulb life. Capped at 15 years.
2. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Table 3.2 Lighting Hours of Use in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
3. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Table 3.2 Coincidence Factor for Lighting in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. 2014 Focus on Energy Program Data; verified with average price of lamps on 1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013. Assumes T8 and CEE ballast as baseline.

Revision History

Version Number	Date	Description of Change
01	12/2012	Updated savings values

LED, Omnidirectional, Connected Lighting Pack

	Measure Details
Measure Master ID	Connected Lighting Pack, Hub-Based, 4432 Connected Lighting Pack, Non-Hub, 4433
Measure Unit	Per kit
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure and sector
Peak Demand Reduction (kW)	Varies by measure and sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure and sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15 (see Assumptions)
Incremental Cost ($/unit)	$65.33 for MMID 4432;[1] $79.98 for MMID 4433[2]

Measure Description

Connected lighting products are retail lighting products that allow users to control the lights remotely, using a mobile app or web user interface. Basic features include the ability to remotely turn the light on and off and adjust its brightness and to set a schedule for the light. More advanced features are also available, such as motion and daylight sensing.

The technology leads to a reduction in energy consumption by providing dimming capabilities to otherwise non-dimmable sockets, as well as a reduction in hours of use by allowing users to turn off lights from anywhere and to schedule lights they would not otherwise put on a timer. Some connected lighting products use a hub to facilitate wireless communication with the lights, which requires additional power and therefore reduces total savings. Other connected lighting products do not use a hub. Although total savings from non-hub products are also reduced as a result of bulb standby power draw associated with the lights being turned off via the application interface, the decrease in total savings is smaller than the decrease associated with using a hub.

Savings values provided are derived from a study conducted in the summer of 2017,[3] in which two-lamp Philips Hue hub-based connected lighting kits were supplied for free and metered in more than 90 homes across Wisconsin.

Description of Baseline Condition

The baseline equipment is a general service 43-watt halogen light bulb.

Description of Efficient Condition

The efficient equipment is a connected light that can communicate either through a hub or directly with users via a readily available short-range telecommunication protocol.

Annual Energy-Savings Algorithm

$$kWh_{SAVED} = (\Delta kWh_{LED} * ISR_{LED}) + (\Delta kWh_{APP} * ISR_{APP}) + (\Delta kWh_{HUB} * ISR_{HUB})$$

$$\Delta kWh_{LED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * HOU * N_{LAMPS}$$

$$\Delta kWh_{APP} = (\Delta kWh_{DIM} + \Delta kWh_{HOU} - \Delta kWh_{STBY}) * N_{LAMPS}$$

$$\Delta kWh_{DIM} = Watts_{EE} / 1{,}000 * \%\Delta Watts_{DIM} * [HOU * (1 - \%\Delta HOU)]$$

$$\Delta kWh_{HOU} = [Watts_{EE} * (1 - \%\Delta Watts_{DIM})] / 1{,}000 * HOU * \%\Delta HOU$$

$$\Delta kWh_{STBY} = Watts_{STBY} / 1{,}000 * HOU_{STBY}$$

$$\Delta kWh_{HUB} = Watts_{HUB} / 1{,}000 * 8{,}760$$

Where:

ΔkWh_{LED} = Reduction in annual energy consumption from upgrading a single bulb

ISR_{LED} = Installation rate for two bulbs (= 90%, see Assumptions)[3]

ΔkWh_{APP} = Reduction in annual energy consumption from using all connected lighting features and standby and hub energy usage

ISR_{APP} = Usage rate of the smart lighting app (= 75%, see Assumptions)[3]

ΔkWh_{HUB} = Increase in annual energy consumption from hub power

ISR_{HUB} = Installation rate for hubs (= 75% for MMID 4432, see Assumptions;[3] = 0 for MMID 4433)

$Watts_{BASE}$ = Baseline wattage (= 43 watts, see Assumptions)

$Watts_{EE}$ = Efficient wattage (= 9.5 watts for MMID 4432;[4] = 11 watts for MMID 4433[5])

1,000 = Conversion from watts to kilowatts

HOU = Hours of use (= 829 hours for single family, 734 hours for multifamily)[6]

N_{LAMPS} = Number of lamps installed (= 2, see Assumptions)

ΔkWh_{DIM} = Reduction in annual energy consumption from app-induced dimming

ΔkWh_{HOU} = Reduction in annual energy consumption from app-induced HOU reduction

ΔkWh_{STBY} = Increase in annual energy consumption from standby power

$\%\Delta Watts_{DIM}$ = Average app-induced percentage decrease in power (= 11%)[3]

$\%\Delta HOU$ = Average app-induced percentage decrease in HOU (= 4%)[3]

$Watts_{STBY}$ = Bulb standby wattage (= 0.3 watts for MMID 4432;[3] = 0.5 watts for MMID 4433,[5] see Assumptions)

HOU_{STBY} = Bulb standby hours of use (= 160 hours)[3]

$Watts_{HUB}$ = Hub wattage (= 1.6 watts for MMID 4432;[3] = 0 watts for MMID 4433)

Summer Coincident Peak Savings Algorithm

$$kW_{SAVED} = (\Delta kW_{LED} * ISR_{LED}) + (\Delta kW_{APP} * ISR_{HUB})$$

$$\Delta kW_{LED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * CF * N_{LAMPS}$$

$$\Delta kW_{APP} = (\Delta kW_{DIM} - \Delta kW_{STBY}) * N_{LAMPS} - \Delta kW_{HUB}$$

$$\Delta kW_{DIM} = Watts_{EE} * \%\Delta Watts_{DIM} * CF / 1{,}000$$

$$\Delta kW_{STBY} = Watts_{STBY} * CF_{STBY} / 1{,}000$$

$$\Delta kW_{HUB} = Watts_{HUB} / 1{,}000$$

Where:

CF = Coincidence factor for bulb usage time (= 12%)[3]

CF_{STBY} = Coincidence factor for bulb standby time (= 2%)[3]

Lifecycle Energy-Savings Algorithm

$$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$$

Where:

EUL = Effective useful life (= 15 years, see Assumptions)

Deemed Savings

Savings for Pack-Based Connected Lighting Bulbs

Measure	MMID	Sector	Annual Savings (kWh)	Demand Reduction (kW)	Lifecycle Savings (kWh)
Connected Lighting Pack, Hub-Based	4432	Single family	41	0.0062	615
		Multifamily	35	0.0062	525
Connected Lighting Pack, Non-Hub	4433	Single family	50	0.0071	750
		Multifamily	44	0.0071	660

Assumptions

The savings are based on data used in a study conducted by Cadmus on behalf of the Wisconsin Focus on Energy program.[3] The connected lighting used by the study was the Philips Hue bulb, which uses a hub-based communication network. The power consumption of two baseline lights was metered, then the power consumption of two connected lights that replaced the baseline lights was metered. Participants were asked to change the lights on the summer solstice, so that both conditions occurred with the same average amount of sunlight per day. Most meters logged data from mid-May through early to late August. Most participants received meters in the mail, which they were instructed to connect in series with the lamp where the connected lights would be set up. They then received the kits in the mail in June, and were asked to install on June 21. Participants were asked to return the meters by mail. Data was retrieved from 109 participants in Wisconsin, 95 of which were confirmed to have used the technology.

The coincidence factor was calculated as the percentage of connected lighting runtime during Wisconsin's peak period, and did not receive any adjustment based on dimming during the peak times. The standby coincidence factor was calculated as the percentage of time the bulbs were in standby mode during the peak period. The $\%\Delta Watts_{DIM}$ represents the average percentage reduction in wattage due to dimming, calculated as the difference between the maximum observed wattage and the average observed wattage for each household, divided by the maximum observed wattage. The $\%\Delta HOU$ was calculated similarly, as the difference between the observed hours of use before and after the connected lighting was installed, divided by the observed hours of use before it was installed.

The study revealed that 90% of participants installed both bulbs that came with the kit, 0% installed only one bulb, and 10% installed no bulbs. The study also revealed that 75% of participants installed and used the hub along with the light bulbs.

The maximum output of a Philips Hue bulb is 840 lumens,[4] and it is 1,100 lumens for LIFX bulbs.[5] In accordance with the lumen equivalence method as specified in the *Uniform Methods Project*,[7] a Philips

Hue bulb would replace a 43-watt halogen bulb and a LIFX bulb would replace a 52-watt halogen bulb. However, it is assumed that LIFX bulbs will generally be kept as dim as Philips bulbs, and therefore LIFX bulbs will generally replace 43-watt halogen bulbs as well.

The study revealed 2.21 hours of use per day on average for connected lighting bulbs (808 hours per year), but this value holds only for the summer study period, rather than the entire year. Therefore, this workpaper used the previously measured value of 829 hours for single family residents and 734 hours for multifamily residents.[6] The value for %ΔHOU, derived from the study, is maintained as a percentage rather than an absolute.

The study revealed an average Philips Hue standby wattage of 0.3. The study did not examine LIFX bulbs, but the LIFX website[5] lists a standby wattage of < 0.5, and this workpaper uses a value of 0.5 watts.

The claimed lifetime is 25,000 hours for both LIFX[5] and Philips Hue[4] bulbs. With an HOU of 829, the calculated lifetime is 30 years. However, a 15-year EUL cap has been deemed for most residential screw-base LED measures, as a result of measure persistence concerns[8] and LED lifetime cap practices of other programs (in CT, DC, IL, MA, MN, RI, and VT). While connected lighting products are less susceptible to persistence issues, they also have many more electronic components than standard LED products and are therefore likely more subject to early failure.[9] Therefore, the 15-year EUL cap is maintained for these measures.

Sources

1. Wisconsin Focus on Energy. Quote from Philips for two-bulb Hue kit.
2. Wisconsin Focus on Energy. Quote from LIFX for two A19 LIFX bulbs.
3. Iaccarino, Joseph, C. Kelly, S. Cofer, J. Fontaine. *Only as Smart as Its Owner: A Connected Device Study.* August 2018. https://cadmusgroup.com/papers-reports/only-as-smart-as-its-owner-a-connected-device-study/
4. Philips Hue. “Specifications of the Hue White Starter Kit.” https://www2.meethue.com/en-us/p/hue-white-starter-kit-e26/046677455286/specifications
5. LIFX. “LIFX Color A19 LED Smart Bulb.” https://www.lifx.com/products/lifx
6. Cadmus. “Focus on Energy Evaluated Deemed Savings Changes.” November 26, 2013. https://focusonenergy.com/sites/default/files/FOC_XC_Deemed_WriteUp_12122013%20%282%29.pdf
7. National Renewable Energy Laboratory. *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures*. “Chapter 21: Residential Lighting Evaluation Protocol.” NREL/SR-7A40-63205. Table 2. February 2015. http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf

8. NEEP. *Residential Lighting Deep Dive Brief: A Comparison of Savings Assumptions across the Northeast and Mid-Atlantic*. January 2016. http://www.neep.org/sites/default/files/resources/ResLightingDeeperDiveFINAL1.pdf
9. Next Generation Lighting Industry Alliance. *LED Luminaire Lifetime: Recommendations for Testing and Reporting*. September 2016. https://energy.gov/sites/prod/files/2015/01/f19/led_luminaire_lifetime_guide_sept2014.pdf

Revision History

Version Number	Date	Description of Change
01	01/2018	Initial TRM entry
02	04/2018	Added multifamily sector

LED, Standard Bulb, Pack-Based

	Measure Details
Measure Master ID	LED, Pack-Based, 9 Watt, 4277 LED, Pack-Based, 11 Watt, 4278
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	9 watt = $2.58 (MMID 4277); 11 watt = $4.85 (MMID 4278)[2]

Measure Description

This measure is the installation of a general purpose, ENERGY STAR-qualified, screw-in LED A-lamp in place of an incandescent screw-in bulb. Pack-based measures assume the lamp was provided as part of a package, so an installation rate less than 100% is applied.

Description of Baseline Condition

The *Uniform Methods Project* (UMP) provides guidelines, based on EIA and the lumen output of the bulb and bulb type, for determining globe bulb baselines.[5] The 9-watt lamp is a TCP model LED9A19D27K, with output ranging from 825 lumens to 850 lumens. According to the *Uniform Methods Project*,[5] this corresponds to a baseline of 43 watts. The 11-watt lamp is a TCP model L11A19D2527K, with output ranging from 1,150 lumens to 1,225 lumens. According to the *Uniform Methods Project*, this corresponds to a baseline of 53 watts.

Description of Efficient Condition

The pack-based bulb models described above consume 9 watts and 11 watts, respectively.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * HOU * IR$

Where:

$Watts_{BASE}$ = Baseline wattage (= 43 watts for MMID 4277; = 53 watts for MMID 4278; see Description of Baseline Condition)

$Watts_{EE}$ = Efficient wattage (= 9 watts for MMID 4277; = 11 watts for MMID 4278)

1,000 = Kilowatt conversion factor

HOU = Hours of use (= 829 for single family, 734 for multifamily)[3]

IR = Installation rate (= 92% for pack-based)[4]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * CF * IR$

Where:

CF = Coincidence factor (= 0.075 for single family, 0.055 for multifamily)[3]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Single Family Savings

$Watts_{EE}$	MMID	Sector	Annual kWh_{SAVED}	kW_{SAVED}	Lifecycle $kWh_{LIFECYCLE}$
9	4277	Single Family	26	0.0023	390
		Multifamily	23	0.0017	345
11	4278	Single Family	32	0.0029	480
		Multifamily	28	0.0021	420

Sources

1. TCP. "Residential Lighting." Accessed January 2018. https://www.tcpi.com
   Rated life is 15,000 for the 9-watt lamp and 25,000 hours for the 11-watt lamp. With an HOU of 829, the calculated lives are 18 years and 30 years, respectively. However, a 15-year EUL cap has been deemed for most residential screw-base LED measures as a result of measure persistence concerns (http://www.neep.org/sites/default/files/resources/ResLightingDeeperDiveFINAL1.pdf) and LED lifetime cap practices of other programs (in Connecticut, Illinois, Massachusetts, Minnesota, Rhode Island, Vermont, and Washington DC).
2. Wisconsin Focus on Energy. The incremental measure cost for pack-based measures is the cost to the program, which is equivalent to the incentive.
3. Cadmus. *Focus on Energy Deemed Savings Changes*. September 12, 2016. https://focusonenergy.com/sites/default/files/2016%20Deemed%20Savings%20Review.pdf
4. Cadmus. *Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2014.* May 15, 2015. Figures were calculated for single-family households; it is assumed in the absence of other sources that the installation rate would remain the same in multifamily settings. https://www.efis.psc.mo.gov/mpsc/commoncomponents/view_itemno_details.asp?caseno=EO-2012-0142&attach_id=2015027784
5. National Renewable Energy Laboratory. "The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures." Chapter 21: Residential Lighting Evaluation Protocol. NREL/SR-7A40-63205. February 2015. http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	01/2018	Updated sourcing, added 9-watt and 11-watt models
03	04/2018	Added multifamily sector

LED, Pack-Based, 5 Watt Globe G25 Lamp

	Measure Details
Measure Master ID	LED, Pack-Based, 5 Watt, G25 Lamp, 3896
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	15 for single family, 14 for multifamily
Peak Demand Reduction (kW)	0.0014 for single family, 0.0010 for multifamily
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	230 for single family, 210 for multifamily
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost	$2.64[2]

Measure Description

ENERGY STAR-rated LED replacement globe lamps save energy by reducing the total input wattage of the luminaire as compared to standard wattage incandescent globe lamps. This measure provides an energy-efficient alternative to using incandescent globe lamps in individual units. Pack-based measures assume the lamp was provided as part of a package, so an installation rate of 92% is applied.

Description of Baseline Condition

The Uniform Methods Project provides guidelines, based on EISA and on the lumen output of the bulb and the bulb type, for determining globe bulb baselines. The pack-based bulb model is a TCP LED5G25D27KF and has an output of 300 lumens (baseline of 25 watts).[3]

Description of Efficient Condition

The efficient equipment is an ENERGY STAR-rated G25 LED lamp of 5 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1{,}000 * IR$

Where:

$Watts_{BASE}$ = Power consumption of baseline incandescent fixtures (= 25 watts)[3]

$Watts_{EE}$ = Power consumption of efficient LED product (= 5 watts)[1]

HOU = Hours of use (= 829 for single family, = 734 for multifamily)[4]
1,000 = Kilowatt conversion factor
IR = Installation rate (= 92%)[5]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{LED}) / 1,000 * CF * IR$

Where:

CF = Coincidence factor (= 0.075 for single family, = 0.055 for multifamily)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED G25 Lamp

Measure	MMID	Sector	Annual		Lifecycle
			kWh	kW	kWh
Pack-Based 5-Watt LED Lamp Replacing Incandescent G25 Lamp	3896	Single family	15	0.0014	225
		Multifamily	14	0.0010	210

Sources

1. *ENERGY STAR Qualified Product List*. Accessed July 2017.
   https://www.energystar.gov/productfinder/
   Average rated life of 3,453 omnidirectional and decorative LEDs is 21,787 hours. With an HOU of 734 or 803, the calculated life is 30 years or 27 years, respectively. However, a 15-year EUL cap has been deemed for most residential screw-base LED measures. This comes as a result of measure persistence concerns (http://www.neep.org/sites/default/files/resources/ResLightingDeeperDiveFINAL1.pdf) and LED lifetime cap practices of other programs (in Connecticut, Illinois, Massachusetts, Minnesota, Rhode Island, Vermont, and Washington DC).
2. Focus on Energy.
   The incremental cost for pack-based measures is the cost to the program, which is equivalent to the incentive offering.
3. National Renewable Energy Laboratory. *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures*. “Chapter 21: Residential Lighting Evaluation

Protocol." NREL/SR-7A40-63205. Table 3. February 2015. http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf

4. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. June 10, 2016. https://www.focusonenergy.com/sites/default/files/2016%20Deemed%20Savings%20Review.pdf
5. Cadmus. *Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2014*. Table 2, p. 4. May 15, 2015. https://www.efis.psc.mo.gov/mpsc/commoncomponents/view_itemno_details.asp?caseno=EO-2012-0142&attach_id=2015027784

Figures were calculated for single-family households: it is assumed in the absence of other sources that the installation rate would remain the same in multifamily settings.

Installation rate for LEDs provided in kit based program.

Revision History

Version Number	Date	Description of Change
01	10/13/2015	Initial TRM entry
02	05/10/2016	Added pack-based measure
03	10/2015	Updated effective useful life for MMID 3734
04	04/2018	Added multifamily sector, updated single family savings, and removed direct install measure

LED, Pack-Based, 5 Watt, B11, Decorative Candelabra Base

	Measure Details
Measure Master ID	LED, Pack-Based, 5 Watt, B11, 4042
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	27 for single family, 24 for multifamily
Peak Demand Reduction (kW)	0.0024 for single family, 0.0018 for multifamily
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	405 for single family, 360 for multifamily
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost	$2.66[2]

Measure Description

ENERGY STAR-rated LED replacement candelabra base (B11) lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with standard wattage incandescent candelabra base lamps. This measure provides an energy-efficient alternative to incandescent candelabra base lamps in individual units. Pack-based measure savings are based on lamps provided as part of a package, so an installation rate of 92% is applied.[5]

Description of Baseline Condition

The Uniform Methods Project provides guidelines, based on EISA and the lumen output of the bulb and bulb type, for determining globe bulb baselines.[3] The pack-based bulb model is a TCP LED5E12B1127K with an output of 300 lumens (or a baseline of 40 watts).

Description of Efficient Condition

The pack-based bulb model is a TCP LED5E12B1127K, which consumes 5 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000 * IR$

Where:

$Watts_{BASE}$ = Power consumption of baseline incandescent fixtures (= 40 watts for pack-based bulbs; see Assumptions)

$Watts_{EE}$ = Power consumption of efficient LED product (= 5.0 watts for pack-based bulbs)

HOU = Hours of use (= 829 for single family, = 734 for multifamily)[4]

1,000 = Kilowatt conversion factor

IR = Installation rate (= 92% for pack-based bulbs)[5]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{LED}) / 1,000 * CF * IR$

Where:

CF = Coincidence factor (= 0.075 for single family, = 0.055 for multifamily)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years for pack-based bulbs)[1]

Assumptions

The baseline of 40 watts for pack-based bulbs is based on bulb models and UMP guidelines.[3]

Deemed Savings

Average Annual Deemed Savings for LED Candelabra Base (E12) Lamp

Measure	MMID	Sector	Annual Savings		Lifecycle Savings
			kWh	kW	kWh
LED, Pack-Based, 5 Watt, B11	4042	Single family	27	0.0024	405
		Multifamily	24	0.0018	360

Sources

1. *ENERGY STAR Qualified Product List.* Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 3,453 omnidirectional and decorative LEDs is 21,787 hours. With an HOU of 734 or 803, the calculated life is either 30 years or 27 years, respectively. However, a 15-year EUL cap has been deemed for most residential screw-base LED measures as a result of measure persistence concerns (http://www.neep.org/sites/default/files/resources/ResLightingDeeperDiveFINAL1.pdf) and LED lifetime cap practices of other programs (in Connecticut, Illinois, Massachusetts, Minnesota, Rhode Island, Vermont, and Washington DC).
2. Focus on Energy.
   The incremental cost for pack-based measures is the cost to the program, which is equivalent to the incentive.
3. National Renewable Energy Laboratory. *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures*. "Chapter 21: Residential Lighting Evaluation Protocol." NREL/SR-7A40-63205. February 2015. http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf
4. Cadmus. *Focus on Energy Evaluated Deemed Savings*. June 10, 2016. https://focusonenergy.com/sites/default/files/2016%20Deemed%20Savings%20Review.pdf
5. Cadmus. *Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2014.* May 15, 2015. https://www.efis.psc.mo.gov/mpsc/commoncomponents/view_itemno_details.asp?caseno=EO-2012-0142&attach_id=2015027784
   Figures were calculated for single family households: it is assumed in the absence of other sources that the installation rate would remain the same in multifamily settings.

Revision History

Version Number	Date	Description of Change
01	10/13/2015	Initial TRM entry
02	05/10/2016	Added pack-based bulbs
03	10/2017	Updated EUL
04	04/2018	Removed direct install measure and added multifamily sector for pack-based measure

LED, Pack-Based, 8 Watt, BR30

	Measure Details
Measure Master ID	LED, Pack-Based, 8 Watt BR30, 4276
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	43 for single family, 38 for multifamily
Peak Demand Reduction (kW)	0.0039 for single family, 0.0029 for multifamily
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	645 for single family, 570 for multifamily
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$3.43[2]

Measure Description

ENERGY STAR-rated LED replacement BR30 lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with standard wattage incandescent or halogen BR30 lamps. This measure provides an energy-efficient alternative to using incandescent or halogen BR30 lamps in several applications. Pack-based measure savings assume that the lamp was provided as part of a package, so an installation rate less than 100% is applied.

Description of Baseline Condition

The baseline equipment is a 65-watt incandescent BR30 reflector lamp, which is the most common reflector lamp installed in residential recessed can applications. BR30 shaped lamps are exempt from EISA lumen per-watt standards, and instead follow standards set forth in a 2009 Lamps Ruling.[3]

Description of Efficient Condition

The efficient equipment is an 8-watt, ENERGY STAR-rated BR30 LED lamp provided as part of an energy efficiency pack (pack-based).

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * HOU * IR$

Where:

$Watts_{BASE}$ = Power consumption of baseline fixture (= 65 watts)

$Watts_{EE}$ = Power consumption of efficient LED product (= 8 watts)

1,000 = Kilowatt conversion factor

HOU = Hours of use (= 829 for single family, = 734 for multifamily)[4]

IR = Installation rate (= 92%)[5]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{LED}) / 1{,}000 * CF * IR$

Where:

CF = Coincidence factor (= 0.075 for single family, = 0.055 for multifamily)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Deemed Savings for LED BR30 Lamp

Measure	MMID	Sector	kW	Annual kWh	Lifecycle kWh
Pack-Based 8-Watt LED BR30 Lamp Replacing BR30 Incandescent	4276	Single Family	0.0039	43	645
		Multifamily	0.0029	38	570

Assumptions

The 8-watt BR30 lamp is a Newleaf model NLL8WBR3027DLED, corresponding to a baseline wattage of 65 watts.

Sources

1. *ENERGY STAR Certified Product List*. Accessed January 2018. https://www.energystar.gov/productfinder/product/certified-light-bulbs/details/2297151 Rated life is 25,000 hours. With an HOU of 829, the calculated life is 30 years. However, a 15-year EUL cap has been deemed for most residential screw-base LED measures. This comes as a result of measure persistence concerns (http://www.neep.org/sites/default/files/resources/ResLightingDeeperDiveFINAL1.pdf) and LED lifetime cap practices of other programs in Connecticut, Illinois, Massachusetts, Minnesota, Rhode Island, Vermont, and Washington DC).
2. Wisconsin Focus on Energy. Cost reflects bulk pricing cost to implementer.
3. U.S. Department of Energy. "10 CFR Part 430 Energy Conservation Program: Energy Conservation Standards and Test Procedures for General Service Fluorescent Lamps and Incandescent Reflector Lamps; Final Rule." July 14, 2009. https://www.gpo.gov/fdsys/pkg/FR-2009-07-14/pdf/E9-15710.pdf
4. Cadmus. *Focus on Energy Evaluated Deemed Savings*. June 10, 2016. https://focusonenergy.com/sites/default/files/2016%20Deemed%20Savings%20Review.pdf
5. Cadmus. *Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2014.* Table 2, p. 4. May 15, 2015. https://www.efis.psc.mo.gov/mpsc/commoncomponents/view_itemno_details.asp?caseno=EO-2012-0142&attach_id=2015027784 Installation rate for LEDs provided in kit-based program.

Revision History

Version Number	Date	Description of Change
01	10/13/2015	Initial TRM entry
02	05/10/2016	Added pack-based measures
03	06/10/2017	Updated wattage
04	04/19/2018	Added multifamily sector

LED, Omnidirectional, Retail Store Markdown

	Measure Details
Measure Master ID	LED, Omnidirectional, Retail Store Markdown: 310-749 Lumens, 3553 310-749 Lumens, Long Lifetime, 4307 750-1,049 Lumens, 4308 750-1,049 Lumens, Long Lifetime, 4309 1,050-1,489 Lumens, 4310 1,050-1,489 Lumens, Long Lifetime, 4311 1,490-2,600 Lumens, 4312 1,490-2,600 Lumens, Long Lifetime, 4313
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Varies by light output
Peak Demand Reduction (kW)	Varies by light output
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by light output
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Standard = 15 (MMIDs 3553, 4308, 4310, and 4312);[1] Long lifetime = 17 (MMIDs 4307, 4309, 4311, and 4313)[2]
Incremental Cost ($/unit)	310-749 Lumens = $0.64 (MMIDs 3553 and 4307)[3] 750-1,049 Lumens = $0.53 (MMIDs 4308 and 4309)[4] 1,050-1,489 Lumens = $3.62 (MMIDs 431 and 4310)[5] 1,450-2,600 Lumens = $3.49 (MMIDs 4312 and 4313)[6]

Measure Description

This measure is installing an ENERGY STAR-certified omnidirectional LED bulb that was purchased through a retail outlet to replace an incandescent or halogen bulb. The assumptions were based on a time-of-sale purchase for installation in a residential location.

Description of Baseline Condition

The baseline equipment is a general service incandescent light bulb (standard or EISA compliant halogen). The wattage of the baseline bulb is determined by the lumens equivalence method.

Description of Efficient Condition

The efficient equipment is an ENERGY STAR-certified omnidirectional LED bulb. Typical values are used in this workpaper, but the actual wattage of the installed bulb is used to calculate savings for the evaluation.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = \Delta Watts * HOU / 1{,}000 * ISR$

Where:

ΔWatts = Change in wattage, calculated by subtracting efficient bulb wattage from baseline wattage determined from its lumen bin (= varies by lumen bin; see table below)[6]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= 996 [(2.20 * 93.4% + 10.2 * 6.6%) * 365 days/year]; see table in Assumptions)[7]

ISR = In-service rate (= 87%)[8]

Wattage Reduction by Lumen Bin[6]

Lifetime Group	Measure Name	MMID	Evaluated Gross ΔWatts
Standard, Long	LED, Omnidirectional, Retail Store Markdown, 310-749 Lumens	3553, 4307	29
	LED, Omnidirectional, Retail Store Markdown, 750-1,049 Lumens	4308, 4309	34
	LED, Omnidirectional, Retail Store Markdown, 1,050-1,489 Lumens	4310, 4311	41
	LED, Omnidirectional, Retail Store Markdown, 1,490-2,600 Lumens	4312, 4313	57

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = \Delta Watts * CF / 1{,}000 * ISR$

Where:

CF = Coincidence factor (= 0.1162 [0.0699 * 93.4% + 0.77 * 6.6%]; see table in Assumptions)[7]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years for standard measures;[1] = 17 years for long lifetime measures)[2]

Deemed Savings

Deemed Savings per Lumen Bin

Lifetime Group	Lumen Bin	MMID	Annual Energy Savings (kWh)	Lifecycle Energy Savings (kWh)	Coincident Peak Demand Reduction (kW)
Standard	310-749	3553	25	375	0.0029
	750-1,049	4308	29	435	0.0034
	1,050-1,489	4310	36	540	0.0041
	1,490-2,600	4312	49	735	0.0058
Long	310-749	4307	25	425	0.0029
	750-1,049	4309	29	493	0.0034
	1,050-1,489	4311	36	612	0.0041
	1,490-2,600	4313	49	833	0.0058

Assumptions

The HOU and CF was calculated using the cross-sector sales weighting shown in the table below.

Cross-Sector Sales HOU and CF Weighting[7]

Sector	Weighting	HOU per Day	CF
Residential	**93.4%**	**2.20**	**0.0699**
Multifamily	25.3%	2.01	0.0550
Single Family	74.7%	2.27	0.0075
Commercial	**6.6%**	**10.20**	**0.7700**

Because of high retail markdown participation, standard and long lifetime versions of these measures are introduced to encourage participants to purchase products with greater long-term savings. Bulb models used for standard measure versions have an ENERGY STAR rated lifetime of < 20,000 hours, and the 15-year EUL cap is in place for most residential screw-base LED measures.[1] Long lifetime measures are restricted to products with rated lifetimes at or above 20,000 hours, and have an EUL cap of 20 years. While persistence concerns may still apply to these long lifetime products, it is assumed that these measures will generally have a longer useful life than the standard retail markdown measures. However, only bulbs in the residential population hit this 20 year cap, with commercial population bulbs having an EUL of six years. The overall EUL reflects the total lifetime savings divided by the total annual savings, across both populations, and is 17 years.[2]

Sources

1. Average rated life of omnidirectional LEDs with rated life < 20,000 hours is generally 15,000 – 20,000 hours. With an HOU of 996, the EUL is 15 – 20 years. However, a 15-year EUL cap has been deemed for standard retail markdown residential screw-base LED measures. This comes as a result of measure persistence concerns (http://www.neep.org/sites/default/files/resources/ResLightingDeeperDiveFINAL1.pdf) and LED lifetime cap practices of other programs (in Connecticut, Washington DC, Massachusetts, Rhode Island, Vermont, Illinois, and Minnesota).
2. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. December 2018. https://focusonenergy.com/sites/default/files/FoE_Deemed_Savings_Report_%20CY_18_v1.6.pdf
3. August 2018 online lookups of 11 base and efficient models show an average efficient lamp price of $1.92 and base lamp price of $1.28, for an incremental cost of $0.64.
4. August 2018 online lookups of 12 base and efficient models show an average efficient lamp price of $1.99 and base lamp price of $1.46, for an incremental cost of $0.53.
5. August 2018 online lookups of 11 base and efficient models show an average efficient lamp price of $5.25 and base lamp price of $1.63, for an incremental cost of $3.62.
6. Cadmus. *Focus on Energy Calendar Year 2017 Evaluation Report: Volume II.* May 22, 2018. https://focusonenergy.com/sites/default/files/WI%20FOE%20CY%202017%20Volume%20II%20FINAL.pdf
7. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. September 12, 2016. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2016_v1%207.pdf
8. Cadmus. *Focus on Energy Calendar Year 2017 Evaluation Report: Volume II*. May 22, 2018. https://focusonenergy.com/sites/default/files/WI%20FOE%20CY%202017%20Volume%20II%20FINAL.pdf
9. August 2018 online lookups of 12 base and efficient models show an average efficient lamp price of $6.42 and base lamp price of $2.93, for an incremental cost of $3.49.

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	01/2017	Updated HOU, CF, and delta watts per 2016 Focus on Energy Deemed Savings Changes report.[4] Corrected EUL to 20 years per ENERGY STAR requirements.[1]
03	11/2017	Added long lifetime measures
04	12/2018	Updated incremental cost, added ISR, and updated EUL
05	05/2018	Corrected listed incremental cost for MMIDs 4312 and 4313

LED, Reflector, 12 Watt, Retail Store Markdown

	Measure Details
Measure Master ID	LED, Reflector, 12 Watt, Retail Store Markdown, 3557 LED, Reflector, 12 Watt, Retail Store Markdown, Long Lifetime, 4306
Measure Unit	Per reflector
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- upstream
Annual Energy Savings (kWh)	46
Peak Demand Reduction (kW)	0.0051
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Standard = 690 (MMID 3557); Long Lifetime = 782 (MMID 4306)
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Standard = 15 (MMID 3557)[1]; Long Lifetime = 17 (MMID 4306)[2]
Incremental Cost ($/unit)	$1.65[3]

Measure Description

This measure is installing an ENERGY STAR-certified LED reflector or LED recessed downlight that was purchased through a retail outlet to replace an incandescent bulb. The savings are based on a time-of-sale purchase for installation in a residential location.

Description of Baseline Condition

The baseline is an incandescent 65-watt reflector or downlight. Reflectors are exempt from EISA legislation.

Description of Efficient Condition

The efficient equipment is a standard screw-based 12-watt ENERGY STAR-certified LED reflector or downlight.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = \Delta Watts * HOU / 1{,}000 * ISR$

Where:

ΔWatts = Change in wattage, calculated by subtracting efficient bulb wattage from baseline wattage determined from its lumen bin (= 50 watts)[4]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= 996 [(2.20 * 93.4% + 10.2 * 6.6%) * 365 days/year]; see Assumptions)[5]

ISR = In-service rate (= 87%)[6]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = \Delta Watts * CF / 1{,}000 * ISR$

Where:

CF = Coincidence factor (= 0.1162 [0.0699 * 93.4% + 0.77 * 6.6%]; see Assumptions)[5]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years for standard measures;[1] = 17 years for long lifetime measures)[2]

Deemed Savings

Deemed Savings

Lifetime Group	MMID	Annual Energy Savings (kWh)	Lifecycle Energy Savings (kWh)	Coincident Peak Demand Reduction (kW)
Standard	3557	46	690	0.0051
Long	4306	46	782	0.0051

Assumptions

The HOU and CF were calculated using the cross-sector sales weighting shown in the table below.

Cross-Sector Sales HOU and CF Weighting[5]

Sector	Weighting[3]	HOU per Day	CF
Residential	**93.4%**	**2.20**	**0.0699**
Multifamily	25.3%	2.01	0.0550
Single Family	74.7%	2.27	0.0750
Commercial	**6.6%**	**10.20**	**0.7700**

Because of high retail markdown participation, standard and long lifetime versions of these measures are introduced to encourage participants to purchase products with greater long-term savings. Bulb models used for standard measure versions have an ENERGY STAR rated lifetime of < 20,000 hours, and have the 15-year EUL cap in place for most residential screw-base LED measures.[1] Long lifetime measures are restricted to products with rated lifetimes at or above 20,000 hours, and have an EUL cap of 20 years. While persistence concerns may still apply to these long lifetime products, it is assumed that these measures will generally have a longer useful life than the standard retail markdown measures. However, only bulbs in the residential population hit this 20 year cap, with commercial population bulbs having an EUL of six years. The overall EUL reflects the total lifetime savings divided by the total annual savings, across both populations, and is 17 years.[2]

Sources

1. Average rated life of omnidirectional LEDs with rated life < 20,000 hours is generally 15,000 – 20,000 hours. With an HOU of 996, the EUL is 15 to 20 years. However, a 15-year EUL cap has been deemed for standard retail markdown residential screw-base LED measures. This comes as a result of measure persistence concerns (http://www.neep.org/sites/default/files/resources/ResLightingDeeperDiveFINAL1.pdf) and LED lifetime cap practices of other programs (in Connecticut, Washington DC, Massachusetts, Rhode Island, Vermont, Illinois, and Minnesota).
2. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. December 2018. https://focusonenergy.com/sites/default/files/FoE_Deemed_Savings_Report_%20CY_18_v1.6.pdf
3. August 2018 online lookups of 12 base and efficient models show an average efficient lamp price of $4.92 and base lamp price of $3.27, for an incremental cost of $1.65.
4. Cadmus. *Focus on Energy Calendar Year 2017 Evaluation Report: Volume II.* May 22, 2018. https://focusonenergy.com/sites/default/files/WI%20FOE%20CY%202017%20Volume%20II%20FINAL.pdf
5. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. September 12, 2016. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2016_v1%207.pdf
6. Cadmus. *Focus on Energy Calendar Year 2017 Evaluation Report: Volume II*. May 22, 2018. https://focusonenergy.com/sites/default/files/WI%20FOE%20CY%202017%20Volume%20II%20FINAL.pdf

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	01/2017	Updated HOU, CF, and delta watts per 2016 Focus on Energy Deemed Savings Changes report.[4] Corrected EUL to 20 years per ENERGY STAR requirements.[1]
03	11/2017	Added long lifetime measures
04	12/2018	Updated incremental cost, added ISR, and updated EUL

LED Fixture, Exterior, CALP

	Measure Details
Measure Master ID	LED Fixture, Exterior, 12 Hours, CALP, 3735
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	184
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	2,024
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$12.46[2]

Measure Description

Hardwired LED incentives apply only to complete new fixtures, and only for the replacement of incandescent fixtures. LEDs provide the same or better light output than incandescent lamps while using significantly less energy.

Description of Baseline Condition

The baseline condition is a one-lamp, 72-watt, 65-watt, 43-watt, or 29-watt incandescent fixture; a two-lamp, 43-watt, or 29-watt incandescent fixture; or a three-lamp, 29-watt incandescent fixture on a switch, photocell, or timer that is used for 12 hours per day.

Description of Efficient Condition

The efficient condition is complete replacement of incandescent fixtures.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{INCANDESCENT} - Watts_{LED}) / 1{,}000 * HOU * CNTRL$

Where:

$Watts_{INCANDESCENT}$ = Weighted average annual electricity consumption of incandescent fixture (=63.7 watts)

$Watts_{LED}$ = Weighted average annual electricity consumption of ENERGY STAR® or DLC-listed LED fixtures, filtered to respective EISA lumen equivalents (=20.93 watts)[4]

1,000 = Kilowatt conversion factor

HOU = Run time of exterior fixtures based on an annual average of 12 hours per day from NOAA data.[3] This includes times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting (= 4,380 hours).

CNTRL = Controls factor allowing for a more conservative estimate of savings. Based on project experience, less than 10% of exterior fixtures on the market have additional controls to operate at conditions other than dusk to dawn (= 0.90)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure due to the operation of fixtures during off-peak hours.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Assumptions

Incandescent weighted average estimates were reviewed by staff with National Council on Qualifications for the Lighting Professions (NCQLP), LC (Lighting Certified) credentials, and were based on feedback from MESP program managers, energy advisors and direct install staff. Lamp wattages were adjusted to meet EISA legislation as listed in the table below.

Baseline Incandescent Weighted Average Assumptions

Lamp Wattage	100W (72W)	65W	(2) 60W (43W)	60W (43W)	(3) 40W (29W)	(2) 40W (29W)	40W (29W)
Weighted Average	5%	25%	25%	25%	5%	10%	5%

Sources

1. DesignLights Consortium. Qualified Product List. Accessed August 2017. https://www.designlights.org/lighting-controls/download-the-qpl/
   Average rated life of models participating in LED fixture measures is 50161 hours. With an HOU of 4,380, the EUL is 11 years.
2. Online research. March 2016. Material cost is average sales price of LED downlight. https://www.1000bulbs.com/category/led-downlights/
3. U.S. Department of Commerce | National Oceanic & Atmospheric Administration | NOAA Research - NOAA Solar Calculator. http://www.esrl.noaa.gov/gmd/grad/solcalc/
4. DesignLights Consortium™ qualified product list data, October 7, 2015 and October 13, 2015.

Revision History

Version Number	Date	Description of Change
01	10/21/2015	Initial measure entry
02	10/2017	Updated EUL source

LED Fixture, Interior, Above 12 Hours to 24 Hours, CALP

	Measure Details
Measure Master ID	LED Fixture, Interior, 12 Hours, CALP, 3603 LED Fixture, Interior, 24 Hours, CALP, 3604
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Varies by measure
Incremental Cost ($/unit)	$12.46[2]

Measure Description

This measure is installing hardwired LEDs to complete new fixtures. Incentives are only provided for replacing incandescent fixtures. LEDs provide the same or better light output than incandescent lamps while using significantly less energy.

Description of Baseline Condition

The baseline condition is a 1-lamp 72-watt, 65-watt, 43-watt, or 29-watt; a 2-lamp 43-watt or 29-watt; or a 3-lamp 29-watt incandescent fixture on a switch, photocell, or timer that is used for 12 or more hours per day up to 24 hours a day.

Description of Efficient Condition

LED incentives apply only to complete, new, hardwired fixtures that are ENERGY STAR or DLC qualified and meet the EISA lumen equivalency of their incandescent baselines. Incentives are only for replacing incandescent fixtures.

The contractor and/or Program Implementer verifies the hours of use during assessments and/or pre-installs. Typically, lights in the common areas are on for 24 hours, especially those in interior spaces and corridors, and are on for 12 to 16 hours on timers or photocells in the entries and/or lobbies with windows.

The effective useful life of this measure is based on the average rated hours for qualifying products, divided by 12 hours and 24 hours, then rounded.

Annual Energy-Savings Algorithm

$KWh_{SAVED} = (Watts_{INCANDESCENT} - Watts_{LED}) / 1{,}000 * HOU$

Where:

$Watts_{INCANDESCENT}$ = Power consumption of baseline measure (= 63.7 watts; see table below)[3]

Baseline Wattage

Baseline Bulb	Wattage	Weighting	Contribution to Baseline (watts)
1L EISA 100w incand	72	5%	3.60
1L 65w BR30 incand	65	25%	16.25
2L EISA 60w incand	86	25%	21.50
1L EISA 60w incand	43	25%	10.75
3L EISA 40w incand	87	5%	4.35
2L EISA 40w incand	58	10%	5.80
1L EISA 40w incand	29	5%	1.45
Total		**100%**	**63.70**

$Watts_{LED}$ = Power consumption of efficient measure (= 20.93 watts; see table below)[4]

Efficient Wattage

Bulb	Wattage	Weighting	Contribution to Efficient (watts)
LED (1,490-2,600 lumens) replacing 1L EISA 100w incand	32.14	5%	1.6000
LED (600-750 lumens) replacing 1L 65w BR30 incand	13.03	25%	3.
LED (750-1,049 lumens) replacing 2L EISA 60w incand	31.18	25%	7.7950
LED (750-1,049 lumens) replacing 1L EISA 60w incand	15.59	25%	3.8975
LED (310-749 lumens) replacing 3L EISA 40w incand	32.81	5%	1.6405
LED (310-749 lumens) replacing 2L EISA 40w incand	21.88	10%	2.1880
LED (310-749 lumens) replacing 1L EISA 40w incand	10.94	5%	0.5470
Total		**100%**	**20.9325**

1,000 = Kilowatt conversion factor

HOU = Average annual hours of use (= 4,380 for 12-hour use; = 8,760 for 24-hour use)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{INCANDESCENT} - Watts_{LED}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= 0.0 to 1.0 for 24-hour use)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = (= 11 years for 12 hour fixtures; = 6 years for 24 hour fixtures)[1]

Deemed Savings

Annual Savings

Measure	MMID	Multifamily	
		kWh	kW
LED Fixture, Interior, 12 Hours, CALP	3603	187	0.0000
LED Fixture, Interior, 24 Hours, CALP	3604	375	0.0428

Lifecycle Savings

Measure	MMID	Multifamily (kWh)
LED Fixture, Interior, 12 Hours, CALP	3603	2,057
LED Fixture, Interior, 24 Hours, CALP	3604	2,250

Assumptions

Lamp weightings were developed through previous CALP workpapers and based on typical lamp wattages in common area light fixtures such as downlights, wall sconces, and flush/ceiling mounts, using typical lamping configuration data from manufacturers. This information was gathered from previous 12-hour and 24-hour use CFL fixture installations, field assessments in 2014, and data on currently available qualifying fixtures.

Sources

1. DesignLights Consortium. Qualified Product List. Accessed August 2017. https://www.designlights.org/lighting-controls/download-the-qpl/
   Average rated life of models participating in LED fixture measures is 50,161 hours. With an HOU of 4,380, the EUL is 11 years for MMID 3603. With an HOU of 8,760, the EUL is 6 years for MMID 3604.
2. Online research. March 2016. Material cost is average sales price of LED downlight. https://www.1000bulbs.com/category/led-downlights/
3. EISA equivalent wattages for common incandescent lamps.
4. Average wattage of equivalent qualifying ENERGY STAR and DLC-listed LED fixtures as of January 30, 2015.

Revision History

Version Number	Date	Description of Change
01	01/30/2015	Initial TRM entry
02	03/30/2015	Revised and combined 12 hour and 24 hour workpapers
03	10/2017	Updated EUL

LED, ENERGY STAR, Replacing Incandescent > 40 Watts

	Measure Details
Measure Master ID	LED, ENERGY STAR, Replacing Incandescent > 40 Watts: In Unit, 3159 Common Area, 3160
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Varies by measure
Incremental Cost ($/unit)	$5.36[2]

Measure Description

ENERGY STAR-rated LED replacement lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with standard wattage incandescent lamps. This measure provides an energy-efficient alternative to incandescent lamps in several applications.

Description of Baseline Condition

The baseline measure is standard 60-watt, 65-watt, 75-watt, 90-watt, 100-watt, and 120-watt incandescent lamps.

Description of Efficient Condition

The efficient measure is an ENERGY STAR-rated LED.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{LED} - kWh_{INCANDESCENT}$

Where:

KWh_{LED} = Annual electricity consumption of ENERGY STAR-rated LED with a lumen output rating equivalent to a > 40-watt incandescent

$KWh_{INCANDESCENT}$ = Annual electricity consumption of standard 60-watt, 65-watt, 75-watt, 90-watt, 100-watt, or 120-watt incandescent lamp

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = Wattage / 1{,}000 * CF$

Where:

Wattage = Unit wattage
1,000 = Kilowatt conversion factor
CF = Coincidence factor (= 0.77 common area; = 0.0825 in-unit)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years in unit;[1] = 4 years common area)[6]

Deemed Savings

Average Annual Deemed Savings for LED Lamp Replacing Incandescent Lamp > 40 Watts

Measure	MMID	Existing Building	New Construction
LED Replacing Incandescent Lamp > 40 Watts, In Unit	3159	58.0 kWh 0.0057 kW	43.0 kWh 0.0042 kW
LED Replacing Incandescent Lamp > 40 Watts, Common Area	3160	414.0 kWh 0.0536 kW	305.0 kWh 0.0395 kW

Average Lifecycle Deemed Savings for LED Lamp Replacing Incandescent Lamp > 40 Watts

Measure	MMID	Existing Building	New Construction
LED Replacing Incandescent Lamp > 40 Watts, In Unit	3159	870 kWh	645 kWh
LED Replacing Incandescent Lamp > 0 Watts, Common Area	3160	2,070 kWh	1,525 kWh

Assumptions

Existing Building/Common Area: Assumes 5,949.5 annual operating hours

- An average of 16.67% each of 60-watt, 65-watt, 75-watt, 90-watt, 100-watt, and 120-watt incandescent lamps was used to generate baseline usage
- An average of 33% each of 11.68-watt, 16.70-watt, and 17.81-watt ENERGY STAR-rated LEDs was used to generate new measure usage

Existing Building/In Unit: Assumes 839.5 annual operating hours

- An average of 16.67% each of 60-watt, 65-watt, 75-watt, 90-watt, 100-watt, and 120-watt incandescent lamps was used to generate baseline usage
- An average of 33% each of 11.68-watt, 16.70-watt, and 17.81-watt ENERGY STAR-rated LEDs was used to generate new measure usage

New Construction/Common Area: Assumes 5,939.5 annual operating hours

- An average of 16.67% each of 53-watt incandescent, 60-watt incandescent and halogen, 65-watt incandescent, 70-watt halogen, 72-watt halogen, and 80-watt halogen lamps was used to generate the baseline usage
- An average of 33% each of 11.68-watt, 16.70-watt, and 17.81-watt ENERGY STAR-rated LEDs was used to generate new measure usage

New Construction / In Unit: Assumes 839.5 annual operating hours

- An average of 16.67% each of 53-watt incandescent, 60-watt incandescent and halogen, 65-watt incandescent, 70-watt halogen, 72-watt halogen, and 80-watt halogen lamps was used to generate the baseline usage
- An average of 33% each 11.68-watt, 16.70-watt, and 17.81-watt ENERGY STAR-rated LEDs was used to generate new measure usage

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/ Average rated life of 3,453 omnidirectional and decorative LEDs is 21787 hours. With an HOU of 829, the EUL is 26 years. However, a 15-year EUL cap has been deemed for most residential screw-base LED measures. This comes as a result of measure persistence concerns (http://www.neep.org/sites/default/files/resources/ResLightingDeeperDiveFINAL1.pdf) and LED lifetime cap practices of other programs (in Connecticut, Illinois, Massachusetts, Minnesota, Rhode Island, Vermont, and Washington DC).
2. August 2018 online lookups of four base and efficient models show an average efficient lamp price of $6.15 and base lamp price of $0.79, for an incremental cost of $5.36.
3. Tetra Tech. "ACES Deemed Savings Desk Review." November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
4. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3.2 Coincidence Factor for Lighting in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
6. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/ Average rated life of 3,453 omnidirectional and decorative LEDs is 21,787 hours. With an HOU of 5,950, the EUL is 4 years.

Revision History

Version Number	Date	Description of Change
01	12/26/2012	Initial TRM entry
02	10/2017	Updated EUL
03	12/2018	Updated incremental cost

LED Upgrades, CALP

	Measure Details
Measure Master ID	CALP Interior 12+ Hours, 3967 CALP Exterior, 3968
Measure Unit	Per watt reduced
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	6.61 for MMID 3967; 4.38 for MMID 3968
Peak Demand Reduction (kW)	0.0008 for MMID 3967; 0 for MMID 3968
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	53 for MMID 3967; 48 for MMID 3968
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	CALP interior = 8 (MMID 3967); CALP exterior = 11 (MMID 3968)[1]
Incremental Cost ($/unit)	$1.20[2]

Measure Description

These measures are intended for the replacement of incandescent, HID, or fluorescent lighting technologies with more efficient LEDs, including complete exit signs. LEDs provide the same or better light output than incumbent technologies while using significantly less energy.

Description of Baseline Condition

The baseline condition is any incandescent, HID, or fluorescent fixtures, including complete exit signs.

Description of Efficient Condition

The efficient condition is any ENERGY STAR fixture or DesignLights Consortium-listed LED product. Exit signs must be LED and complete units. Retrofit kits are not eligible.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{REDUCED}) * HOU / 1{,}000 = Watts_{REDUCED} * HOU / 1{,}000$

Where:

$Watts_{REDUCED}$ = $Watts_{BASE} - Watts_{LED}$

$Watts_{BASE}$ = Power consumption of currently installed lighting (= actual; provided by Trade Ally for each project)

$\text{Watts}_{\text{LED}}$ = Power consumption of efficient LED product (= actual; provided by Trade Ally for each project)

1,000 = Kilowatt conversion factor

HOU = Hours of use (= 6,614 for MMID 3967[3]; = 4,380 for MMID 3968)[4]

$\text{Watts}_{\text{REDUCED}}$ = Watts reduced

Summer Coincident Peak Savings Algorithm

$\text{kW}_{\text{SAVED}} = (\text{Watts}_{\text{BASE}} - \text{Watts}_{\text{LED}}) / 1{,}000 * \text{CF}$

Where:

CF = Coincidence factor (= 0.77 for MMID 3967[5]; = 0.00 for MMID 3968)

Lifecycle Energy-Savings Algorithm

$\text{kWh}_{\text{LIFECYCLE}} = \text{kWh}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (= 3967 = 8 years, 3968 = 11 years)[1]

Deemed Savings

Annual Savings (per watt reduced)

Measure	MMID	Multifamily	
		kWh	kW
LED Interior 12+ Hours, CALP	3967	6.61	0.0008
LED Exterior, CALP	3968	4.38	0.0000

Lifecycle Savings (per watt reduced)

Measure	MMID	Multifamily
LED Interior 12+ Hours, CALP	3967	53
LED Exterior, CALP	3968	48

Sources

1. DesignLights Consortium. Qualified Product List. Accessed August 2017. https://www.designlights.org/lighting-controls/download-the-qpl/
   Average rated life of models participating in LED fixture measures is 50,161 hours. With an HOU of 6,614, the EUL is eight years for MMID 3967. With an HOU of 4,380, the EUL is 11 years for MMID 3968.
2. SPECTRUM. Average incremental costs. 2017. CALP LED measure master IDs 3735, 3603, 3604 and 3200, converted to dollars per watt saved.
   Online research. March 2016. https://www.1000bulbs.com/category/led-downlights/
   Material cost for MMIDs 3603, 3604, and 3735 is average sales price of LED downlight.
   Average sales price of LED Exit Signs for MMID 3200 on 1000bulbs.com = $26.43; RSMeans, 2015 labor cost for install of signs, interior electric exit sign, wall mounted, 6-inch = $72.00. [$26.43 (material cost) + $72.00 (labor cost) = $98.43].
3. Historical Focus on Energy project data from January 1, 2015 through November 15, 2016. Weighted average of 12-hour versus 24-hour fixture replacements under MMIDs 3199, 3197, 3198, 3735, 3603, 3604, 3200, 3196, and 3195 (where 49% of replaced fixtures operated 12 hours or more and 51% operated 24 hours).
4. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/
   This also includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
5. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs; see Table 4-1 showing multifamily housing (in unit) coincidence factor of 65% to 83%.

Revision History

Version Number	Date	Description of Change
01	11/15/2016	Initial TRM entry
02	10/2017	Updated EUL

ENERGY STAR Fluorescent Porch Fixtures

	Measure Details
Measure Master ID	ENERGY STAR Fluorescent Porch Fixtures, 3513
Measure Unit	Per luminaire
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Fluorescent, Compact (CFL)
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	54
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	381
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	7[1]
Incremental Cost ($/unit)	$32.00[3]

Measure Description

This measure is an exterior wall or ceiling-mounted ENERGY STAR-certified fluorescent fixture installed in a porch space that was purchased through a retail outlet, either to replace or in lieu of an incandescent fixture. The savings are based on a time-of-sale purchase, for installation in a residential location. This measure is not eligible for peak demand reduction because operation is primarily during off-peak hours.

Description of Baseline Condition

The baseline equipment is an incandescent lamp or luminaire (EISA compliant halogen) fixture. The baseline wattage is determined using the lumens equivalence method in conjunction with the lumen output of the efficient bulb.

Description of Efficient Condition

The efficient measure is an exterior wall or ceiling-mounted ENERGY STAR-certified fluorescent fixture installed in a porch location.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Baseline wattage (= varies by lumen bin; see table below for values)

$Watts_{EE}$ = Efficient wattage (= varies by lumen bin; see table below for values)

1,000 = Kilowatt conversion factor

HOU = Annual hours of use (= 1,460)[2]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * CF$

Where:

CF = Summer coincidence factor (= 0; for this measure, operation will primarily occur during off-peak hours)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 7 years)[1]

Deemed Savings

Deemed Savings by Lumens Bin

Lumen Bin[4]	$Watts_{BASE}$[4]	$Watts_{EE}$[5]	Annual kWh_{SAVED}	$kW_{SAVED, SUMMER PEAK}$	$kWh_{LIFECYCLE}$
750-1,049	43	13	44	0.0000	308
1,050-1,489	53	18	51	0.0000	357
1,490-2,600	72	25	69	0.0000	483
Overall Average	**56**	**19**	**54**	**0.0000**	**381**

Assumptions

A straight baseline lamp average was used to calculate savings, which was deemed appropriate based on a combination of feedback from energy audit experience, Lighting Certified individuals through the National Council on Qualifications for the Lighting Professions, and individuals with lighting sales experience.

Sources

1. ENERGY STAR® Products List. April 15, 2016. Filtered by fluorescent technology and porch fixture type (10,000 / 1,490 = 6.7 years, rounded to 7 years).
2. California Energy Commission. *Impact Analysis: 2005 Update to the California Energy Efficiency Standards for Residential and Nonresidential Buildings.* Table 5 – Annual Hours of Operation for Residential Lighting (average of hours of use figures presented for Outdoor – Front Porch and Outdoor – Back Porch, Garage Porch). June 20, 2003. http://www.regie-energie.qc.ca/audiences/3526-04/DocumentsAudi3526/ASTROLab_3526_Engag-ImpactAnalysis_20mai04.pdf
3. https://www.energystar.gov/products/lighting_fans/light_bulbs
4. “Energy Independence and Security Act (EISA) of 2007 Efficiency Standards for Light Bulbs.” General service incandescent lumen ranges. http://www.lightingfacts.com/Library/Content/EISA
5. *ENERGY STAR® average input power pulled from products list*. Filtered by fluorescent technology, porch fixture type and lumen binned as of April 15, 2016, filtered by fluorescent technology, Porch fixture type and lumen bin.

Revision History

Version Number	Date	Description of Change
01	10/31/2014	Initial TRM entry

ENERGY STAR LED Porch Fixtures

	Measure Details
Measure Master ID	ENERGY STAR LED Porch Fixtures, 3157
Measure Unit	LED Porch Luminaire
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	77.0 Existing Building; 58.0 New Construction
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	1,155 Existing Building; 870 New Construction
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	$55.14[2]

Measure Description

ENERGY STAR-qualified LED porch lights are verified to meet both performance and efficiency thresholds, which ensures that an LED product’s performance is similar to other time-tested technologies used for the same applications and meets ENERGY STAR efficiency criteria.

Description of Baseline Condition

The baseline condition is standard, screw-based incandescent lamps/luminaires.

Description of Efficient Condition

The efficient equipment is an ENERGY STAR-rated LED porch light.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{STANDARD} - kWh_{ES}$

Where:

$kWh_{STANDARD}$ = Annual electricity consumption of standard incandescent porch luminaire

kWh_{ES} = Annual electricity consumption of ENERGY STAR-rated LED porch luminaire

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / HOU * CF$

Where:

HOU = Average annual run hours (= 1,131.5)[3]

CF = Coincidence factor (= 0.082)[3]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 20 years)[1]

Deemed Savings

Average Annual Deemed Savings for ENERGY STAR-Rated LED Porch Fixtures

Measure	Existing Building	New Construction
ENERGY STAR-Rated LED Porch Fixtures	77 kWh	58 kWh

Average Lifecycle Deemed Savings for ENERGY STAR-Rated LED Porch Fixtures

Measure	Existing Building	New Construction
ENERGY STAR-Rated LED Porch Fixtures	1,155 kWh	870 kWh

Assumptions

It was assumed the annual operating hours are 1,131.5.[3] For existing buildings, an average of 33% 60-watt, 33% 75-watt, and 33% 100-watt A-19 halogen and incandescent lamps that meet EISA 2007 as of January 1, 2013 were used to generate the baseline usage. For new construction, an average of 33% 53-watt, 33% 60-watt, and 33% 72-watt lamps were used to generate the baseline usage.

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 207 LED porch fixtures is 45,121 hours. With an HOU of 1,132, the EUL is 40 years. Lighting EULs are capped at 20 years.
2. August 2018 online lookups of seven base and efficient models show an average efficient fixture price of $56.38 and base bulb price of $1.24, for an incremental cost of $55.14.
3. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review.” Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	12/26/2012	Initial TRM entry
02	10/2017	Updated EUL source
03	12/2018	Updated incremental cost

Motors and Drives

ECM, Furnace or Air Handler

	Measure Details
Measure Master ID	ECM, Furnace, New or Replacement, 2989
Measure Unit	Per motor
Measure Type	Prescriptive
Measure Group	Motors and Drives
Measure Category	Motor
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	415
Peak Demand Reduction (kW)	0.0792
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	7,470
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	18[1]
Incremental Cost ($/unit)	$97.00[3]

Measure Description

Conventional natural gas furnaces and air handlers contain a PSC blower motor to deliver the treated air to the home. This motor can be replaced with a brushless DC motor, commonly called an ECM, for electrical savings.

Description of Baseline Condition

The baseline is a furnace or air handler with a PSC motor.

Description of Efficient Condition

The efficient condition is an ECM motor replacing a PSC motor in a furnace or air handler.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = \Delta kWh_{COOL} + \Delta kWh_{HEAT} + \Delta kWh_{CIRC}$

$kWh_{COOL} = Tons * EFLH_{COOL} * 12\ kBtu/ton * (1/SEER_{BASE} - 1/SEER_{ECM}) * \%\ AC$

$kWh_{HEAT} = HOU_{HEAT} * \Delta kW_{HEAT}$

$kWh_{CIRC} = HOU_{CIRC} * \Delta kW_{CIRC}$

Where:

$Tons$ = Air conditioner capacity in tons (= 2.425)[2]

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= varies by city; see table below)[2]

Equivalent Full-Load Cooling Hours by Location

Location	$EFLH_{COOL}$	Weighting by Participant
Green Bay	344	22%
Lacrosse	323	3%
Madison	395	18%
Milwaukee	457	48%
Wisconsin Average	380	9%
Overall	**410**	

$SEER_{BASE}$ = Baseline SEER (= 12)[2]

$SEER_{ECM}$ = Efficient condition SEER (= 13)[2]

% AC = Percentage of furnaces with AC (= 92.5%)[2]

HOU_{HEAT} = Hours of heating operation (= 1,158)[2]

ΔkW_{HEAT} = Energy savings in heating (= 0.116 kW)[2]

HOU_{CIRC} = Hours of fan-only operation (= 1,020)[2]

ΔkW_{CIRC} = Energy savings in fan-only (= 0.207 kW)[2]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = Tons * 12kBtu/ton * (1/EER_{BASE} - 1/EER_{ECM}) * CF * \%AC$

Where:

EER_{BASE} = Baseline EER (= 10.5)[2]

EER_{ECM} = Efficient condition EER (= 11)[2]

CF = Coincidence factor (= 68%)[2]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 18 years)[1]

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Focus on Energy, Deemed Savings Report. November 14, 2014.
3. Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 5.0, Volume 3 (2015). p. 89. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Final/IL-TRM_Effective_060116_v5.0_Vol_3_Res_021116_Final.pdf

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry

Air Source Heat Pump, ≥ 16 SEER

	Measure Details
Measure Master ID	Air Source Heat Pump, ≥ 16 SEER, 2992
Measure Unit	Per heat pump
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Other
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	928
Peak Demand Reduction (kW)	0.2823
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	16,704
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	18[1]
Incremental Cost ($/unit)	$849.40[2]

Measure Description

A residential-sized air-source heat pump has an input capacity of ≤ 65,000 Btu/hour. The deemed measure algorithms and associated savings for the air-source heat pump were derived from the use of the Illinois Statewide Technical Reference Manual – Section 5.3.1 Air Source Heat Pumps.[2]

Description of Baseline Condition

The baseline measure is a federal standard baseline air-source heat pump of SEER 13 and HSPF 7.7.[2]

Description of Efficient Condition

The efficient measure is a residential-sized air-source heat pump of SEER 16 and HSPF 8.4.[2]

Annual Energy-Savings Algorithm

$$kWh_{SAVED} = ((EFLH_{COOL} * CAP * (1/SEER_{BASE} - 1/SEER_{EE}))/ 1{,}000) + ((EFLH_{HEAT} * CAP * (1 / HPSF_{BASE} - 1 / HSPF_{EE})) / 1{,}000)$$

Where:

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 321)

CAP = Capacity (= 37,000 Btu/hour)

$SEER_{BASE}$ = Baseline seasonal energy efficiency ratio (= 13)

$SEER_{EE}$ = Efficient measure seasonal energy efficiency ratio (= 16)

1,000 = Kilowatt conversion factor

$EFLH_{HEAT}$ = Equivalent full-load heating hours (= 1,890)[3]

$HSPF_{BASE}$ = Baseline heating seasonal performance factor (= 7.7)

$HSPF_{EE}$ = Efficient measure heating seasonal performance factor (= 8.4)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (CAP * (1/ EER_{BASE} - 1 / EER_{EE})) / 1{,}000 * CF$

Where:

EER_{BASE} = Baseline energy efficiency ratio (= 11.2)[2]

EER_{EE} = Efficient energy efficiency ratio (= 12.8)[2]

CF = Coincidence factor (= 0.68)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=18 years)[1]

Assumptions

Measure characteristics assume an all-electric heated and cooled home.

The capacity of residential heat pumps is assumed to be 3.1 tons for equipment installed in the Wisconsin market, based on analysis of 75 air-source heat pumps installed between 2013 and 2015 through the Focus on Energy Residential Prescriptive Program. At 12,000 Btu/hour per ton, the assumed average capacity is 37,200 Btu/hr.

Supporting inputs for heating load hours in several Wisconsin cities are shown in the table below.

Equivalent Full-Load Heating Hours by Location

Location	$EFLH_{HEAT}$[3]
Green Bay	1,852
La Crosse	1,966
Madison	1,934
Milwaukee	1,883
Wisconsin Average	1,909
Weighted Average	**1,890**

Incremental cost is based on the Illinois TRM reported IMC of $411/ton, multiplied by an installed capacity of 3.1 tons.

Cooling hours are based on the cooling hours for an air conditioner in the Deemed Savings Report[4] adjusted for the larger capacity system (410 hours at 2.425 tons is equivalent to 284 hours at 3.5 tons).

Sources

1. 2007 GDS study for New England working group: http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf
2. Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 5.0, Volume 3. p. 59. 2015. $274.00 per ton for a time-of-sale 16 SEER ASHP. The Program assumes a value of 3.1 tons (37,000 MBh), as such $274.00 per ton produces an IMC of $849.40. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Final/IL-TRM_Effective_060116_v5.0_Vol_3_Res_021116_Final.pdf
3. Several Cadmus metering studies reveal that the ENERGY STAR calculator EFLH are over-estimated by 25%. The EFLHHEAT were adjusted by population-weighted HDD and TMY-3 values.
4. Focus on Energy, Deemed Savings Report. November 14, 2014.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	01/2015	Updated EFLH
03	12/2018	Updated EFLH for heating

Other

Room Air Cleaner, ENERGY STAR

	Measure Details
Measure Master ID	Room Air Cleaner, ENERGY STAR, 4034
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	Other
Measure Category	Filtration
Sector(s)	Residential- upstream
Annual Energy Savings (kWh)	214
Peak Demand Reduction (kW)	0.0244
Annual Therm Savings (Therms)	0
Life-cycle Energy Savings (kWh)	1,926
Life-cycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	9[1]
Incremental Cost ($/unit)	$56.00[1]
Important Comments	Measure under Retail Product Platform (RPP) Pilot

Measure Description

A room air cleaner is a portable, electric appliance that removes fine particles, such as dust and pollen, from indoor air. This measure consists of ENERGY STAR-certified room air cleaner units that meet the ENERGY STAR Version 1.2 requirements. ENERGY STAR-certified units are 40% more efficient that non-qualified models.[2]

Description of Baseline Condition

The baseline condition consists of non-ENERGY STAR-certified room air cleaner units.

Description of Efficient Condition

The efficient condition consists of ENERGY STAR-certified room air cleaner units that meet ENERGY STAR Version 1.2 requirements.[2]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = UEC_{BASE} - UEC_{EE}$

Where:

UEC_{BASE} = Annual unit energy consumption of baseline unit (= 530.98 kWh)[1]

UEC_{EE} = Annual unit energy consumption of efficient unit (= 317.1 kWh)[1]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / Hours * CF$

Where:

Hours = Average hours of use per year (= 5,844)[3]

CF = Summer peak coincidence factor (= 66.7%)[3]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 9 years)[1]

Sources

1. ENERGY STAR. *Retail Products Platform: Product Analysis for Room Air Cleaners*. Effective May 11, 2016. https://drive.google.com/open?id=0B9Fd3ckbKJp5OEpWSHg1eksyZ1U
   ENERGY STAR assumes a nine-year useful life, based on: Lawrence Berkeley National Laboratory. *2008 Status Report - Savings Estimates for the ENERGY STAR Voluntary Labeling Program.* Accessed November 21, 2016. http://enduse.lbl.gov/Info/LBNL-56380(2008).pdf
2. *ENERGY STAR Version 1.2 Product Specification for Room Air Cleaners.* Accessed November 21, 2016. https://www.energystar.gov/sites/default/files/specs/private/Room_Air_Cleaners_Final_V1.2_Specification.pdf
   Baseline and ENERGY STAR energy consumption are the weighted average of five product category sub types: 51-100 CADR, 101-150 CADR, 151-200 CADR, 201-250 CADR, and > 250 CADR. Wattages for all five product sub types are derived from Association of Home Appliance Manufacturers data. Duty cycle assumes 16 hours per day, 365 days per year based on filter replacement instructions.
3. *Illinois Technical Reference Manual*. 2016 Version 5.0. Accessed November 21, 2016. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Almost_Final_PDF/IL_TRM_Effective_060116_Version_5.0_Vol_3_RES_012216_Clean.pdf

Illinois TRM assumes that the purifier usage is evenly spread throughout the year (therefore the coincident peak is calculated as 5,844/8,766 = 66.7%).
U.S Environmental Protection Agency and U.S. Department of Energy. “Savings Calculator for ENERGY STAR Qualified Appliances.” ENERGY STAR Qualified Room Air Cleaner Calculator. https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx
Calculator assumes 16 hours per day (16 * 365.25 = 5,844).

Revision History

Version Number	Date	Description of Change
01	06/24/2016	Initial TRM entry

Whole Home Completion

	Measure Details
Measure Master ID	Project Completion, Electric Heat, 4883 Project Completion, Natural Gas Heat, 4884 Project Completion, Tier 2, Electric Heat, 4885 Project Completion, Tier 2, Natural Gas Heat, 4886
Measure Unit	Per residence
Measure Type	Prescriptive
Measure Group	Other
Measure Category	Insulation
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	Varies by measure[2]

Measure Description

This measure is insulation and air sealing work completed by a contractor in a home. Whole Home Completion covers work completed in several areas: attic, wall, foundation, and duct. Any combination of improvements may be completed. This measure covers all insulation and air sealing improvements completed as a single entity with combined savings:

- Blower door guided air sealing: pre and post blower door testing required
- Attic insulation: basic air sealing installed to *Materials and Installation* standards,[3] at least 600 square feet of attic area must be improved
- Foundation insulation: at least 50% of the sill or foundation wall area must be improved
- Wall insulation: at least 800 square feet of exterior wall must be improved, or at least 400 square feet of framed floor must be improved
- Duct sealing: not applicable to ductwork in a conditioned space (such as a basement or unvented crawlspace); all ductwork outside the conditioned space must be sealed and insulated

These measures have had *ex ante* savings calculated on a custom basis in previous program years using Snugg Pro modeling tools. A billing analysis approach was used in the CY 2017 evaluation to produce evaluated savings.[4] As part of this analysis, billing data from 849 projects was analyzed and incorporated into final results. Those results are used here to produce prescriptive savings for each site instead of continuing to use modeling for individual projects.

To inform future program planning, the program will track installed measures at each home in SPECTRUM, including additional detail regarding the amount and types of measures installed per home.

Description of Baseline Condition

The baseline condition is the air sealing and insulation levels of an existing home, with the following maximum existing conditions:

- Blower door guided air sealing: no air sealing work performed
- Attic insulation: no air sealing work performed, open cavity with an effective insulation of R-19 or less, closed cavity with no effective insulation
- Foundation insulation: no effective existing insulation
- Wall insulation: wall cavity with no effective insulation, framed floor with an effective insulation of R-19 or less
- Duct sealing: unsealed or uninsulated duct in an unconditioned space

Description of Efficient Condition

The efficient condition is the air sealing and insulation levels of an existing home after work is completed by the contractor, with the following minimum conditions:

- Blower door guided air sealing: air sealing work performed
- Attic insulation: air sealing work performed, open cavity with insulation of R-38 or greater, closed cavity filled with insulation
- Foundation insulation: sill and/or wall insulation of R-5 or greater
- Wall insulation: closed cavity filled with insulation, framed floor cavity filled with insulation
- Duct sealing: ductwork sealed and insulated to R-8

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{BA}$

$Therm_{SAVED} = Therm_{BA}$

Where:

kWh_{BA} = Average kilowatt-hours saved per site, as determined by CY 2017 billing analysis data (= 641 for Tier 1 natural gas heat (MMID 4883), = 2,465 for Tier 1 electric heat (MMID 4884), = 749 for Tier 2 natural gas heat (MMID 4885), = 2,880 for Tier 2 electric heat (MMID 4886); see Assumptions)

$Therm_{BA}$ = Average therms saved per site, as determined by CY 2017 billing analysis (= 150 for Tier 1 natural gas heat (MMID 4883), = 238 for Tier 2 natural gas heat(MMID 4885), = 0 for Tier 1 and Tier 2 electric heat (MMIDs 4884 and 4886); see Assumptions)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kW_{NET}$

Where:

kW_{NET} = Net kilowatts saved per site (= 0.3151 for Tier 1 (MMIDs 4883 and 4884), = 0.3688 for Tier 2 (MMIDs 4885 and 4886); see Assumptions)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Assumptions

The billing analysis results presented in the *Focus on Energy Calendar Year 2017 Evaluation Report*[4] reflect savings for the billing analysis sample, including 471 Tier 1 sites with natural gas heat, 26 Tier 1 sites with electric heat, and 158 Tier 2 sites.

As seen in that report's Table 63 and Table 67, Tier 1 sites have 150 therm savings with ±9% precision at 90% confidence. Tier 2 sites save 238 therms with ±15% precision at 90% confidence. These values are specifically for sites with natural gas heat only, and therefore apply directly to therms savings for MMIDs 4884 and 4886.

However, the savings values for kilowatt-hours as shown in that report's Table 64 reflect the savings for the entire billing analysis sample, including sites with natural gas heat and sites with electric heat.

Separate analyses were conducted for the Tier 1 sites with natural gas heat and the Tier 1 sites with electric heat. Results are shown in the table below, along with the sample-wide average kilowatt-hour savings.

Billing Analysis Sample Average Kilowatt-Hour Savings for Tier 1 Sites

Site Type	MMID	Site Count	Verified Net Model Savings	Precision at 90% Confidence
All Tier 1 sites	4883, 4884	497	737	±16%
Tier 1 natural gas heat sites	4884	471	641	±15%
Tier 1 electric heat sites	4883	26	2,465	±53%

Based on the results shown in the table above, is it appropriate to allot 641 kWh savings to sites with natural gas heat. This savings amount likely derives largely from air conditioning savings in summer, as well as fan consumption savings in winter. Savings for sites with electric heat is 2,465 kWh, which only has ±53% precision at 90% confidence, which is not as precise as desired. However, it may reflect precision and accuracy that is on par with a calculated value, so was also used to calculated deemed savings.

Tier 2 sites average 861 kWh of savings, with ±28% precision at 90% confidence. This is the average value for all 158 Tier 2 sites, regardless of heating fuel. Dividing the sample into electric and natural gas heat subsamples would produce average subsample savings values with precision that is too poor to use. Instead, the Tier 1 savings values are used to normalize Tier 2 savings. Tier 2 natural gas heat savings are deemed to be 861 * 641 / 737 = 749 kWh, and Tier 2 electric heat savings are deemed to be 861 * 2,465 / 737 = 2,880 kWh.

Demand reduction cannot be derived from billing analysis results. To calculate demand reduction per unit, the total net demand reduction from 2017 was divided by the total site count from 2017 (1,244 Tier 1 and 282 Tier 2 sites). The net demand reduction was calculated by applying billing analysis derived kilowatt-hour net-to-gross ratios to the Snugg Pro calculated demand reduction. This approach is unaffected by whether a site has electric or natural gas heat, since it is assumed that no heating occurs during peak demand periods.

Net demand reduction from 2017 is shown in Table 83 of the *Focus on Energy Calendar Year 2017 Evaluation Report*.[4] This approach produces 392 / 1,244 = 0.3151 kW for Tier 1 sites and 104 / 282 = 0.3688 kW for Tier 2 sites.

Annual Savings and Cost

Measure	MMID	Cost[2]	kW[4]	kWh[4]	Therms[4]
Project Completion, Electric Heat	4883	$4,687.83	0.3151	2,465	0
Project Completion, Natural Gas Heat	4884	$4,687.83	0.3151	641	150
Project Completion, Tier 2, Electric Heat	4885	$4,745.14	0.3688	2,880	0
Project Completion, Tier 2, Natural Gas Heat	4886	$4,745.14	0.3688	749	238

Lifecycle Savings

Measure	MMID	kWh[4]	Therms[4]
Project Completion, Electric Heat	4883	49,300	0
Project Completion, Natural Gas Heat	4884	12,820	3,000
Project Completion, Tier 2, Electric Heat	4885	57,600	0
Project Completion, Tier 2, Natural Gas Heat	4886	14,980	4,760

Sources

1. GDS Associates. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*. Table 1, Ventilation. June 2007. http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf
   20-year value for weatherization is used.
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. January 2017 to December 2018. Average actual measure cost based on 2,819 projects.
3. Focus on Energy. *Material and Installation Standards.* September 2018. https://focusonenergy.com/sites/default/files/inline-files/0618-FOE-HP-1188339-M%26I%20Standards-Book-R2k_CLEAN.pdf
4. Cadmus. *Focus on Energy Calendar Year 2017 Evaluation Report*. May 22, 2018. https://focusonenergy.com/sites/default/files/WI%20FOE%20CY%202017%20Volume%20II%20FINAL.pdf

Revision History

Version Number	Date	Description of Change
01	01/01/2019	Initial TRM entry

Multifamily Benchmarking Incentive

	Measure Details
Measure Master ID	Multifamily Benchmarking Incentive, 2746
Measure Unit	Per application
Measure Type	Custom
Measure Group	Other
Measure Category	Other
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	Varies by project
Peak Demand Reduction (kW)	Varies by project
Annual Therm Savings (Therms)	Varies by project
Lifecycle Energy Savings (kWh)	Varies by project
Lifecycle Therm Savings (Therms)	Varies by project
Water Savings (gal/year)	0
Effective Useful Life (years)	Varies by project
Incremental Cost ($/unit)	$0.00 (no cost in addition to initial project cost)

Measure Description

This measure is benchmark tracking incentives, which are progressive, require 12 months of pre-project utility usage, 12 months of post-project completion usage for tracking participation, and are awarded for projects that exceed projected energy savings. The incentive amount is based on the levels of energy savings and peak demand reduction. Owners may sign up for benchmarking at Tier 1 and Tier 2 incentive levels when submitting a custom application, but Tier 3 benchmarking is mandatory to validate these savings because the most savings and financial risk is associated with Tier 3:

- Tier 1 Benchmarking (initial project savings < 15%): $0.40/therm, $0.03/kWh, and $50/peak kW
- Tier 2 Benchmarking (initial project savings > 15%): $0.63/therm, $0.04/kWh, and $75/peak kW
- Tier 3 Benchmarking (initial project savings > 20%): $0.75/therm, $0.05/kWh, and $100/peak kW

This incentive is provided one time and is not available for multiple years of benchmarking. Original project savings estimates tend to be conservative for calculations and assumptions. To verify that the savings are accurate and conservative, benchmarking can include accounting for any shortfalls in the estimates and tracking the accuracy of the calculations.

By offering benchmarking for all tier levels, customers are validated and rewarded for any savings difference between expected and actual. This accounts for any conservative calculation tendencies and rewards savings from measures that could not be offered as prescriptive or custom.

Description of Baseline Condition

The baseline condition varies based on the building use of electricity and/or natural gas as calculated in the original analysis for the measures installed. This baseline is the actual utility usage, minus the calculated savings for the original efficiency project. A dual baseline may be used to calculate lifecycle savings for equipment that is nearing the end of its useful life or is impacted by EISA lighting phase-outs.

Description of Efficient Condition

The efficient condition varies based on equipment installed and equipment performance once installed in reducing electric and/ or natural gas use beyond the original analysis for the measures indicated. All active kWh- and therm-saving program measures are eligible for benchmarking.

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}}$ = Benchmark Therm Savings - Initial Project Savings Estimates

$\text{kWh}_{\text{SAVED}}$ = Benchmark kWh Savings - Initial Project Savings Estimates

kW_{SAVED} = Benchmark kW Savings - Initial Project Savings Estimates

Therm Savings

$\text{Therm}_{\text{SAVED}}$ = Annual $\text{Therm}_{\text{PRE}}$ - Annual $\text{Therm}_{\text{POST}}$

Annual $\text{Therm}_{\text{PRE}}$ = Sum $\text{Therm}_{\text{PRE}}$ calculation for all 12 months (Jan + Feb + Mar +…+ Dec)

$\text{Therm}_{\text{PRE}}$ = (Total Building Monthly Consumption - Building Baseline Monthly Consumption) / (Actual Monthly HDDs) * (Average Historical Monthly HDDs + Building Baseline Monthly Consumption)

Annual $\text{Therm}_{\text{POST}}$ = Sum $\text{Therm}_{\text{POST}}$ calculation for all 12 months (Jan + Feb + Mar +…+ Dec)

$\text{Therm}_{\text{POST}}$ = (Total Building Monthly Consumption - Building Baseline Monthly Consumption) / Actual Monthly HDDs * Average Historical Monthly HDDs + Building Baseline Monthly Consumption

Where:

Annual $\text{Therm}_{\text{PRE}}$ = Total yearly weather-normalized therm consumption before efficiency upgrades

Annual $\text{Therm}_{\text{POST}}$ = Total yearly weather-normalized therm consumption after efficiency upgrades

$\text{Therm}_{\text{PRE}}$ = Total monthly weather-normalized therm consumption before efficiency upgrades

Total Building Monthly Consumption = Therm consumption from utility history

Building Baseline Monthly Consumption = Minimum therm consumption of June, July, or August

Actual Monthly HDDs = Heating degree days from nearest weather station for actual utility month[1]

Average Historical Monthly HDDs = From NOAA 30-year average data[2]

$\text{Therm}_{\text{POST}}$ = Total monthly weather-normalized therm consumption after efficiency upgrades

kWh Savings

$\text{kWh}_{\text{SAVED}}$ = Annual kWh_{PRE} - Annual kWh_{POST}

Annual kWh_{PRE} = Sum kWh_{PRE} calculation for all 12 months (Jan + Feb + Mar +…+ Dec)

kWh_{PRE} = (Total Building Monthly Consumption - Building Baseline Monthly Consumption) / Actual Monthly CDDs * Average Historical Monthly CDDs + Building Baseline Monthly Consumption

Annual kWh_{POST} = Sum kWh_{POST} calculation for all 12 months (Jan + Feb + Mar +…+ Dec)

kWh_{POST} = (Total Building Monthly Consumption - Building Baseline Monthly Consumption) / Actual Monthly CDDs * Average Historical Monthly CDDs + Building Baseline Monthly Consumption

Where:

Annual kWh_{PRE} = Total yearly weather-normalized kWh consumption before efficiency upgrades

Annual kWh_{POST} = Total yearly weather-normalized kWh consumption after efficiency upgrades

kWh_{PRE} = Total monthly weather-normalized kWh consumption before efficiency upgrades

Total Building Monthly Consumption = kWh consumption from utility history

Building Baseline Monthly Consumption = Minimum kWh consumption of all 12 months

Actual Monthly CDDs = Cooling degree days from nearest weather station for actual utility month[1]

Average Historical Monthly CDDs = From NOAA 30-year average data[2]

kWh_{POST} = Total monthly weather-normalized kWh consumption after efficiency upgrades

kW Savings

kW_{SAVED} = Annual kW_{PRE} - Annual kW_{POST}

Where:

Annual kW_{PRE} = Highest kW usage from 12-month utility history before efficiency upgrades

Annual kW_{POST} = Highest kW usage from 12-month utility history after efficiency upgrades

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = Annual kW_{PRE} - Annual kW_{POST}

Where:

Annual kW_{PRE} = Highest kW usage from 12-month utility history before efficiency upgrades

Annual kW_{POST} = Highest kW usage from 12-month utility history after efficiency upgrades

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = EUL * kWh_{SAVED}

$Therm_{LIFECYCLE}$= EUL * $Therm_{SAVED}$

Where:

EUL = Weighted effective useful life of the original measures

Lifecycle savings account for the impacts of EISA for affected lighting technologies. A dual baseline lifecycle savings will be used for equipment that is nearing the end of its useful life.

Dual Baseline EUL Example: Boiler EUL deemed at 20 years

- Existing boiler being replaced is 13 years and has an efficiency of 70%.
- New boiler has an efficiency of 92.5%.
- A code baseline boiler has an efficiency of 80%.
- $Therm_{SAVED}$ = Existing (70%) vs. New (92.5%) = 10,000 therms
- $Therm_{SAVED}$ = Code (80%) vs. New (92.5%) = 4,500 therms
- $Therm_{LIFECYCLE}$ = (4,500 * 13) + (10,000 * 7) = 128,500 therms

Deemed Savings

The annual and lifecycle savings are calculated on a per-project basis from weather-normalized data.

Lifecycle savings are based on the original measure life or the weighted average of multiple measures.

Assumptions

Projects are only rewarded benchmarking incentives if they exceed initial savings estimates.

If additional efficiency measures or building alterations occur during any part of the benchmarking and data collection time period, that additional energy use or savings will be added or subtracted from the total consumption before weather normalization.

Benchmarking utility data will be collected for the 12 months closest to the project start and 12 months closest to project completion, but will not include the implementation and construction months.

If a customer enrolls in the benchmarking and provide the utility data needed to quantify project savings as well as additional savings after one year, the program claims the additional electricity or natural gas and rewards the customer at a discounted incentive rate of 50%. The building was benchmarked prior to work beginning, an application was submitted for the initial project, and it is possible to know when to start the utility tracking for post install benchmarking.

The minimum energy consumptions for calculating baseline monthly consumption is the lowest consumption value for the time period. This lowest value will not consist of any weather-dependent consumption for natural gas during peak summer months, or weather-dependent electric usage during the winter heating season.

Since this is a custom measure, engineers can and will account for other conditions at their discretion; however, most of the measures are weather dependent or run hour dependent and were included in this workpaper. Other adjustments include, but are not limited to, change of occupancy, equipment failures, and implementing other energy efficiency measures beyond the original scope.

Sources

1. State of Wisconsin Department of Administration. “Heating, Cooling and Growing Degree Days.” http://www.doa.state.wi.us/degreedays/
2. National Oceanographic and Atmospheric Administration, National Climatic Data Center. “Heating and Cooling Degree Day Data.” Wisconsin state-level data. http://www.ncdc.noaa.gov/oa/documentlibrary/hcs/hcs.html

Revision History

Version Number	Date	Description of Change
01	11/01/2013	Initial TRM entry

Soundbar, ENERGY STAR

	Measure Details
Measure Master ID	Soundbar, ENERGY STAR, 4033
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	Other
Measure Category	Other
Sector(s)	Residential- upstream
Annual Energy Savings (kWh)	52
Peak Demand Reduction (kW)	0.0033
Annual Therm Savings (Therms)	0
Life-cycle Energy Savings (kWh)	364
Life-cycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	7[1]
Incremental Cost ($/unit)	$0.00[1]

Measure Description

A soundbar is a special enclosure for a loudspeaker that creates a reasonable stereo effect from a single cabinet. Soundbars are much wider than they are tall, both for acoustical reasons and so they can be mounted above or below a display device, such as a computer monitor, television, or home theater screen. This measure consists of ENERGY STAR-certified soundbar units that meet efficiency levels 15% greater than the ENERGY STAR Version 3.0 audio visual product requirements.[3]

Description of Baseline Condition

The baseline condition consists of a market-based mix of both ENERGY STAR-certified and non-ENERGY STAR certified soundbar units.[4]

Description of Efficient Condition

The efficient condition consists of ENERGY STAR-certified soundbar units that meet efficiency standards 15% greater than ENERGY STAR Version 3.0 audio visual product requirements.[2]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = UEC_{BASE} - UEC_{EE}$

Where:

UEC_{BASE} = Annual unit energy consumption of baseline unit (= 77 kWh)[1]

UEC_{EE} = Annual unit energy consumption of efficient unit (= 25 kWh)[1]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kW_{SAVED,\ ACTIVE} + kW_{SAVED,\ IDLE/SLEEP}$

$kW_{SAVED,\ ACTIVE} = (UEC_{BASE,\ ACTIVE} - UEC_{EE,\ ACTIVE}) / 8{,}760 * CF_{ACTIVE}$

$kW_{SAVED,\ IDLE/SLEEP} = (UEC_{BASE,\ IDLE/SLEEP} - UEC_{EE,\ IDLE/SLEEP}) / 8{,}760 * CF_{IDLE/SLEEP}$

Where:

$UEC_{BASE,\ ACTIVE}$ = Yearly baseline consumption in active mode (= 36.09 kWh, which is 4.3 * 8.62 * 2.65 * 365 / 1,000)[1]

$UEC_{EE,\ ACTIVE}$ = Yearly efficient consumption in active mode (=13.62 kWh, which is 4.3 * 8.62 * 365 / 1,000)[1]

CF_{ACTIVE} = Coincidence factor for the active condition (= 10%)[4]

8,760 = Hours per year

$UEC_{BASE,\ IDLE/SLEEP}$ = Yearly baseline consumption in idle and sleep modes (= 40.61 kWh, which is [2.0 * 8.42 * 2.65 + 17.7 * 1.42 * 2.65] * 365 / 1,000)[1]

$UEC_{EE,\ IDLE/SLEEP}$ = Yearly efficient consumption in idle and sleep modes (= 11.23 kWh, which is [0.4 * 8.42 + 19.3 * 1.42] * 365 / 1,000)[1]

$CF_{IDLE/SLEEP}$ = Coincidence factor for the idle and sleep conditions (= 90%)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 7 years)[1]

Sources

1. ENERGY STAR. “Retail Products Platform: Product Analysis for Sound Bars.” Effective May 11, 2016. https://drive.google.com/open?id=0B9Fd3ckbKJp5OEpWSHg1eksyZ1U
   An efficient soundbar consumes 8.62 watts in active mode for 4.3 hours per day, 8.42 watts in idle mode for 0.4 hours per day, and 1.42 watts in sleep mode for 19.3 hours per day, for a total of 25 kWh per year. A baseline soundbar is in active mode for 4.3 hours per day, in idle mode for 2.0 hours per day, and in sleep mode for 17.7 hours per day. The power consumption during these periods is not specified, but increasing energy use of the efficient mode by a factor of 2.65 for the baseline case produces 77 kWh per year.
   There is no incremental cost. Additional market barriers are being investigated by ENERGY STAR.

2. *ENERGY STAR Version 3.0.* Specification for audio visual products. Accessed November 21, 2016. https://www.energystar.gov/ia/partners/prod_development/revisions/downloads/audio_video/Final_Version_3_AV_Program_Requirements.pdf?5442-a1e8.
3. Fraunhofer Center for Sustainable Energy Systems. “Energy Consumption of Consumer Electronics in U.S. Households.” 2010. Accessed November 21, 2016. http://www.cse.fraunhofer.org/publications/energy-consumption-of-consumer-electronics-us-households-2010
   Due to the high market penetration of ENERGY STAR-certified soundbars, a weighted average of the unit energy consumption of both non-ENERGY STAR and ENERGY STAR models was used to calculate savings estimates.
4. The coincidence factor for soundbars in active use is assumed to be 10%, based on engineering judgement. The coincidence factor for idle and sleep modes is therefore 100% - 10% = 90%.

Revision History

Version Number	Date	Description of Change
01	06/24/2016	Initial TRM entry

Refrigeration

Freezer, ENERGY STAR

	Measure Details
Measure Master ID	Freezer, Chest, ENERGY STAR, 4036 Freezer, Upright, ENERGY STAR, 4037
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Refrigerator/Freezer
Sector(s)	Residential- upstream
Annual Energy Savings (kWh)	4 for chest freezer, 44 for upright freezer
Peak Demand Reduction (kW)	.0039 for chest freezer, 0.0071 for upright freezer
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	264 for chest freezer, 484 for upright freezer
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	Chest freezer = $6.62 (MMID 4036) Upright freezer = $12.14 (MMID 4037)[2]
Important Comments	Measure under Retail Product Platform (RPP) Pilot

Measure Description

A freezer is a cabinet designed as a unit for freezing and storing food at temperatures of 0°F (-17.8°C) or below, and having a source of refrigeration requiring single phase, alternating current electric energy input only. These measures consist of chest and upright ENERGY STAR-certified freezer units that meet the ENERGY STAR Version 5.0 requirements. ENERGY STAR-certified units are at least 10% more efficient the federal minimum standard.[3]

Description of Baseline Condition

The baseline condition consists of non-ENERGY STAR-certified freezer units. Baseline energy consumption is based on the federal standard effective September 15, 2014.[2]

Description of Efficient Condition

The efficient condition is ENERGY STAR-certified freezer units that meet the ENERGY STAR V5.0 requirements.[3]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = UEC_{BASE} - UEC_{EE}$

Where:

UEC_{BASE} = Annual unit energy consumption of baseline unit in kWh (= based on unit type, see Annual Energy Savings table below)[1]

UEC_{EE} = Annual unit energy consumption of measure unit in kWh (= based on unit type, see Annual Energy Savings table below)[1]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (kWh_{SAVED} / 8{,}760) * TAF * LSAF$

Where:

TAF = Temperature adjustment factor (= 1.23)[4]

LSAF = Load shape adjustment factor (= 1.15)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFE\text{-}CYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Annual Energy Savings (kWh)

Unit Type and MMID	Baseline UEC[2]	Measure UEC[1]	Annual Savings (kWh)
Chest, 4036	239	215	24
Upright, 4037	439	395	44

Peak Demand Reduction (kW)

Unit Type and MMID	Demand Reduction (kW)
Chest, 4036	0.0039
Upright, 4037	0.0071

Lifecycle Energy Savings (kWh)

Unit Type and MMID	Annual Savings (kWh)	EUL (years)	Lifecycle Energy Savings (kWh)
Chest, 4036	24	11	264
Upright, 4037	44	11	484

Sources

1. ENERGY STAR. *Retail Products Platform: Product Analysis for Clothes Dryers*. Effective May 11, 2016. https://drive.google.com/open?id=0B9Fd3ckbKJp5OEpWSHg1eksyZ1U
   For EUL, ENERGY STAR assumes 11 years based on Appliance Magazine, U.S. Appliance Industry: Market Value, Life Expectancy & Replacement Picture for 2005-2012, 2011.
2. Energy Efficiency and Renewable Energy Office. "Technical Support Document for Energy Conservation Standards for Residential Refrigerators, Refrigerator-Freezers, and Freezers." Table 8.2.7. Accessed November 21, 2016. www.regulations.gov/contentStreamer?documentId=EERE-2008-BT-STD-0012-0128&disposition=attachment&contentType=pdf
   Incremental costs are based on the Freezer TSD Life-Cycle Cost and Payback Analysis.
3. ENERGY STAR. Program Requirements -Product Specification for Residential Refrigerators and Freezers Eligibility Criteria. Version 5. Accessed November 21, 2016. https://www.energystar.gov/sites/default/files/specs/private/ENERGY%20STAR%20Final%20Version%205.0%20Residential%20Refrigerators%20and%20Freezers%20Program%20Requirements.pdf
4. Prepared by Shelter Analytics; Facilitated and Managed by Northeast Energy Efficiency Partnership. "Mid-Atlantic Technical Reference Manual Version 4.0." June 2014. http://www.neep.org/sites/default/files/resources/Mid_Atlantic_TRM_V4_FINAL.pdf
   Blasnik, Michael. "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study." p. 47. July 29, 2004.
   Temperature adjustment factor based on Blasnik and assuming 78% of refrigerators are in cooled space from [Mathew Greenwald & Associates. *Energy Use Survey, Report of Findings*. Prepared for Baltimore Gas & Electric. December 2005.] and 22% in uncooled space. Although this evaluation is based on refrigerators only, it is considered a reasonable estimate of the impact of cycling on freezers and gave exactly the same result as an alternative methodology based on Freezer eShape data. Daily load shape adjustment factor also based on Blasnik 2004 (page 48, extrapolated by taking the ratio of existing NEEP summer to existing annual profile for hours ending 15 through 18, and multiplying by new annual NEEP profile).

Revision History

Version Number	Date	Description of Change
01	06/24/2016	Initial TRM entry

Refrigerator and Freezer Recycling

	Measure Details
Measure Master ID	Refrigerator, Recycling and Replacement, 2955 Freezer, Recycling and Replacement, 2956
Measure Unit	Per unit recycled
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Other
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	MMID 2955 = 827; MMID 2956 = 704
Peak Demand Reduction (kW)	MMID 2955 = 0.0954; MMID 2956 = 0.0868
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	MMID 2955 = 8,270; MMID 2956 = 7,040
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$110.00[4]

Measure Description

This measure involves removing an operable refrigerator or freezer from service prior to its natural end of life. The average age of a harvested unit is anticipated to be 20+ years. Savings are based on the estimated energy consumption during the remaining life of the unit, per unit characteristics at the time of removal.

Description of Baseline Condition

The baseline is an existing, inefficient unit in working order not being removed from service.

Description of Efficient Condition

The efficient condition is to remove an existing inefficient unit from circulation and send it for recycling.

Annual Energy-Savings Algorithm

kWh_{SAVED} = Unadjusted gross annual kWh savings/unit * Part_Use

Wisconsin Focus on Energy's evaluation work for CY 2017 provides data to update both variables in the annual energy-savings equation. First, a modeling update in the CY 2017 report provides an estimate of the Wisconsin-specific gross annual savings, which results in a slight decrease in assumed savings for refrigerators and freezers. Second, the determined part-use factor for refrigerators is decreased from 0.875 to 0.86, and that for freezers is increased from 0.73 to 0.76.[2]

The annual energy savings is a deemed value based on an evaluation, measurement, and verification analyses,[2] with adjustments for the envisioned Wisconsin conditions as noted below.

Refrigerator and Freezer Variables

Metric	Refrigerators	Freezers
Unadjusted gross annual kWh savings/unit[2]	962	926
Part-use factor	0.86	0.76
Adjusted gross annual kWh savings/unit	827	704

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = [(kWh savings/unit) / HOURS] * P *Part_Use

Where:

HOURS = Annual operating hours (= 8,760)

P = Peak intensity factor; this captures the increase in compressor cycling time in summer peak conditions relative to average annual conditions (= 1.01 for refrigerators; = 1.08 for freezers)[2]

Part_Use = Part-use factor determined by Evaluation Team (= 0.86 for refrigerators; = 0.76 for freezers)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life of replaced refrigerator (= 10 years)[1]

For this technology, ten years is technically the remaining useful life of the equipment; however, for consistency it is represented as the EUL.

Deemed Savings

Deemed Savings by Measure

	Refrigerator (MMID 2955)	Freezer (MMID 2956)
Annual Energy Savings (kWh)	827	704
Peak Demand Reduction (kW)	0.0954	0.0868
Lifecycle Energy Savings (kWh)	8,270	7,040

Assumptions

The per-unit deemed energy saving and demand reduction values quantify the early retirement of inefficient refrigerators and freezers. These values should be reviewed and updated every two or three years to quantify expected gradual improvements in the average unit efficiency (i.e., as reflected in lower kWh/unit).

Sources

1. Southern California Edison. *SCE's 2010-2012 Energy Efficiency Proposed Program Plan Workpapers (Amended)*. July 2, 2009. https://www.sce.com/wps/wcm/connect/d6b04314-457c-4338-8b0c-213d9a1ed779/A0807021EE_PP_PPP_Workpapers.pdf?MOD=AJPERES&ContentCache=NONE
2. Cadmus. *Focus on Energy Calendar Year 2017 Evaluation Report: Volume II.* May 22, 2018. https://focusonenergy.com/sites/default/files/WI%20FOE%20CY%202017%20Volume%20II%20FINAL.pdf
3. Cadmus. *Appliance Recycling Measure Savings Study*. Memo prepared for Michigan Evaluation Working Group. August 20, 2012.
4. Cost to implementer for appliance pick-up.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	2015	Updated savings based on CY 2014 findings
03	04/2017	Updated savings based on CY 2015 findings
04	10/2017	Updated EUL source
05	12/2018	Updated savings based on CY 2017 findings, updated incremental cost

Renewable Energy

Ground Source Heat Pump, Residential, Natural Gas and Electric Backup

	Measure Details
Measure Master ID	Ground Source Heat Pump: Electric Back-Up, 2820 Natural Gas Back-Up, 2821
Measure Unit	Per heat pump
Measure Type	Prescriptive
Measure Group	Renewable Energy
Measure Category	Geothermal
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	5,102
Peak Demand Reduction (kW)	1.033
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	76,530
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Based on actual program data in current year

Measure Description

This measure is installing residential-sized geothermal (ground source) heat pump systems in residential applications. Geothermal heat pump systems use the earth as a source of heating and cooling by installing an exterior underground loop that works in combination with an interior heat pump unit. The measure provides sites with a centralized heating and cooling system similar to that of a standard air-source heat pump.

Description of Baseline Condition

The baseline is a 13 SEER air-source heat pump. For estimating therm savings, the calculated results are converted to Btus.

Description of Efficient Condition

A qualifying product must meet a minimum of 15 EER in a closed-loop application, but Focus on Energy will accept program applications for open or closed loop systems. Additionally, the procedures followed to install the equipment must conform to the ACCA Standard 5 Quality Installation requirements.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = \{EFLH_{COOL} * Btu/h_{COOL} * [1/SEER_{BASE} - 1/(EER_{EE} * 1.02)]\} / 1,000 + \{EFLH_{HEAT} * Btu/h_{HEAT} * [1 / HSPF_{BASE} - 1 / (COP_{EE} * 3.412)]\} / 1,000$

Where:

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 410)[2]

Btu/h_{COOL} = Cooling capacity of equipment (= 56,020 Btu/h)[3]

$SEER_{BASE}$ = Seasonal energy efficiency ratio of baseline equipment (= 13)[4]

EER_{EE} = Energy efficiency ratio of efficient equipment (= 18.51 kBtu/kWh)[3]

1.02 = Factor to determine SEER based on its EER

1,000 = Kilowatt conversion factor

$EFLH_{HEAT}$ = Equivalent full-load heating hours (= 1,890)[2]

Btu/h_{HEAT} = Heating capacity of the equipment (= 45,680 Btu/h)[3]

$HSPF_{BASE}$ = Heating seasonal performance factor of baseline equipment (= 7.7 kBtu/kWh)[4]

COP_{EE} = Coefficient of performance (= 3.80)[3]

3.412 = Conversion from watts to Btu

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Btu/h_{COOL} * (1 / EER_{BASE} - 1 / EER_{EE})) / 1,000 * CF$

Where:

EER_{BASE} = Energy efficiency ratio of baseline equipment (= 11)[4]

CF = Coincidence factor (= 0.5)[6]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

This system life expectancy is generally constrained by the heat pump exchanger and compressor equipment. The actual ground loop installation itself often has a much longer life expectancy.

Supporting inputs for load hours in several Wisconsin cities are shown in the table below.[2]

Equivalent Full-Load Cooling and Heating Hours by City

Location	EFLH$_{COOL}$[7]	EFLH$_{HEAT}$[7]
Green Bay	344	1,852
La Crosse	323	1,966
Madison	395	1,934
Milwaukee	457	1,883
Wisconsin Average	380	1,909
Weighted Average	**410**	**1,890**

The efficient capacities, SEER, EER, and HSPF are based on a 2016 review of 10 residential projects.[3]

Sources

1. GDS Associates, Inc. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures.* June 2007. https://library.cee1.org/system/files/library/8842/CEE_Eval_MeasureLifeStudyLights%2526HVACGDS_1Jun2007.pdf
2. Several Cadmus metering studies reveal that the ENERGY STAR calculator EFLHs are over-estimated by 30% for cooling and by 25% for heat pump heating hours. The heating and cooling EFLH values used are adjusted by population-weighted CDD and HDD TMY3 values.
3. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. August 31, 2017. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf
4. International Energy Conservation Code. Table 503.2.3(1). 2009. https://codes.iccsafe.org/public/chapter/content/4718/
5. Proposed update to 2011 *Pennsylvania Technical Reference Manual*.
6. Energy Center of Wisconsin. *Update of Geothermal Analysis*. p. 19–21. August 31, 2009. http://www.ecw.org/sites/default/files/249-1.pdf.
7. Several Cadmus metering studies reveal that the ENERGY STAR calculator EFLH are over-estimated by 25%. The EFLH$_{HEAT}$ were adjusted by population-weighted HDD and TMY3 values.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	01/2015	Updated EFLH
03	05/2018	Updated based on evaluation findings

Solar Photovoltaic

	Measure Details
Measure Master ID	Solar PV, 2819
Measure Unit	Per kWDC installed
Measure Type	Hybrid
Measure Group	Renewable Energy
Measure Category	Photovoltaics
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Varies by Type
Peak Demand Reduction (kW)	Varies by Type
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by Type
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	25[1]
Incremental Cost ($/unit)	Actual cost to be provided annually

Measure Description

PV systems generate DC electric current through the photovoltaic effect when exposed to light. The DC power in one or more series of PV modules, called strings, is converted to AC power by an inverter. Inverters can either be classified as string inverters, which are centrally located and combine the output of multiple modules or strings of modules, or as microinverters, which are installed at the module and convert each module’s DC output to AC individually.

AC modules are growing in popularity. They provide AC output without the need for external inverters. Once the output of the PV system is converted into AC current that is compatible with the local utility grid, the system is interconnected to the residence wiring system.

The total system output is affected by the tilt and azimuth of the modules, module temperature, inverter efficiency, and shading factors. Ideal systems are designed to face south, have minimal shading, have a tilt close to the local latitude, and are installed in a safe area. The most common application is fixed-mounted panels on a south-facing rooftop, but other configurations can include ground-mounted or pole-mounted arrays and can be in fixed, manual, or automatic sun tracking configurations.

Panels may also be installed facing to the east or west, with reduced savings.

The average installed capacity of residential PV systems in Wisconsin was 6.6 kWDC for the 2016 program year.[2]

Description of Baseline Condition

The baseline for this measure is having no PV system installed at the site.

Description of Efficient Condition

South-facing PV arrays are designed to be installed within 45 degrees of due south (azimuth angle ≥ 45 degrees and ≤ 225 degrees) in a safe area, where there is 10% or less shading. East-facing PV arrays may be installed between 45 degrees of due south and straight east (azimuth angle < 45 degrees and ≥ 90 degrees). West-facing PV arrays may be installed between 45 degrees of due south and straight west (azimuth angle > 225 degrees and ≤ 270 degrees.

Arrays can have a tilt between 10 degrees and 50 degrees of the local latitude. A central inverter is typically installed in a mechanical room. In some cases, microinverters are used for one or two PV modules, which convert DC to AC power.

Annual Energy-Savings Algorithm

The energy savings from PV systems is calculated using PVWatts,[5] a tool that uses TMY3 solar radiation data, combined with user-entered capacity, array type, tilt, azimuth, and derate factor, to calculate hourly AC energy output and annual energy output. The table below summarizes the expected savings per kWDC installed by location. Note that these general calculations do not reflect the actual conditions at any site but are a general representation of typical PV systems installed in Wisconsin.

System Derate Factor = DerateFactor * (1 - ShadeFactor) * (1 - SnowFactor)

Where:

DerateFactor = Amount of power maintained in DC to AC conversion (= 88.6%; see Assumptions)

ShadeFactor = Percentage of time system is shaded (= 2.7%; see Assumptions)

SnowFactor = Percentage of time system in covered in snow (= 2% for 34° tilt)[3]

Installed Capacity by City

Reference City	Reference Zip Code	AC kWh/kWDC Installed Capacity		
		South Facing	East Facing	West Facing
Milwaukee	53220	1,360	1,064	1,073
Madison	53706	1,348	1,046	1,053
Green Bay	54302	1,370	1,070	1,060
Average		**1,360**	**1,060**	**1,062**

Summer Coincident Peak Savings Algorithm

The peak period demand reduction is calculated by summarizing the modeled PV Watts kilowatt-hour output over the Focus on Energy peak period of 1 p.m. to 4 p.m. on weekdays in June, July, and August, then dividing by the number of hours in that period.

$kW_{SAVED} = kWh_{PEAK} / Hours_{PEAK}$

Where:

kWh_{PEAK} = Total kilowatt-hours generated during peak times

$Hours_{PEAK}$ = Total peak period hours (= 197.14; see Assumptions)

Installed Capacity by City

Direction	Reference City	Total Peak Period (kWh)	Amount Reduced (kW)
South	Milwaukee	88.1	0.45
	Madison	87.7	0.44
	Green Bay	87.8	0.45
	Average	**87.9**	**0.45**
East	Milwaukee	45.7	0.23
	Madison	46.7	0.24
	Green Bay	44.3	0.22
	Average	**45.6**	**0.23**
West	Milwaukee	103.1	0.52
	Madison	101.3	0.51
	Green Bay	101.8	0.52
	Average	**102.1**	**0.52**

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 25 years)[1]

Assumptions

Throughout this document, kWDC is used to refer to the nameplate installed capacity of solar at standard test conditions of 25°C and 1,000 W/m^2 irradiance.

Generation estimates were made in accordance with PV system guidelines[3] or, where available, are Residential Rewards program-specific data:

- Array azimuth of 180° for south facing, 90° for east facing, 270° for west facing
- Fixed (non-tracking) array
- Array tilt of 34°

All results were normalized to installed kWDC capacity and can be scaled to actual installed capacity on a one-to-one basis (for example, a 2 kW system will produce twice the output and peak demand reduction of a 1 kW system).

A derate factor of 88.6% was used based on results produced by an updated version of PVWatts.[4]

A shade factor of 2.7% was used based on desktop reviews and site visits.[4]

Peak period hours were calculated as follows: there are 30 + 31 + 31 = 92 days in June, July, and August. Five out of every seven days are weekdays, with three peak hours per weekday. Therefore, $Hours_{PEAK}$ = 92 * (5 / 7) * 3 = 197.14.

Sources

1. National Renewable Energy Laboratory. “Useful Life.” Website. Accessed December 2018. https://www.nrel.gov/analysis/tech-footprint.html
   Site provides range of 25 to 40 years; bottom of range selected to account for uncertainties of lifetime measurement and consistency with historical program assumptions.
2. Cadmus. Analysis of 2016 Renewable Rewards program data for 24 funded PV systems.
3. Tetra Tech. *State of Wisconsin Public Service Commission Focus on Energy Evaluation: Standard Calculation Recommendations for Renewable Energy Systems.* January 18, 2011. https://focusonenergy.com/sites/default/files/standardcalculationrecommendationsCY10_evaluationreport.pdf

4. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. August 31, 2017. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf
5. National Renewable Energy Laboratory. *PVWatts Calculator*. https://pvwatts.nrel.gov/pvwatts.php

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	05/2018	Updated savings based on evaluation findings
03	12/2018	Added east and west facing savings

Vending and Plug Loads

Advanced Power Strip

	Measure Details
Measure Master ID	Advanced Power Strip: Retail, APS Tier 1, 4275 Pack-Based, APS Tier 1, 3895 Pack-Based, APS Tier 2, 4120
Measure Unit	Per advanced power strip
Measure Type	Prescriptive
Measure Group	Vending and Plug Loads
Measure Category	Controls
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Retail Tier 1 = 55 (MMID 4275); Pack-Based Tier 1 = 46 (MMID 3895); Pack-Based Tier 2 = 65 (MMID 4120)
Peak Demand Reduction (kW)	Retail Tier 1 = 0.0073 (MMID 4275); Pack-Based Tier 1 = 0.0061 (MMID 3895); Pack-Based Tier 2 = 0.0086 (MMID 4120)
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Retail Tier 1 = 330 (MMID 4275); Pack-Based Tier 1 = 276 (MMID 3895); Pack-Based Tier 2 = 390 (MMID 4120)
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	6[1,2]
Incremental Cost	Tier 1 Retail = $15.00[8] (MMID 4275); Tier 1 Pack-based = $11.15[3] (MMID 3895); Tier 2 Pack-Based = $49.14[3] (MMID 4120)

Measure Description

This measure is the installation of a Tier 1 or Tier 2 advanced power strip (APS) in a home entertainment application. APSs differ from standard power strips in that they have two sets of outlets: always on and switched outlets, with peripheral loads (such as a DVD player, gaming console, home theater, or printer) generally being plugged into the switched outlets and main loads (such as a DVR, router, or clock) being plugged into the always on outlets. Tier 1 APSs have the ability to automatically disconnect peripheral loads when the main load is off. Tier 2 APS have the additional ability to automatically disconnect peripheral loads when unit does not sense infrared remote control signals for a period of time. APS units are therefore able to reduce standby power loss and wasted energy from going to the switched outlets when the control device is off. Pack-based measure savings are based the APS being provided as part of a package, so an installation rate less than 100% is applied.

Description of Baseline Condition

The baseline equipment is a standard power strip that does not control connected loads.

Description of Efficient Condition

This measure applies to the efficient use of an APS.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{BASE} * SF * IR$

Where:

kWh_{BASE} = Baseline wattage (= 356 kWh)[4]

SF = Savings factor (= 19% for Tier 1,[5] see Assumptions; = 33% for Tier 2[4])

IR = Installation rate (= 81% for Retail Tier 1,[7] = 68% for Pack-Based Tier 1,[5,6] see Assumptions; = 55% for Pack-Based Tier 2,[4] see Assumptions)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} * CF / HOU$

Where:

HOU = Hours of use (= 6,588, see Assumptions)[5]

CF = Coincidence factor (= 0.87, see Assumptions)[2]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 6 years; see Assumptions)[1,2]

Assumptions

It is assumed that Tier 1 and Tier 2 APSs have the same baseline consumption value of 356 kWh, derived from the ACEEE paper that examined sites in Wisconsin.[4] It is also assumed that single-family and multifamily sites have the same baseline consumption, savings factors, and installation rates.

A savings factor of 19% for Tier 1 APSs comes from the Illume study,[5] showing 75 kWh of savings and 391.5 kWh of baseline consumption (75 / 391.5 = 19%).

An installation rate of 68% is assumed for pack-based Tier 1 APSs, based on an average of recent evaluations of Ameren Missouri and Potomac Edison,[6] and PPL Electric Utilities[7] kit programs, in which APS Tier 1 was included in kits. This assumption can be verified when more data is available.

An installation rate of 55% is assumed for pack-based Tier 2 APSs. This comes from the ACEEE paper examining Tier 2 power strips,[4] showing that "45% of participants either removed or didn't install the APS device..." and that the in-service rate was generally lower for Tier 2 devices due to usability issues.

For hours of use, the Illume whitepaper[5] cites a 2014 Nielsen study that reports an average daily television operation time of 5.95 hours. The APS is assumed to operate whenever the TV is not on, or 6,588 hours (8,760 – (365 * 5.95)).

The coincidence factor was calculated using the 2015 Vermont TRM[2] coincidence factor of 17.0% for televisions, which employs a peak period of four hours. Adjusting that value for the Wisconsin peak period of three hours yields 0.13 (0.17 * 3/4); therefore, the coincidence factor for a power strip is 0.87 (1 – 0.13).

The EUL of six years is an average of two values. A value of four years is from the Vermont 2015 TRM,[2] and a value of eight years is from the 2017 Minnesota TRM.[1]

Sources

1. State of Minnesota. *Technical Reference User Manual (TRM): For Energy Conservation Improvement Programs.* p. 298. January 1, 2017. http://mn.gov/commerce-stat/pdfs/mn-trm-v2.0-041616.pdf
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Revision History

Version Number	Date	Description of Change
01	09/2016	Initial TRM entry
02	02/2017	Created Tier 2 workpaper
03	04/2018	Merged workpapers and added multifamily sector

Windows

Low-E Storm Windows

	Measure Details
Measure Master ID	Low-E Storm Window, Single Family, 4681 Low-E Storm Window, Multifamily, 4682
Measure Unit	Per low-E storm window
Measure Type	Prescriptive
Measure Group	Windows and Doors
Measure Category	Windows
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	7.3
Peak Demand Reduction (kW)	0.0077
Annual Therm Savings (Therms)	4.2
Lifecycle Energy Savings (kWh)	146
Lifecycle Therm Savings (Therms)	84
Water Savings (gal/year)	0
Effective Useful Life (years)	20[1]
Measure Incremental Cost	Single family = $126; multifamily = $160 (see Assumptions)

Measure Description

Modern low emissivity (low-E) storm windows are a glazing attachment added to single-pane or double-pane windows. Low-E metal oxide coating (low-E storm windows/panels) decreases the winter heat loss and summer heat gain of an existing window by reducing thermal transmission. A low-E storm window may be installed on the interior or exterior of the existing window assembly. They are typically permanently mounted and operable. The products reduce thermal transmission in three ways:

- The low-E metal oxide coating acts as a selective heat mirror that reflects infrared light (that is, heat) back into the home during the winter and back outside during the summer.
- The marine-quality glazing and caulked or compression-sealed interface reduces air leakage and infiltration.
- The dead air space created between the existing window and new storm window frame further reduces thermal transmission during both the winter and summer.

Description of Baseline Condition

The baseline condition is an existing single-pane or double-pane window assembly according to manufacturer specifications.

Description of Efficient Condition

The efficient condition is a low-E storm window over an existing single-pane or double-pane window assembly.

Annual Energy-Savings Algorithm

The deemed savings are derived from building models performed by the EPA using the RESFEN building modeling software.[2] For further details on how the savings are calculated, please refer to the Assumptions.

The following simplified algorithm is used to calculate energy savings per low-E storm window.

$kWh_{SAVED} = (W_7 * CS_7 + W_6 * CS_6) * Area$

$Therms_{SAVED} = (W_7 * HS_7 + W_6 * HS_6) * Area$

Where:

W_7 = Weighting for Climate Zone 7 (= 0.05; see Assumptions)
CS_7 = Average cooling savings per square foot in Climate Zone 7 (see Assumptions)
W_6 = Weighting for Climate Zone 6 (= 0.95; see Assumptions)
CS_6 = Average cooling savings per square foot in Climate Zone 6 (see Assumptions)
Area = Average window area (= 13.2 sq ft)[3]
HS_7 = Average heating savings per square foot in Climate Zone 7 (see Assumptions)
HS_6 = Average heating savings per square foot in Climate Zone 6 (see Assumptions)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED,COOL} / EFLH_{COOL} * CF$

Where:

$kWh_{SAVED,COOL}$ = Cooling portion of kWh_{SAVED}
$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 410)[4]
CF = Coincidence factor (0.66)[5]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therms_{LIFECYCLE} = Therms_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 20 years)[1]

Assumptions

The EPA's analysis presents savings for a variety of low-E storm windows emissivity levels installed over single-pane windows, for two types of natural gas–heated homes (new and old), and in various climate zones.[2] To arrive at the savings presented in this workpaper, savings from the EPA's analysis for the different low-E storm windows and home types were averaged, then weighted between the relevant climate zones according to population geographical distributions in Wisconsin. The results were used to extrapolate savings for homes heated with a non-natural gas source. Finally, the weighted savings for all home heating types were calculated using heating system distributions in Wisconsin.

The savings for double-pane windows was calculated as the ratio of the savings resulting from the installation of a low-E storm window on a single-pane window to the savings resulting from the installation of a low-E storm windows on a double-pane windows from the PNNL study cited,[6] which is then used to scale the single-pane window results appropriately.

Each assumption is discussed in more detail below.

Window Characteristics

The EPA analysis shows U-factor and solar heat gain coefficient (SHGC) values for a variety of low-E storm window assemblies, as compared to single-pane wood frame primary windows.[2] The properties of the low-E storm window used in the building models are shown in the table below.

Properties of Modeled Window Glasses[2]

Window Type	Glass Options (3 mm)	Emissivity	Solar Transmission	U-factor	SHGC
Standard	Clear	0.84	0.86	0.466	0.537
Low-E	AGC Comfort Select 73	0.15	0.69	0.356	0.458
	Guardian IS20	0.20	0.77	0.364	0.502
	PPG Sungate 500	0.22	0.69	0.367	0.468

This workpaper assumes equal weighting between the three low-E storm window glass options.

Building Characteristics

The savings calculations are based on modeling two types of prototypical residential homes: one-story (1,700 sq ft) existing construction and two-story (2,800 sq ft) new construction. All modeled homes have a 15% window-to-floor-area ratio.[2, 6] This workpaper assumes equal weighting between the two building types. The model building assumptions are shown in the table below.

Characteristics of Modeled Homes[6]

Characteristic	Existing Construction	New Construction
Area	1,700 sq ft	2,800 sq ft
Window Area	255 sq ft (15 % of floor area)	420 sq ft (15 % of floor area)
Foundation	Basement	
Insulation	RESFEN 5[7]	2006 IECC[8]
HVAC System	Natural gas furnace and air conditioning	
HVAC Efficiency	Natural gas furnace AFUE = 0.78 Air conditioner SEER = 10	Natural gas furnace AFUE = 0.90 Air conditioner SEER = 13

Climate Zone

The savings were weighted by climate zone. Based on United States Census county-level data[9] and IECC assignments of climate zone by county, 5% of Wisconsin residents are located in Climate Zone 7 and the other 95% are located in Climate Zone 6.[10] Savings from Minneapolis and Duluth were used as proxies for Wisconsin Climate Zones 6 and 7, respectively.

Stock HVAC System Normalization

To account for differences between stock HVAC system efficiencies and modeled HVAC system efficiencies, the savings results were normalized. The efficiencies used to normalize the savings results found in the study are shown in the table below.

Normalizing Efficiencies of the HVAC System

System	Modeled Homes (EPA Study)[6]	Wisconsin Stock Homes (Potential Study)[3]
Natural Gas Furnace (AFUE)	0.84 (average of 0.78 and 0.90)	91.4%
Air Conditioner (SEER)	11.5 (average of 10 and 13)	12.1%

As shown below, a small fraction of homes are assumed to have air-source heat pump or electric baseboard heat. Homes with an air-source heat pump are assumed to have a SEER of 12.1 and heating seasonal performance factor of 7.7.

Cooling savings, except in air-source heat pump–heated homes, were multiplied by 84% to account for homes in Wisconsin without air conditioners.[3] It was assumed that all homes with an air-source heat pump have an air conditioner installed.

Normalized Savings Across HVAC Systems

The table below shows savings results for homes with different HVAC systems.

Low-E Storm Window Deemed Savings for Single Pane Windows[11, 12]

HVAC System	Annual Savings Per Unit (kWh)		Annual Savings Per Unit (therm)	
	Single Pane	Double Pane	Single Pane	Double Pane
Natural Gas Furnace	5.01	4.39	10.79	3.89
Propane Furnace	5.01	4.39	--	--
Wood Stove	5.01	4.39	--	--
Natural Gas Boiler	5.01	4.39	--	--
Electric Baseboard	294.04	107.81	--	--
Air-Source Heat Pump	134.04	50.21	--	--

HVAC System Distribution

The results were weighted according to HVAC system distributions in Wisconsin,[3] shown in the table below.

Normalizing Efficiencies of the HVAC System

HVAC System	Percentage of Wisconsin Homes[3]
Natural Gas Furnace	82%
Propane Furnace	7%
Wood Stove	5%
Natural Gas Boiler	4%
Electric Baseboard	2%
Air-Source Heat Pump	1%

Single-Pane and Double Pane Window Savings

The EPA analysis presents savings for low-E storm windows installed on single-pane windows. To calculate the savings for low-E storm windows installed on double-pane windows, the single-pane savings from the EPA analysis were multiplied by the ratios of savings between single-pane and double-pane windows in a study published by PNNL.[6]

The final weighted savings are for installation on a window of unknown type. Potential Study data[3] shows that single family homes in Wisconsin are 18% single pane and 82% double pane. The following table summarizes weighted lifecycle and annual savings.

Peak Demand and Lifecycle Savings per Low-E Storm Window[11, 12]

Window Type	MMID	Peak Savings (kW)	Annual Savings (kWh)	Lifecycle Savings (kWh)	Annual Savings (therms)	Lifecycle Savings (therms)
Single Pane	N/A	0.0085	10.95	219.09	8.81	176.17
Double Pane	N/A	0.0075	6.51	130.14	3.17	63.36
Weighted Average[13]	**N/A**	**0.0077**	**7.3**	**146**	**4.2**	**84**

Incremental Measure Cost

The incremental cost for a low-E storm window includes the product cost and the installation cost. Because the baseline condition is an existing single-pane or double-pane window assembly, the incremental product cost is the full cost of the low-E storm window. It is assumed that single family residence low-E storm windows are installed by homeowners 80% of the time, and that multifamily residence low-E storm windows are always installed by contractors.[14] As a result, the installation cost for multifamily residences reflects the full installation cost per window, while the installation cost for single family homes is weighted between self-install and contractor installations. The $115 cost of a low-E window is the average of the $80 to $150 range given. The installation cost of a self-install is assumed to be $2, while the cost of a professional installation is $45.[15] The single family installation cost is a weighted average ($2 * 80% + $45 * 20% = $10.60).

Estimate of Incremental Measure Cost[14, 15]

Type of Residence	Average Measure Product Cost (per unit)	Measure Installation Cost (per unit)	Total Incremental Cost (per unit)
Single Family	$115	$10.60	$126
Multifamily	$115	$45	$160

Sources

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2. Environmental Protection Agency and D+R International. "ENERGY STAR for Exterior and Interior Storm Windows, Analysis of Additional Low-E Glass Options." April 4, 2018.

https://www.energystar.gov/sites/default/files/ES%20Storm%20Windows%20Additional%20Analysis.pdf

3. Cadmus. *2016 Potential Study for Focus on Energy*.
   Data maintained by Cadmus and Wisconsin PSC. Audits of 120 single family sites show 1,592 total windows and 21,040 total square feet, for an average window size of 13.2 square feet. Audits also show that 18% of windows are single pane and 82% are double pane.
4. Cadmus. *Focus on Evaluated Energy Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
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11. Wisconsin Focus on Energy. “Low-E Storm Window Energy Savings Calculations.xlsx”
12. Environmental Protection Agency. “ENERGY STAR Program Requirements for Exterior and Interior Storm Windows. Draft 2 Version 1.” April 2018. https://www.energystar.gov/sites/default/files/ES%20Storm%20Windows%20Draft%202%20Version%201%20Specification.pdf
13. U.S. Energy Information Administration. *Residential Energy Consumption Survey.* Table HC2.7. Structural and geographic characteristics of homes in the Northeast and Midwest regions, 20151. Assumption for split of single-pane versus double-pane windows.

14. Pacific Northwest National Laboratory (Cort, K.A.). *Low-E Storm Windows: Market Assessment and Pathways to Market Transformation.* Table 2.1. 2013. PNNL-22565. Richland, Washington. http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22565.pdf
15. Drumheller, S. Craig, C. Kohler, S. Minen. "Field Evaluation of Low-E Storm Windows." Paper presented at the Thermal Performance of the Exterior Envelopes of Whole Buildings X International Conference, Clearwater Beach, Fl, December 2–7, 2007. https://eetd.lbl.gov/sites/all/files/publications/1940e.pdf

Revision History

Version Number	Date	Description of Change
01	6/14/2018	Initial TRM entry

Appendix A: List of Acronyms

AC	Alternating current
	Air conditioning
AFUE	Annual Fuel Utilization Efficiency
ACH	Air changes per hour
Btu	British thermal units
CDD	Cooling degree day
CEE	Consortium for Energy Efficiency
CFL	Compact fluorescent light bulb
CMH	Ceramic metal halide
COP	Coefficient of performance
DC	Direct current
DDC	Direct digital control
DHW	Domestic hot water
DLC	Design Lights Consortium
DOE	U.S. Department of Energy
EBTU	Express Building Tune Up
ECM	Electronically commutated motor
EER	Energy efficiency ratio
EF	Energy factor
EFLH	Equivalent full-load hours
EISA	Energy Independence and Security Act
EM&V	Evaluation, measurement, and verification
ERV	Energy recovery ventilator
ETL	Intertek's ETL Mark
EUL	Effective useful life
FSTC	Food Service Technology Center
HDD	Heating degree day
HESCC	High-efficiency sealed combustion condensing
HESCCM	High-efficiency sealed combustion condensing modulating
HID	High-intensity discharge
HO	High output
HOU	Hours of use
hp	horsepower
HP	High performance
HSPF	Heating Season Performance Factor
IECC	International Energy Conservation Code
IPLV	Integrated part load volume

ISR	In-service rate
kWDC	Direct current kilowatts
LED	Light-emitting diode
NAIMA	North American Insulation Manufacturers Association
NPS	Nominal Pipe Size
NREL	National Renewable Energy Laboratory
NRTL	Nationally Recognized Testing Laboratory
OAT	Outside Air Temperature
PIR	Passive infrared
PSC	Public Service Commission of Wisconsin
	Permanent split capacitor
PSMH	Pulse-start metal halide
PTAC	Packaged terminal air conditioner
PTHP	Packaged terminal heat pump
PV	Photovoltaic
QPL	Qualified Product List
RCA	Refrigerant charge and airflow
RFP	Request for proposals
RH	Relative humidity
RTU	Rooftop unit
RW	Reduced wattage
SAM	System Advisor Model
SEER	Seasonal energy efficiency ratio
SP	Shaded pole
STC	Standard test conditions
SWH	Solar water heating
TE	Thermal efficiency
TMY	Typical meteorological year
TRC	Total Resource Cost
TRM	Technical Reference Manual
UL	Underwriters Laboratories
VAV	Variable air volume
VFD	Variable frequency drive
VHO	Very high output
VSD	Variable speed drive

Appendix B: Common Variables

Hours of use

Compressed Air

HOU = Average annual run hours (= 5,702)[3]

Commercial/Industrial Lighting

Commercial/Industrial Lighting HOU by Sector

Sector	HOU
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239

Source: PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Table 3.2 Lighting Hours of Use in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Multifamily Lighting (Daily HOU for In-Unit Room estimates)

HOU = Average annual run hours (= 5,950 for multifamily common areas)[4]

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[3] Cadmus. Focus on Energy Evaluated Deemed Savings Changes. August 31, 2017. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf

[4] Tetra Tech. "ACES Deemed Savings Desk Review." Multifamily Applications for Common Areas.November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf

Multifamily Lighting Hours of use by Room Type

Room Type	HOU
Bathroom	2.26
Bedroom	1.32
Dining	2.34
Kitchen	2.92
Living Room	2.67
Other (Hall and Office)	0.51

Single Family Residential Lighting (Daily HOU)

Single Family Lighting Hours of use by Room Type

Room Type	HOU
Bathroom	1.00
Bedroom	1.62
Dining	3.18
Kitchen	0.65
Living Room	2.17
Other	0.66
Average Daily Use	2.77

Source: Cadmus. *Focus on Energy Residential Single Family Lighting Hours of Use and Peak Coincidence Factor Findings Memo*. July 2, 2014.

Retail Lighting

Because retail lighting incentives are covered through retail price markdowns at the store level, the program does not collect participant-specific data for where purchased bulbs will be installed. General figures are calculated using the following weighting assumptions:

- Single Family Weighting, 74.7%[5]
- Multifamily Weighting, 25.3%[6]
- Single Family HOU, 2.27 hours per day[7]

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[5] U.S. Census Bureau. Percentage of Wisconsin housing stock that is single family. 2013 Estimates.

[6] U.S. Census Bureau. Percentage of Wisconsin housing stock that is multifamily. 2013 Estimates.

[7] Cadmus. Single family light logger study, 2013.

- Multifamily HOU, 2.01 hours per day[8]
- Residential Weighting 93%[9]
- Commercial Weighting 7%[10]
- Residential HOU Average, 2.20
- Commercial HOU Average, 10.2[11]
- Single Family Coincidence Factor 7.5%[12]
- Multifamily Coincidence Factor 5.5%[13]
- Residential, Averaged, Coincidence Factor 6.99%
- Commercial Coincidence Factor 77%[14]

Average annual HOU based on weighting metrics outlined above = 1,011

Coincidence factor based on weighting metrics outline above = 0.1189

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[8] Cadmus. Multifamily light logger study. 2013.

[9] Cadmus. In-store intercept surveys. 2012.

[10] Ibid.

[11] *Wisconsin Business Deemed Savings*. 2010.

[12] U.S. Census Bureau. Percentage of Wisconsin housing stock that is single family. 2013 Estimates.

[13] U.S. Census Bureau. Percentage of Wisconsin housing stock that is multifamily. 2013 Estimates.

[14] PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Lighting in Commercial Applications. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Coincidence Factors

Commercial/Industrial/Multifamily Lighting Coincidence Factors

Sector	CF
Commercial*	0.77
Industrial	0.77
Schools & Government	0.64
Agriculture	0.67
Multifamily Common Area	0.77
In-Residence**	0.055

* PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Table 3.2 Coincidence Factor for Lighting in Commercial Applications. Updated March 22, 2010.
https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
** Cadmus. Field Study: Residential Lighting. October 18, 2013. (Report based on using CFL bulbs to replace incandescent bulbs. Since LEDs will initially be treated the same as CFLs, those values were used.)

Equivalent Full-Load Hours

Residential Natural Gas Measures

EFLH = 1,158 hours[15]

Residential Heat Pumps and Split HVAC

Equivalent Full-Load Hours for Air Sealing, Air-Source Heat Pumps, Ground-Source Heat Pumps, and Split A/C System.

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[15] Cadmus. *Focus on Evaluated Energy Deemed Savings Changes*. November 14, 2014.
https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

Equivalent Full-Load Hours

Location	$EFLH_{COOL}$	$EFLH_{HEAT}$	Weighting by Participant
Green Bay	344	1,852	22%
La Crosse	323	1,966	3%
Madison	395	1,934	18%
Milwaukee	457	1,883	48%
Wisconsin Average	380	1,909	9%
Overall	**410**	**1,890**	

* Full load hours calculated using an average from Illinois Statewide Technical Reference Manual, applied to Wisconsin CDDs.

Flow Rates

Faucet Aerators

$GPM_{EXISTING}$ = Baseline flow rate (= 2.2 GPM)[16]

Low-Flow Showerheads

$GPM_{EXISTING}$ = Baseline flow rate (= 2.5 GPM)[17]

Temperature (Water)

Water Heaters

T_{WH} = Water heater temperature setpoint (= 125°F)[18]

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[16] Federal minimum at 80 psi.

[17] Federal minimum at 80 psi.

[18] The water heater setpoint is assumed to be 125°F, as Wisconsin building code 704.06 requires landlords to set water heaters to 125°F: https://docs.legis.wisconsin.gov/statutes/statutes/704/06. Water heater setpoints typically range between 120°F and 140°F because temperatures below 120°F are susceptible to Legionella bacteria (which lead to Legionnaires Disease) and heaters set to temperatures above 140°F can quickly scald users: http://www.nrel.gov/docs/fy12osti/55074.pdf. Most TRMs assume water heater setpoints of 120°F, 125°F, or 130°F, though most of these are unsourced engineering assumptions. (Residential water heater setpoints include: Connecticut 2012 TRM PSD: 130°F for natural gas DWH and 125°F for tank wrap, HPWH, and temperature reduction; Mid- Atlantic TRM v3.0: 130°F for tank wrap and pipe insulation; Illinois TRM v2.0: 125°F for pipe insulation, natural gas water heater, HPWH, and tank wrap and 120°F for temperature reduction; and Indiana TRM v1.0: 130°F for pipe insulation.)

$T_{ENTERING}$ = Temperature of water entering water heater (= 52.3°F)[19]

Faucet Aerators (Kitchen)

$T_{POINT\ OF\ USE}$ = Temperature of water at point of use (= 93°F)[20]

Faucet Aerators (Bathroom)

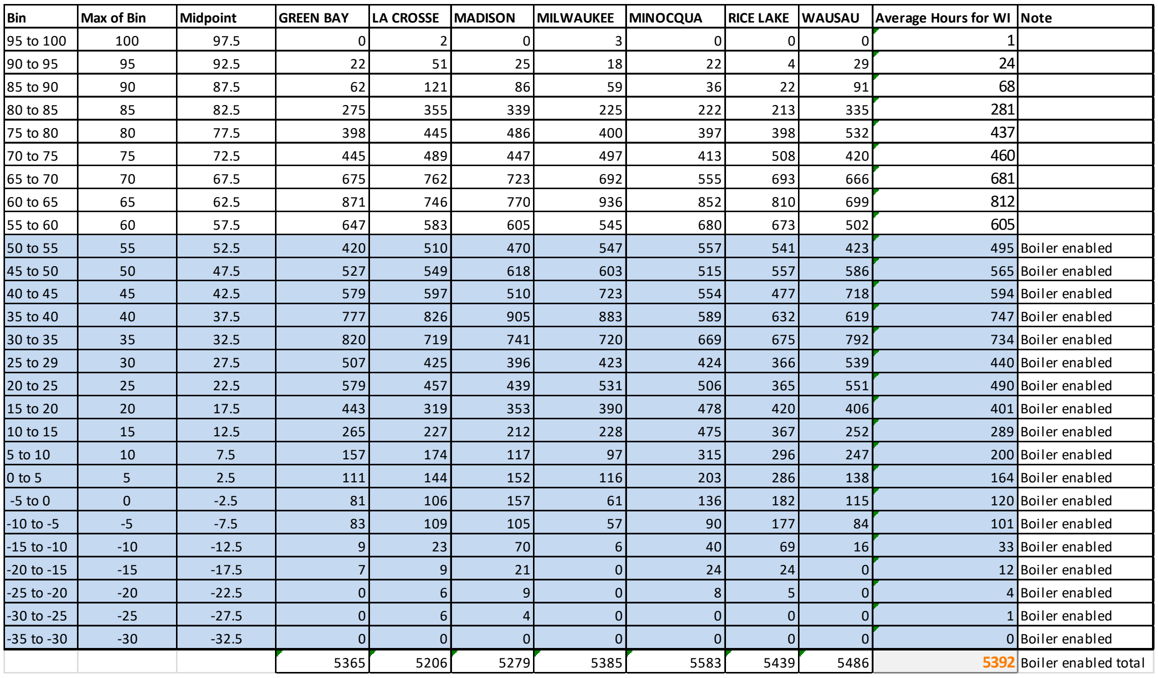
$T_{POINT\ OF\ USE}$ = Temperature of water at point of use (= 86°F)[20]

Low-Flow Showerheads

$T_{POINT\ OF\ USE}$ = Temperature of water at point of use (= 101°F)[20]

Outside Air Temperature Bin Analysis

Bin Analysis



Bin	Max of Bin	Midpoint	GREEN BAY	LA CROSSE	MADISON	MILWAUKEE	MINOCQUA	RICE LAKE	WAUSAU	Average Hours for WI	Note
95 to 100	100	97.5	0	2	0	3	0	0	0	1	
90 to 95	95	92.5	22	51	25	18	22	4	29	24	
85 to 90	90	87.5	62	121	86	59	36	22	91	68	
80 to 85	85	82.5	275	355	339	225	222	213	335	281	
75 to 80	80	77.5	398	445	486	400	397	398	532	437	
70 to 75	75	72.5	445	489	447	497	413	508	420	460	
65 to 70	70	67.5	675	762	723	692	555	693	666	681	
60 to 65	65	62.5	871	746	770	936	852	810	699	812	
55 to 60	60	57.5	647	583	605	545	680	673	502	605	
50 to 55	55	52.5	420	510	470	547	557	541	423	495	Boiler enabled
45 to 50	50	47.5	527	549	618	603	515	557	586	565	Boiler enabled
40 to 45	45	42.5	579	597	510	723	554	477	718	594	Boiler enabled
35 to 40	40	37.5	777	826	905	883	589	632	619	747	Boiler enabled
30 to 35	35	32.5	820	719	741	720	669	675	792	734	Boiler enabled
25 to 29	30	27.5	507	425	396	423	424	366	539	440	Boiler enabled
20 to 25	25	22.5	579	457	439	531	506	365	551	490	Boiler enabled
15 to 20	20	17.5	443	319	353	390	478	420	406	401	Boiler enabled
10 to 15	15	12.5	265	227	212	228	475	367	252	289	Boiler enabled
5 to 10	10	7.5	157	174	117	97	315	296	247	200	Boiler enabled
0 to 5	5	2.5	111	144	152	116	203	286	138	164	Boiler enabled
-5 to 0	0	-2.5	81	106	157	61	136	182	115	120	Boiler enabled
-10 to -5	-5	-7.5	83	109	105	57	90	177	84	101	Boiler enabled
-15 to -10	-10	-12.5	9	23	70	6	40	69	16	33	Boiler enabled
-20 to -15	-15	-17.5	7	9	21	0	24	24	0	12	Boiler enabled
-25 to -20	-20	-22.5	0	6	9	0	8	5	0	4	Boiler enabled
-30 to -25	-25	-27.5	0	6	4	0	0	0	0	1	Boiler enabled
-35 to -30	-30	-32.5	0	0	0	0	0	0	0	0	Boiler enabled
			5365	5206	5279	5385	5583	5439	5486	5392	Boiler enabled total

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[19] U.S. Department of Energy. *Domestic Hot Water Scheduler.* Average water main temperature of all locations measured in Wisconsin by scheduler, weighted by city populations.

[20] Cadmus. *Showerhead and Faucet Aerator Meter Study*. Memo to Michigan Evaluation Working Group. June 2013.

Heating and Cooling Degree Days

Heating and Cooling Degree Days for Residential Applications*

Location	HDD	CDD
Milwaukee	7,276	548
Green Bay	7,725	516
Wausau	7,805	654
Madison	7,599	630
La Crosse	7,397	729
Minocqua	8,616	423
Rice Lake	8,552	438
Statewide Weighted	**7,616**	**565**

* Cadmus. *Michigan Water Meter Study.* 2012.

Appendix C: Effective Useful Life Table

MMID	Measure Name	EUL
598	Greenhouse Climate Controls, Hybrid	10
1981	Gas Furnace with ECM, 95+ AFUE (Existing)	20
1983	Hot Water Boiler, 95%+ AFUE	20
1985	Water Heater, Power Vented, EF >= 0.67	13
1986	Water Heater, Condensing	13
1988	Water Heater, Indirect	15
1989	Water Heater, Electric, EF 0.93 or greater	15
2139	Low-flow Showerhead, 1.5 gpm, Gas	10
2145	Low-flow Showerhead, 1.5 gpm, Electric MF	10
2196	VSD Air Compressor, Hybrid	15
2197	Anti-sweat heater controls, on freezer case with low-heat door	12
2198	Anti-sweat heater controls, on freezer case with no-heat door	12
2199	Anti-sweat heater controls, on freezer case with standard door	12
2200	Anti-sweat heater controls, on refrigerated case with low-heat or no-heat doors	12
2201	Anti-sweat heater controls, on refrigerated case with standard door	12
2202	Beverage Cooler Controls	5
2203	High Turn Down Burner - NEW	20
2205	Linkageless Boiler Control, per hp	15
2206	Boiler oxygen trim controls, per hp	5
2211	Boiler Tune-up - service buy down	1
2218	Boiler, Hot Water, Modulating, >=90% AFUE, < 300 mbh	20
2221	Boiler Control - Outside Air Reset/Cutout	5
2234	Case door, freezer, low heat	11
2235	Case door, freezer, no heat	11
2236	Case door, refrigerated, no heat	11
2249	High Efficiency Chillers - Retrofit, air cooled all sizes	20
2250	High Efficiency Chillers - Retrofit, water cooled < 150 tons	20
2251	High Efficiency Chillers - Retrofit, water cooled >= 300 tons	20
2252	High Efficiency Chillers - Retrofit, water cooled >= 150 tons and < 300 tons	20
2253	Agricultural Circulation Fan, High Efficiency, Per Inch od Fan Diameter -	15
2254	Compressed Air Condensate Drains, No Loss Drain	20
2255	Pressure/Flow Controllers, NEW	15
2257	Compressed Air Heat Recovery, Space Heating	13
2258	Compressed Air Mist Eliminators, NEW	5 (new construction), 3 (retrofit)

MMID	Measure Name	EUL
2259	Compressed Air Nozzles, Air Entraining	15
2264	Cycled Refrigeration Thermal Mass Air Dryers NEW	15
2269	Cooler Evaporator Fan Control	16
2271	Night Curtains for Open Coolers, per linear foot	5
2276	DELAMPING, DIRECT INSTALL, 4 FOOT LAMP	10
2277	Delamping, T8 to T8	10
2280	Dishwasher, Low Temp, Door Type, Energy Star, Energy Star, Electric	10
2281	Dishwasher, High Temp, Electric Booster, Door Type, Energy Star, Electric	10
2282	Dishwasher, High Temp, Electric Booster, Door Type, Energy Star, NG	10
2283	Dishwasher, High Temp, Electric Booster, Multi Tank Conveyor, Energy Star, Electric	10
2284	Dishwasher, High Temp, Electric Booster, Multi Tank Conveyor, Energy Star, NG	10
2285	Dishwasher, High Temp, Electric Booster, Single Tank Conveyor, Energy Star, Electric	10
2286	Dishwasher, High Temp, Electric Booster, Single Tank Conveyor, Energy Star, NG	10
2287	Dishwasher, High Temp, Electric Booster, Under Counter, Energy Star, Electric	10
2288	Dishwasher, High Temp, Electric Booster, Under Counter, Energy Star, NG	10
2289	Dishwasher, High Temp, Gas Booster, Door Type, Energy Star, NG	10
2290	Dishwasher, High Temp, Gas Booster, Multi Tank Conveyor, Energy Star, NG	10
2291	Dishwasher, High Temp, Gas Booster, Single Tank Conveyor, Energy Star, NG	10
2292	Dishwasher, High Temp, Gas Heat, Gas Booster, Under Counter, Energy Star, NG	10
2293	Dishwasher, Low Temp, Door Type, Energy Star, NG	10
2294	Dishwasher, Low Temp, Multi Tank Conveyor, Energy Star, Electric	10
2296	Dishwasher, Low Temp, Single Tank Conveyor, Energy Star, Electric	10
2298	Dishwasher, Low Temp, Under Counter, Energy Star, Electric	10
2299	Dishwasher, Low Temp, Under Counter, Energy Star, NG	10
2301	Dock Ramp/Pit Seal, Replacement	10
2302	Dock Seal, Added to Existing Barrier	10
2303	Dock Ramp/Pit Seal, From SPECTRUM	10
2303	Dock Seals, New	10
2305	Drycooler, Computer Room Air Conditioner Economizer	15
2306	Compressor Cooler Motor, ECM - NEW	15
2307	ECM (electronically commutated) Condenser/Condensing Unit Fan Motor	16
2308	ECM (electronically commutated) evaporator fan motor replacing shaded-pole motor, <1/20 hp, in walk-in cooler	15
2309	ECM (electronically commutated) evaporator fan motor replacing shaded-pole motor, >=1/20 hp, <1hp, in walk-in cooler	15

MMID	Measure Name	EUL
2310	ECM (electronically commutated) evaporator fan motor replacing shaded-pole motor, <1/20 hp, in walk-in freezer	15
2311	ECM (electronically commutated) evaporator fan motor replacing shaded-pole motor, >=1/20 hp, <1hp, in walk-in freezer	15
2312	ECM (electronically commutated) motor replacing shaded-pole motor in refrig/freezer case	15
2314	Energy Recovery Ventilator	15
2322	Freezer, Chest, Glass Door, 15-29 cu ft, Energy Star	12
2323	Freezer, Chest, Glass Door, 30-49 cu ft, Energy Star	12
2324	Freezer, Chest, Glass Door, 50+ cu ft, Energy Star	12
2325	Freezer, Chest, Solid Door, < 15 cu ft, Energy Star	12
2326	Freezer, Chest, Solid Door, 15-29 cu ft, Energy Star	12
2327	Freezer, Chest, Solid Door, 30-49 cu ft, Energy Star	12
2330	Freezer, Vertical, Glass Door, 15-29 cu ft, Energy Star	12
2331	Freezer, Vertical, Glass Door, 30-49 cu ft, Energy Star	12
2332	Freezer, Vertical, Glass Door, 50+ cu ft,Energy Star	12
2333	Freezer, Vertical, Solid Door, < 15 cu ft, Energy Star	12
2334	Freezer, Vertical, Solid Door, 15-29 cu ft, Energy Star	12
2335	Freezer, Vertical, Solid Door, 30-49 cu ft, Energy Star	12
2336	Freezer, Vertical, Solid Door, 50+ cu ft, Energy Star	12
2337	Fryer, Energy Star, Electric	12
2338	Fryer, Energy Star, NG	12
2371	Griddle, Energy Star, Electric	11
2372	Griddle, Energy Star, NG	11
2373	Guest Room Energy Management Controls, Electric Heat PTAC Systems	8
2374	Guest Room Energy Management Controls, Not Otherwise Specified	8
2422	Infrared Heating Units, High or Low Intensity	15
2429	Steam Fittings Insulation - NEW	10
2430	Steam Piping Insulation - NEW	10
2434	Irrigation Pressure Reduction, Nozzle Installation	15
2456	LED, Reach-In Refrigerated Case, Replaces T12 or T8	7
2471	Occupancy Sensors - Ceiling Mount <= 500 Watts	8
2472	Occupancy Sensors - Ceiling Mount >= 1001 Watts	8
2473	Occupancy Sensors - Ceiling Mount 501-1000 Watts	8
2474	Occupancy Sensors - Fixture Mount <= 200 Watts	8
2475	Occupancy Sensors - Fixture Mount > 200 Watts	8
2482	Occupancy Sensor, LED Refrigerated Case Lights	8
2483	Occupancy Sensors - Wall Mount <= 200 Watts	8

MMID	Measure Name	EUL
2484	Occupancy Sensors - Wall Mount >= 201 Watts	8
2485	Oven, Convection, Energy Star, Electric	12
2486	Oven, Convection, Energy Star, NG	12
2487	Oven, Rack Type, Gas, Double Compartment, High Efficiency	12
2488	Oven, Rack Type, Gas, Single Compartment, High Efficiency	12
2490	Plastics Equipment, Radiant Heater Band Retrofit	15
2494	PreRinse Sprayers, 0.65 GPM Ultra Low Flow- Electric NEW	5
2495	PreRinse Sprayers, 0.65 GPM Ultra Low Flow- Gas NEW	5
2496	Pressure Screen Rotor	15
2507	Radiant tube inserts installed in exhaust of radiant tube burners, Hybrid	5
2509	Open Multideck Cases Replaced by Reach-in Cases with Doors- NEW	15
2522	Refrigerator, Chest, Glass Door, 15-29 cu ft, Energy Star	12
2523	Refrigerator, Chest, Glass Door, 30-49 cu ft, Energy Star	12
2524	Refrigerator, Chest, Glass Door, 50+ cu ft, Energy Star	12
2525	Refrigerator, Chest, Solid Door, < 15 cu ft, Energy Star	12
2526	Refrigerator, Chest, Solid Door, 15-29 cu ft, Energy Star	12
2527	Refrigerator, Chest, Solid Door, 30-49 cu ft, Energy Star	12
2528	Refrigerator, Chest, Solid Door, 50+ cu ft, Energy Star	12
2529	Refrigerator, Vertical, Glass Door, < 15 cu ft, Energy Star	12
2530	Refrigerator, Vertical, Glass Door, 15-29 cu ft, Energy Star	12
2531	Refrigerator, Vertical, Glass Door, 30-49 cu ft, Energy Star	12
2532	Refrigerator, Vertical, Glass Door, 50+ cu ft, Energy Star	12
2533	Refrigerator, Vertical, Solid Door, < 15 cu ft, Energy Star	12
2534	Refrigerator, Vertical, Solid Door, 15-29 cu ft, Energy Star	12
2535	Refrigerator, Vertical, Solid Door, 30-49 cu ft, Energy Star	12
2536	Refrigerator, Vertical, Solid Door, 50+ cu ft, Energy Star	12
2538	Repulper Rotor	15
2556	T8 1L-4 ft Reduced Wattage with CEE Ballast - 25 Watts (Low BF)	15
2557	T8 1L-4 ft Reduced Wattage with CEE Ballast - 28 Watts (Low BF)	15
2558	T8 1L 4', 28W, CEE, BF > 0.78	15
2564	T8 2L-4 ft Reduced Wattage with CEE Ballast - 28 Watts (Low BF)	15
2565	T8 2L-4 ft Reduced Wattage with CEE Ballast - 28 Watts	15
2571	T8 3L-4 ft Low Watt with CEE Ballast - 25 Watts (Low BF)	15
2573	T8 3L-4 ft Reduced Wattage with CEE Ballast - 28 Watts (Low BF)	15
2574	T8 3L 4', 28W, CEE, BF > 0.78	15
2579	T8 4L-4 ft Reduced Wattage with CEE Ballast - 28 Watts (Low BF)	15
2580	T8 4L 4', 28W, CEE, BF > 0.78	15
2590	T8 Low Watt Relamp - 25 Watts	15

MMID	Measure Name	EUL
2591	T8 Low Watt Relamp - 28 Watts	15
2602	Thermal Curtain, Poly Film Walls and Ceiling, Under Bench Heating	5
2603	Thermal Curtain, Single Pane Glass Walls and Ceiling, Overhead Heating	5
2608	Unit Heater, >= 90% thermal efficiency, per input MBh, for retrofit	15
2611	Vending Machine Controls, Occupancy Based, Cold Beverage Machine	5
2612	Vending Machine Controls, Occupancy Based, Snack Machine	5
2613	Vending Machine Controls, Sales Based, Cold Beverage Machine	5
2621	Kitchen Hood Ventilation Controls, Temperature Only, Retrofit, BONUS for controlling MUA fan	10
2623	Kitchen Hood Ventilation Controls, Temperature Only, Retrofit, Exhaust Fan Controlled	10
2625	Kitchen Hood Ventilation Controls, Temp and Optical, Retrofit, BONUS for controlling MUA fan	10
2627	Kitchen Hood Ventilation Controls, Temp and Optical, Retrofit, Exhaust Fan Controlled	10
2635	Agricultural Exhaust Fan, High Efficiency - 55"	16
2637	Agricultural Exhaust Fan, High Efficiency - 60"	16
2639	VFD, Ag Second Use Water System	15
2640	VFD, Boiler Draft Fan	15
2641	VFD, Cooling Tower Fan	15
2643	VFD, HVAC Fan	15
2644	VFD, HVAC Heating Pump	15
2646	VFD, Pool Pump Motor	15
2647	VFD, Process Fan	15
2648	VFD Pump, Hybrid	15
2651	Storage Water Heater EF >0.67	10
2652	Water Heater, ≥ 0.82 EF, Tankless, Residential, Natural Gas	20
2660	Waterer, Livestock, <250 Watts	10
2665	T8 Reduced Wattage Relamp 8 ft - 54 Watts	15
2666	Air Cooled Chiller System Tune Up, Service Buy Down <=500 Tons	5
2667	Air Cooled Chiller System Tune Up, Service Buy Down>500 Tones	5
2668	Water Cooled Chiller System Tune Up, Service Buy Down <=500 Tons	5
2669	Water Cooled Chiller System Tune Up, Service Buy Down >500 Tons	5
2677	Hot Food Holding Cabinet, V = 13-28 cu. ft., Energy Star	12
2678	Hot Food Holding Cabinet, V < 13 cu. ft., Energy Star	12
2679	Hot Food Holding Cabinet, V ≥ 28 cu. ft., Energy Star	12
2699	PTHP <8,000 Btu/h	15
2700	PTHP ≥13,000 Btu/h	15

MMID	Measure Name	EUL
2701	PTHP 10,000–12,999 Btu/h	15
2702	PTHP 8,000–9,999 Btu/h	15
2711	Insulation, Project Based, Attic	35
2712	Insulation, Sidewall, Foam	25
2713	Insulation, Foundation - Interior	20
2714	Insulation, Sill Box	20
2726	VFD, Chilled Water Distribution Pump	15
2743	Boiler, Hot Water, Modulating, >=90% AFUE,≤300 MBH	20
2744	Boiler Tune Up	1
2745	Air Sealing	20
2746	Multifamily Benchmarking Incentive	Varies
2747	Boiler, ≥ 90% AFUE, NG	20
2756	Clothes Washer, ENERGY STAR Tier 3, Electric	11
2757	Clothes Washer, ENERGY STAR Tier 3, Gas	11
2760	Domestic Hot Water Plant Replacement	15
2764	Furnace, with ECM fan motor, for space heating (AFUE >= 95%)	18
2768	LED Exit Sign, Retrofit	10
2772	Steam Trap Radiator Repair or Replace	6
2810	ENGINE BLOCK HEATER TIMER	15
2819	Solar PV	25
2820	Ground Source Heat Pump, Electric Back-up	15
2820	Ground Source Heat Pump, Electric Back-Up	15
2821	Ground Source Heat Pump, NG Back-up	15
2821	Ground Source Heat Pump, Natural Gas Back-Up	15
2853	Demand Control Ventillation for AHU or Rooftop - NEW	10
2902	Water Heater, Power Vented, EF = .67-.82, Storage, NG	15
2955	Refrigerator Recycling	10
2956	Freezer Recycling	10
2989	ECM, Furnace, New or Replacement	18
2990	Furnace and A/C, ECM, 95%+ AFUE, ≥ 16 SEER	20 (furnace), 24 (AC)
2992	Air Source Heat Pump, >= 16 SEER	18
3016	Parking Garage Ventilation Controls	5
3018	Waterer, Livestock, Energy Free	10
3019	Lighting Fixture, Agricultural Daylighting <= 155 Watts	15
3020	Lighting Fixture, Agricultural Daylighting 156 - 250 Watts	15
3021	Lighting Fixture, Agricultural Daylighting 251 - 365 Watts	15
3022	Split System A/C	15

MMID	Measure Name	EUL
3045	Water Heater, High Usage, >=90% TE, NG	15
3046	Water Heater, High Usage, >= 0.82 EF, Tankless, NG	20
3047	Water Heater, High Usage, >= 2 EF, Heat Pump Storage, Electric	13
3066	Economizer, RTU Optimization	10
3084	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 320 Watt HID, Exterior	15
3091	LED Fixture, <155 Watts, Replacing 250 Watt HID, High Bay	9
3092	LED Fixture, <250 Watts, Replacing 320-400 Watt HID, High Bay	9
3093	LED Fixture, <250 Watts, Replacing 400 Watt HID, High Bay	12
3094	LED Fixture, <365 Watts, Replacing 400 Watt HID, High Bay	9
3095	LED Fixture, <500 Watts, Replacing 1000 Watt HID, High Bay	12
3096	LED Fixture, <800 Watts, Replacing 1000 Watt HID, High Bay	12
3097	LED Fixture, Bilevel, Stairwell and Passageway	8
3099	LED Fixture, Replacing 150-175 Watt HID, Exterior	13
3102	LED Fixture, Replacing 250 Watt HID, Exterior	13
3107	LED Fixture, Replacing 400 Watt HID, Exterior	13
3108	LED Fixture, Replacing 70-100 Watt HID, Exterior	13
3111	LED Troffer, 2x4, Replacing 4' 3-4 Lamp T8 Troffer	14
3112	LED, <= 40 Watt, ENERGY STAR, Replacing Incandescent	5
3113	LED, > 40 Watt, ENERGY STAR, Replacing Incandescent	5
3114	LED, Horizontal Case Lighting	7
3118	Oven, Combination, Energy Star, Electric	12
3119	Oven, Combination, Energy Star, NG	12
3121	Programmable Thermostat, RTU Optimization Standard	8
3122	T8 2L 4', HPT8 or RWT8, Replacing T12 1L 8', 0.78 < BF < 1.00	15
3123	T8 2L 4', HPT8 or RWT8, Replacing T12 1L 8', BF <= 0.78	15
3124	T8 2L 4', HPT8 or RWT8, Replacing T12HO 1L 8', 0.78 < BF < 1.00	15
3125	T8 2L-4ft High Performance HBF Replacing T12HO 1L-8 ft	15
3126	T8 2L 4', HPT8 or RWT8, Replacing T12HO 1L 8', BF > 1.00	15
3127	T8 4L-4-4ft High Performance Replacing T12 2L-8 ft	15
3128	T8 4L 4', HPT8 or RWT8, Replacing T12 2L 8', BF <= 0.78	15
3129	T8 4L-4ft High Performance Replacing T12HO 2L-8 ft -	15
3130	T8 4L 4', HPT8 or RWT8, Replacing T12HO 2L 8', BF <= 0.78	15
3131	T8 4L 4', HPT8 or RWT8, Replacing T12HO 2L 8', BF > 1.00	15
3132	T8 4L-4ft High Performance Replacing T12HO/VHO 2L-8 ft	15
3133	T8 4L 4', HPT8 or RWT8, Replacing T12VHO 2L 8', BF <= 0.78	15
3134	T8 4L 4', HPT8 or RWT8, Replacing T12VHO 2L 8', BF > 1.00	15
3136	Dishwasher, High Temp, Electric Booster, Pots/Pans Type, Energy Star, Electric	10
3137	Dishwasher, High Temp, Electric Booster, Pots/Pans Type, Energy Star, NG	10

MMID	Measure Name	EUL
3138	Dishwasher, High Temp, Gas Booster, Pots/Pans Type, Energy Star, NG	10
3148	T8 2L 4', HPT8 or RWT8, Replacing T12HO 1L 8', BF > 1.00, Parking Garage	15
3152	T8 4L 4', HPT8 or RWT8, Replacing T12HO 2L 8', 0.78 < BF < 1.00, Parking Garage	15
3153	T8 4L 4', HPT8 or RWT8, Replacing T12HO 2L 8', BF <= 0.78, Parking Garage	15
3157	LED, Porch Fixture, Energy Star	20
3159	LED, Energy Star, Replacing Incandescent > 40W, In Unit	15
3160	LED, Energy Star, Replacing Incandescent > 40W, Common Area	4
3183	Strip Curtain, Walk-In Freezers and Coolers	4
3195	Linear Fluorescent, 2L 4’RWT8 Replacements, 24 Hours, CALP	15
3196	T8 2L-4ft High Performance Tandem Replacing T12 2L-8ft	15
3201	Occupancy Sensor, Wall or Ceiling Mount <=200 Watts, CALP	8
3244	Process Exhaust Filtration	15
3251	Lighting Controls, Bilevel, Exterior and Parking Garage Fixtures, Dusk to Dawn	8
3252	Lighting Controls, Bilevel, Parking Garage Fixtures, 24 Hour	8
3253	Lighting Controls, Photocell with Internal Timer or Wireless Schedule, Exterior	8
3266	Demand Control Ventilation, RTU Optimization	15
3275	Boiler Plant Retrofit, Hybrid Plant, >=1 MMBh	20
3276	Boiler, Hot Water, Condensing, >=90% AFUE, >=300 mbh	20
3277	Boiler, Hot Water, Near Condensing, >=85% AFUE, >=300 mbh	20
3280	VFD, Constant Torque	15
3320	Delamping, T12 to T8, 8', SBP A La Carte	10
3386	Grain Dryer, Energy Efficient, Hybrid	20
3393	LED Fixture,<=180 Watts, Replacing 4 lamp T5 or 6 lamp T8, High Bay, DLC Listed	20
3394	LED Fixture, Downlights, <=18 Watts, Replacing 1 lamp pin based CFL Downlight	10
3400	LED Fixture, 2x2, Low Output, DLC Listed	11
3401	LED Fixture, 2x2, High Output, DLC Listed	11
3403	LED Lamp, Energy Star, Replacing Incandescent Lamp >40 Watts, Exterior	5
3404	LED Fixture, Downlights, >18 Watts, Replacing Incandescent Downlight, Exterior	11
3405	LED Fixture, Downlights, <=18 Watts, Replacing Incandescent Downlight, Exterior	11
3406	Daylighting Controls	8
3409	Retrofit Open Refrigerated Cases with Doors	12
3440	NG Furnace with ECM, 97%+ AFUE	20
3491	Furnace with ECM, ≥95%+ AFUE, NG	18
3492	Furnace with ECM, ≥90%+ AFUE, NG	18
3493	Parking Garage Ventilation Controls with Heating	5
3494	Variable Speed ECM Pump, < 100 Watts Max Input, Domestic Hot Water Recirculation	15

MMID	Measure Name	EUL
3495	Variable Speed ECM Pump, 100 - 500 Watts Max Input, Domestic Hot Water Recirculation	15
3497	Variable Speed ECM Pump, < 100 Watts Max Input, Heating Water Circulation	15
3498	Variable Speed ECM Pump, 100 - 500 Watts Max Input, Heating Water Circulation	15
3499	Variable Speed ECM Pump, > 500 Watts Max Input, Heating Water Circulation	15
3502	Variable Speed ECM Pump, > 500 Watts Max Input, Cooling Water Circulation	15
3504	Variable Speed ECM Pump, 100 - 500 Watts Max Input, Water Loop Heat Pump Circulation	15
3505	Variable Speed ECM Pump, > 500 Watts Max Input, Water Loop Heat Pump Circulation	15
3511	LED Replacement of 4’ T8 Lamps w/Integral or External Driver	11
3512	LED Replacement of 4’ T8 Lamps utilizing existing ballast	11
3513	ENERGY STAR Fluorescent Porch Fixtures	7
3548	CFL, Standard Bulb, 310-749 Lumens, Retail Store Markdown	8
3549	CFL, Standard Bulb, 750-1049 Lumens, Retail Store Markdown	8
3550	CFL, Standard Bulb, 1050-1489 Lumens, Retail Store Markdown	8
3551	CFL, Standard Bulb, 1490-2600 Lumens, Retail Store Markdown	8
3552	CFL, Reflector, 15 watt, Retail Store Markdown	8
3553	LED, Omnidirectional, 310-749 Lumens, Retail Store Markdown	15
3557	LED, Reflector, 12 watt, Retail Store Markdown	15
3559	Boiler, 95%+ AFUE, With DHW, NG	20
3584	Condensing Water Heater, NG, 90%+, Claim Only	13
3585	Water Heater, Indirect, Claim Only	15
3586	Water Heater, Electric, EF of 0.93 or greater, Claim Only	15
3587	Water Heater, >= 0.67 EF, Storage, NG, Claim Only	10
3588	Water Heater, >= 0.82 EF, Tankless, Residential, NG, Claim Only	13
3603	LED Fixture, Interior, 12 Hours, CALP	11
3604	LED Fixture, Interior, 24 Hours, CALP	6
3605	Occupancy Sensor, Fixture Mount, <=200 Watts, CALP	8
3606	Occupancy Sensor, Fixture Mount, >200 Watts, CALP	8
3612	Smart Thermostat, Installed with 95% AFUE NG Furnace	10
3613	Smart Thermostat, Installed with 95% AFUE NG Boiler	10
3614	Smart Thermostat, Installed with Furnace and A/C	10
3615	Smart Thermostat, Installed with Air Source Heat Pump	10
3619	Occupancy Sensor, Fixture Mount, ≤ 60 Watts, SBP Package	8
3621	Occupancy Sensor, Fixture Mount, ≤ 60 Watts, SBP After A La Carte	8
3632	HVAC Controls, Surgery Occupancy	5
3652	DEET, Savings Period 1	4

MMID	Measure Name	EUL
3653	DEET, Savings Period 2	4
3654	DEET, Savings Period 3	4
3655	DEET, Savings Period 4	4
3656	DEET, Savings Period 5	4
3657	DEET, Savings Period 6	4
3658	DEET, Savings Persistence	4
3659	Chiller Plant Chilled Water Setpoint Adjustment	5
3660	Chiller Plant Condenser Water Setpoint Adjustment	5
3661	Economizer Optimization	5
3662	Hot Water Supply Reset	5
3663	Outside Air Intake Optimization	5
3672	Supply Air Temperature Reset, Heating	5
3673	Supply Air Temperature Reset, Cooling	5
3674	Temperature Sensor Calibration	5
3675	Valve Repair, Chilled Water	5
3676	Valve Repair, Hot Water	5
3677	VFD Fan Motor Control Restoration	5
3678	VFD Pump Control Restoration	5
3679	LP Furnace with ECM, 90%+ AFUE (Existing)	20
3680	Spring-loaded Garage Door Hinge, 55 Degree Indoor Temperature Setpoint	20
3681	Spring-loaded Garage Door Hinge, 60 Degree Indoor Temperature Setpoint	20
3682	Spring-loaded Garage Door Hinge, 65 Degree Indoor Temperature Setpoint	20
3683	Spring-loaded Garage Door Hinge, 70 Degree Indoor Temperature Setpoint	20
3684	Water Heater, High Usage, ≥90% TE, K-12 School	15
3685	Insulation, 1/2" and 3/4" Pipe, Hot Water Space Heat, Natural Gas	15
3686	Insulation, 1" and 1 1/4" Pipe, Hot Water Space Heat, Natural Gas	15
3687	Insulation, 1 1/2" and 2" Pipe Hot Water Space Heat, Natural Gas	15
3688	Insulation, 3" and 4" Pipe, Hot Water Space Heat, Natural Gas	15
3689	Insulation, 1/2" and 3/4" Pipe, Hot Water Space Heat, Electric	15
3690	Insulation, 1" and 1 1/4" Pipe, Hot Water Space Heat, Electric	15
3691	Insulation, 1 1/2" and 2" Pipe Hot Water Space Heat, Electric	15
3692	Insulation, 3" and 4" Pipe, Hot Water Space Heat, Electric	15
3693	Single package vertical HVAC unit, ≥90%+ Thermal Efficiency, ≥10.0 EER Cooling, NG	23
3694	Single package vertical HVAC unit, ≥90%+ Thermal Efficiency, NG	23
3695	Insulation, 1/2" and 3/4" Pipe, Domestic Hot Water, Natural Gas	15
3696	Insulation, 1" and 1 1/4" Pipe, Domestic Hot Water, Natural Gas	15
3697	Insulation, 1 1/2" and 2" Pipe, Domestic Hot Water, Natural Gas	15

MMID	Measure Name	EUL
3698	Insulation, 3" and 4" Pipe, Domestic Hot Water, Natural Gas	15
3699	Insulation, 1/2" and 3/4" Pipe, Domestic Hot Water, Electric	15
3700	Insulation, 1" and 1 1/4" Pipe, Domestic Hot Water, Electric	15
3701	Insulation, 1 1/2" and 2" Pipe, Domestic Hot Water, Electric	15
3702	Insulation, 3" and 4" Pipe, Domestic Hot Water, Electric	15
3703	Insulation, Wall, NG heat with Cooling	25
3704	Insulation, Wall, NG heat without Cooling	25
3705	Insulation, Wall, Electric heat with Cooling	25
3706	Insulation, Wall, Electric heat without Cooling	25
3707	Insulation, Attic, NG heat with Cooling, Existing Insulation ≤R-11	25
3708	Insulation, Attic, NG heat without Cooling, Existing Insulation ≤R-11	25
3709	Insulation, Attic, NG heat with Cooling, Existing Insulation R-12 to R-19	25
3710	Insulation, Attic, NG heat without Cooling, Existing Insulation R-12 to R-19	25
3711	Insulation, Attic, Electric heat with Cooling, Existing Insulation ≤R-11	25
3712	Insulation, Attic, Electric heat without Cooling, Existing Insulation ≤R-11	25
3713	Insulation, Attic, Electric heat with Cooling, Existing Insulation R-12 to R-19	25
3714	Insulation, Attic, Electric heat without Cooling, Existing Insulation R-12 to R-19	25
3735	LED Fixture, Exterior, 12 Hours, CALP	11
3738	LED Fixture, Linear Ambient, Replacing 1 or 2 T5 lamp(s) in Cross Section	11
3739	LED Fixture, Linear Ambient, Replacing 3 or 4 T5 lamps in Cross Section	11
3740	LED Fixture, Linear Ambient, Replacing 1 or 2 T8/T12 lamp(s) in Cross Section	11
3741	LED Fixture, Linear Ambient, Replacing 3 or 4 T8/12 lamps in Cross Section	11
3742	LED Lamp, Energy Star, Replacing ≥ 23 Watt CFL	5
3743	LED Lamp, Energy Star, Replacing ≥ 23 Watt CFL, Common Area	4
3744	LED Lamp, Energy Star, Replacing ≥ 23 Watt CFL, In Unit	15
3745	LED Lamp, Energy Star, Replacing < 23 Watt CFL	5
3747	LED Lamp, Energy Star, Replacing < 23 Watt CFL, In Unit	15
3749	LED Fixture, Downlight, > 18 Watts	10
3751	Insulation, 1/2" and 3/4" Pipe, Steam Space Heat, Natural Gas	15
3752	Insulation, 1" and 1 1/4" Pipe, Steam Space Heat, Natural Gas	15
3753	Insulation, 1 1/2" and 2" Pipe, Steam Space Heat, Natural Gas	15
3754	Insulation, 3" and 4" Pipe, Steam Space Heat, Natural Gas	15
3755	Insulation, 1/2" and 3/4" Pipe, Steam Space Heat, Electric	15
3756	Insulation, 1" and 1 1/4" Pipe, Steam Space Heat, Electric	15
3757	Insulation, 1 1/2" and 2" Pipe, Steam Space Heat, Electric	15
3758	Insulation, 3" and 4" Pipe, Steam Space Heat, Electric	15
3759	LED Replacement of 4’ T8 Lamps, Direct Wire	11
3760	LED Troffer, 1x4, Replacing 4' 1-2 Lamp T8 Troffer	11

MMID	Measure Name	EUL
3761	A/C Split or Packaged System, High Efficiency, Multifamily	15
3767	Circulation Fan, HS/HE, 36"-47", Ag	15
3768	Circulation Fan, HS/HE, 48"-52", Ag	15
3769	Circulation Fan, HS/HE, ≥ 53", Ag	15
3770	Ventilation Fan, HS/HE, 24"-35", Ag	16
3771	Ventilation Fan, HS/HE, 36"-47", Ag	16
3772	Ventilation Fan, HS/HE, 48"-52", Ag	16
3773	Ventilation Fan, HS/HE, ≥ 53", Ag	16
3776	VFD, Variable Torque, Irrigation Well Pump	15
3777	VFD, High Speed Ventilation/Circulation Fan, Ag	15
3778	Boiler, Tier 2, 95%+ AFUE, With DHW, NG	20
3779	Furnace and A/C, Tier 2, ECM, 95% + AFUE, ≥ 16 SEER	20 (furnace), 24 (AC)
3780	Hot Water Boiler, Tier 2, 95%+ AFUE	20
3781	LP Furnace with ECM, Tier 2, 90%+ AFUE (Existing)	20
3782	NG Furnace with ECM, Tier 2, 95%+ AFUE (Existing)	20
3783	NG Furnace, Tier 2, 95%+ AFUE	20
3784	Water Heater, Indirect, Tier 2	15
3785	Insulation, Tier 2, Project Based, Attic	35
3786	Insulation, Tier 2, Project Based, Foundation	20
3787	Insulation, Tier 2, Project Based, Sillbox	20
3788	Insulation, Tier 2, Project Based, Wall	25
3799	T8 2L 4', HPT8, CEE, BF <= 0.78, Agriculture	15
3801	T8 2L 4', HPT8 or RWT8, Replacing T12HO 1L 8', 0.78 < BF < 1.00, Agriculture	15
3802	T8 2L 4', HPT8 or RWT8, Replacing T12HO 1L 8', BF > 1.00, Agriculture	15
3803	T8 4L 4', HPT8 or RWT8, Replacing T12 2L 8', 0.78 < BF < 1.00, Agriculture	15
3804	T8 4L 4', HPT8 or RWT8, Replacing T12HO 2L 8', 0.78 < BF < 1.00, Agriculture	15
3805	T8 4L 4', HPT8 or RWT8, Replacing T12HO 2L 8', BF > 1.00, Agriculture	15
3806	LED Fixture, <155 Watts, Replacing 250 Watt HID, High Bay, Agriculture	14
3807	LED Fixture, <250 Watts, Replacing 400 Watt HID, High Bay, Agriculture	14
3809	LED Fixture,<=180 Watts, Replacing 4 lamp T5 or 6 lamp T8, High Bay, DLC Listed, Agriculture	11
3810	LED Fixture, <250 Watts, Replacing 320-400 Watt HID, High Bay, Agriculture	14
3811	T8 4L Replacing 250-399 W HID, Agriculture	14
3812	T8 6L Replacing 400-999 W HID, Agriculture	14
3813	T5HO 4L Replacing 400-999 W HID, Agriculture	14
3814	T5HO 6L Replacing 400-999 W HID, Agriculture	14
3815	Induction, PSMH/CMH, Replacing 250 Watt HID, High Bay	15

MMID	Measure Name	EUL
3816	Induction, PSMH/CMH, <=250 Watt, Replacing 320-400 Watt HID, High Bay, Agriculture	15
3817	Induction, PSMH/CMH, <=250 Watt, Replacing 400 Watt HID, High Bay, Agriculture	15
3819	LED Fixture, Downlights, ≤18 Watts, Agriculture	10
3820	LED Fixture, Downlights, > 18 Watts, Agriculture	10
3821	LED, > 40 Watt, ENERGY STAR, Replacing Incandescent, Agriculture	5
3822	LED Replacement of 4’ T8 Lamps w/Integral or External Driver, Agriculture	11
3823	LED Replacement of 4’ T8 Lamps utilizing existing ballast, Agriculture	11
3824	LED Fixture, Replacing 150-175 Watt HID, Exterior, Agriculture	13
3825	LED Fixture, Replacing 250 Watt HID, Exterior, Agriculture	13
3826	LED Fixture, Replacing 320-400 Watt HID, Exterior, Agriculture	13
3827	LED Fixture, Replacing 400 Watt HID, Exterior, Agriculture	13
3828	LED Fixture, Replacing 70-100 Watt HID, Exterior, Agriculture	13
3829	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 150-175 Watt HID, Exterior, Agriculture	15
3830	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 250 Watt HID, Exterior, Agriculture	15
3831	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 320-400 Watt HID, Exterior, Agriculture	15
3832	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 400 Watt HID, Exterior, Agriculture	15
3833	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 70-100 Watt HID, Exterior, Agriculture	15
3834	Lighting Controls, Photocell with Internal Timer or Wireless Schedule, Exterior, Agriculture	8
3835	VFD, Process Pump, Agriculture	15
3836	VFD, Constant Torque, Agriculture	15
3837	LED Lamp, Energy Star, Replacing ≥ 23 Watt CFL, Agriculture	5
3838	LED Lamp, Energy Star, Replacing < 23 Watt CFL, Agriculture	5
3839	LED Replacement of 4’ T8 Lamps, Direct Wire, Agriculture	11
3842	Air Sealing, Tier 2, Project Based	20
3861	LED, 10 Watt, Pack-based	15
3862	Faucet Aerator, Kitchen, 1.5 GPM, Pack-based	10
3863	Faucet Aerator, Bathroom, 1.0 GPM, Pack-based	10
3868	Natural Gas Furnace with ECM: 96% + AFUE	20
3869	Natural Gas Furnace with ECM: 98% + AFUE	20
3870	Natural Gas Furnace with ECM: Tier 2, 96% + AFUE	20

MMID	Measure Name	EUL
3871	Natural Gas Furnace with ECM: Tier 2, 97% + AFUE	20
3872	Natural Gas Furnace with ECM: Tier 2, 98% + AFUE	20
3874	Ductless Mini-Split, Replacing Electric Resistance and CAC	18
3875	Ductless Mini-Split, Replacing Electric Resistance and Room AC	18
3876	Ductless Mini-Split, Replacing Electric Furnace and CAC	18
3877	Ductless Mini-Split, Replacing Electric Resistance and No AC	18
3891	Ductless Mini-Split, Replacing Electric Resistance and CAC, Tier 2	18
3892	Ductless Mini-Split, Replacing Electric Resistance and Room AC, Tier 2	18
3893	Ductless Mini-Split, Replacing Electric Furnace and CAC, Tier 2	18
3894	Ductless Mini-Split, Replacing Electric Resistance and No AC, Tier 2	18
3895	Advanced Power Strip Pack-Based, APS Tier 1	6
3896	LED, Pack-based, 5 Watt, G25	15
3897	LED, Pack-based, 10 Watt, BR30	15
3903	LED Signage Retrofit, Interior	11
3904	LED Signage Retrofit, Exterior	11
3906	ENERGY STAR® Commercial Ice Machine, Ice Making Head	10
3907	ENERGY STAR® Commercial Ice Machine, Remote Condensing Unit	10
3908	ENERGY STAR® Commercial Ice Machine, Self-Contained Unit	10
3909	A/C Split System, Condensing Unit Only, High Efficiency	15
3910	ECM HVAC Fan Motors, Heating	18
3911	ECM HVAC Fan Motors, Cooling	18
3912	ECM HVAC Fan Motors, Occupied Ventilation	18
3913	ECM HVAC Fan Motors, 24/7 Ventilation	18
3916	Natural Gas Furnace Tune-Up, Small Business	2
3928	Vacuum Pump Heat Recovery, Space Heating	13
3929	LED Lamp, ENERGY STAR, Replacing Exterior Directional CFL, ≥ 23W CFL	6
3930	LED Lamp, ENERGY STAR, Replacing Exterior Directional CFL, 14W-22W CFL	6
3931	LED Lamp, ENERGY STAR, Replacing Exterior Directional CFL, ≤ 13W	6
3932	LED Lamp, ENERGY STAR, Replacing Interior Directional CFL, ≥ 23W CFL	6
3933	LED Lamp, ENERGY STAR, Replacing Interior Directional CFL, 14W-22W CFL	6
3934	LED Lamp, ENERGY STAR, Replacing Interior Directional CFL, ≤ 13W	6
3935	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, 120W – 250W Incandescent	6
3936	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, 100W – 119W Incandescent	6
3937	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, 75W – 99W Incandescent	6

MMID	Measure Name	EUL
3938	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, 55W – 74W Incandescent	6
3939	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, 36W – 54W Incandescent	6
3940	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, ≤ 35W Incandescent	6
3941	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, 120W – 250W	6
3942	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, 100W – 119W	6
3943	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, 75W – 99W	6
3944	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, 55W – 74W	6
3945	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, 36W – 54W	6
3946	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, ≤ 35W	6
3947	LED Lamp, ENERGY STAR, 1,600 – 1,999 Lumens, Exterior	5
3948	LED Lamp, ENERGY STAR, 1,100 – 1,599 Lumens, Exterior	5
3949	LED Lamp, ENERGY STAR, 800 – 1,099 Lumens, Exterior	5
3950	LED Lamp, ENERGY STAR, 450 – 799 Lumens, Exterior	5
3951	LED Lamp, ENERGY STAR, 250 – 449 Lumens, Exterior	5
3952	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 1,600 – 1,999 Lumens	5
3953	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 1,100 – 1,599 Lumens	5
3954	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 800 – 1,099 Lumens	5
3955	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 450 – 799 Lumens	5
3956	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 250 – 449 Lumens	5
3957	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 1,600 – 1,999 Lumens, in unit	15
3958	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 1,100 – 1,599 Lumens, in unit	15
3959	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 800 – 1,099 Lumens, in unit	15

MMID	Measure Name	EUL
3960	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 450 – 799 Lumens, in unit	15
3961	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 250 – 449 Lumens, in unit	15
3962	LED Lamp, DLC, High/Low-Bay Mogul Screw-Base (E39)	13
3963	LED Lamp, DLC, Mogul Screw-Base (E39), Exterior	13
3964	Advanced Rooftop Unit Controller	10
3965	NLC Low Lumen Tier	16
3966	NLC High Lumen Tier	16
3967	LED Fixture, Interior, 12+ Hours, CALP	8
3968	LED Fixture, Exterior, CALP	11
3969	Lighting Controls, Interior, CALP	8
3975	Dairy Scroll Compressor Replacement with Pre-Cooler and VFD Milk Pump	15
3976	Dairy Scroll Compressor Replacement with Pre-Cooler	15
3977	Dairy Scroll Compressor Replacement without Pre-Cooler	15
3978	Occupancy Sensor, On/Off, High Bay, General	8
3979	Bi Level Controls, High Bay Fixtures, General	8
3982	Plate Heat Exchanger and Well Water Pre-Cooler (<135 Milking Cows)	15
3983	Plate Heat Exchanger and Well Water Pre-Cooler (>=135 Milking Cows)	15
3984	Refrigeration System Tune-Up Without Milk Pre-Cooler	5
3985	Refrigeration System Tune-Up With Milk Pre-Cooler	5
3986	Refrigeration System Tune-Up With Milk Pre-Cooler and VFD Milk Pump	5
3987	Agriculture, VFD, Vacuum Pump	15
3988	VFD, Dairy Milk Pump, Agriculture	15
3989	Natural Gas WH With milk Pre-cooler &Milk Pump VFD	15
3990	Natural Gas WH With milk Pre-cooler	15
3991	Natural Gas WH Without milk Pre-cooler	15
3992	Electric WH With milk Pre-cooler &Milk Pump VFD	15
3993	Electric WH With milk Pre-cooler	15
3994	Electric WH Without milk Pre-cooler	15
3995	Natural Gas to Natural Gas Commercial Water Heater Storage	15
3996	Electric to Electric Commercial Water Heater (<150 Milking Cows)	15
3997	Electric to Electric Commercial Water Heater (≥150 Milking Cows)	15
3998	Fans, High Volume Low Speed (HVLS), General	15
3999	Steam Trap Repair, < 10 psig, Industrial	6
4000	Steam Trap Repair, Industrial, 10-49 psig	6
4001	Steam Trap Repair, Industrial, 50-124 psig	6
4002	Steam Trap Repair, Industrial, 125-225 psig	6

MMID	Measure Name	EUL
4003	Steam Trap Repair, Industrial, >225 psig	6
4004	Steam Trap Repair, <10 psig, General Heating, Prescriptive: 7/32” or Smaller	6
4005	Steam Trap Repair, <10 psig, General Heating, Prescriptive: 1/4”	6
4006	Steam Trap Repair, <10 psig, General Heating, Prescriptive: 5/16”	6
4007	Steam Trap Repair, <10 psig, General Heating, Prescriptive: 3/8” or Larger	6
4008	Steam Trap Repair, 10-49 psig, General Heating, Prescriptive: 7/32” or Smaller	6
4009	Steam Trap Repair, 10-49 psig, General Heating, Prescriptive: 1/4”	6
4010	Steam Trap Repair, 10-49 psig, General Heating, Prescriptive: 5/16”	6
4011	Steam Trap Repair, 10-49 psig, General Heating, Prescriptive: 3/8” or Larger	6
4012	Steam Trap Repair, 50-124 psig, General Heating, Prescriptive: 7/32” or Smaller	6
4013	Steam Trap Repair, 50-124 psig, General Heating, Prescriptive: 1/4”	6
4014	Steam Trap Repair, 50-124 psig, General Heating, Prescriptive: 5/16”	6
4015	Steam Trap Repair, 50-124 psig, General Heating, Prescriptive: 3/8” or Larger	6
4016	Steam Trap Repair, 125-225 psig, General Heating, Prescriptive: 7/32” or Smaller	6
4017	Steam Trap Repair, 125-225 psig, General Heating, Prescriptive: 1/4”	6
4018	Steam Trap Repair, 125-225 psig, General Heating, Prescriptive: 5/16”	6
4019	Steam Trap Repair, 125-225 psig, General Heating, Prescriptive: 3/8” or Larger	6
4020	Steam Trap Repair, > 225 psig, General Heating, Prescriptive: 7/32” or Smaller	6
4021	Steam Trap Repair, > 225 psig, General Heating, Prescriptive: 1/4”	6
4022	Steam Trap Repair, > 225 psig, General Heating, Prescriptive: 5/16”	6
4023	Steam Trap Repair, > 225 psig, General Heating, Prescriptive: 3/8” or Larger	6
4024	LED Lamp, ENERGY STAR, Replacing Interior Directional CFL, ≥ 23W CFL, In Unit	15
4025	LED Lamp, ENERGY STAR, Replacing Interior Directional CFL, 14W-22W CFL, In Unit	15
4026	LED Lamp, ENERGY STAR, Replacing Interior Directional CFL, ≤ 13W CFL, In Unit	15
4027	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, 120W – 250W Incandescent, In Unit	15
4028	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, 100W – 119W Incandescent, In Unit	15
4029	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, 75W – 99W Incandescent, In Unit	15
4030	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, 55W – 74W Incandescent, In Unit	15
4031	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, 36W – 54W Incandescent, In Unit	15
4032	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, ≤ 35W Incandescent, In Unit	15
4033	Soundbar, ENERGY STAR	7

MMID	Measure Name	EUL
4034	Room Air Cleaner, ENERGY STAR	9
4035	Room Air Conditioner, ENERGY STAR	9
4036	Freezer, Chest, ENERGY STAR	11
4037	Freezer, Upright, ENERGY STAR	11
4038	Electric Clothes Dryer, ENERGY STAR	12
4039	Natural Gas Clothes Dryer, ENERGY STAR	12
4042	LED, Pack-Based, 5 Watt, B11	15
4043	VFD, Agriculture Primary Use Water System	15
4052	TLED Trial, Replacement of 4' T8 Lamps utilizing existing ballast	12
4054	Smart Thermostat, Installed with Smart Thermostat, Installed with 96% AFUE NG Furnace	10
4055	Smart Thermostat, Installed with 97% AFUE NG Furnace	10
4056	Smart Thermostat, Installed with 98% AFUE NG Furnace	10
4108	Heat Pump Water Heater	13
4120	Advanced Power Strip Pack-Based, APS Tier 2	6
4262	DEET, V2.0, Year 1	4
4263	DEET, V2.0, Year 2	4
4264	DEET, V2.0, Year 3	4
4265	DEET, V2.0, Year 4	4
4271	DHW Temperature Turn Down, Pack Based, Blended Natural Gas & Electric	15
4272	Insulation, DHW Pipe, Pack-based	15
4273	Showerhead, Handheld, 1.5 GPM, Pack-based	10
4274	Showerhead, Upgraded, 1.5 GPM, Pack-based	10
4275	Advanced Power Strip Retail, APS Tier 1	6
4276	LED, Pack-Based, 8 Watt BR30	15
4277	LED, Pack-Based, 9 Watt	15
4278	LED, Pack-Based, 11 Watt	15
4280	LED, Exterior Fixture, Low Output, <= 4,999 lumens	13
4281	LED, Exterior Fixture, Mid Output, 5,000-9,999 lumens	13
4282	LED, Exterior Fixture, High Output, 10,000-29,999 lumens	13
4283	LED, Exterior Fixture, Very High Output, >= 30,000 lumens	13
4284	Permanent Magnet Synchronous (PMS) Evaporator Fan Motor, Refrigerated Case, Replacement	15
4286	Circulation Fan, HS/HE, 36”-47”, Ag	15
4287	Circulation Fan, HS/HE, 36”-47”, Ag	15
4288	Circulation Fan, HS/HE, 48”-52”, Ag	15
4289	Circulation Fan, HS/HE, 48”-52”, Ag	15
4290	Circulation Fan, HS/HE, ≥53”, Ag	15

MMID	Measure Name	EUL
4291	Circulation Fan, HS/HE, ≥53”, Ag	15
4292	Ventilation Fan, HS/HE, 36”-47”, Ag	16
4293	Ventilation Fan, HS/HE, 36”-47”, Ag	16
4294	Ventilation Fan, HS/HE, 48”-52”, Ag	16
4295	Ventilation Fan, HS/HE, 48”-52”, Ag	16
4296	Ventilation Fan, HS/HE, ≥53”, Ag	16
4297	Ventilation Fan, HS/HE, ≥53”, Ag	16
4298	Communicating Thermostat, Existing Natural Gas Boiler	10
4299	Communicating Thermostat, Existing Natural Gas Furnace	10
4300	Communicating Thermostat, Existing Natural Gas Boiler	10
4301	Smart Thermostat, Existing Natural Gas Boiler	10
4302	Smart Thermostat, Existing Natural Gas Furnace	10
4303	Smart Thermostat, Existing Air-Source Heat Pump	10
4304	Smart Thermostat, Pack-Based	10
4305	Communicating Thermostat, Pack-Based	10
4306	LED, Reflector, 12 Watt, Retail Store Markdown, Long Lifetime	17
4307	LED, Omnidirectional, 310-749 Lumens, Long Lifetime, Retail Store Markdown	17
4308	LED, Omnidirectional, 750-1,049 Lumens, Retail Store Markdown	15
4309	LED, Omnidirectional, 750-1,049 Lumens, Long Lifetime, Retail Store Markdown	17
4310	LED, Omnidirectional, 1,050-1,489 Lumens, Retail Store Markdown	15
4311	LED, Omnidirectional, 1,050-1,489 Lumens, Long Lifetime, Retail Store Markdown	17
4312	LED, Omnidirectional, 1,490-2,600 Lumens, Retail Store Markdown	15
4313	LED, Omnidirectional, 1,490-2,600 Lumens, Long Lifetime, Retail Store Markdown	17
4314	4FT Linear LED 2L, Replacing 8FT 1L T8 or T12	12
4315	4FT Linear LED 2L, Replacing 8FT 1L T8 or T12, Exterior	12
4316	4FT Linear LED 2L, Replacing 8FT 1L T8 or T12, 24/7	6
4317	4FT Linear LED 2L, Replacing 8FT 1L T8HO or T12HO	12
4318	4FT Linear LED 2L, Replacing 8FT 1L T8HO or T12HO, Exterior	12
4319	4FT Linear LED 2L, Replacing 8FT 1L T8HO or T12HO, 24/7	6
4320	4FT Linear LED 4L, Replacing 8FT 2L T8 or T12	12
4321	4FT Linear LED 4L, Replacing 8FT 2L T8 or T12, Exterior	12
4322	4FT Linear LED 4L, Replacing 8FT 2L T8 or T12, 24/7	6
4323	4FT Linear LED 4L, Replacing 8FT 2L T8HO or T12HO	12
4324	4FT Linear LED 4L, Replacing 8FT 2L T8HO or T12HO, Exterior	12
4325	4FT Linear LED 4L, Replacing 8FT 2L T8HO or T12HO, 24/7	6
4326	4FT Linear LED 2L, Replacing 8FT 2L T8 or T12	12
4327	4FT Linear LED 2L, Replacing 8FT 2L T8 or T12, Exterior	12
4328	4FT Linear LED 2L, Replacing 8FT 2L T8 or T12, 24/7	6

MMID	Measure Name	EUL
4329	4FT Linear LED 2L, Replacing 8FT 2L T8HO or T12HO	12
4330	4FT Linear LED 2L, Replacing 8FT 2L T8HO or T12HO, Exterior	12
4331	4FT Linear LED 2L, Replacing 8FT 2L T8HO or T12HO, 24/7	6
4332	LED Fixture, 2x2, Low Output w/LLLC, DLC Listed	11
4333	LED Fixture, 2x2, High Output w/LLLC, DLC Listed	11
4334	LED Troffer, 1x4, Replacing 4' 1-2 Lamp T8 Troffer w/LLLC	11
4335	LED Troffer, 2x4, Replacing 4' 3-4 Lamp T8 Troffer w/LLLC	11
4336	Interior New Construction Lighting LPD ≥ 20% below code	15
4337	Interior New Construction Lighting LPD ≥ 30% below code	15
4338	Interior New Construction Lighting LPD ≥ 40% below code	15
4339	ELO, LED, Fixture, Low Output, ≤4,999 lumens	12
4340	ELO, LED, Fixture, Low Output, ≤4,999 lumens w/NLC	20
4341	ELO, LED, Fixture, Mid Output, 5,000-9,999 lumens	12
4342	ELO, LED, Fixture, Mid Output, 5,000-9,999 lumens w/NLC	20
4343	ELO, LED, Fixture, High Output, 10,000-29,999 lumens	12
4344	ELO, LED, Fixture, High Output, 10,000-29,999 lumens w/NLC	20
4345	ELO, LED, Fixture, Very High Output, ≥ 30,000 lumens	12
4346	ELO, LED, Fixture, Very High Output, ≥ 30,000 lumens w/NLC	20
4347	LED Fixture, ≤250 Watts, Replacing 8-lamp T8 or 6-lamp T5HO, High Bay	20
4348	LED Replacement of 4-Foot T8 Lamps Utilizing Existing Ballast, Exterior	11
4349	LED Replacement of 4-Foot T8 Lamps Utilizing Existing Ballast, Exterior, 24/7	11
4350	LED Replacement of 4-Foot T8 Lamps, Direct Wire, Exterior	15
4351	LED Replacement of 4-Foot T8 Lamps, Direct Wire, Exterior, 24/7	15
4352	LED Replacement of 4-Foot T8 Lamps, w/External Driver, Exterior	11
4353	LED Replacement of 4-Foot T8 Lamps, w/External Driver, Exterior, 24/7	11
4354	LED Fixture, Downlights, Interior	10
4355	LED Fixture, Downlights, In Unit	10
4356	LED Fixture, Downlights, Exterior	10
4357	LED Fixture, Quantity Modification, Interior	15
4358	LED Fixture, Quantity Modification, Exterior	15
4359	Salamander Broiler, Infrared, Nautral Gas, Per input MBh	12
4360	Floating Head Pressure Control- NEW	10
4361	VSD Vacuum Pump, Variable Torque, 4361	15
4362	VSD Vacuum Pump, Constant Torque	15
4363	Dew Point Controls for Desiccant Dryers	15
4368	A/C Split or Packaged System, High Efficiency, ≥ 5.42 to < 11.25 tons	15
4369	A/C Split or Packaged System, High Efficiency, ≥ 11.25 to < 20.00 tons	15
4370	A/C Split or Packaged System, High Efficiency, ≥ 20.00 to < 63.33 tons	15

MMID	Measure Name	EUL
4371	A/C Split or Packaged System, High Efficiency, ≥ 63.33 tons	15
4372	Communicating Thermostat, Natural Gas Boiler	10
4373	Communicating Thermostat, Natural Gas Furnace with AC	10
4374	Communicating Thermostat, Natural Gas Rooftop Unit with AC	10
4375	Smart Thermostat, Natural Gas Boiler	10
4376	Smart Thermostat, Natural Gas Furnace with AC	10
4377	Smart Thermostat, Natural Gas Rooftop Unit	10
4379	Insulation, Attic, NG heat without Cooling, New Construction to R-50	25
4380	Insulation, Attic, Electric heat with Cooling, New Construction to R-50	25
4381	Insulation, Attic, Electric heat without Cooling, New Construction to R-50	25
4384	Faucet Aerator, 1.5 GPM, Kitchen, Electric	10
4385	Faucet Aerator, 1.5 GPM, Kitchen, NG	10
4386	Faucet Aerator, 1.0 GPM, Kitchen, Electric	10
4387	Faucet Aerator, 1.0 GPM, Kitchen, NG	10
4388	Faucet Aerator, 0.5 GPM, Kitchen, Electric	10
4389	Faucet Aerator, 0.5 GPM, Kitchen, NG	10
4390	Faucet Aerator, 0.5/1.0/1.5 Variable GPM, Kitchen, Electric	10
4391	Faucet Aerator, 0.5/1.0/1.5 Variable GPM, Kitchen, NG	10
4392	Faucet Aerator, 1.5 GPM, Bath, Electric	10
4393	Faucet Aerator, 1.5 GPM, Bath, NG	10
4394	Faucet Aerator, 1.0 GPM, Bath, Electric	10
4395	Faucet Aerator, 1.0 GPM, Bath, NG	10
4396	Faucet Aerator, 0.5 GPM, Bath, Electric	10
4397	Faucet Aerator, 0.5 GPM, Bath, NG	10
4398	Showerhead, 1.5 GPM, Shower, Electric	10
4399	Showerhead, 1.5 GPM, Shower, NG	10
4400	Showerhead, 1.25 GPM, Shower, Electric	10
4401	Showerhead, 1.25 GPM, Shower, NG	10
4403	Refrigeration System Tune-up, Agriculture	1
4407	Schedule Optimization, Weekday Heating	5
4408	Schedule Optimization, Weekday Cooling	5
4409	Schedule Optimization, Weekend Heating	5
4410	Schedule Optimization, Weekend Cooling	5
4411	VFD, Agriculture Secondary Use Water System, Low HOU	15
4412	VFD, Constant Torque	15
4413	VFD, Ventilation/Circulation Fan, Low HOU	15
4414	VFD Pump, Hybrid	15
4415	VFD, Irrigation Well Pump, Low HOU	15

MMID	Measure Name	EUL
4419	Boiler Tune Up	1
4432	Connected Lighting Pack, Hub-Based	15
4433	Connected Lighting Pack, Non-Hub	15
4436	Smart Thermostat, Value, Pack-Based	10
4441	LED, Exterior Fixture, Low Output, <= 4,999 lumens, SBP	13
4442	LED, Exterior Fixture, Mid Output, 5,000-9,999 lumens, SBP	13
4443	LED, Exterior Fixture, High Output, 10,000-29,999 lumens, SBP	13
4444	LED, Exterior Fixture, Very High Output, >= 30,000 lumens, SBP	13
4445	4FT Linear LED 2L, Replacing 8FT 1L T8 or T12, SBP	12
4446	4FT Linear LED 2L, Replacing 8FT 1L T8 or T12, Exterior, SBP	12
4447	4FT Linear LED 2L, Replacing 8FT 1L T8 or T12, 24/7, SBP	6
4448	4FT Linear LED 2L, Replacing 8FT 1L T8HO or T12HO, SBP	12
4449	4FT Linear LED 2L, Replacing 8FT 1L T8HO or T12HO, Exterior, SBP	12
4450	4FT Linear LED 2L, Replacing 8FT 1L T8HO or T12HO, 24/7, SBP	6
4451	4FT Linear LED 4L, Replacing 8FT 2L T8 or T12, SBP	12
4452	4FT Linear LED 4L, Replacing 8FT 2L T8 or T12, Exterior, SBP	12
4453	4FT Linear LED 4L, Replacing 8FT 2L T8 or T12, 24/7, SBP	6
4454	4FT Linear LED 4L, Replacing 8FT 2L T8HO or T12HO, SBP	12
4455	4FT Linear LED 4L, Replacing 8FT 2L T8HO or T12HO, Exterior, SBP	12
4456	4FT Linear LED 4L, Replacing 8FT 2L T8HO or T12HO, 24/7, SBP	6
4457	4FT Linear LED 2L, Replacing 8FT 2L T8 or T12, SBP	12
4458	4FT Linear LED 2L, Replacing 8FT 2L T8 or T12, Exterior, SBP	12
4459	4FT Linear LED 2L, Replacing 8FT 2L T8 or T12, 24/7, SBP	6
4460	4FT Linear LED 2L, Replacing 8FT 2L T8HO or T12HO, SBP	12
4461	4FT Linear LED 2L, Replacing 8FT 2L T8HO or T12HO, Exterior, SBP	12
4462	4FT Linear LED 2L, Replacing 8FT 2L T8HO or T12HO, 24/7, SBP	6
4463	LED Fixture, 2x2, Low Output w/LLLC, DLC Listed, SBP	11
4464	LED Fixture, 2x2, High Output w/LLLC, DLC Listed, SBP	11
4465	LED Troffer, 1x4, Replacing 4' 1-2 Lamp T8 Troffer w/LLLC, SBP	11
4466	LED Troffer, 2x4, Replacing 4' 3-4 Lamp T8 Troffer w/LLLC, SBP	11
4467	LED Fixture,<=180 Watts, Replacing 4 lamp T5 or 6 lamp T8, High Bay, DLC Listed, SBP	20
4468	LED Fixture, ≤250 Watts, Replacing 8-lamp T8 or 6-lamp T5HO, High Bay, SBP	20
4469	LED Replacement of 4-Foot T8 Lamps Utilizing Existing Ballast, Exterior, SBP	11
4470	LED Replacement of 4-Foot T8 Lamps Utilizing Existing Ballast, Exterior, 24/7, SBP	11
4471	LED Replacement of 4-Foot T8 Lamps, Direct Wire, Exterior, SBP	15
4472	LED Replacement of 4-Foot T8 Lamps, Direct Wire, Exterior, 24/7, SBP	15
4473	LED Replacement of 4-Foot T8 Lamps, w/External Driver, Exterior, SBP	11

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4474	LED Replacement of 4-Foot T8 Lamps, w/External Driver, Exterior, 24/7, SBP	11
4475	LED Fixture, Downlights, Interior, SBP	10
4476	LED Fixture, Downlights, Exterior, SBP	10
4477	LED Fixture, Quantity Modification, Interior, SBP	15
4478	LED Fixture, Quantity Modification, Exterior, SBP	15
4481	Dew Point Controls for Desiccant Dryers	15
4483	Cycled Refrigeration Thermal Mass Air Dryers NEW	15
4487	Case door, freezer, low heat	11
4488	Case door, freezer, no heat	11
4489	Case door, refrigerated, no heat	11
4492	Compressed Air Condensate Drains, No Loss Drain	20
4493	Pressure/Flow Controllers, NEW	15
4494	Compressed Air Heat Recovery, Space Heating	13
4495	Compressed Air Mist Eliminators, NEW	5 (new construction), 3 (retrofit)
4496	Compressed Air Nozzles, Air Entraining	15
4497	Dishwasher, Low Temp, Door Type, Energy Star, Energy Star, Electric, SBP	10
4498	Dishwasher, High Temp, Electric Booster, Door Type, Energy Star, Electric, SBP	10
4499	Dishwasher, High Temp, Electric Booster, Door Type, Energy Star, NG, SBP	10
4500	Dishwasher, High Temp, Electric Booster, Multi Tank Conveyor, Energy Star, Electric, SBP	10
4501	Dishwasher, High Temp, Electric Booster, Multi Tank Conveyor, Energy Star, NG, SBP	10
4502	Dishwasher, High Temp, Electric Booster, Single Tank Conveyor, Energy Star, Electric, SBP	10
4503	Dishwasher, High Temp, Electric Booster, Single Tank Conveyor, Energy Star, NG, SBP	10
4504	Dishwasher, High Temp, Electric Booster, Under Counter, Energy Star, Electric, SBP	10
4506	Dishwasher, High Temp, Gas Booster, Door Type, Energy Star, NG, SBP	10
4507	Dishwasher, High Temp, Gas Booster, Multi Tank Conveyor, Energy Star, NG, SBP	10
4508	Dishwasher, High Temp, Gas Booster, Single Tank Conveyor, Energy Star, NG, SBP	10
4509	Dishwasher, High Temp, Gas Heat, Gas Booster, Under Counter, Energy Star, NG, SBP	10
4510	Dishwasher, Low Temp, Door Type, Energy Star, NG, SBP	10
4511	Dishwasher, Low Temp, Multi Tank Conveyor, Energy Star, Electric, SBP	10
4512	Dishwasher, Low Temp, Multi Tank Conveyor, Energy Star, NG, SBP	10

MMID	Measure Name	EUL
4513	Dishwasher, Low Temp, Single Tank Conveyor, Energy Star, Electric, SBP	10
4514	Dishwasher, Low Temp, Single Tank Conveyor, Energy Star, NG, SBP	10
4515	Dishwasher, Low Temp, Under Counter, Energy Star, Electric, SBP	10
4516	Dishwasher, Low Temp, Under Counter, Energy Star, NG, SBP	10
4521	Energy Recovery Ventilator	15
4522	Freezer, Chest, Glass Door, < 15 cu ft, Energy Star, SBP	12
4523	Freezer, Chest, Glass Door, 15-29 cu ft, Energy Star, SBP	12
4524	Freezer, Chest, Glass Door, 30-49 cu ft, Energy Star, SBP	12
4525	Freezer, Chest, Glass Door, 50+ cu ft, Energy Star, SBP	12
4526	Freezer, Chest, Solid Door, < 15 cu ft, Energy Star, SBP	12
4527	Freezer, Chest, Solid Door, 15-29 cu ft, Energy Star, SBP	12
4528	Freezer, Chest, Solid Door, 30-49 cu ft, Energy Star, SBP	12
4529	Freezer, Chest, Solid Door, 50+ cu ft, Energy Star, SBP	12
4530	Freezer, Vertical, Glass Door, < 15 cu ft, Energy Star, SBP	12
4531	Freezer, Vertical, Glass Door, 15-29 cu ft, Energy Star, SBP	12
4532	Freezer, Vertical, Glass Door, 30-49 cu ft, Energy Star, SBP	12
4533	Freezer, Vertical, Glass Door, 50+ cu ft,Energy Star, SBP	12
4534	Freezer, Vertical, Solid Door, < 15 cu ft, Energy Star, SBP	12
4535	Freezer, Vertical, Solid Door, 15-29 cu ft, Energy Star, SBP	12
4536	Freezer, Vertical, Solid Door, 30-49 cu ft, Energy Star, SBP	12
4537	Freezer, Vertical, Solid Door, 50+ cu ft, Energy Star, SBP	12
4538	Fryer, Energy Star, NG, SBP	12
4539	Griddle, Energy Star, NG, SBP	12
4543	Insulation, Steam Fitting, Removable, Natural Gas	10
4544	Insulation, Steam Piping, Natural Gas	10
4545	Oven, Convection, Energy Star, Electric, SBP	12
4546	Oven, Convection, Energy Star, NG, SBP	12
4547	Oven, Rack Type, Gas, Double Compartment, High Efficiency	12
4548	Oven, Rack Type, Gas, Single Compartment, High Efficiency	12
4551	Refrigerator, Chest, Glass Door, < 15 cu ft, Energy Star, SBP	12
4552	Refrigerator, Chest, Glass Door, 15-29 cu ft, Energy Star, SBP	12
4553	Refrigerator, Chest, Glass Door, 30-49 cu ft, Energy Star, SBP	12
4554	Refrigerator, Chest, Glass Door, 50+ cu ft, Energy Star, SBP	12
4555	Refrigerator, Chest, Solid Door, < 15 cu ft, Energy Star, SBP	12
4556	Refrigerator, Chest, Solid Door, 15-29 cu ft, Energy Star, SBP	12
4557	Refrigerator, Chest, Solid Door, 30-49 cu ft, Energy Star, SBP	12
4558	Refrigerator, Chest, Solid Door, 50+ cu ft, Energy Star, SBP	12
4559	Refrigerator, Vertical, Glass Door, < 15 cu ft, Energy Star, SBP	12

MMID	Measure Name	EUL
4560	Refrigerator, Vertical, Glass Door, 15-29 cu ft, Energy Star, SBP	12
4561	Refrigerator, Vertical, Glass Door, 30-49 cu ft, Energy Star, SBP	12
4562	Refrigerator, Vertical, Glass Door, 50+ cu ft, Energy Star, SBP	12
4563	Refrigerator, Vertical, Solid Door, < 15 cu ft, Energy Star, SBP	12
4564	Refrigerator, Vertical, Solid Door, 15-29 cu ft, Energy Star, SBP	12
4565	Refrigerator, Vertical, Solid Door, 30-49 cu ft, Energy Star, SBP	12
4566	Refrigerator, Vertical, Solid Door, 50+ cu ft, Energy Star, SBP	12
4578	VFD, HVAC Fan	15
4579	VFD, HVAC Heating Pump	15
4580	VFD, Pool Pump Motor	15
4581	VFD, Process Fan	15
4582	VFD Pump, Hybrid	15
4583	Hot Food Holding Cabinet, V = 13-28 cu. ft., Energy Star, SBP	12
4584	Hot Food Holding Cabinet, V < 13 cu. ft., Energy Star, SBP	12
4585	Hot Food Holding Cabinet, V ≥ 28 cu. ft., Energy Star, SBP	12
4594	Oven, Combination, Energy Star, Electric, SBP	12
4595	Oven, Combination, Energy Star, NG, SBP	12
4596	Dishwasher, High Temp, Electric Booster, Pots/Pans Type, Energy Star, Electric, SBP	10
4597	Dishwasher, High Temp, Electric Booster, Pots/Pans Type, Energy Star, NG, SBP	10
4598	Dishwasher, High Temp, Gas Booster, Pots/Pans Type, Energy Star, NG, SBP	10
4599	Dishwasher, Low Temp, Pots/Pans Type, Energy Star, Electric, SBP	10
4600	Dishwasher, Low Temp, Pots/Pans Type, Energy Star, NG, SBP	10
4601	VFD, Constant Torque	15
4602	Variable Speed ECM Pump, Domestic Hot Water Recirculation, < 100 Watts Max Input	15
4603	Variable Speed ECM Pump, Domestic Hot Water Recirculation, 100 - 500 Watts Max Input	15
4604	Variable Speed ECM Pump, Domestic Hot Water Recirculation, > 500 Watts Max Input	15
4605	Variable Speed ECM Pump, Heating Water Circulation, < 100 Watts Max Input	15
4606	Variable Speed ECM Pump, Heating Water Circulation, 100 - 500 Watts Max Input	15
4607	Variable Speed ECM Pump, Heating Water Circulation, > 500 Watts Max Input	15
4608	Variable Speed ECM Pump, Cooling Water Circulation, < 100 Watts Max Input	15
4609	Variable Speed ECM Pump, Cooling Water Circulation, 100 - 500 Watts Max Input	15
4610	Variable Speed ECM Pump, Cooling Water Circulation, > 500 Watts Max Input	15
4611	Variable Speed ECM Pump, Water Loop Heat Pump Circulation, < 100 Watts Max Input	15

MMID	Measure Name	EUL
4612	Variable Speed ECM Pump, Water Loop Heat Pump Circulation, 100 - 500 Watts Max Input	15
4613	Variable Speed ECM Pump, Water Loop Heat Pump Circulation, > 500 Watts Max Input	15
4614	Spring-loaded Garage Door Hinge, 55 Degree Indoor Temperature Setpoint	20
4615	Spring-loaded Garage Door Hinge, 60 Degree Indoor Temperature Setpoint	20
4616	Spring-loaded Garage Door Hinge, 65 Degree Indoor Temperature Setpoint	20
4617	Spring-loaded Garage Door Hinge, 70 Degree Indoor Temperature Setpoint	20
4618	LED Fixture, Linear Ambient, Replacing 1 or 2 T5 lamp(s) in Cross Section, SBP	11
4619	LED Fixture, Linear Ambient, Replacing 3 or 4 T5 lamps in Cross Section, SBP	11
4620	LED Fixture, Linear Ambient, Replacing 1 or 2 T8/T12 lamp(s) in Cross Section, SBP	11
4621	LED Fixture, Linear Ambient, Replacing 3 or 4 T8/12 lamps in Cross Section, SBP	11
4622	ENERGY STAR® Commercial Ice Machine, Ice Making Head, SBP	10
4623	ENERGY STAR® Commercial Ice Machine, Remote Condensing Unit, SBP	10
4624	ENERGY STAR® Commercial Ice Machine, Self-Contained Unit, SBP	10
4625	ECM HVAC Fan Motors, Heating	18
4626	ECM HVAC Fan Motors, Cooling	18
4627	ECM HVAC Fan Motors, Occupied Ventilation	18
4628	ECM HVAC Fan Motors, 24/7 Ventilation	18
4629	Vacuum Pump Heat Recovery, Space Heating	13
4630	LED Lamp, ENERGY STAR, Replacing Exterior Directional CFL, ≥ 23W CFL, SBP	6
4631	LED Lamp, ENERGY STAR, Replacing Exterior Directional CFL, 14W-22W CFL, SBP	6
4632	LED Lamp, ENERGY STAR, Replacing Exterior Directional CFL, ≤ 13W, SBP	6
4633	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, 120W – 250W Incandescent, SBP	6
4634	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, 100W – 119W Incandescent, SBP	6
4635	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, 75W – 99W Incandescent, SBP	6
4636	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, 55W – 74W Incandescent, SBP	6
4637	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, 36W – 54W Incandescent, SBP	6
4638	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, ≤ 35W Incandescent, SBP	6
4639	LED Lamp, ENERGY STAR, 1,600 – 1,999 Lumens, Exterior, SBP	5
4640	LED Lamp, ENERGY STAR, 1,100 – 1,599 Lumens, Exterior, SBP	5

MMID	Measure Name	EUL
4641	LED Lamp, ENERGY STAR, 800 – 1,099 Lumens, Exterior, SBP	5
4642	LED Lamp, ENERGY STAR, 450 – 799 Lumens, Exterior, SBP	5
4643	LED Lamp, ENERGY STAR, 250 – 449 Lumens, Exterior, SBP	5
4644	LED Lamp, DLC, High/Low-Bay Mogul Screw-Base (E39), SBP	13
4645	LED Lamp, DLC, Mogul Screw-Base (E39), Exterior, SBP	13
4646	Advanced Rooftop Unit Controller	10
4648	Steam Trap Repair, <10 psig, General Heating, Prescriptive: 7/32” or Smaller	6
4649	Steam Trap Repair, <10 psig, General Heating, Prescriptive: 1/4”	6
4650	Steam Trap Repair, <10 psig, General Heating, Prescriptive: 5/16”	6
4651	Steam Trap Repair, <10 psig, General Heating, Prescriptive: 3/8” or Larger	6
4652	Permanent Magnet Synchronous (PMS) Evaporator Fan Motor, Refrigerated Case, Replacement	15
4653	VFD, Boiler Draft Fan	15
4654	VFD, Cooling Tower Fan	15
4655	VFD, Chilled Water Distribution Pump	15
4659	Boiler Tune-Up, Single Family	2
4660	Furnace Tune-Up, Single Family	2
4661	Salamander Broiler, Infrared, Nautral Gas, Per input MBh	12
4666	Smart Thermostat, Existing Natural Gas Boiler	10
4667	Smart Thermostat, Existing Natural Gas Furnace	10
4668	Smart Thermostat, Existing Air-Source Heat Pump	10
4681	Low-E Storm Window, Single Family	20
4682	Low-E Storm Window, Multifamily	20
4684	7 Outlet Advanced Power Strip, Business, Pack Based	8
4685	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, BR30, Pack-Based	15
4686	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 800 Lumens, Pack-Based	15
4687	LED Exit Sign, Retrofit, Pack-Based	10
4688	Kitchen Aerator, 1.5 GPM, Small Office, Electric or Natural Gas, Pack Based	10
4689	Kitchen Aerator, 1.5 GPM, Restaurant, Electric or Natural Gas, Pack Based	10
4690	Bathroom Aerator, 1.0 GPM, Small Office, Electric or Natural Gas, Pack Based	10
4691	Bathroom Aerator, 1.0 GPM, Restaurant, Electric or Natural Gas, Pack Based	10
4692	Bathroom Aerator, 1.0 GPM, Retail, Electric or Natural Gas, Pack Based	10
4693	Pre-Rinse Sprayer, 1.1 GPM, Electric or Natural Gas, Pack Based	5
4710	Steamer, ENERGY STAR, Electric	12
4711	Steamer, ENERGY STAR, NG	12
4712	Chiller, Air Cooled, < 150 tons, Path A	20

MMID	Measure Name	EUL
4713	Chiller, Air Cooled, ≥ 150 tons, Path A	20
4714	Chiller, Air Cooled, < 150 tons, Path B	20
4715	Chiller, Air Cooled, ≥ 150 tons, Path B	20
4716	Chiller, Water Cooled, Positive Displacement, < 75 tons, Path A	20
4717	Chiller, Water Cooled, Positive Displacement, ≥ 75 and < 150 tons, Path A	20
4718	Chiller, Water Cooled, Positive Displacement, ≥ 150 and < 300 tons, Path A	20
4719	Chiller, Water Cooled, Positive Displacement, ≥ 300 and < 600 tons, Path A	20
4720	Chiller, Water Cooled, Positive Displacement, ≥ 600 tons, Path A	20
4721	Chiller, Water Cooled, Positive Displacement, < 75 tons, Path B	20
4722	Chiller, Water Cooled, Positive Displacement, ≥ 75 and < 150 tons, Path B	20
4723	Chiller, Water Cooled, Positive Displacement, ≥ 150 and < 300 tons, Path B	20
4724	Chiller, Water Cooled, Positive Displacement, ≥ 300 and < 600 tons, Path B	20
4725	Chiller, Water Cooled, Positive Displacement, ≥ 600 tons, Path B	20
4726	Chiller, Water Cooled, Centrifugal, < 150 tons, Path A	20
4727	Chiller, Water Cooled, Centrifugal, ≥ 150 and < 300 tons, Path A	20
4728	Chiller, Water Cooled, Centrifugal, ≥ 300 and < 400 tons, Path A	20
4729	Chiller, Water Cooled, Centrifugal, ≥ 400 and < 600 tons, Path A	20
4730	Chiller, Water Cooled, Centrifugal, ≥ 600 tons, Path A	20
4731	Chiller, Water Cooled, Centrifugal, < 150 tons, Path B	20
4732	Chiller, Water Cooled, Centrifugal, ≥ 150 and < 300 tons, Path B	20
4733	Chiller, Water Cooled, Centrifugal, ≥ 300 and < 400 tons, Path B	20
4734	Chiller, Water Cooled, Centrifugal, ≥ 400 and < 600 tons, Path B	20
4735	Chiller, Water Cooled, Centrifugal, ≥ 600 tons, Path B	20
4736	A/C Split System, ≤ 65 MBh, SEER 15	15
4737	A/C Split System, ≤ 65 MBh, SEER 16	15
4738	A/C Split System, ≤ 65 MBh, SEER 17	15
4739	A/C Split System, ≤ 65 MBh, SEER 18+	15
4740	A/C Single Package, ≤ 65 MBh, SEER 15	15
4741	A/C Single Package, ≤ 65 MBh, SEER 16	15
4742	A/C Single Package, ≤ 65 MBh, SEER 17	15
4743	A/C Single Package, ≤ 65 MBh, SEER 18+	15
4744	Air-Source Heat Pump, ≤ 65 MBh, SEER 15 and 9.0 HSPF	15
4745	Air-Source Heat Pump, ≤ 65 MBh, SEER 16 and 9.0 HSPF	15
4746	Air-Source Heat Pump, ≤ 65 MBh, SEER 17 and 9.0 HSPF	15
4747	Air-Source Heat Pump, ≤ 65 MBh, SEER 18 and 9.0 HSPF	15
4748	Guest Room Energy Management Controls, PTHP Systems	8
4749	Air Sealing, Natural Gas Heat with Cooling	15
4750	Air Sealing, Natural Gas Heat without Cooling	15

MMID	Measure Name	EUL
4751	Air Sealing, Electric Heat with Cooling	15
4752	Air Sealing, Electric Heat without Cooling	15
4753	Unit Heater, ≥ 90% Thermal Efficiency, Heating Setpoint = 70°F	15
4754	Unit Heater, ≥ 90% Thermal Efficiency, Heating Setpoint = 65°F	15
4755	Unit Heater, ≥ 90% Thermal Efficiency, Heating Setpoint = 60°F	15
4756	Unit Heater, ≥ 90% Thermal Efficiency, Heating Setpoint = 55°F	15
4757	VFD, Domestic Water Pump	15
4758	Demand Defrost Controls	10
4759	Evaporator Fan Control for Reach-in Cooler/Freezer	16
4760	Process Boiler Burner, 10:1 High Turn Down	20
4761	Process Boiler Control, Linkageless	15
4762	Process Boiler, Oxygen Trim Combustion Controls	5
4763	High Efficiency Side Entry Agitator	15
4764	Spline Rotor Upgrade for Refiners	15
4765	Industrial High Frequency Battery Chargers	15
4766	Compressed Air System Leak Survey and Repair	2
4767	Compressed Air System Leak Survey and Repair-Agriculture	2
4768	Split System, SEER 15, <5.4 tons, Data Center/Telecom	15
4769	Split System, SEER 15, <5.4 tons, Data Center/Telecom	15
4770	Split System, SEER 15, <5.4 tons, Data Center/Telecom	15
4771	Split System, SEER 15, <5.4 tons, Data Center/Telecom	15
4772	Single Package, SEER 15, <5.4 tons, Data Center/Telecom	15
4773	Single Package, SEER 15, <5.4 tons, Data Center/Telecom	15
4774	Single Package, SEER 15, <5.4 tons, Data Center/Telecom	15
4775	Single Package, SEER 15, <5.4 tons, Data Center/Telecom	15
4776	Air-Side Economizer, Data Center/Telecom	10
4777	Efficient UPS	10
4778	Efficient Rectifier	10
4779	DLC Listed, Four Pin-Base Lamp Replacing CFL, Interior	11
4780	DLC Listed, Four Pin-Base Lamp Replacing CFL, Exterior	11
4781	LED Fixture, Linear Ambient, Replacing 1 or 2 T8/T12 Lamp(s) in Cross Section, Exterior, 24 hour	6
4782	LED Fixture, Linear Ambient, Replacing 1 or 2 T8/T12 Lamp(s) in Cross Section, Exterior, 12 hour	12
4783	LED Fixture, Linear Ambient, Replacing 3 or 4 T8/T12 Lamps in Cross Section, Exterior, 24 hour	6
4784	LED Fixture, Linear Ambient, Replacing 3 or 4 T8/T12 Lamps in Cross Section, Exterior, 12 hour	12

MMID	Measure Name	EUL
4785	LED Fixture, Linear Ambient, Replacing 1 or 2 T5 Lamp(s) in Cross Section, Exterior, 24 hour	6
4786	LED Fixture, Linear Ambient, Replacing 1 or 2 T5 Lamp(s) in Cross Section, Exterior, 12 hour	12
4787	LED Fixture, Linear Ambient, Replacing 3 or 4 T5 Lamps in Cross Section, Exterior, 24 hour	6
4788	LED Fixture, Linear Ambient, Replacing 3 or 4 T5 Lamps in Cross Section, Exterior, 12 hour	12
4789	LED Fixture, Linear Ambient, Replacing 1 or 2 T8/T12 Lamp(s) in Cross Section, In Unit	11
4790	LED Fixture, Linear Ambient, Replacing 3 or 4 T8/T12 Lamps in Cross Section, In Unit	11
4791	LED Fixture, Linear Ambient, Replacing 1 or 2 T5 Lamp(s) in Cross Section, In Unit	11
4792	LED Fixture, Linear Ambient, Replacing 3 or 4 T5 Lamps in Cross Section, In Unit	11
4793	LED Troffer, 2x4, Replacing 4-Foot 1- or 2-Lamp T8 Troffer	14
4794	LED Troffer, 2x4, Replacing 4-Foot 1- or 2-Lamp Troffer with Luminaire Level Lighting Controls	14
4795	LED Fixture, ≤ 300 Watts, Replacing 10 Lamp T8 or 8 Lamp T5HO, High Bay	20
4796	LED Fixture, ≤ 350 Watts, Replacing 12 Lamp T8 or 10 Lamp T5HO, High Bay	20
4797	LED Replacement of 2-Foot T8 Lamps w/ External Driver	11
4798	LED Replacement of 2-Foot T8 Lamps, Direct Wire	15
4799	LED Replacement of 2-Foot Lamps Using Existing Ballast	11
4800	LED Replacement of U-Bend T8 Lamps w/ External Driver	11
4801	LED Replacement of U-Bend T8 Lamps, Direct Wire	15
4802	LED Replacement of U-Bend T8 Lamps Using Existing Ballast	11
4803	LED Replacement of 4-Foot T5 Lamps w/ External Driver	11
4804	LED Replacement of 4-Foot T5HO Lamps w/ External Driver	11
4805	LED Replacement of 4-Foot T5 Lamps, Direct Wire	15
4806	LED Replacement of 4-Foot T5HO Lamps, Direct Wire	15
4807	LED Replacement of 4-Foot T5 Lamps Using Existing Ballast	11
4808	LED Replacement of 4-Foot T5HO Lamps Using Existing Ballast	11
4809	LED Replacement of 8’ T8 or T12 Lamp w/ External Driver (UL Type C)	11
4810	LED Replacement of 8’ T8 or T12 Lamps, Direct Wire (UL Type B)	15
4811	LED Replacement of 8’ T8 or T12 Lamp Utilizing Existing Ballast (UL Type A)	11
4812	Non-High Bay Occupancy/Vacancy Sensor	8
4813	LED Fixture, Track/Mono/Accent	11
4814	LED Fixture, Track/Mono/Accent, In-Unit	11
4824	Insulation, Attic, NG heat with Cooling, New Construction to R-49	25

MMID	Measure Name	EUL
4830	LED Replacement of 8’ T8 or T12 Lamp Utilizing Existing Ballast (UL Type A), Exterior	11
4831	LED Replacement of 8’ T8 or T12 Lamp w/ External Driver (UL Type C), Exterior	11
4832	LED Replacement of 8’ T8 or T12 Lamps, Direct Wire (UL Type B), Exterior	15
4833	LED Replacement of 8’ T8 or T12 Lamp Utilizing Existing Ballast (UL Type A), Exterior 24/7	11
4834	LED Replacement of 8’ T8 or T12 Lamp w/ External Driver (UL Type C) Exterior 24/7	11
4835	LED Replacement of 8’ T8 or T12 Lamps, Direct Wire (UL Type B), Exterior 24/7	15
4836	Tankless Water Heater, NG, EF ≥ 0.90	20
4838	Residential AC Tune-Up	
4841	Horticultural Lighting, Vertical Farming, Agriculture	11
4842	Horticultural Lighting, Non-Stacked Indoor, Agriculture	13
4843	Horticultural Lighting, Supplemented Greenhouse, Agriculture	20
4852	Boiler, Hot Water, Modulating, ≥ 90% AFUE, < 300 MBh, Propane-Fueled	20
4866	Boiler, Condensing, ≥ 90% AFUE, ≥ 300 MBh, Propane-Fueled	20
4867	Boiler, Hot Water, Near Condensing, ≥ 85% AFUE, ≥ 300 MBh, Propane-Fueled	20
4868	Grain Dryer, Energy Efficient, Hybrid, Propane-Fueled	20
4877	Propane Commercial Water Heater Storage	15
4878	Unit Heater, ≥ 90% Thermal Efficiency, Propane-Fueled, Heating Setpoint = 70°F	15
4879	Unit Heater, ≥ 90% Thermal Efficiency, Propane-Fueled, Heating Setpoint = 65°F	15
4880	Unit Heater, ≥ 90% Thermal Efficiency, Propane-Fueled, Heating Setpoint = 60°F	15
4881	Unit Heater, ≥ 90% Thermal Efficiency, Propane-Fueled, Heating Setpoint = 55°F	15
4883	Project Completion, Electric Heat	20
4884	Project Completion, Natural Gas Heat	20
4885	Project Completion, Tier 2, Electric Heat	20
4886	Project Completion, Tier 2, Natural Gas Heat	20

Appendix D: Incremental Costs

MMID	Measure Name	Source	Incremental Cost
598	Greenhouse Climate Controls, Hybrid	Historical Project Data, 2016. Agriculture, Schools and Government Program; 4 Projects, 01/2016 to 06/2016. Average Cost is $0.11 per square foot.	$0.11/sq ft
1981	Gas Furnace with ECM, 95+ AFUE (Existing)	CLEAResult. Survey of trade allies, summer 2018.	$388.72
1983	Hot Water Boiler, 95%+ AFUE	2013, Program Implementer CLEAResult surveyed 40 Trade Allies and took the average reported cost for an 82% boiler and subtracted that amount from the average reported cost for a 95% boiler.	$3,105.00
1985	Water Heater, Power Vented, EF >= 0.67	U.S. Department of Energy. Water Heater Market Profile. p. 15. September 2009. https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/Water_Heater_Market_Profile_Sept2009.pdf	$400.00
1986	Water Heater, Condensing	Illinois Stakeholder Advisory Group. Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 6.0, Volume 3: Residential Measures. p. 170. February 8, 2017. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_3_Res_020817_Final.pdf	$685.00
1988	Water Heater, Indirect	New York Statewide Residential Gas High Efficiency Heating Equipment Programs: Evaluation of 2009-2011 Programs. Average of mean and median costs using both approaches, Table 1-4. http://www.coned.com/energyefficiency/PDF/EEPS%20CY1%20NY%20HEHE%20Evaluation%20Report%20FINAL%20APPROVED%202014-08-21.pdf	$988.50
1989	Water Heater, Electric, EF 0.93 or greater	California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” June 2, 2008. http://www.deeresources.com/index.php/ex-ante-databaseRSMeans. Facilities Construction Cost Data. 2011.	$25.16
2139	Low-flow Showerhead, 1.5 gpm, Gas	$5.00 = WESCO Distribution Pricing ($3.11) + Labor ($1.89)	$5.00

MMID	Measure Name	Source	Incremental Cost
2145	Low-flow Showerhead, 1.5 gpm, Electric MF	$5.00 = WESCO Distribution Pricing ($3.11) + Labor ($1.89)	$5.00
2196	VSD Air Compressor, Hybrid	Illinois Technical Reference Manual. p. 141. 2013. $127 per horsepower. 2016 program data has an average compressor of 60 hp; 360 projects. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf	7620
2197	Anti-sweat heater controls, on freezer case with low-heat door	San Diego Gas & Electric. Work Paper WPSDGENRRN0009. Anti-Sweat Heat (ASH) Controls. Revision# 0. Cost per linear foot = $34.00; Cost calculated per door assuming 2.5 ft. door average.	$85.00
2198	Anti-sweat heater controls, on freezer case with no-heat door	San Diego Gas & Electric. Work Paper WPSDGENRRN0009. Anti-Sweat Heat (ASH) Controls. Revision# 0. Cost per linear foot = $34.00; Cost calculated per door assuming 2.5 ft. door average.	$85.00
2199	Anti-sweat heater controls, on freezer case with standard door	San Diego Gas & Electric. Work Paper WPSDGENRRN0009. Anti-Sweat Heat (ASH) Controls. Revision# 0. Cost per linear foot = $34.00; Cost calculated per door assuming 2.5 ft. door average.	$85.00
2200	Anti-sweat heater controls, on refrigerated case with low-heat or no-heat doors	San Diego Gas & Electric. Work Paper WPSDGENRRN0009. Anti-Sweat Heat (ASH) Controls. Revision# 0. Cost per linear foot = $34.00; Cost calculated per door assuming 2.5 ft. door average.	$85.00
2201	Anti-sweat heater controls, on refrigerated case with standard door	San Diego Gas & Electric. Work Paper WPSDGENRRN0009. Anti-Sweat Heat (ASH) Controls. Revision# 0. Cost per linear foot = $34.00; Cost calculated per door assuming 2.5 ft. door average.	$85.00

MMID	Measure Name	Source	Incremental Cost
2202	Beverage Cooler Controls	Pacific Gas & Electric. “PGECOREF111 R5 Vending Machine Controller.” Workpaper. (Use Category: “Appliance or Plug Load”, PA: “PGE”, Other Fields: “Any”) Measure life: p. 4. Hours per day off: p. 6. Light wattage: p. 12. Labor cost: p. 16. November 10, 2015. http://deeresources.net/workpapers Website for USA Tech, the manufacturer of CoolerMiser for beverage coolers, VendingMiser for beverage vending machines, and SnackMiser for snack vending machines. Accessed May 2018. https://store.usatech.com/collections/energymiser-products	$233.00
2203	High Turn Down Burner - NEW	Actual Program Data, 2013-2014. 10 Projects, Average is $94.52 per bhp.	$94.52/bhp
2205	Linkageless Boiler Control, per hp	Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 27 units over 21 projects from 2016 to 2018.	$79.61
2206	Boiler oxygen trim controls, per hp	Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 459 units over 44 projects from 2012 to 2018.	$55.54
2211	Boiler Tune-up - service buy down	Illinois Technical Reference Manual. p. 160. 2013. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf	$0.83/MBh per tune-up
2218	Boiler, Hot Water, Modulating, >=90% AFUE, < 300 mbh	Full cost of $37.16/MBh is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 456 boilers over 237 projects, from 1/1/2016 to 6/30/2018. August 2018 online lookups of 18 baseline and 22 efficient boiler models less than 300 MBh on www.supplyhouse.com and www.grainger.com reveal an efficient cost that is 27.6% higher than the baseline cost. The incremental cost is therefore 27.6% * $37.16 = $10.27/MBh.	$10.26

MMID	Measure Name	Source	Incremental Cost
2221	Boiler Control - Outside Air Reset/Cutout	Illinois Technical Reference Manual. p. 187. 2013. Boiler outside air reset/cutout controls cost is $612.00 per set of controls. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf	$612.00
2234	Case door, freezer, low heat	Price sheets for Styleline Classic II Plus and Hybridoor freezers, and Anthony 401, 101, and Infinity freezers. September 2016.	$548.67
2235	Case door, freezer, no heat	Price sheets for Styleline Classic II Plus freezer, and Anthony ELM, ELM 2, and 401 freezers. September 2016.	$121.00
2236	Case door, refrigerated, no heat	Price sheets for Styleline Classic II Plus cooler, and Anthony ELM, ELM 2, 101, 101 No Heat, 401, Infinity, Vista C, and Vista B coolers. September 2016.	$208.83
2249	High Efficiency Chillers - Retrofit, air cooled all sizes	Northeast Energy Efficiency Partnerships. January 2013. Incremental Cost Study Phase Two Final Report: A Report on 12 Energy Efficiency Measure Incremental Costs in Six Northeast and Mid-Atlantic Markets. $300.00 is average cost of Air-Cooled Chiller Incremental Cost/Ton Estimates Baseline EER = 9.60 and Efficient EER= 10.52. Capacity is 50- 400 tons. http://www.neep.org/incremental-cost-study-phase-2	$300.00/ton
2250	High Efficiency Chillers - Retrofit, water cooled < 150 tons	Northeast Energy Efficiency Partnerships. January 2013. Incremental Cost Study Phase Two Final Report: A Report on 12 Energy Efficiency Measure Incremental Costs in Six Northeast and Mid-Atlantic Markets. $42.00 is cost of 150 Ton Water-Cooled Scroll/Screw Chiller Incremental Cost/Ton. Baseline Efficiency= 0.78 kW per ton and Efficient Condition = 0.68 kW per ton. http://www.neep.org/incremental-cost-study-phase-2	$42.00/ton
2251	High Efficiency Chillers - Retrofit, water cooled >= 300 tons	Northeast Energy Efficiency Partnerships. January 2013. Incremental Cost Study Phase Two Final Report: A Report on 12 Energy Efficiency Measure Incremental Costs in Six Northeast and Mid-Atlantic Markets. $31.00 is cost of 400 Ton Water-Cooled Scroll/Screw Chiller Incremental Cost/Ton. Baseline Efficiency= 0.78 kW per ton and Efficient Condition = 0.68 kW per ton. http://www.neep.org/incremental-cost-study-phase-2	$31.00/ton

MMID	Measure Name	Source	Incremental Cost
2252	High Efficiency Chillers - Retrofit, water cooled >= 150 tons and < 300 tons	Northeast Energy Efficiency Partnerships. January 2013. Incremental Cost Study Phase Two Final Report: A Report on 12 Energy Efficiency Measure Incremental Costs in Six Northeast and Mid-Atlantic Markets. $61.00 is cost of 200 Ton Water-Cooled Scroll/Screw Chiller Incremental Cost/Ton. Baseline Efficiency= 0.78 kW per ton and Efficient Condition = 0.68 kW per ton. http://www.neep.org/incremental-cost-study-phase-2	$61.00/ton
2253	Agricultural Circulation Fan, High Efficiency, Per Inch od Fan Diameter -	Illinois Technical Reference Manual. 2013. Agriculture circulation or exhaust fan incremental cost (all sizes) is $150.00 each. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf	$150.00
2254	Compressed Air Condensate Drains, No Loss Drain	2016/2017 historical project data. Average cost for 118 projects is $448.93 per drain.	$448.93
2255	Pressure/Flow Controllers, NEW	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 309 units over 31 projects, from 2016 to 2018.	$26.46
2257	Compressed Air Heat Recovery, Space Heating	Historical project data. 105 applications across 2015 and 2016.	$112.41
2258	Compressed Air Mist Eliminators, NEW	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 135 units over 59 projects, from 2016 to 2018.	$28.24
2259	Compressed Air Nozzles, Air Entraining	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 228 units over 16 projects, from 2012 to 2017.	$35.49
2264	Cycled Refrigeration Thermal Mass Air Dryers NEW	Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 5.0, Volume 2. p. 476. 2016. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Final/IL-TRM_Effective_060116_v5.0_Vol_2_C_and_I_021116_Final.pdf	$6.00

MMID	Measure Name	Source	Incremental Cost
2269	Cooler Evaporator Fan Control	Regional Technical Forum. “Evaporator Fan Controls and Evaporator Fan Uniform Energy Savings Measures Calculations.” 2010. https://nwcouncil.app.box.com/s/pt7getqkjxzmlvm5f87wn3eydvidvjb5 Cost adjusted from $141 in 2010 dollars to $155 in 2017 dollars based on http://www.usinflationcalculator.com/	$155.00
2271	Night Curtains for Open Coolers, per linear foot	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 2,570 units over 26 projects, from 2016 to 2018.	$44.14
2276	DELAMPING, DIRECT INSTALL, 4 FOOT LAMP	Actual program cost from 2015-16 program data, where available, 23 applications.	$51.75
2277	Delamping, T8 to T8	Actual program cost from 2015-16 program data, where available, 23 applications.	$11.59
2280	Dishwasher, Low Temp, Door Type, Energy Star, Energy Star, Electric	ENERGY STAR. “Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.” Calculator. 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx	$662.00
2281	Dishwasher, High Temp, Electric Booster, Door Type, Energy Star, Electric		$662.00
2282	Dishwasher, High Temp, Electric Booster, Door Type, Energy Star, NG		$995.00
2283	Dishwasher, High Temp, Electric Booster, Multi Tank Conveyor, Energy Star, Electric		$970.00
2284	Dishwasher, High Temp, Electric Booster, Multi Tank Conveyor, Energy Star, NG		$970.00
2285	Dishwasher, High Temp, Electric Booster, Single Tank Conveyor, Energy Star, Electric		$2,050.00

MMID	Measure Name	Source	Incremental Cost
2286	Dishwasher, High Temp, Electric Booster, Single Tank Conveyor, Energy Star, NG	ENERGY STAR. "Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment." Calculator. 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx	$2,050.00
2287	Dishwasher, High Temp, Electric Booster, Under Counter, Energy Star, Electric		$2,025.00
2288	Dishwasher, High Temp, Electric Booster, Under Counter, Energy Star, NG		$2,025.00
2289	Dishwasher, High Temp, Gas Booster, Door Type, Energy Star, NG		$995.00
2290	Dishwasher, High Temp, Gas Booster, Multi Tank Conveyor, Energy Star, NG		$970.00
2291	Dishwasher, High Temp, Gas Booster, Single Tank Conveyor, Energy Star, NG		$2,050.00
2292	Dishwasher, High Temp, Gas Heat, Gas Booster, Under Counter, Energy Star, NG		$2,025.00
2293	Dishwasher, Low Temp, Door Type, Energy Star, NG		$662.00
2294	Dishwasher, Low Temp, Multi Tank Conveyor, Energy Star, Electric		$970.00
2296	Dishwasher, Low Temp, Single Tank Conveyor, Energy Star, Electric		$0.00

MMID	Measure Name	Source	Incremental Cost
2298	Dishwasher, Low Temp, Under Counter, Energy Star, Electric	ENERGY STAR. “Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.” Calculator. 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx	$234.00
2299	Dishwasher, Low Temp, Under Counter, Energy Star, NG		$234.00
2301	Dock Ramp/Pit Seal, Replacement	Implementer online retailer research. Accessed January 2016. Price per dock ramp/pit seal, Material cost is $1,000.00 and $250.00 is labor, Incremental Cost = $1,250.00. https://appliedhandling.com/loading-docks/dock-seals-and-shelters/	$1,250
2302	Dock Seal, Added to Existing Barrier	Implementer online retailer research, Global Equipment Company, Inc. , Grainger, Northern Tool. Accessed January 2016. Per dock seal, Material cost is $1,020.41 and $350.00 is labor, Incremental Cost = $1,370.41. http://www.globalindustrial.com/c/material-handling/dock-truck/dock-seals-shelters-roll-up-doors; https://www.grainger.com/category/dock-seals/dock-equipment/material-handling/ecatalog/N-9r6; http://www.northerntool.com/shop/tools/category_material-handling+loading-dock-equipment+dock-seals-shelters	$1,370.41
2303	Dock Ramp/Pit Seal, From SPECTRUM		
2303	Dock Seals, New		
2305	Energy-Efficient Drycooler for Data Center	Wisconsin Focus on Energy. Historical Focus on Energy Project Data obtained from SPECTRUM. Business Incentive and Agriculture, Schools and Government Programs had six projects from 2012 to 2015 with an average cost of $4,882.57/ton.	$4,882.57
2306	Compressor Cooler Motor, ECM - NEW	Regional Technical Forum, UES Measures. “Commercial: Grocery - Compressor Head Fan Motor Retrofit to ECM.” Measure Workbook 2.2, June 29, 2016. $260.00 for all Compressor Head Fan Motor Retrofit to ECM measures. http://rtf.nwcouncil.org/measures/measure.asp?id=106	$260.00
2307	ECM (electronically commutated) Condenser/Condensing Unit Fan Motor		
2308	ECM (electronically commutated) evaporator fan motor replacing shaded-pole motor, <1/20 hp, in walk-in cooler		

MMID	Measure Name	Source	Incremental Cost
2309	ECM (electronically commutated) evaporator fan motor replacing shaded-pole motor, >=1/20 hp, <1hp, in walk-in cooler	Regional Technical Forum, UES Measures. "Commercial: Grocery - ECMs for Walk-ins." Measure Workbook 2.2, June 29, 2016. $260.00 for all ECMs for Walk-ins measures. http://rtf.nwcouncil.org/measures/measure.asp?id=162	$260.00
2310	ECM (electronically commutated) evaporator fan motor replacing shaded-pole motor, <1/20 hp, in walk-in freezer		
2311	ECM (electronically commutated) evaporator fan motor replacing shaded-pole motor, >=1/20 hp, <1hp, in walk-in freezer		
2312	ECM (electronically commutated) motor replacing shaded-pole motor in refrig/freezer case	Full cost of $84.88 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 7,926 units over 135 projects, from 2016 to 2018. Base cost of $66 from RTF current practice for display cases, workbook version 3.3: https://rtf.nwcouncil.org/measure/ecms-display-cases?id=107. The incremental cost is therefore $18.88.	$18.88
2314	Energy Recovery Ventilator	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 151 projects, from 2016 to 2018.	$6.63
2322	Freezer, Chest, Glass Door, 15-29 cu ft, Energy Star	ENERGY STAR® Calculator Commercial Kitchen Equipment. Accessed January 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx	$0.00
2323	Freezer, Chest, Glass Door, 30-49 cu ft, Energy Star		
2324	Freezer, Chest, Glass Door, 50+ cu ft, Energy Star		

MMID	Measure Name	Source	Incremental Cost
2325	Freezer, Chest, Solid Door, < 15 cu ft, Energy Star	ENERGY STAR® Calculator Commercial Kitchen Equipment. Accessed January 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx	$0.00
2326	Freezer, Chest, Solid Door, 15-29 cu ft, Energy Star		
2327	Freezer, Chest, Solid Door, 30-49 cu ft, Energy Star		
2330	Freezer, Vertical, Glass Door, 15-29 cu ft, Energy Star		
2331	Freezer, Vertical, Glass Door, 30-49 cu ft, Energy Star		
2332	Freezer, Vertical, Glass Door, 50+ cu ft,Energy Star		
2333	Freezer, Vertical, Solid Door, < 15 cu ft, Energy Star		
2334	Freezer, Vertical, Solid Door, 15-29 cu ft, Energy Star		
2335	Freezer, Vertical, Solid Door, 30-49 cu ft, Energy Star		
2336	Freezer, Vertical, Solid Door, 50+ cu ft, Energy Star		
2337	Fryer, Energy Star, Electric	ENERGY STAR® Commercial Kitchen Savings Calculator. Accessed March 11, 2016. https://www.energystar.gov/products/commercial_food_service_equipment	$1,120.00

MMID	Measure Name	Source	Incremental Cost
2338	Fryer, Energy Star, NG	Illinois Technical Reference Manual. p. 89. 2013. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf. Gas fryer incremental cost is $1,200.00 per fryer.	$1,200.00
2371	Griddle, Energy Star, Electric	ENERGY STAR® Commercial Kitchen Savings Calculator. Accessed March 11, 2016. https://www.energystar.gov/products/commercial_food_service_equipment	$0.00
2372	Griddle, Energy Star, NG	ENERGY STAR® Commercial Kitchen Savings Calculator. Accessed March 11, 2016. https://www.energystar.gov/products/commercial_food_service_equipment	$360.00
2373	Guest Room Energy Management Controls, Electric Heat PTAC Systems	Illinois Statewide Technical Reference Manual for Energy Efficiency. Version 6.0. p. 158. February 8, 2017. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Version_6.0_dated_February_8_2017_Final_Volumes_1-4_Compiled.pdf	$260.00
2374	Guest Room Energy Management Controls, Not Otherwise Specified	Illinois Statewide Technical Reference Manual for Energy Efficiency. Version 6.0. p. 158. February 8, 2017. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Version_6.0_dated_February_8_2017_Final_Volumes_1-4_Compiled.pdf	$260.00
2422	Infrared Heating Units, High or Low Intensity	Historical Focus on Energy project data. 2016 to June 2018. Eighty-nine projects, 262 total unit heaters. Average unit heater cost is $22.64/MBh, minus the baseline unit heater cost of $7.08/MBh (based on a review of www.supplyhouse.com pricing, accessed June 2018, for Reznor and Modine unit heaters. See the 2018 Focus on Energy Incremental Measure Cost study for details.	$15.56
2429	Steam Fittings Insulation - NEW	Actual Program Data, 2015-2016. 20 projects with average actual cost of $37.63 per fitting.	$37.63
2430	Steam Piping Insulation - NEW	Actual Program Data, 2015-2016. 18 projects with average actual cost of $8.40 per foot	$8.40

MMID	Measure Name	Source	Incremental Cost
2434	Irrigation Pressure Reduction, Nozzle Installation	PacifiCorp and Cascade Energy. 2014. Review and Update: Industrial/Agricultural Incentive Table Measures – Utah. http://www.psc.state.ut.us/utilities/electric/14docs/14035T03/254603Exhibit%20B%205-15-2014.pdf	$6.92/ nozzle
2456	LED, Reach-In Refrigerated Case, Replaces T12 or T8	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 11599 units over 454 projects from 2016 to 2018	$141.71
2471	Occupancy Sensors - Ceiling Mount <= 500 Watts	WESCO Distribution Pricing, 2013 ($95.00)+ Labor ($25.00) = $120.00	$120.00
2472	Occupancy Sensors - Ceiling Mount >= 1001 Watts		
2473	Occupancy Sensors - Ceiling Mount 501-1000 Watts		
2474	Occupancy Sensors - Fixture Mount <= 200 Watts	WESCO Distribution Pricing ($70.00) + Labor ($25.00) = $95.00	$95.00
2475	Occupancy Sensors - Fixture Mount > 200 Watts		
2482	Occupancy Sensor, LED Refrigerated Case Lights	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 3,450 units over 22 projects, from 2015 to 2018.	$37.92
2483	Occupancy Sensors - Wall Mount <= 200 Watts	WESCO Distribution Pricing, 2013 ($18.75) + Labor ($16.25) = $35.00	$35.00
2484	Occupancy Sensors - Wall Mount >= 201 Watts	WESCO Distribution Pricing, 2013 ($18.75) + Labor ($16.25) = $35.00	$35.00
2485	Oven, Convection, Energy Star, Electric	ENERGY STAR. "Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment." Calculator. 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx	$388.00
2486	Oven, Convection, Energy Star, NG		$170.00

MMID	Measure Name	Source	Incremental Cost
2487	Oven, Rack Type, Gas, Double Compartment, High Efficiency	ENERGY STAR® Commercial Kitchen Savings Calculator. Accessed March 11, 2016. All Rack Ovens Incremental Cost = $0.00. https://www.energystar.gov/products/commercial_food_service_equipment	$0.00
2488	Oven, Rack Type, Gas, Single Compartment, High Efficiency		
2490	Plastics Equipment, Radiant Heater Band Retrofit	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 6 units, from 2013 to 2016.	$267.99
2494	PreRinse Sprayers, 0.65 GPM Ultra Low Flow-Electric NEW	Midwest program data suggests $35.00 incremental cost.California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” June 2, 2008. http://www.deeresources.com/index.php/ex-ante-database. An installation cost of $16.74 can be estimated from DEER 2008, assuming cost of installing a showerhead is equivalent to a pre-rinse sprayer.	$51.74
2495	PreRinse Sprayers, 0.65 GPM Ultra Low Flow-Gas NEW		
2496	Pressure Screen Rotor	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 12 units, from 2012 to 2014.	$200.77
2507	Radiant tube inserts installed in exhaust of radiant tube burners, Hybrid	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 330 units over 6 projects, from 2012 to 2015.	$368.64
2509	Open Multideck Cases Replaced by Reach-in Cases with Doors- NEW	California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” Version 2011 4.01. Cost Values and Summary Documentation. http://www.deeresources.com/	$574.87
2522	Refrigerator, Chest, Glass Door, 15-29 cu ft, Energy Star	ENERGY STAR® Calculator Commercial Kitchen Equipment. Accessed March 2016. Commercial refrigerator incremental cost is $0.00 for all. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx	$0.00

MMID	Measure Name	Source	Incremental Cost
2523	Refrigerator, Chest, Glass Door, 30-49 cu ft, Energy Star	ENERGY STAR® Calculator Commercial Kitchen Equipment. Accessed March 2016. Commercial refrigerator incremental cost is $0.00 for all. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx	$0.00
2524	Refrigerator, Chest, Glass Door, 50+ cu ft, Energy Star		
2525	Refrigerator, Chest, Solid Door, < 15 cu ft, Energy Star		
2526	Refrigerator, Chest, Solid Door, 15-29 cu ft, Energy Star		
2527	Refrigerator, Chest, Solid Door, 30-49 cu ft, Energy Star		
2528	Refrigerator, Chest, Solid Door, 50+ cu ft, Energy Star		
2529	Refrigerator, Vertical, Glass Door, < 15 cu ft, Energy Star		
2530	Refrigerator, Vertical, Glass Door, 15-29 cu ft, Energy Star		
2531	Refrigerator, Vertical, Glass Door, 30-49 cu ft, Energy Star		
2532	Refrigerator, Vertical, Glass Door, 50+ cu ft, Energy Star		
2533	Refrigerator, Vertical, Solid Door, < 15 cu ft, Energy Star		
2534	Refrigerator, Vertical, Solid Door, 15-29 cu ft, Energy Star		

MMID	Measure Name	Source	Incremental Cost
2535	Refrigerator, Vertical, Solid Door, 30-49 cu ft, Energy Star	ENERGY STAR® Calculator Commercial Kitchen Equipment. Accessed March 2016. Commercial refrigerator incremental cost is $0.00 for all. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx	$0.00
2536	Refrigerator, Vertical, Solid Door, 50+ cu ft, Energy Star		
2538	Repulper Rotor	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 3 units, from 2014 to 2016.	$271.39
2556	T8 1L-4 ft Reduced Wattage with CEE Ballast - 25 Watts (Low BF)	2014 Focus on Energy Program Data; verified with average price of lamps on 1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013. Assumes T8 and CEE ballast as baseline.	$2.45
2557	T8 1L-4 ft Reduced Wattage with CEE Ballast - 28 Watts (Low BF)		$2.07
2558	T8 1L 4', 28W, CEE, BF > 0.78		$2.07
2564	T8 2L-4 ft Reduced Wattage with CEE Ballast - 28 Watts (Low BF)		$4.13
2565	T8 2L-4 ft Reduced Wattage with CEE Ballast - 28 Watts		$4.13
2571	T8 3L-4 ft Low Watt with CEE Ballast - 25 Watts (Low BF)		$7.35
2573	T8 3L-4 ft Reduced Wattage with CEE Ballast - 28 Watts (Low BF)		$6.2
2574	T8 3L 4', 28W, CEE, BF > 0.78		$6.2

MMID	Measure Name	Source	Incremental Cost
2579	T8 4L-4 ft Reduced Wattage with CEE Ballast - 28 Watts (Low BF)	2014 Focus on Energy Program Data; verified with average price of lamps on 1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013. Assumes T8 and CEE ballast as baseline.	$8.27
2580	T8 4L 4', 28W, CEE, BF > 0.78		$8.27
2590	T8 Low Watt Relamp - 25 Watts		$2.45
2591	T8 Low Watt Relamp - 28 Watts		$2.07
2602	Thermal Curtain, Poly Film Walls and Ceiling, Under Bench Heating	Work Paper PGECOAGR101 Greenhouse Thermal Curtains. 2008. https://www.socalgas.com/regulatory/documents/a-08-07-022/amendedWorkpapers/SW-AgB/Greenhouse%20Thermal%20Curtains%20PGECOAGR101%20R0.pdf	$1.50/sq ft
2603	Thermal Curtain, Single Pane Glass Walls and Ceiling, Overhead Heating	Work Paper PGECOAGR101 Greenhouse Thermal Curtains. 2008. https://www.socalgas.com/regulatory/documents/a-08-07-022/amendedWorkpapers/SW-AgB/Greenhouse%20Thermal%20Curtains%20PGECOAGR101%20R0.pdf	$1.50/sq ft
2608	Unit Heater, >= 90% thermal efficiency, per input MBh, for retrofit	Actual Program Data, 2015-2016. 49 projects with average actual cost of $18.00 per MBh.	$18.00/MBh
2611	Vending Machine Controls, Occupancy Based, Cold Beverage Machine	Pacific Gas & Electric. “PGECOREF111 R5 Vending Machine Controller.” Workpaper. (Use Category: “Appliance or Plug Load”, PA: “PGE”, Other Fields: “Any”) Measure life: p. 4. Hours per day off: p. 6. Light wattage: p. 12. Labor cost: p. 16. November 10, 2015. http://deeresources.net/workpapers	$258.00
2612	Vending Machine Controls, Occupancy Based, Snack Machine	Website for USA Tech, the manufacturer of CoolerMiser for beverage coolers, VendingMiser for beverage vending machines, and SnackMiser for snack vending machines. Accessed May 2018. https://store.usatech.com/collections/energymiser-products	$224.00

MMID	Measure Name	Source	Incremental Cost
2613	Vending Machine Controls, Sales Based, Cold Beverage Machine	Website for USA Tech, the manufacturer of CoolerMiser for beverage coolers, VendingMiser for beverage vending machines, and SnackMiser for snack vending machines. Accessed May 2018. https://store.usatech.com/collections/energymiser-products VendingMiserStore.com. Model VM2iQ. Accessed May 2018. https://www.vendingmiserstore.com/product/energymiser-vending-miser-internal-unit-model-vm150?gclid=Cj0KCQjw5-TXBRCHARIsANLixNxtO00k8MlEY1DyQ-WPMOfbvTolGpURNlbleQJMRN4K4tQwNnI8YJIaAsATEALw_wcB	$159.00
2621	Kitchen Hood Ventilation Controls, Temperature Only, Retrofit, BONUS for controlling MUA fan	Actual Program Data, 2015-2016. 1 project with average actual cost of $629.57.	$629.57
2623	Kitchen Hood Ventilation Controls, Temperature Only, Retrofit, Exhaust Fan Controlled	Actual Program Data, 2015-2016. 5 projects with average actual cost of $2,079.04.	$2,079.04
2625	Kitchen Hood Ventilation Controls, Temp and Optical, Retrofit, BONUS for controlling MUA fan	Actual Program Data, 2015-2016. 8 projects with average actual cost of $1,373.63.	$1,373.63
2627	Kitchen Hood Ventilation Controls, Temp and Optical, Retrofit, Exhaust Fan Controlled	Actual Program Data, 2015-2016. 13 projects with average actual cost of $1,966.46.	$1,966.46
2635	Agricultural Exhaust Fan, High Efficiency - 55"	Similar to measure 2634. Historical Focus on Energy project data, 2012-2013. 12 projects, 289 fans; fan average total cost is $1,139.00.	$1,139

MMID	Measure Name	Source	Incremental Cost
2637	Agricultural Exhaust Fan, High Efficiency - 60"	Historical Focus on Energy project data, 2012-2013. 3 projects, 141 fans; fan average total cost is $2,010.00.	$2,010
2639	VFD, Ag Second Use Water System	Evaluator and implementer consensus for setting cost on a per hp basis, instead of per motor. For variable torque VFDs, cost set at $210.52 per hp, based on 2016-2017 data of 1,069 projects.	$210.52
2640	VFD, Boiler Draft Fan		
2641	VFD, Cooling Tower Fan		
2643	VFD, HVAC Fan		
2644	VFD, HVAC Heating Pump		
2646	VFD, Pool Pump Motor		
2647	VFD, Process Fan		
2648	VFD Pump, Hybrid		
2651	Storage Water Heater EF >0.67	Ohio TRM. p. 123. 2010. Gas storage DHW EF > 0.67 incremental cost is $400.00 per water heater. http://s3.amazonaws.com/zanran_storage/amppartners.org/ContentPages/2464316647.pdf	$400.00
2652	Water Heater, ≥ 0.82 EF, Tankless, Residential, Natural Gas	Ohio Technical Reference Manual. p. 123. 2010. http://s3.amazonaws.com/zanran_storage/amppartners.org/ContentPages/2464316647.pdf Tankless DHW EF > 0.82 incremental cost is $605.00 per water heater.	$605.00
2660	Waterer, Livestock, <250 Watts	Full cost of $788.41 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 131 units over 30 projects, from 2016 to 2018. Retrofit baseline cost of $213.07 reflects cost of standard small waterer and 1000 watt de-icer, derived from five product lookups on www.farmandfleet.com and amazon.com. Retrofit incremental cost is $788.41 - $213.07 = $575.35. New construction baseline cost of $221.68 reflects cost of standard small waterer and 500 watt de-icer, derived from five product lookups on www.chewy.com and amazon.com. Retrofit incremental cost is $788.41 - $221.68 = $566.73.	$575.35 (retrofit), $566.73 (NC)
2665	T8 Reduced Wattage Relamp 8 ft - 54 Watts	2014 Focus on Energy Program Data; verified with average price of lamps on 1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013. Assumes T8 and CEE ballast as baseline.	$4.33

MMID	Measure Name	Source	Incremental Cost
2666	Air Cooled Chiller System Tune Up, Service Buy Down <=500 Tons	Illinois Technical Reference Manual. p. 154. 2013. Incremental Cost source listed as: Act on Energy Commercial Technical Reference Manual No. 2010-4. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf	$35.00
2667	Air Cooled Chiller System Tune Up, Service Buy Down>500 Tones		
2668	Water Cooled Chiller System Tune Up, Service Buy Down <=500 Tons		
2669	Water Cooled Chiller System Tune Up, Service Buy Down >500 Tons		
2677	Hot Food Holding Cabinet, V = 13-28 cu. ft., Energy Star	ENERGY STAR. Commercial Kitchen Equipment Calculator. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx Used for both incremental cost and calculation inputs (hours per day and days per year)	$902.00
2678	Hot Food Holding Cabinet, V < 13 cu. ft., Energy Star		
2679	Hot Food Holding Cabinet, V ≥ 28 cu. ft., Energy Star		
2699	PTHP <8,000 Btu/h	Grainger. Website. www.grainger.com. Accessed May 2018. Total Home Supply. Website. www.totalhomesupply.com. Accessed May 2018. Pricing lookups performed for baseline PTACs with electric heat, and efficient PTHPs. Amana, Friedrich, LG, and GE brands examined.	$58.00
2700	PTHP ≥13,000 Btu/h		$69.00
2701	PTHP 10,000–12,999 Btu/h		$77.00
2702	PTHP 8,000–9,999 Btu/h		$49.00
2711	Insulation, Project Based, Attic	Illinois Technical Reference Manual. p. 141. 2013. This measure includes air sealing costs. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf	$2.69/sq ft

MMID	Measure Name	Source	Incremental Cost
2712	Insulation, Sidewall, Foam	California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." Revised Measure Cost Summary. June 2, 2008. http://www.deeresources.com/. Cost for Wall 2x6 R-19 Batts + R-5 Rigid.	$0.94/sq ft
2713	Insulation, Foundation - Interior	Illinois Technical Reference Manual. p. 141. 2013. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf	$2.93/sq ft
2714	Insulation, Sill Box	Illinois Technical Reference Manual. p. 141. 2013. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf	$5.97/sq ft
2726	VFD, Chilled Water Distribution Pump	Evaluator and implementer consensus for setting cost on a per hp basis, instead of per motor. For variable torque VFDs, cost set at $210.52 per hp, based on 2016-2017 data of 1,069 projects.	$210.52
2743	Boiler, Hot Water, Modulating, >=90% AFUE,≤300 MBH	Full cost of $45.45/MBh is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 203 boilers over 168 projects, from 1/1/2016 to 6/30/2018. August 2018 online lookups of 18 baseline and 22 efficient boiler models less than 300 MBh on www.supplyhouse.com and www.grainger.com reveal an efficient cost that is 27.6% higher than the baseline cost. The incremental cost is therefore 27.6% * $45.45 = $12.55/MBh.	$12.55
2744	Boiler Tune Up	Illinois Technical Reference Manual. p. 185. 2013. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf	$0.83
2745	Air Sealing	Varies by project	Varies by project
2746	Multifamily Benchmarking Incentive	No cost in addition to initial project cost	$0.00

MMID	Measure Name	Source	Incremental Cost
2747	Boiler, ≥ 90% AFUE, NG	Illinois Technical Reference Manual. p. 141. 2013. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf	$50.82
2756	Clothes Washer, ENERGY STAR Tier 3, Electric	Illinois Technical Reference Manual. p. 141. 2013. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf	$325.40
2757	Clothes Washer, ENERGY STAR Tier 3, Gas		
2760	Domestic Hot Water Plant Replacement	Full cost of $31.39/MBh is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 213 water heaters over 118 projects, from 2016 to 2018. August 2018 online lookups of 43 baseline and 29 efficient boiler models on www.grainger.com and www.supplyhouse.com allow for a linear fit of cost to MBh for baseline and efficient models. This fit was applied to the spead of water heater sizes in Focus program data, revealing an efficient cost 14.4% higher than the baseline cost. Therefore the incremental cost is 14.4% * $31.39 = $4.53/MBh.	$4.53
2764	Furnace, with ECM fan motor, for space heating (AFUE >= 95%)	NEEP Regional Evaluation, Measurement & Verification Forum, A Report on Costs in Six Northeast & Mid-Atlantic Markets. 2011. Navigant Consulting. Navigant study completed 15 interviews for this measure. http://www.neep.org/Assets/uploads/files/emv/emv-products/Incremental%20Cost_study_FINAL_REPORT_2011Sep23.pdf	$1,667.84
2768	LED Exit Sign, Retrofit	October 2018 online lookups of 6 base and efficient models show an average efficient fixture price of $18.31 and base bulb price of $2.07, for an incremental cost of $16.24.	$16.24
2772	Steam Trap Radiator Repair or Replace	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 1,018 units over 21 projects, from 2013 to 2018.	$58.31
2810	ENGINE BLOCK HEATER TIMER	Implementer research, 2013. Average online cost of Engine Block Heat Timer.	$25.00
2819	Solar PV	Actual cost to be provided annually	Actual

MMID	Measure Name	Source	Incremental Cost
2820	Ground Source Heat Pump, Electric Back-up	Actual Program Data in Current Year	Actual Program Data in Current Year
2820	Ground Source Heat Pump, Electric Back-Up	Actual Program Data in Current Year	Actual Program Data in Current Year
2821	Ground Source Heat Pump, NG Back-up	Actual Program Data in Current Year	Actual Program Data in Current Year
2821	Ground Source Heat Pump, Natural Gas Back-Up	Actual Program Data in Current Year	Actual Program Data in Current Year
2853	Demand Control Ventillation for AHU or Rooftop - NEW	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 23 projects, from 2017 to 2018.	$1.34
2902	Water Heater, Power Vented, EF = .67-.82, Storage, NG	Ohio TRM. p. 123. 2010. Tankless DHW EF > 0.82 incremental cost is $605 per water heater. http://s3.amazonaws.com/zanran_storage/amppartners.org/ContentPages/2464316647.pdf	$400.00
2955	Refrigerator Recycling	Cost to implementer for appliance pick-up.	$110.00
2956	Freezer Recycling	Cost to implementer for appliance pick-up.	$110.00
2989	ECM, Furnace, New or Replacement	Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 5.0, Volume 3 (2015). p. 89. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Final/IL-TRM_Effective_060116_v5.0_Vol_3_Res_021116_Final.pdf	$97.00
2990	Furnace and A/C, ECM, 95%+ AFUE, ≥ 16 SEER	Incremental costs based on a fall 2014 review of residential prescriptive trade allies. Costs are different for the two tiers because the measures use different baselines.	$1,451.66

MMID	Measure Name	Source	Incremental Cost
2992	Air Source Heat Pump, >= 16 SEER	Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 5.0, Volume 3. p. 59. 2015. $274.00 per ton for a time-of-sale 16 SEER ASHP. The Program assumes a value of 3.1 tons (37,000 MBh), as such $274.00 per ton produces an IMC of $849.40. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Final/IL-TRM_Effective_060116_v5.0_Vol_3_Res_021116_Final.pdf	$849.40
3016	Parking Garage Ventilation Controls	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 16 units over 3 projects, from 2013 to 2014.	$827.88
3018	Waterer, Livestock, Energy Free	Full cost of $921.46 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 306 units over 49 projects, from 2017 to 2018. Baseline cost of $358.58 reflects cost of standard large waterer and 1000 watt de-icer, derived from five product lookups on www.farmandfleet.com and amazon.com. Incremental cost is $921.46 - $358.58 = $562.89.	$562.89
3019	Lighting Fixture, Agricultural Daylighting <= 155 Watts	WESCO Distribution Pricing, 2013 + Labor * 10% add for barn install location = $325.87	$325.87
3020	Lighting Fixture, Agricultural Daylighting 156 - 250 Watts	WESCO Distribution Pricing, 2013 + Labor * 10% add for barn install location = $325.87	$325.87
3021	Lighting Fixture, Agricultural Daylighting 251 - 365 Watts	WESCO Distribution Pricing, 2013 + Labor * 10% add for barn install location = $535.04	$535.04
3022	Split System A/C	NEEP. Incremental Cost Study Phase Three Final Report. Average of CEE Tier 2 values ($126.84 and $37.83) from Table 10. http://www.neep.org/incremental-cost-study-phase-3	$82.34

MMID	Measure Name	Source	Incremental Cost
3045	Water Heater, High Usage, >=90% TE, NG	Full cost of $7,230.27 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 179 water heaters over 93 projects, from 2016 to 2018. August 2018 online lookups of 43 baseline and 29 efficient water heater models on www.grainger.com and www.supplyhouse.com allow for a linear fit of cost to MBh for baseline and efficient models. This fit was applied to the spead of water heater sizes in Focus program data, revealing an efficient cost 16.3% higher than the baseline cost. Therefore the incremental cost is 16.3% * $7,230.27 = $1,176.58.	$1,176.58
3046	Water Heater, High Usage, >= 0.82 EF, Tankless, NG	Ohio TRM. p. 123. 2010.Tankless DHW EF > 0.82 incremental cost is $605.00 per water heater. http://s3.amazonaws.com/zanran_storage/amppartners.org/ContentPages/2464316647.pdf	$605.00
3047	Water Heater, High Usage, >= 2 EF, Heat Pump Storage, Electric	Northeast Energy Efficiency Partnerships. Mid-Atlantic Technical Reference Manual, Version 7.0. May 2017. https://neep.org/sites/default/files/resources/Mid_Atlantic_TRM_V7_FINAL.pdf	$1,338.00
3066	Economizer, RTU Optimization	RSMeans. Facilities Construction Cost Data. 29th Edition. 2013. Assumed $54.00 per hour labor rate for work performed on air cooling equipment. Estimated 2 hours for completion based on project experience.	$108.00
3084	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 320 Watt HID, Exterior	2015 Implementer assessment of measure cost.	$340.00
3091	LED Fixture, <155 Watts, Replacing 250 Watt HID, High Bay	Online research. March 2016. Average cost of LED round high bay fixtures under 155-watt replacement. https://www.1000bulbs.com/category/round-high-bays/	$204.99
3092	LED Fixture, <250 Watts, Replacing 320-400 Watt HID, High Bay		$387.82
3093	LED Fixture, <250 Watts, Replacing 400 Watt HID, High Bay		$387.82

MMID	Measure Name	Source	Incremental Cost
3094	LED Fixture, <365 Watts, Replacing 400 Watt HID, High Bay	Online research. March 2016. Average cost of LED round high bay fixtures under 155-watt replacement. https://www.1000bulbs.com/category/round-high-bays/	$398.41
3095	LED Fixture, <500 Watts, Replacing 1000 Watt HID, High Bay		$398.41
3096	LED Fixture, <800 Watts, Replacing 1000 Watt HID, High Bay		$398.41
3097	LED Fixture, Bilevel, Stairwell and Passageway	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 1,939 units over 101 projects, from 2016 to 2018.	$215.15
3099	LED Fixture, Replacing 150-175 Watt HID, Exterior	Full cost of $267.15 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 12,545 fixtures over 1,706 projects, from 2016 to 2018. Online lookups of 6 baseline lamps on www.1000bulbs.com show a baseline cost of $10.09 per replacement bulb. The incremental cost is therefore $257.06.	$257.06
3102	LED Fixture, Replacing 250 Watt HID, Exterior	Full cost of $356.45 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 12,660 fixtures over 1,759 projects, from 2016 to 2018. Online lookups of 6 baseline lamps on www.1000bulbs.com show a baseline cost of $9.62 per replacement bulb. The incremental cost is therefore $346.83.	$346.83
3107	LED Fixture, Replacing 400 Watt HID, Exterior	Full cost of $473.61 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 16,097 fixtures over 2,029 projects, from 2016 to 2018. Online lookups of 6 baseline lamps on www.1000bulbs.com show a baseline cost of $11.98 per replacement bulb. The incremental cost is therefore $461.62.	$461.62

MMID	Measure Name	Source	Incremental Cost
3108	LED Fixture, Replacing 70-100 Watt HID, Exterior	Full cost of $223.18 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 7,721 fixtures over 1,070 projects, from 2016 to 2018. Online lookups of 6 baseline lamps on www.1000bulbs.com show a baseline cost of $8.61 per replacement bulb. The incremental cost is therefore $214.57.	$214.57
3111	LED Troffer, 2x4, Replacing 4' 3-4 Lamp T8 Troffer	Online research. March 2016. Average price of 2x4 led troffer fixtures. Actual cost. www.1000bulbs.com/category/2x4-led-troffer-fixtures/	$168.29
3112	LED, <= 40 Watt, ENERGY STAR, Replacing Incandescent	Online lookups of 4 base and efficient models show an average efficient lamp price of $2.88 and base lamp price of $0.76, for an incremental cost of $2.12.	$2.12
3113	LED, > 40 Watt, ENERGY STAR, Replacing Incandescent	Online lookups of 4 base and efficient models show an average efficient lamp price of $2.88 and base lamp price of $1.24, for an incremental cost of $1.64.	$1.64
3114	LED, Horizontal Case Lighting	Full cost of $40.82 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 26,555 feet over 202 projects, from 2016 to 2018. Base cost of $0.73 per foot. The incremental cost is therefore $40.09.	$40.09
3118	Oven, Combination, Energy Star, Electric	ENERGY STAR® Commercial Kitchen Savings Calculator. Accessed March 11, 2016. All Rack Ovens Incremental Cost=$0.00. https://www.energystar.gov/products/commercial_food_service_equipment	$0.00
3119	Oven, Combination, Energy Star, NG		
3121	Programmable Thermostat, RTU Optimization Standard	California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com/	$150.00
3122	T8 2L 4', HPT8 or RWT8, Replacing T12 1L 8', 0.78 < BF < 1.00	2014 Focus on Energy Program Data; verified with average price of lamps on 1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013. Assumes T8 and CEE ballast as baseline.	$4.90
3123	T8 2L 4', HPT8 or RWT8, Replacing T12 1L 8', BF <= 0.78		
3124	T8 2L 4', HPT8 or RWT8, Replacing T12HO 1L 8', 0.78 < BF < 1.00		$4.90

MMID	Measure Name	Source	Incremental Cost
3125	T8 2L-4ft High Performance HBF Replacing T12HO 1L-8 ft	2014 Focus on Energy Program Data; verified with average price of lamps on www.1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013. Assumes T8 and CEE ballast as baseline.	$4.90
3126	T8 2L 4', HPT8 or RWT8, Replacing T12HO 1L 8', BF > 1.00		$4.90
3127	T8 4L-4-4ft High Performance Replacing T12 2L-8 ft		$9.80
3128	T8 4L 4', HPT8 or RWT8, Replacing T12 2L 8', BF <= 0.78		$9.80
3129	T8 4L-4ft High Performance Replacing T12HO 2L-8 ft -		$9.80
3130	T8 4L 4', HPT8 or RWT8, Replacing T12HO 2L 8', BF <= 0.78		$9.80
3131	T8 4L 4', HPT8 or RWT8, Replacing T12HO 2L 8', BF > 1.00		$9.80
3132	T8 4L-4ft High Performance Replacing T12HO/VHO 2L-8 ft		$9.80
3133	T8 4L 4', HPT8 or RWT8, Replacing T12VHO 2L 8', BF <= 0.78		$9.80
3134	T8 4L 4', HPT8 or RWT8, Replacing T12VHO 2L 8', BF > 1.00		$9.80
3136	Dishwasher, High Temp, Electric Booster, Pots/Pans Type, Energy Star, Electric	ENERGY STAR® Calculator Commercial Kitchen Equipment. Accessed January 2016. Pot, pan, and utensil high temperature type. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx	$1,710.00

MMID	Measure Name	Source	Incremental Cost
3137	Dishwasher, High Temp, Electric Booster, Pots/Pans Type, Energy Star, NG	ENERGY STAR® Calculator Commercial Kitchen Equipment. Accessed January 2016. Pot, pan, and utensil high temperature type. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx	$1,710.00
3138	Dishwasher, High Temp, Gas Booster, Pots/Pans Type, Energy Star, NG		
3148	T8 2L 4', HPT8 or RWT8, Replacing T12HO 1L 8', BF > 1.00, Parking Garage	2014 Focus on Energy Program Data; verified with average price of lamps on 1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013.	$9.80
3152	T8 4L 4', HPT8 or RWT8, Replacing T12HO 2L 8', 0.78 < BF < 1.00, Parking Garage		
3153	T8 4L 4', HPT8 or RWT8, Replacing T12HO 2L 8', BF <= 0.78, Parking Garage		
3157	LED, Porch Fixture, Energy Star	August 2018 online lookups of 7 base and efficient models show an average efficient fixture price of $56.38 and base bulb price of $1.24, for an incremental cost of $55.14.	$55.14
3159	LED, Energy Star, Replacing Incandescent > 40W, In Unit	August 2018 online lookups of 4 base and efficient models show an average efficient lamp price of $6.15 and base lamp price of $0.79, for an incremental cost of $5.36.	$5.36
3160	LED, Energy Star, Replacing Incandescent > 40W, Common Area		
3183	Strip Curtain, Walk-In Freezers and Coolers	WESCO Distribution Pricing ($45.00) + Labor ($5.00) = $50.00	$50.00
3195	Linear Fluorescent, 2L 4'RWT8 Replacements, 24 Hours, CALP	Actual cost from 2015-16 program data, 30 applications.	$34.97
3196	T8 2L-4ft High Performance Tandem Replacing T12 2L-8ft	2014 Focus on Energy Program Data; verified with average price of lamps on www.1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013. Assumes T8 and CEE ballast as baseline.	$9.80

MMID	Measure Name	Source	Incremental Cost
3201	Occupancy Sensor, Wall or Ceiling Mount <=200 Watts, CALP	WESCO Distribution Pricing ($18.75) + Labor ($16.25) = $35.00 for Wall Mount. WESCO Distribution Pricing, 2013 + Labor = $120.00 for Ceiling Mount. $77.50 is the average.	$77.50
3244	Process Exhaust Filtration	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 21 units over 21 projects in 2018	$3.95
3251	Lighting Controls, Bilevel, Exterior and Parking Garage Fixtures, Dusk to Dawn	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 800 units over 38 projects, from 2016 to 2018.	$81.41
3252	Lighting Controls, Bilevel, Parking Garage Fixtures, 24 Hour	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 5,321 units over 21 projects, from 2016 to 2018.	$47.54
3253	Lighting Controls, Photocell with Internal Timer or Wireless Schedule, Exterior	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 643 units over 31 projects, from 2014 to 2018.	$65.52
3266	Demand Control Ventilation, RTU Optimization	Historical data (1/1/14-8/10/16 paid proj) for MMID3266 = $2,796.00 per AHU. This excludes 1 project with $20.00 per AHU and 3 projects > $19,000.00 per AHU.	$2,796.00/ AHU
3275	Boiler Plant Retrofit, Hybrid Plant, >=1 MMBh	Full cost of $17.33/MBh is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 20 boilers over 11 projects, from 2016 to 2018. August 2018 online lookups of 4 baseline and 19 efficient boiler models over 300 MBh on www.supplyhouse.com and www.grainger.com reveal an efficient cost that is 38.1% higher than the baseline cost. The incremental cost is therefore 38.1% * $17.33 = $6.60/MBh.	$6.60
3276	Boiler, Hot Water, Condensing, >=90% AFUE, >=300 mbh	Full cost of $23.06/MBh is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 90 boilers over 50 projects, from 2016 to 2018. August 2018 online lookups of 4 baseline and 19 efficient boiler models over 300 MBh on www.supplyhouse.com and www.grainger.com reveal an efficient cost that is 38.1% higher than the baseline cost. The incremental cost is therefore 38.1% * $23.06 = $8.79/MBh.	$8.79

MMID	Measure Name	Source	Incremental Cost
3277	Boiler, Hot Water, Near Condensing, >=85% AFUE, >=300 mbh	Full cost of $11.96/MBh is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 67 boilers over 36 projects, from 2016 to 2018. August 2018 online lookups of 4 baseline and 19 efficient boiler models over 300 MBh on www.supplyhouse.com and www.grainger.com reveal an efficient cost that is 38.1% higher than the baseline cost. The incremental cost is therefore 38.1% * $11.96 = $4.56/MBh.	$4.56
3280	VFD, Constant Torque	Evaluator and implementer consensus for setting cost on a per hp basis, instead of per motor. For constant torque VFDs, cost set at $122.48 per hp, based on 2016-2017 data of 111 projects.	$122.48
3320	Delamping, T12 to T8, 8', SBP A La Carte	Mid-Atlantic TRM Version 6.0. p. 323. http://www.neep.org/mid-atlantic-technical-reference-manual-v6	$10.80
3386	Grain Dryer, Energy Efficient, Hybrid	Average of unit pricing values from Mathews Company Grain Dryer Price Book based on suggested base retail prices for their new grain dryer equipment offerings. Print.	$179.00
3393	LED Fixture,<=180 Watts, Replacing 4 lamp T5 or 6 lamp T8, High Bay, DLC Listed	August 2018 online lookups of 4 base and efficient models show an average efficient fixture price of $214.99 and base bulb price of $12.76, for an incremental cost of $202.23.	$202.23
3394	LED Fixture, Downlights, <=18 Watts, Replacing 1 lamp pin based CFL Downlight	August 2018 online lookups of 4 base and efficient models show an average efficient lamp price of $9.28 and base lamp price of $4.40, for an incremental cost of $4.88.	$4.88
3400	LED Fixture, 2x2, Low Output, DLC Listed	August 2018 online lookups of 4 base and efficient models show an average efficient fixture price of $55.6 and base bulb price of $16.89, for an incremental cost of $38.71.	$38.71
3401	LED Fixture, 2x2, High Output, DLC Listed	August 2018 online lookups of 4 base and efficient models show an average efficient fixture price of $127.93 and base bulb price of $16.89, for an incremental cost of $111.04.	$111.04
3403	LED Lamp, Energy Star, Replacing Incandescent Lamp >40 Watts, Exterior	Online lookups of 6 base and efficient models show an average efficient lamp price of $5.48 and base lamp price of $2.55, for an incremental cost of $2.93.	$2.93

MMID	Measure Name	Source	Incremental Cost
3404	LED Fixture, Downlights, >18 Watts, Replacing Incandescent Downlight, Exterior	August 2018 online lookups of 4 base and efficient models show an average efficient lamp price of $29.32 and base lamp price of $9.29, for an incremental cost of $20.03.	$20.03
3405	LED Fixture, Downlights, <=18 Watts, Replacing Incandescent Downlight, Exterior	August 2018 online lookups of 4 base and efficient models show an average efficient lamp price of $3.97 and base lamp price of $1.79, for an incremental cost of $2.18.	$2.18
3406	Daylighting Controls	Actual cost from 2015-16 program data, 21 applications	$0.73
3409	Retrofit Open Refrigerated Cases with Doors	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 1556 units over 18 projects from 2014 to 2018.	$424.04
3440	NG Furnace with ECM, 97%+ AFUE	CLEAResult. Survey of trade allies, summer 2018.	$1,538.08
3491	Furnace with ECM, ≥95%+ AFUE, NG	"Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces." Table 8.5.1. February 10, 2015. https://www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0027 Difference between North region's 80% and 95% furnaces (for MMID 3491) and between 80% and 90% furances (for MMID 3492).	$723.00
3492	Furnace with ECM, ≥90%+ AFUE, NG		$575.00
3493	Parking Garage Ventilation Controls with Heating	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 16 units over 3 projects, from 2013 to 2014.	$827.88
3494	Variable Speed ECM Pump, < 100 Watts Max Input, Domestic Hot Water Recirculation	Pricing research, Nov 2014. PSC and ECM pump motors from Viridian, Stratos, Star, Top, and other brands were examined across taco-hvac.com, wilo-usa.com, and nz.grundfos.com.	$690.79
3495	Variable Speed ECM Pump, 100 - 500 Watts Max Input, Domestic Hot Water Recirculation		$1,324.75

MMID	Measure Name	Source	Incremental Cost
3497	Variable Speed ECM Pump, < 100 Watts Max Input, Heating Water Circulation	Pricing research, Nov 2014. PSC and ECM pump motors from Viridian, Stratos, Star, Top, and other brands were examined across taco-hvac.com, wilo-usa.com, and nz.grundfos.com.	$690.79
3498	Variable Speed ECM Pump, 100 - 500 Watts Max Input, Heating Water Circulation		$1,324.75
3499	Variable Speed ECM Pump, > 500 Watts Max Input, Heating Water Circulation		$1,844.58
3502	Variable Speed ECM Pump, > 500 Watts Max Input, Cooling Water Circulation		$1,844.58
3504	Variable Speed ECM Pump, 100 - 500 Watts Max Input, Water Loop Heat Pump Circulation		$1,324.75
3505	Variable Speed ECM Pump, > 500 Watts Max Input, Water Loop Heat Pump Circulation		$1,844.58

MMID	Measure Name	Source	Incremental Cost
3511	LED Replacement of 4’ T8 Lamps w/Integral or External Driver	Energy Avenue. Website. Philips Advance ICN-2P32-N. www.energyavenue.com ASL Supply. Website. Philips ICN-2P32-N. www.adlsupply.com The Lighting Spot. Website. GE-232-MV-N. http://www.lighting-spot.com Bulb America. Website. SKU 49853. www.bulbamerica.com 1000Bulbs. Website. Philips 281535. www.1000bulbs.com ALB. Website. Halco F32T8/835/ECO. www.atlantalightbulbs.com Bulbs.com. Website. SKU U3000100. www.bulbs.com Average baseline cost data from retail sources is $10.79. SPECTRUM measure participation from January 2017 through December 2017 shows that the average cost for participating products is $24.90 for MMID 3511. Therefore, the incremental cost is $14.11 ($24.90 - $10.79).	$14.11
3512	LED Replacement of 4’ T8 Lamps utilizing existing ballast	August 2018 online lookups of 6 base and efficient models show an average efficient lamp price of $7.4 and base lamp price of $1.92, for an incremental cost of $5.48.	$5.48
3513	ENERGY STAR Fluorescent Porch Fixtures	ENERGY STAR® Products List. Filtered by fluorescent technology, porch fixture type and lumen bin. April 15, 2016.	$32.00
3548	CFL, Standard Bulb, 310-749 Lumens, Retail Store Markdown	Light bulb sales data obtained by Cadmus for California- 2010 through 2012. Note that the CFL average lamp costs include incented lamps.	$1.21
3549	CFL, Standard Bulb, 750-1049 Lumens, Retail Store Markdown	Online research. ENERGY STAR®. March 2016. 1000 bulbs.com, Lowes, and HomeDepot.	$1.62
3550	CFL, Standard Bulb, 1050-1489 Lumens, Retail Store Markdown		$2.74
3551	CFL, Standard Bulb, 1490-2600 Lumens, Retail Store Markdown		$1.03
3552	CFL, Reflector, 15 watt, Retail Store Markdown		$2.80

MMID	Measure Name	Source	Incremental Cost
3553	LED, Omnidirectional, 310-749 Lumens, Retail Store Markdown	August 2018 online lookups of 11 base and efficient models show an average efficient lamp price of $1.92 and base lamp price of $1.28, for an incremental cost of $0.64.	$0.64
3557	LED, Reflector, 12 watt, Retail Store Markdown	August 2018 online lookups of 12 base and efficient models show an average efficient lamp price of $4.92 and base lamp price of $3.27, for an incremental cost of $1.65.	$1.65
3559	Boiler, 95%+ AFUE, With DHW, NG	NEEP Regional Evaluation, Measurement & Verification Forum, A Report on Costs in Six Northeast & Mid-Atlantic Markets. 2011. Navigant Consulting. p. A-10. Mid-sized (126 MBh) Residential Combination Heat/Hot Water Incremental Cost 95 CAE = $2,803.00.	$2,803.00
3584	Condensing Water Heater, NG, 90%+, Claim Only	Illinois Stakeholder Advisory Group. Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 6.0, Volume 3: Residential Measures. p. 170. February 8, 2017. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_3_Res_020817_Final.pdf	$685.00
3585	Water Heater, Indirect, Claim Only	NEEP Regional Evaluation, Measurement & Verification Forum, A Report on Costs in Six Northeast & Mid-Atlantic Markets. 2011. Navigant Consulting. p. 11. Mid-sized (60 MBh and 48 gals) Residential Indirect Water Heater Incremental Cost Results ($ per unit) Non-Regional Specific.	$1,294.00
3586	Water Heater, Electric, EF of 0.93 or greater, Claim Only	California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” June 2, 2008. http://www.deeresources.com/index.php/ex-ante-databaseRSMeans. Facilities Construction Cost Data. 2011.	$25.16
3587	Water Heater, >= 0.67 EF, Storage, NG, Claim Only	Ohio TRM. p. 123. 2010. Gas storage DHW EF > 0.67 incremental cost is $400.00 per water heater. http://s3.amazonaws.com/zanran_storage/amppartners.org/ContentPages/2464316647.pdf	$400.00
3588	Water Heater, >= 0.82 EF, Tankless, Residential, NG, Claim Only	Ohio TRM. p. 123. 2010. Tankless DHW EF > 0.82 incremental cost is $605.00 per water heater. http://s3.amazonaws.com/zanran_storage/amppartners.org/ContentPages/2464316647.pdf	$605.00

MMID	Measure Name	Source	Incremental Cost
3603	LED Fixture, Interior, 12 Hours, CALP	Online research. March 2016. Material cost is average sales price of LED downlights. https://www.1000bulbs.com/category/led-downlights/	$12.46
3604	LED Fixture, Interior, 24 Hours, CALP		
3605	Occupancy Sensor, Fixture Mount, <=200 Watts, CALP	Similar to MMID 2474. WESCO Distribution Pricing ($70.00) + Labor ($25.00) = $95.00	$115.00
3606	Occupancy Sensor, Fixture Mount, >200 Watts, CALP		
3612	Smart Thermostat, Installed with 95% AFUE NG Furnace	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. July 2017 to December 2017. Average actual measure cost of smart thermostat measures incented by Focus on Energy is $213.00 (MMIDs 3609, 3610, and 3611). Minus the cost of a manual thermostat, which is $39.11 based on online lookups from July 2018.	$173.89
3613	Smart Thermostat, Installed with 95% AFUE NG Boiler		
3614	Smart Thermostat, Installed with Furnace and A/C		
3615	Smart Thermostat, Installed with Air Source Heat Pump		
3619	Occupancy Sensor, Fixture Mount, ≤ 60 Watts, SBP Package	Similar to MMID 3561. Mid-Atlantic Technical Reference Manual Version 5.0. p.302. April 2015. http://www.neep.org/sites/default/files/resources/Mid-Atlantic_TRM_V5_FINAL_5-26-2015.pdf	$200.00
3621	Occupancy Sensor, Fixture Mount, ≤ 60 Watts, SBP After A La Carte		
3632	HVAC Controls, Surgery Occupancy	Historical Program Data- 4 similar projects done under other measure names	$5,500.00
3652	DEET, Savings Period 1	Staff estimate- $2000.00 for energy projects + $10000.00 average staff time in average-sized building	$12,000.00
3653	DEET, Savings Period 2		
3654	DEET, Savings Period 3		
3655	DEET, Savings Period 4		
3656	DEET, Savings Period 5		
3657	DEET, Savings Period 6		

MMID	Measure Name	Source	Incremental Cost
3658	DEET, Savings Persistence	Staff estimate- $2000.00 for energy projects + $10000.00 average staff time in average-sized building	$12,000.00
3659	Chiller Plant Chilled Water Setpoint Adjustment	RSMeans 2013 Facilities Construction Cost Data, 29th Edition	$108.00
3660	Chiller Plant Condenser Water Setpoint Adjustment		
3661	Economizer Optimization	RSMeans. Facilities Construction Cost Data. 29th Edition. 2013. Assumed $54.00 per hour labor rate for work performed on air cooling equipment. Estimated two hours for completion based on project experience.	$108.00
3662	Hot Water Supply Reset	RSMeans 2013 Facilities Construction Cost Data, 29th Edition	$108.00
3663	Outside Air Intake Optimization	RSMeans 2013 Facilities Construction Cost Data, 29th Edition	$212.00
3672	Supply Air Temperature Reset, Heating		$96.00
3673	Supply Air Temperature Reset, Cooling		$96.00
3674	Temperature Sensor Calibration		$108.00
3675	Valve Repair, Chilled Water		$112.00
3676	Valve Repair, Hot Water		$112.00
3677	VFD Fan Motor Control Restoration		$56.00
3678	VFD Pump Control Restoration		$56.00
3679	LP Furnace with ECM, 90%+ AFUE (Existing)	CLEAResult. Survey of trade allies, summer 2018.	$215.91
3680	Spring-loaded Garage Door Hinge, 55 Degree Indoor Temperature Setpoint	2015 Vendor Feedback. The average installation cost is based on the average door size of 10 feet wide by 12 feet tall, with six panels and five sets of hinges at $28.00 per set (trade ally feedback /web quote) plus an estimated installation of $200.00 per door.	$228.00

MMID	Measure Name	Source	Incremental Cost
3681	Spring-loaded Garage Door Hinge, 60 Degree Indoor Temperature Setpoint	2015 Vendor Feedback. The average installation cost is based on the average door size of 10 feet wide by 12 feet tall, with six panels and five sets of hinges at $28.00 per set (trade ally feedback /web quote) plus an estimated installation of $200.00 per door.	$228.00
3682	Spring-loaded Garage Door Hinge, 65 Degree Indoor Temperature Setpoint		
3683	Spring-loaded Garage Door Hinge, 70 Degree Indoor Temperature Setpoint		
3684	Water Heater, High Usage, ≥90% TE, K-12 School	2015 Michigan Energy Measures Database. Supplied by Morgan Marketing Partners. http://www.michigan.gov/mpsc/0,4639,7-159-52495_55129---,00.html	$1,135.00
3685	Insulation, 1/2" and 3/4" Pipe, Hot Water Space Heat, Natural Gas	Illinois Energy Efficiency Statewide Advisory Group. Illinois Statewide Technical Reference Manual. Section 4.4.14, Pipe Insulation. June 1, 2015. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_4/2-13-15_Final/Updated/Illinois_Statewide_TRM_Effective_060115_Final_02-24-15_Clean.pdf This Illinois TRM lists costs for 1-inch and 2-inch pipe insulation, interpolated to determine the cost of 0.5-inch and 1.5-inch pipe insulation.	$9.40
3686	Insulation, 1" and 1 1/4" Pipe, Hot Water Space Heat, Natural Gas	Illinois Energy Efficiency Statewide Advisory Group. Illinois Statewide Technical Reference Manual. Section 4.4.14, Pipe Insulation. June 1, 2015. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_4/2-13-15_Final/Updated/Illinois_Statewide_TRM_Effective_060115_Final_02-24-15_Clean.pdf This Illinois TRM lists costs for 1-inch and 2-inch pipe insulation, interpolated to determine the cost of 0.5-inch and 1.5-inch pipe insulation.	$9.40

MMID	Measure Name	Source	Incremental Cost
3687	Insulation, 1 1/2" and 2" Pipe Hot Water Space Heat, Natural Gas	Illinois Energy Efficiency Statewide Advisory Group. Illinois Statewide Technical Reference Manual. Section 4.4.14, Pipe Insulation. June 1, 2015. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_4/2-13-15_Final/Updated/Illinois_Statewide_TRM_Effective_060115_Final_02-24-15_Clean.pdf This Illinois TRM lists costs for 1-inch and 2-inch pipe insulation, interpolated to determine the cost of 0.5-inch and 1.5-inch pipe insulation.	$9.40
3688	Insulation, 3" and 4" Pipe, Hot Water Space Heat, Natural Gas		$10.53
3689	Insulation, 1/2" and 3/4" Pipe, Hot Water Space Heat, Electric		$9.40
3690	Insulation, 1" and 1 1/4" Pipe, Hot Water Space Heat, Electric		$9.40
3691	Insulation, 1 1/2" and 2" Pipe Hot Water Space Heat, Electric		$9.40
3692	Insulation, 3" and 4" Pipe, Hot Water Space Heat, Electric		$10.53
3693	Single package vertical HVAC unit, ≥90%+ Thermal Efficiency, ≥10.0 EER Cooling, NG	MESP program manager discussion with vendor of single package vertical units early 2015. Vendor noted an incremental cost of $500.00 to $600.00 to upgrade from a 80% to 90% efficient unit. Used $550.00 as the midpoint of this range.	$550.00
3694	Single package vertical HVAC unit, ≥90%+ Thermal Efficiency, NG		
3695	Insulation, 1/2" and 3/4" Pipe, Domestic Hot Water, Natural Gas	Illinois Energy Efficiency Statewide Advisory Group. Illinois Statewide Technical Reference Manual. Section 4.4.14, Pipe Insulation. June 1, 2015. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_4/2-13-15_Final/Updated/Illinois_Statewide_TRM_Effective_060115_Final_02-24-15_Clean.pdf This Illinois TRM lists costs for 1-inch and 2-inch pipe insulation, interpolated to determine the cost of 0.5-inch and 1.5-inch pipe insulation.	$7.15

MMID	Measure Name	Source	Incremental Cost
3696	Insulation, 1" and 1 1/4" Pipe, Domestic Hot Water, Natural Gas	Illinois Energy Efficiency Statewide Advisory Group. Illinois Statewide Technical Reference Manual. Section 4.4.14, Pipe Insulation. June 1, 2015. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_4/2-13-15_Final/Updated/Illinois_Statewide_TRM_Effective_060115_Final_02-24-15_Clean.pdf This Illinois TRM lists costs for 1-inch and 2-inch pipe insulation, interpolated to determine the cost of 0.5-inch and 1.5-inch pipe insulation.	$7.15
3697	Insulation, 1 1/2" and 2" Pipe, Domestic Hot Water, Natural Gas		$8.28
3698	Insulation, 3" and 4" Pipe, Domestic Hot Water, Natural Gas		$9.40
3699	Insulation, 1/2" and 3/4" Pipe, Domestic Hot Water, Electric		$7.15
3700	Insulation, 1" and 1 1/4" Pipe, Domestic Hot Water, Electric		$7.15
3701	Insulation, 1 1/2" and 2" Pipe, Domestic Hot Water, Electric		$8.28
3702	Insulation, 3" and 4" Pipe, Domestic Hot Water, Electric		$9.40
3703	Insulation, Wall, NG heat with Cooling	California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." Revised Measure Cost Summary. June 2, 2008. http://www.deeresources.com/. Cost for Wall 2x6 R-19 Batts + R-5 Rigid	$1.86 for retrofit, $0.82 for new construction
3704	Insulation, Wall, NG heat without Cooling		
3705	Insulation, Wall, Electric heat with Cooling		
3706	Insulation, Wall, Electric heat without Cooling		
3707	Insulation, Attic, NG heat with Cooling, Existing Insulation ≤R-11	California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." Revised Measure Cost Summary. June 2, 2008. http://www.deeresources.com/index.php/deer-versions/deer2008-for-09-11-planning-reporting	$1.36

MMID	Measure Name	Source	Incremental Cost
3708	Insulation, Attic, NG heat without Cooling, Existing Insulation ≤R-11	California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." Revised Measure Cost Summary. June 2, 2008. http://www.deeresources.com/index.php/deer-versions/deer2008-for-09-11-planning-reporting	$1.36
3709	Insulation, Attic, NG heat with Cooling, Existing Insulation R-12 to R-19		$1.04
3710	Insulation, Attic, NG heat without Cooling, Existing Insulation R-12 to R-19		$1.04
3711	Insulation, Attic, Electric heat with Cooling, Existing Insulation ≤R-11	California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." Revised Measure Cost Summary. June 2, 2008. http://www.deeresources.com/index.php/deer-versions/deer2008-for-09-11-planning-reporting	$1.36
3712	Insulation, Attic, Electric heat without Cooling, Existing Insulation ≤R-11		
3713	Insulation, Attic, Electric heat with Cooling, Existing Insulation R-12 to R-19		$1.04
3714	Insulation, Attic, Electric heat without Cooling, Existing Insulation R-12 to R-19		
3735	LED Fixture, Exterior, 12 Hours, CALP	Online research. March 2016. Material cost is average sales price of LED downlights. https://www.1000bulbs.com/category/led-downlights/	$12.46
3738	LED Fixture, Linear Ambient, Replacing 1 or 2 T5 lamp(s) in Cross Section	1000 Bulbs. Website. Accessed July 2018. www.1000bulbs.com Top Bulb. Website. Accessed July 2018. www.topbulb.com Average efficient cost of $16.35 and base cost of $3.76 for MMIDs 3738, 4618, 4791, 4785, and 4786. Average efficient cost of $38.15 and base cost of $8.77 for MMIDs 3739, 4619, 4792, 4787, and 4788.	$12.59

MMID	Measure Name	Source	Incremental Cost
3739	LED Fixture, Linear Ambient, Replacing 3 or 4 T5 lamps in Cross Section	1000 Bulbs. Website. Accessed July 2018. www.1000bulbs.com Top Bulb. Website. Accessed July 2018. www.topbulb.com Average efficient cost of $16.35 and base cost of $3.76 for MMIDs 3738, 4618, 4791, 4785, and 4786. Average efficient cost of $38.15 and base cost of $8.77 for MMIDs 3739, 4619, 4792, 4787, and 4788.	$29.38
3740	LED Fixture, Linear Ambient, Replacing 1 or 2 T8/T12 lamp(s) in Cross Section	August 2018 online lookups of 6 base and efficient models show an average efficient lamp price of $12.82 and base lamp price of $2.94, for an incremental cost of $9.89.	$9.89
3741	LED Fixture, Linear Ambient, Replacing 3 or 4 T8/12 lamps in Cross Section	August 2018 online lookups of 6 base and efficient models show an average efficient lamp price of $29.93 and base lamp price of $6.85, for an incremental cost of $23.08.	$23.08
3742	LED Lamp, Energy Star, Replacing ≥ 23 Watt CFL	August 2018 online lookups of 4 base and efficient models show an average efficient lamp price of $8.18 and base lamp price of $3.26, for an incremental cost of $4.92.	$4.92
3743	LED Lamp, Energy Star, Replacing ≥ 23 Watt CFL, Common Area	August 2018 online lookups of 4 base and efficient models show an average efficient lamp price of $8.18 and base lamp price of $3.26, for an incremental cost of $4.92.	$4.92
3744	LED Lamp, Energy Star, Replacing ≥ 23 Watt CFL, In Unit		
3745	LED Lamp, Energy Star, Replacing < 23 Watt CFL	August 2018 online lookups of 4 base and efficient models show an average efficient lamp price of $2.88 and base lamp price of $1.89, for an incremental cost of $0.99.	$0.99
3747	LED Lamp, Energy Star, Replacing < 23 Watt CFL, In Unit		
3749	LED Fixture, Downlight, > 18 Watts	August 2018 online lookups of 4 base and efficient models show an average efficient lamp price of $19.9 and base lamp price of $3.14, for an incremental cost of $16.76.	$16.76

MMID	Measure Name	Source	Incremental Cost
3751	Insulation, 1/2" and 3/4" Pipe, Steam Space Heat, Natural Gas	Illinois Energy Efficiency Statewide Advisory Group. Illinois Statewide Technical Reference Manual. Section 4.4.14, Pipe Insulation. June 1, 2015. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_4/2-13-15_Final/Updated/Illinois_Statewide_TRM_Effective_060115_Final_02-24-15_Clean.pdf This Illinois TRM lists costs for 1-inch and 2-inch pipe insulation, interpolated to determine the cost of 0.5-inch and 1.5-inch pipe insulation.	$11.65
3752	Insulation, 1" and 1 1/4" Pipe, Steam Space Heat, Natural Gas	Illinois Energy Efficiency Statewide Advisory Group. Illinois Statewide Technical Reference Manual. Section 4.4.14, Pipe Insulation. June 1, 2015. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_4/2-13-15_Final/Updated/Illinois_Statewide_TRM_Effective_060115_Final_02-24-15_Clean.pdf This Illinois TRM lists costs for 1-inch and 2-inch pipe insulation, interpolated to determine the cost of 0.5-inch and 1.5-inch pipe insulation.	$11.65
3753	Insulation, 1 1/2" and 2" Pipe, Steam Space Heat, Natural Gas		
3754	Insulation, 3" and 4" Pipe, Steam Space Heat, Natural Gas		
3755	Insulation, 1/2" and 3/4" Pipe, Steam Space Heat, Electric		
3756	Insulation, 1" and 1 1/4" Pipe, Steam Space Heat, Electric		
3757	Insulation, 1 1/2" and 2" Pipe, Steam Space Heat, Electric		
3758	Insulation, 3" and 4" Pipe, Steam Space Heat, Electric		
3759	LED Replacement of 4’ T8 Lamps, Direct Wire	August 2018 online lookups of 6 base and efficient models show an average efficient lamp price of $8.21 and base lamp price of $1.92, for an incremental cost of $6.29.	$6.29

MMID	Measure Name	Source	Incremental Cost
3760	LED Troffer, 1x4, Replacing 4' 1-2 Lamp T8 Troffer	Light Mart. Website. Accessed August 2015. www.lightmart.com Home Depot. Website. Accessed August 2015. www.homedepot.com Exit Sign Warehouse. Website. Accessed August 2015. www.exitsignwarehouse.com	$77.00
3761	A/C Split or Packaged System, High Efficiency, Multifamily	Based on a review of TRM incremental cost assumptions from Vermont (Vermont Technical Reference Manual. August 2013. and California Municipal Utilities (CMUA Savings Estimation Technical Reference Manual). 2014. http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf; http://cmua.org/energy-efficiency-technical-reference-manual	$100.00
3767	Circulation Fan, HS/HE, 36"-47", Ag	Illinois Energy Efficiency Stakeholder Advisory Group. “Illinois Technical Reference Manual.” Version 4.0. p. 62 referencing ‘Act on Energy Commercial Technical Reference Manual No. 2010-4’. January 22, 2016. http://www.ilsag.info/il_trm_version_4.html	$150.00
3768	Circulation Fan, HS/HE, 48"-52", Ag		
3769	Circulation Fan, HS/HE, ≥ 53", Ag		
3770	Ventilation Fan, HS/HE, 24"-35", Ag	Illinois Energy Efficiency Stakeholder Advisory Group. “Illinois Technical Reference Manual.” Version 4.0. p. 62 referencing ‘Act on Energy Commercial Technical Reference Manual No. 2010-4’. January 22, 2016. http://www.ilsag.info/il_trm_version_4.html	$150.00
3771	Ventilation Fan, HS/HE, 36"-47", Ag		
3772	Ventilation Fan, HS/HE, 48"-52", Ag		
3773	Ventilation Fan, HS/HE, ≥ 53", Ag		
3776	VFD, Variable Torque, Irrigation Well Pump	Evaluator and implementer consensus for setting cost on a per hp basis, instead of per motor. For variable torque VFDs, cost set at $210.52 per hp, based on 2016-2017 data of 1,069 projects.	$210.52
3777	VFD, High Speed Ventilation/Circulation Fan, Ag		
3778	Boiler, Tier 2, 95%+ AFUE, With DHW, NG	NEEP Regional Evaluation, Measurement & Verification Forum, A Report on Costs in Six Northeast & Mid-Atlantic Markets. 2011. Navigant Consulting. p. A-10. Mid-sized (126 MBh) Residential Combination Heat/Hot Water Incremental Cost 95 CAE = $2,803.00.	$2,803.00

MMID	Measure Name	Source	Incremental Cost
3779	Furnace and A/C, Tier 2, ECM, 95% + AFUE, ≥ 16 SEER	Incremental costs based on a fall 2014 review of residential prescriptive trade allies. Costs are different for the two tiers because the measures use different baselines.	$2,238.73
3780	Hot Water Boiler, Tier 2, 95%+ AFUE	2013, Program Implementer CLEAResult surveyed 40 Trade Allies and took the average reported cost for an 82% boiler and subtracted that amount from the average reported cost for a 95% boiler.	$3,105.00
3781	LP Furnace with ECM, Tier 2, 90%+ AFUE (Existing)	Implementer Trade Ally Survey, CLEAResult, 2014. Documented in Wisconsin Public Service Commission. Incremental Cost Database. December 2014.	$432.00
3782	NG Furnace with ECM, Tier 2, 95%+ AFUE (Existing)		$1,565.00
3783	NG Furnace, Tier 2, 95%+ AFUE		$1,194.00
3784	Water Heater, Indirect, Tier 2	New York Statewide Residential Gas High Efficiency Heating Equipment Programs: Evaluation of 2009-2011 Programs. Average of mean and median costs using both approaches, in Table 1-4. http://www.coned.com/energyefficiency/PDF/EEPS%20CY1%20NY%20HEHE%20Evaluation%20Report%20FINAL%20APPROVED%202014-08-21.pdf	$988.50
3785	Insulation, Tier 2, Project Based, Attic	Illinois Technical Reference Manual. p. 141. 2013. This measure includes air sealing costs. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf	$2.69/sq ft
3786	Insulation, Tier 2, Project Based, Foundation		$2.93/sq ft
3787	Insulation, Tier 2, Project Based, Sillbox		$5.97/sq ft
3788	Insulation, Tier 2, Project Based, Wall	California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." Revised Measure Cost Summary. June 2, 2008. http://www.deeresources.com/cost for Wall 2x6 R-19 Batts + R-5 Rigid	$0.94/sq ft
3799	T8 2L 4', HPT8, CEE, BF <= 0.78, Agriculture	2014 Focus on Energy Program Data; verified with average price of lamps on 1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013. There is no additional cost for ballasts.	$15.40

MMID	Measure Name	Source	Incremental Cost
3801	T8 2L 4', HPT8 or RWT8, Replacing T12HO 1L 8', 0.78 < BF < 1.00, Agriculture	2014 Focus on Energy Program Data; verified with average price of lamps on 1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013. Assumes T8 and CEE ballast as baseline.	$4.90
3802	T8 2L 4', HPT8 or RWT8, Replacing T12HO 1L 8', BF > 1.00, Agriculture		
3803	T8 4L 4', HPT8 or RWT8, Replacing T12 2L 8', 0.78 < BF < 1.00, Agriculture		$9.80
3804	T8 4L 4', HPT8 or RWT8, Replacing T12HO 2L 8', 0.78 < BF < 1.00, Agriculture		
3805	T8 4L 4', HPT8 or RWT8, Replacing T12HO 2L 8', BF > 1.00, Agriculture		
3806	LED Fixture, <155 Watts, Replacing 250 Watt HID, High Bay, Agriculture	Online research. March 2016. Average cost of LED round high bay fixtures under 155-watt replacement. https://www.1000bulbs.com/category/round-high-bays/	$204.99
3807	LED Fixture, <250 Watts, Replacing 400 Watt HID, High Bay, Agriculture		$387.82
3809	LED Fixture,<=180 Watts, Replacing 4 lamp T5 or 6 lamp T8, High Bay, DLC Listed, Agriculture	August 2018 online lookups of 4 base and efficient models on www.1000bulbs.com , www.bulbs.com , www.lightbulbsupply.com , www.topbulb.com , and www.warehouse-lighting.com show an average efficient fixture price of $236.9 and base bulb price of $12.76, for an incremental cost of $224.14	$224.14
3810	LED Fixture, <250 Watts, Replacing 320-400 Watt HID, High Bay, Agriculture	Online research. March 2016. Average cost of LED round high bay fixtures 155-watt to 250-watt replacement. https://www.1000bulbs.com/category/round-high-bays/	$387.82

MMID	Measure Name	Source	Incremental Cost
3811	T8 4L Replacing 250-399 W HID, Agriculture	2014 Focus on Energy Program Data; verified with average price of lamps on www.1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013.	$129.00
3812	T8 6L Replacing 400-999 W HID, Agriculture		$327.12
3813	T5HO 4L Replacing 400-999 W HID, Agriculture		$163.16
3814	T5HO 6L Replacing 400-999 W HID, Agriculture		$210.22
3815	Induction, PSMH/CMH, Replacing 250 Watt HID, High Bay	Actual cost from 2015-16 program data, 1 application.	$100.00
3816	Induction, PSMH/CMH, <=250 Watt, Replacing 320-400 Watt HID, High Bay, Agriculture	2015 Implementer assessment of measure cost.	$290.00
3817	Induction, PSMH/CMH, <=250 Watt, Replacing 400 Watt HID, High Bay, Agriculture	Online research. March 2016. and Program Data. 2015. www.warehouse-lighting.com . Baseline measure is 16" Aluminum (400-watt High Bay Light Fixture, High Pressure Sodium, 120-277v); cost is $181.26. Efficient measure average cost is $341.00 from 2015 Focus on Energy Program application data.	$159.74
3819	LED Fixture, Downlights, ≤18 Watts, Agriculture	August 2018 online lookups of 4 base and efficient models show an average efficient lamp price of $6.56 and base lamp price of $3.11, for an incremental cost of $3.45.	$3.45
3820	LED Fixture, Downlights, > 18 Watts, Agriculture	Online research. March 2016. Material cost is average sales price of LED downlights. https://www.1000bulbs.com/category/led-downlights/	$12.46
3821	LED, > 40 Watt, ENERGY STAR, Replacing Incandescent, Agriculture	Online lookups of 4 base and efficient models show an average efficient lamp price of $2.88 and base lamp price of $1.24, for an incremental cost of $1.64.	$1.64

MMID	Measure Name	Source	Incremental Cost
3822	LED Replacement of 4' T8 Lamps w/Integral or External Driver, Agriculture	Energy Avenue. Website. Philips Advance ICN-2P32-N. www.energyavenue.com ASL Supply. Website. Philips ICN-2P32-N. www.adlsupply.com The Lighting Spot. Website. GE-232-MV-N. http://www.lighting-spot.com Bulb America. Website. SKU 49853. www.bulbamerica.com 1000Bulbs. Website. Philips 281535. www.1000bulbs.com ALB. Website. Halco F32T8/835/ECO. www.atlantalightbulbs.com Bulbs.com. Website. SKU U3000100. www.bulbs.com Average baseline cost data from retail sources is $10.79. SPECTRUM measure participation from January 2017 through December 2017 shows that the average cost for participating products is $24.90 for MMID 3511. Therefore, the incremental cost is $14.11 ($24.90 - $10.79).	$14.11
3823	LED Replacement of 4' T8 Lamps utilizing existing ballast, Agriculture	August 2018 online lookups of 6 base and efficient models show an average efficient lamp price of $7.4 and base lamp price of $1.92, for an incremental cost of $5.48.	$5.48
3824	LED Fixture, Replacing 150-175 Watt HID, Exterior, Agriculture	Full cost of $338.10 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 72 fixtures over 26 projects, from 2016 to 2018. Online lookups of 6 baseline lamps on www.1000bulbs.com show a baseline cost of $10.09 per bulb. The incremental cost is therefore $328.01.	$328.01
3825	LED Fixture, Replacing 250 Watt HID, Exterior, Agriculture	Full cost of $371.94 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 182 fixtures over 53 projects, from 2016 to 2018. Online lookups of 6 baseline lamps on www.1000bulbs.com show a baseline cost of $9.62 per bulb. The incremental cost is therefore $371.94.	$371.94

MMID	Measure Name	Source	Incremental Cost
3826	LED Fixture, Replacing 320-400 Watt HID, Exterior, Agriculture	Actual cost from 2015-16 program data = $337.33. 283 applications, primary fixture types are a mixture of architectureal floods, pole/arm mounted and wall packs. Less average price from www.1000bulbs.com search for "320 Watt HID, Exterior = $243.06. Incremental Cost is $408-$243.06 =$164.94. Incremental Cost is $337.33 - $243.06 = $94.27	$94.27
3827	LED Fixture, Replacing 400 Watt HID, Exterior, Agriculture	Full cost of $416.64 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 28 fixtures over 9 projects, from 2016 to 2018. Online lookups of 6 baseline lamps on www.1000bulbs.com show a baseline cost of $11.98 per bulb. The incremental cost is therefore $404.66.	$404.66
3828	LED Fixture, Replacing 70-100 Watt HID, Exterior, Agriculture	Full cost of $268.34 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 17 fixtures over 7 projects, from 2016 to 2018. Online lookups of 6 baseline lamps on www.1000bulbs.com show a baseline cost of $8.61 per bulb. The incremental cost is therefore $259.73.	$259.73
3829	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 150-175 Watt HID, Exterior, Agriculture	Actual cost from 2015-16 program data, 8 applications.	$284.48
3830	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 250 Watt HID, Exterior, Agriculture	Actual cost from 2015-16 program data, 15 applications.	$244.76
3831	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 320-400 Watt HID, Exterior, Agriculture	2015 Implementer assessment of measure cost.	$290.00

MMID	Measure Name	Source	Incremental Cost
3832	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 400 Watt HID, Exterior, Agriculture	Actual cost form 2015-16 program data, 15 applications.	$316.61
3833	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 70-100 Watt HID, Exterior, Agriculture	2015 Implementer assessment of measure cost.	$50.00
3834	Lighting Controls, Photocell with Internal Timer or Wireless Schedule, Exterior, Agriculture	Actual cost from 2015-16 program data, 7 applications.	$101.56
3835	VFD, Process Pump, Agriculture	Evaluator and implementer consensus for setting cost on a per hp basis, instead of per motor. For variable torque VFDs, cost set at $210.52 per hp, based on 2016-2017 data of 1,069 projects.	$210.52
3836	VFD, Constant Torque, Agriculture	Evaluator and implementer consensus for setting cost on a per hp basis, instead of per motor. For constant torque VFDs, cost set at $122.48 per hp, based on 2016-2017 data of 111 projects.	$122.48
3837	LED Lamp, Energy Star, Replacing ≥ 23 Watt CFL, Agriculture	August 2018 online lookups of 4 base and efficient models show an average efficient lamp price of $8.18 and base lamp price of $3.26, for an incremental cost of $4.92.	$4.92
3838	LED Lamp, Energy Star, Replacing < 23 Watt CFL, Agriculture	August 2018 online lookups of 4 base and efficient models show an average efficient lamp price of $2.88 and base lamp price of $1.89, for an incremental cost of $0.99.	$0.99
3839	LED Replacement of 4' T8 Lamps, Direct Wire, Agriculture	August 2018 online lookups of 6 base and efficient models show an average efficient lamp price of $8.21 and base lamp price of $1.92, for an incremental cost of $6.29.	$6.29
3842	Air Sealing, Tier 2, Project Based	Implementer findings	$0.00
3861	LED, 10 Watt, Pack-based	Evaluator Online Cost research from www.1000bulbs.com Lowes, and HomeDepot. Research conducted March 2016 for ENERGY STAR®. Weighted Average of 29 to 43 Watt LEDs.	$5.90

MMID	Measure Name	Source	Incremental Cost
3862	Faucet Aerator, Kitchen, 1.5 GPM, Pack-based	Cost for pack-based measures is the cost to the program, which is equal to the incentive. Incremental cost data was updated on May 22, 2018 for calendar year 2018, and is scheduled to be reviewed by no later than January 2019.	$1.26
3863	Faucet Aerator, Bathroom, 1.0 GPM, Pack-based		$0.48
3868	Natural Gas Furnace with ECM: 96% + AFUE	CLEAResult. Survey of trade allies, summer 2018.	$899.86
3869	Natural Gas Furnace with ECM: 98% + AFUE		$2,219.37
3870	Natural Gas Furnace with ECM: Tier 2, 96% + AFUE	Wisconsin Public Service Commission. Incremental Cost Database. December 2014	$2,007.50
3871	Natural Gas Furnace with ECM: Tier 2, 97% + AFUE		$2,450.00
3872	Natural Gas Furnace with ECM: Tier 2, 98% + AFUE	Wisconsin Public Service Commission. Incremental Cost Database. December 2014	$2,892.50
3874	Ductless Mini-Split, Replacing Electric Resistance and CAC	Swift, Joseph R. and R. Meyer. Ductless Heat Pumps for Residential Customers in Connecticut. Table 5 (p. 2-302). 2010. http://aceee.org/files/proceedings/2010/data/papers/1960.pdf Also used in 2016 Illinois TRM. Adjusted for average Wisconsin equipment capacity of 15,600 Btu/hour. Calculation derived from table data yields equation: IMC = 0.125 * CAPEE + 1,500.	$3,450.00
3875	Ductless Mini-Split, Replacing Electric Resistance and Room AC		
3876	Ductless Mini-Split, Replacing Electric Furnace and CAC		
3877	Ductless Mini-Split, Replacing Electric Resistance and No AC		
3891	Ductless Mini-Split, Replacing Electric Resistance and CAC, Tier 2		

MMID	Measure Name	Source	Incremental Cost
3892	Ductless Mini-Split, Replacing Electric Resistance and Room AC, Tier 2	Swift, Joseph R. and R. Meyer. Ductless Heat Pumps for Residential Customers in Connecticut. Table 5 (p. 2-302). 2010. http://aceee.org/files/proceedings/2010/data/papers/1960.pdf Also used in 2016 Illinois TRM. Adjusted for average Wisconsin equipment capacity of 15,600 Btu/hour. Calculation derived from table data yields equation: IMC = 0.125 * CAPEE + 1,500.	$3,450.00
3893	Ductless Mini-Split, Replacing Electric Furnace and CAC, Tier 2		
3894	Ductless Mini-Split, Replacing Electric Resistance and No AC, Tier 2		
3895	Advanced Power Strip Pack-Based, APS Tier 1	Wisconsin Focus on Energy. Cost for pack-based measures is the cost to the program, which is equivalent to the incentive.	$11.15
3896	LED, Pack-based, 5 Watt, G25	Focus on Energy. The incremental cost for pack-based measures is the cost to the program, which is equivalent to the incentive.	$2.64
3897	LED, Pack-based, 10 Watt, BR30	Home Depot. Website. Accessed May 15, 2016. www.homedepot.com Menards. Website. Accessed May 15, 2016. www.menards.com Pack incremental cost is the average price of BR30 LED – Incandescent replacement	$7.85
3903	LED Signage Retrofit, Interior	KEMA. “Appendix A – Prescriptive Measures.” LED Channel Signs workpaper, p. 64. February 20, 2009. http://ilsagfiles.org/SAG_files/Evaluation_Documents/Ameren/AIU%20Evaluation%20Reports%20EPY2/AIU%20EPY2%20Final/AIU_Appendix_A_Prescriptive_Measures.pdf	$0.48
3904	LED Signage Retrofit, Exterior		
3906	ENERGY STAR® Commercial Ice Machine, Ice Making Head	ENERGY STAR. “Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.” Calculator. 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx	$222.00
3907	ENERGY STAR® Commercial Ice Machine, Remote Condensing Unit		
3908	ENERGY STAR® Commercial Ice Machine, Self-Contained Unit		

MMID	Measure Name	Source	Incremental Cost
3909	A/C Split System, Condensing Unit Only, High Efficiency	Northeast Energy Efficiency Partnerships. "Incremental Cost Study Phase Three Final Report." Table 10. May 2014. http://www.neep.org/incremental-cost-study-phase-3 . Average of CEE Tier 2 values ($126.84 and $37.83)	$82.34
3910	ECM HVAC Fan Motors, Heating	Navigant Consulting Inc. "Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment." Table 2.1, p. 5, Section 2.4.3, p. 16, and Table 4.10, p. 49. Prepared for U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. December 4, 2013. http://energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf	$120.00 per motor
3911	ECM HVAC Fan Motors, Cooling		
3912	ECM HVAC Fan Motors, Occupied Ventilation		
3913	ECM HVAC Fan Motors, 24/7 Ventilation		
3916	Natural Gas Furnace Tune-Up, Small Business	Capital Heating & Cooling. Website. Accessed November 2017. https://www.capitalhvac.com/TipsArticles/furnace-tune-up-cost Cost Helper. Website. Accessed November 2017. http://home.costhelper.com/furnace-tune-up.html Home Improvement Educator. Website. Accessed November 2017. http://www.homeimprovementeducator.com/seasonal/fall-furnace-tuneups.html Engineering judgement based on local pricing and typical furnace size.	$1.53
3928	Vacuum Pump Heat Recovery, Space Heating	Historical project data. 105 applications across 2015 and 2016.	$112.41
3929	LED Lamp, ENERGY STAR, Replacing Exterior Directional CFL, ≥ 23W CFL	Cost data obtained in November 2016 through various online lighting retailers.	$3.83
3930	LED Lamp, ENERGY STAR, Replacing Exterior Directional CFL, 14W-22W CFL		$9.49

MMID	Measure Name	Source	Incremental Cost
3931	LED Lamp, ENERGY STAR, Replacing Exterior Directional CFL, ≤ 13W	Cost data obtained in November 2016 through various online lighting retailers.	$2.14
3932	LED Lamp, ENERGY STAR, Replacing Interior Directional CFL, ≥ 23W CFL	1000 Bulbs. Website. Accessed November 2016. www.1000bulbs.com Home Depot. Website. Accessed November 2016. www.homedepot.com Wal-Mart. Website. Accessed November 2016. www.walmart.com	$3.83
3933	LED Lamp, ENERGY STAR, Replacing Interior Directional CFL, 14W-22W CFL		$9.49
3934	LED Lamp, ENERGY STAR, Replacing Interior Directional CFL, ≤ 13W		$2.14
3935	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, 120W – 250W Incandescent		$0.37
3936	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, 100W – 119W Incandescent		$2.85
3937	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, 75W – 99W Incandescent		$3.56
3938	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, 55W – 74W Incandescent		$4.57

MMID	Measure Name	Source	Incremental Cost
3939	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, 36W – 54W Incandescent	1000 Bulbs. Website. Accessed November 2016. www.1000bulbs.com Home Depot. Website. Accessed November 2016. www.homedepot.com Wal-Mart. Website. Accessed November 2016. www.walmart.com	$3.34
3940	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, ≤ 35W Incandescent		$4.93
3941	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, 120W – 250W	1000 Bulbs. Website. Accessed July 2018. www.1000bulbs.com Home Depot. Website. Accessed July 2018. www.homedepot.com Wal-Mart. Website. Accessed July 2018. www.walmart.com	$0.10
3942	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, 100W – 119W		$2.45
3943	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, 75W – 99W		$2.99
3944	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, 55W – 74W		$3.44
3945	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, 36W – 54W		$2.42

MMID	Measure Name	Source	Incremental Cost
3946	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, ≤ 35W	1000 Bulbs. Website. Accessed July 2018. www.1000bulbs.com Home Depot. Website. Accessed July 2018. www.homedepot.com Wal-Mart. Website. Accessed July 2018. www.walmart.com	$3.59
3947	LED Lamp, ENERGY STAR, 1,600 – 1,999 Lumens, Exterior	1000 Bulbs. Website. Accessed November 2016. www.1000bulbs.com Home Depot. Website. Accessed November 2016. www.homedepot.com LightBulbs.com. Website. Accessed November 2016. www.lightbulbs.com Wal-Mart. Website. Accessed November 2016. www.walmart.com Amazon. Website. Accessed November 2016. www.amazon.com	$11.40
3948	LED Lamp, ENERGY STAR, 1,100 – 1,599 Lumens, Exterior		$8.66
3949	LED Lamp, ENERGY STAR, 800 – 1,099 Lumens, Exterior		$3.61
3950	LED Lamp, ENERGY STAR, 450 – 799 Lumens, Exterior		$3.73
3951	LED Lamp, ENERGY STAR, 250 – 449 Lumens, Exterior		$5.87
3952	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 1,600 – 1,999 Lumens	Historical Focus on Energy project data. SPECTRUM. January 1, 2016 to December 31, 2017. Business Incentive, Chain Stores and Franchise, Ag School and Government, and Large Energy User programs had 1,234 projects, consisting of MMIDs 3112, 3113, 3742, and 3745. Data analysis of actual units installed revealed percentage of lighting technology by total units installed of 9.2% for CFLs and 90.8% for incandescents. Multifamily Energy Savings Program had 279 projects, consisting of MMIDs 3160, 3162, 3743, and 3746. Data analysis of actual units installed revealed percentage of lighting technology by total units installed of 10.7% for CFLs and 89.3% for incandescents.	$11.40
3953	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 1,100 – 1,599 Lumens		$8.66

MMID	Measure Name	Source	Incremental Cost
3954	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 800 – 1,099 Lumens	Historical Focus on Energy project data. SPECTRUM. January 1, 2016 to December 31, 2017. Business Incentive, Chain Stores and Franchise, Ag School and Government, and Large Energy User programs had 1,234 projects, consisting of MMIDs 3112, 3113, 3742, and 3745. Data analysis of actual units installed revealed percentage of lighting technology by total units installed of 9.2% for CFLs and 90.8% for incandescents. Multifamily Energy Savings Program had 279 projects, consisting of MMIDs 3160, 3162, 3743, and 3746. Data analysis of actual units installed revealed percentage of lighting technology by total units installed of 10.7% for CFLs and 89.3% for incandescents.	$3.61
3955	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 450 – 799 Lumens		$3.73
3956	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 250 – 449 Lumens		$5.87
3957	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 1,600 – 1,999 Lumens, in unit		$11.40
3958	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 1,100 – 1,599 Lumens, in unit		$8.66
3959	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 800 – 1,099 Lumens, in unit		$3.61

MMID	Measure Name	Source	Incremental Cost
3960	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 450 – 799 Lumens, in unit	Historical Focus on Energy project data. SPECTRUM. January 1, 2016 to December 31, 2017. Business Incentive, Chain Stores and Franchise, Ag School and Government, and Large Energy User programs had 1,234 projects, consisting of MMIDs 3112, 3113, 3742, and 3745. Data analysis of actual units installed revealed percentage of lighting technology by total units installed of 9.2% for CFLs and 90.8% for incandescents. Multifamily Energy Savings Program had 279 projects, consisting of MMIDs 3160, 3162, 3743, and 3746. Data analysis of actual units installed revealed percentage of lighting technology by total units installed of 10.7% for CFLs and 89.3% for incandescents.	$3.73
3961	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 250 – 449 Lumens, in unit		$5.87
3962	LED Lamp, DLC, High/Low-Bay Mogul Screw-Base (E39)	1000 Bulbs. Website. Accessed November 2016. www.1000bulbs.com Lighting Supply. Website. Accessed November 2016. www.lightingsupply.com Amazon. Website. Accessed November 2016. www.amazon.com	$66.05
3963	LED Lamp, DLC, Mogul Screw-Base (E39), Exterior		
3964	Advanced Rooftop Unit Controller	Average historic project cost for MMID 3651 completed under special offer for advanced rooftop unit controllers in 2015, plus historical project cost under MMID 3964 for projects completed in 2017 and January through March 2018 (35 applications for a total of 68 rooftop units; total of 1,500 tons). Note that no measures were completed under MMID 3650 for the advanced rooftop unit controller special offer, so that MMID was excluded.	$530.10
3965	NLC Low Lumen Tier	Manufacturer's representative quotations for office lighting controls, July 2016. Average of quotations from Lutron and Douglas Lighting Controls.	$1.68
3966	NLC High Lumen Tier		

MMID	Measure Name	Source	Incremental Cost
3967	LED Fixture, Interior, 12+ Hours, CALP	SPECTRUM. Average incremental costs. 2017. CALP LED measure master IDs 3735, 3603, 3604 and 3200, converted to dollars per watt saved. Online research. March 2016. https://www.1000bulbs.com/category/led-downlights/ Material cost for MMIDs 3603, 3604, and 3735 is average sales price of LED downlight. Average sales price of LED Exit Signs for MMID 3200 on 1000bulbs.com = \$26.43; RSMeans, 2015 labor cost for install of signs, interior electric exit sign, wall mounted, 6-inch = \$72.00. [\$26.43 (material cost) + \$72.00 (labor cost) = \$98.43].	\$1.20
3968	LED Fixture, Exterior, CALP		
3969	Lighting Controls, Interior, CALP	Average incremental costs from 2016 CALP LED SPECTRUM measure master IDs 3605, 3606, 3201 and 3202, converted to dollars per watt. 3605: Similar to MMID 2474. WESCO Distribution Pricing (\$70.00) + Labor (\$25.00) = \$95.00 3606: Similar to MMID 2474. WESCO Distribution Pricing (\$70.00) + Labor (\$25.00) = \$95.00 3201: WESCO Distribution Pricing (\$18.75) + Labor (\$16.25) = \$35.00 for Wall Mount. WESCO Distribution Pricing, 2013 + Labor = \$120.00 for Ceiling Mount. \$77.50 is the average. 3202: WESCO Distribution Pricing (\$18.75) + Labor (\$16.25) = \$35.00 for Wall Mount. WESCO Distribution Pricing, 2013 + Labor = \$120.00 for Ceiling Mount. \$77.50 is the average.	\$0.92
3975	Dairy Scroll Compressor Replacement with Pre-Cooler and VFD Milk Pump	Sanford, Scott (University of Wisconsin–Madison). "Energy Efficiency for Dairy Enterprises." Presentation to Agricultural and Life Sciences Program staff. Slides 8, 10, 21, and 26. December 2014. http://farmenergymedia.extension.org/sites/default/files/Dairy%20Energy%20Conservation-2013.pdf	\$400.00
3976	Dairy Scroll Compressor Replacement with Pre-Cooler		
3977	Dairy Scroll Compressor Replacement without Pre-Cooler		
3978	Occupancy Sensor, On/Off, High Bay, General	WESCO Distribution Pricing, 2013. (\$70.00) + Labor (\$25.00) = \$95.00	\$95.00

MMID	Measure Name	Source	Incremental Cost
3979	Bi Level Controls, High Bay Fixtures, General	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 1,732 units over 28 projects, from 2016 to 2018.	$81.06
3982	Plate Heat Exchanger and Well Water Pre-Cooler (<135 Milking Cows)	SPECTRUM. "Dairy Pre-Cooler Supplemental Data Spreadsheet." Pre-cooler Measure Analysis' tab shows sample data of 86 pre-cooler projects from January 2015 to July 2016. The split of single pass to double pass plate coolers installed on Wisconsin dairies was determined from the project inputs of these 86 sample projects. Spreadsheet also shows an average of pre-cooler project cost from the 86 recent project samples.	$5,253.00
3983	Plate Heat Exchanger and Well Water Pre-Cooler (>=135 Milking Cows)		
3984	Refrigeration System Tune-Up Without Milk Pre-Cooler	"Ag Dairy Refrigeration Tune-Up Supplemental Data."Dairy Tune-Up tab shows historical data (54 projects) average of May 2013 through July 2015 approved application kWh savings and project cost data. WI Dairy Statistics tab shows USDA-reported annual data from: U.S. Department of Agriculture. "Milk Production Per Cow, Wisconsin." https://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/Dairy/Historical_Data_Series/mkpercow.pdf	$260.86
3985	Refrigeration System Tune-Up With Milk Pre-Cooler		
3986	Refrigeration System Tune-Up With Milk Pre-Cooler and VFD Milk Pump		
3987	Agriculture, VFD, Vacuum Pump	Vermont Technical Reference Manual. p. 22. March 16, 2015. http://psb.vermont.gov/sites/psb/files/docketsandprojects/electric/majorpendingproceedings/TRM%20User%20Manual%20No.%202015-87C.pdf VFD milk pump cost = $4,014 based on Vermont project data from 2003-2012.	$4,014.00
3988	VFD, Dairy Milk Pump, Agriculture	Efficiency Vermont. "Technical Reference Use Manual." p. 24. August 9, 2013. http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf	$3,004.00
3989	Natural Gas WH With milk Pre-cooler &Milk Pump VFD	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 25 units over 23 projects, from 2017 to 2018.	$3,441.45
3990	Natural Gas WH With milk Pre-cooler		

MMID	Measure Name	Source	Incremental Cost
3991	Natural Gas WH Without milk Pre-cooler	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 25 units over 23 projects, from 2017 to 2018.	$3,441.45
3992	Electric WH With milk Pre-cooler &Milk Pump VFD		
3993	Electric WH With milk Pre-cooler		
3994	Electric WH Without milk Pre-cooler		
3995	Natural Gas to Natural Gas Commercial Water Heater Storage	Full cost of $5,248.13 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 6 units over 5 projects, from 2017 to 2018. August 2018 online lookups of 5 baseline models on www.homeperfect.com , www.afsupply.com , and www.homedepot.com show an average baseline price of $1,726.21. Incremental cost is $5,248.13 - $1,726.21 = $3,521.92.	$3,521.92
3996	Electric to Electric Commercial Water Heater (<150 Milking Cows)	Full cost of $1,215.29 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 16 units from 2017 to 2018. August 2018 online lookups of 7 baseline models on www.essentialhardware.com , www.menards.com , www.acehardware.com , and www.sears.com show an average baseline price of $583.51. Incremental cost is $1,215.29 - $583.31 = $631.98.	$631.98
3997	Electric to Electric Commercial Water Heater (≥150 Milking Cows)		
3998	Fans, High Volume Low Speed (HVLS), General	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 17 units over 8 projects, from 2017 to 2018.	$51.48
3999	Steam Trap Repair, < 10 psig, Industrial	SPECTRUM. Pressure-based extrapolation of costs (2013-2014) for MMIDs 2542, 2548, and 2546 (new MMIDs 4001, 4002, 4003).	$166.23
4000	Steam Trap Repair, Industrial, 10-49 psig	Average of 3 projects for MMID 2542, 2013 – 2014	$276.78
4001	Steam Trap Repair, Industrial, 50-124 psig	Average of 13 projects for MMID 2548, 2013 - 2014. One project with outlier cost excluded.	$194.61
4002	Steam Trap Repair, Industrial, 125-225 psig	Average of 3 projects for MMID 2546, 2013 - 2014	$600.18

MMID	Measure Name	Source	Incremental Cost
4003	Steam Trap Repair, Industrial, >225 psig	Pressure-based extrapolation of costs (2013-14) for MMIDs 2542, 2548, and 2546.	$895.65
4004	Steam Trap Repair, <10 psig, General Heating, Prescriptive: 7/32” or Smaller	Average measure cost of five projects (Radiator Measure MMID 2772) 2012 - 2014 for low-pressure heating measures, with extrapolated industrial costs.	$50.89
4005	Steam Trap Repair, <10 psig, General Heating, Prescriptive: 1/4”	Average measure cost of five projects (Radiator Measure MMID 2772) 2012 - 2014 for low-pressure heating measures, with extrapolated industrial costs.	$50.89
4006	Steam Trap Repair, <10 psig, General Heating, Prescriptive: 5/16”		
4007	Steam Trap Repair, <10 psig, General Heating, Prescriptive: 3/8” or Larger		
4008	Steam Trap Repair, 10-49 psig, General Heating, Prescriptive: 7/32” or Smaller	Average of 15 projects for MMID 3269 in 2014	$100.81
4009	Steam Trap Repair, 10-49 psig, General Heating, Prescriptive: 1/4”	Average of 22 projects for MMID 3270 in 2014. One project with outlier cost excluded.	$79.84
4010	Steam Trap Repair, 10-49 psig, General Heating, Prescriptive: 5/16”	Average of 11 projects for MMID 3271 in 2014	$70.60
4011	Steam Trap Repair, 10-49 psig, General Heating, Prescriptive: 3/8” or Larger	Average of 9 projects for MMID 3272 in 2014. One project with outlier cost excluded.	$231.67
4012	Steam Trap Repair, 50-124 psig, General Heating, Prescriptive: 7/32” or Smaller	Average of 4 projects for MMID 2547 (Repair leaking steam trap, 50-125 psig), 2013 – 2014	$391.02

MMID	Measure Name	Source	Incremental Cost
4013	Steam Trap Repair, 50-124 psig, General Heating, Prescriptive: 1/4”	Average of 4 projects for MMID 2547 (Repair leaking steam trap, 50-125 psig), 2013 – 2014	$391.02
4014	Steam Trap Repair, 50-124 psig, General Heating, Prescriptive: 5/16”		
4015	Steam Trap Repair, 50-124 psig, General Heating, Prescriptive: 3/8” or Larger		
4016	Steam Trap Repair, 125-225 psig, General Heating, Prescriptive: 7/32” or Smaller	1 project for MMID 2545 in 2013	$633.83
4017	Steam Trap Repair, 125-225 psig, General Heating, Prescriptive: 1/4”		
4018	Steam Trap Repair, 125-225 psig, General Heating, Prescriptive: 5/16”	1 project for MMID 2545 in 2013	$633.83
4019	Steam Trap Repair, 125-225 psig, General Heating, Prescriptive: 3/8” or Larger		
4020	Steam Trap Repair, > 225 psig, General Heating, Prescriptive: 7/32” or Smaller	Pressure-based extrapolation of costs for MMIDs 2547, 2545, and average costs for 3269, 3270, 3271, and 3272.	$1,127.66
4021	Steam Trap Repair, > 225 psig, General Heating, Prescriptive: 1/4”		

MMID	Measure Name	Source	Incremental Cost
4022	Steam Trap Repair, > 225 psig, General Heating, Prescriptive: 5/16”	Pressure-based extrapolation of costs for MMIDs 2547, 2545, and average costs for 3269, 3270, 3271, and 3272.	$1,127.66
4023	Steam Trap Repair, > 225 psig, General Heating, Prescriptive: 3/8” or Larger		
4024	LED Lamp, ENERGY STAR, Replacing Interior Directional CFL, ≥ 23W CFL, In Unit	1000 Bulbs. Website. Accessed November 2016. www.1000bulbs.com Home Depot. Website. Accessed November 2016. www.homedepot.com Wal-Mart. Website. Accessed November 2016. www.walmart.com	$3.83
4025	LED Lamp, ENERGY STAR, Replacing Interior Directional CFL, 14W-22W CFL, In Unit		$9.49
4026	LED Lamp, ENERGY STAR, Replacing Interior Directional CFL, ≤ 13W CFL, In Unit		$2.14
4027	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, 120W – 250W Incandescent, In Unit	1000 Bulbs. Website. Accessed July 2018. www.1000bulbs.com Home Depot. Website. Accessed July 2018. www.homedepot.com Wal-Mart. Website. Accessed July 2018. www.walmart.com	$0.10
4028	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, 100W – 119W Incandescent, In Unit	1000 Bulbs. Website. Accessed July 2018. www.1000bulbs.com Home Depot. Website. Accessed July 2018. www.homedepot.com Wal-Mart. Website. Accessed July 2018. www.walmart.com	$2.45
4029	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, 75W – 99W Incandescent, In Unit		$2.99

MMID	Measure Name	Source	Incremental Cost
4030	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, 55W – 74W Incandescent, In Unit	1000 Bulbs. Website. Accessed July 2018. www.1000bulbs.com Home Depot. Website. Accessed July 2018. www.homedepot.com Wal-Mart. Website. Accessed July 2018. www.walmart.com	$3.44
4031	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, 36W – 54W Incandescent, In Unit		$2.42
4032	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, ≤ 35W Incandescent, In Unit		$3.59
4033	Soundbar, ENERGY STAR	ENERGY STAR. “Retail Products Platform: Product Analysis for Sound Bars.” Effective May 11, 2016. https://drive.google.com/open?id=0B9Fd3ckbKJp5OEpWSHg1eksyZ1U	$0.00
4034	Room Air Cleaner, ENERGY STAR		$56.00
4035	Room Air Conditioner, ENERGY STAR		$114.00
4036	Freezer, Chest, ENERGY STAR	Energy Efficiency and Renewable Energy Office. “Technical Support Document for Energy Conservation Standards for Residential Refrigerators, Refrigerator-Freezers, and Freezers.” Table 8.2.7. Accessed November 21, 2016. www.regulations.gov/contentStreamer?documentId=EERE-2008-BT-STD-0012-0128&disposition=attachment&contentType=pdf	$6.62
4037	Freezer, Upright, ENERGY STAR		$12.14

MMID	Measure Name	Source	Incremental Cost
4038	Electric Clothes Dryer, ENERGY STAR	ENERGY STAR. “Retail Products Platform: Product Analysis for Clothes Dryers.” Updated May 11, 2016. https://drive.google.com/open?id=0B9Fd3ckbKJp5OEpWSHg1eksyZ1U ENERGY STAR assumes $224.91 Ventless or Vented Electric, Standard Clothes Dryer; this is based on: the Dryer TSD Life-Cycle Cost and Payback Analysis "2011-04-18_TSD_Chapter_8_Life-Cycle_Cost_and_Payback_Period_Analyses.pdf" 8.2.9 Vented Dryer, Electric, Standard: Consumer Product Costs, Installation Costs, and Total Installed Costs in 2014.	$224.91
4039	Natural Gas Clothes Dryer, ENERGY STAR	ENERGY STAR. “Retail Products Platform: Product Analysis for Clothes Dryers.” Updated May 11, 2016. https://drive.google.com/open?id=0B9Fd3ckbKJp5OEpWSHg1eksyZ1U ENERGY STAR assumes $270.16 Ventless or Vented Gas, Standard Clothes Dryer; this is based on: the Dryer TSD Life-Cycle Cost and Payback Analysis "2011-04-18_TSD_Chapter_8_Life-Cycle_Cost_and_Payback_Period_Analyses.pdf" Table 8.2.12 Vented Dryer, Gas, Standard: Consumer Product Costs, Installation Costs, and Total Installed Costs in 2014.	$270.16
4042	LED, Pack-Based, 5 Watt, B11	Focus on Energy. The incremental cost for pack-based measures is the cost to the program, which is equivalent to the incentive.	$2.66
4043	VFD, Agriculture Primary Use Water System	Evaluator and implementer consensus for setting cost on a per hp basis, instead of per motor. For variable torque VFDs, cost set at $210.52 per hp, based on 2016-2017 data of 1,069 projects.	$210.52
4052	TLED Trial, Replacement of 4' T8 Lamps utilizing existing ballast	Cost for particular product for the TLED Trial special offering, per accepted proposal. Price valid through December 31, 2017.	$4.10
4054	Smart Thermostat, Installed with Smart Thermostat, Installed with 96% AFUE NG Furnace	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. July 2017 to December 2017. Average actual measure cost of smart thermostat measures incented by Focus on Energy is $213.00 (MMIDs 3609, 3610, and 3611). Minus the cost of a manual thermostat, which is $39.11 based on online lookups from July 2018.	$173.89

MMID	Measure Name	Source	Incremental Cost
4055	Smart Thermostat, Installed with 97% AFUE NG Furnace	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. July 2017 to December 2017. Average actual measure cost of smart thermostat measures incented by Focus on Energy is $213.00 (MMIDs 3609, 3610, and 3611). Minus the cost of a manual thermostat, which is $39.11 based on online lookups from July 2018.	$173.89
4056	Smart Thermostat, Installed with 98% AFUE NG Furnace		
4108	Heat Pump Water Heater	Northeast Energy Efficiency Partnerships. Incremental Cost Study Phase Three Final Report. May 28, 2014. http://www.neep.org/incremental-cost-study-phase-3	$1,000.00
4120	Advanced Power Strip Pack-Based, APS Tier 2	Wisconsin Focus on Energy. Cost for pack-based measures is the cost to the program, which is equivalent to the incentive.	$49.14
4262	DEET, V2.0, Year 1	Staff estimate $2,000.00 for energy projects and $10,000.00 average staff time in average-sized building.	$12,000.00
4263	DEET, V2.0, Year 2		
4264	DEET, V2.0, Year 3		
4265	DEET, V2.0, Year 4		
4271	DHW Temperature Turn Down, Pack Based, Blended Natural Gas & Electric	2018 cost of measure to pack-based program implementer.	$0.84
4272	Insulation, DHW Pipe, Pack-based	Incremental cost for pack-based measures is equivalent to the cost to the program, which is equivalent to the incentive rebate offering.	$2.43
4273	Showerhead, Handheld, 1.5 GPM, Pack-based	Cost for pack-based measures is the cost to the program, which is equal to the incentive. Incremental cost data was updated on May 22, 2018 for calendar year 2018, and is scheduled to be reviewed by no later than January 2019.	$5.41
4274	Showerhead, Upgraded, 1.5 GPM, Pack-based		$10.69
4275	Advanced Power Strip Retail, APS Tier 1	Efficiency Vermont. Efficiency Vermont Technical Reference Manual. March 6, 2015. Page 391. https://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf	$15.00
4276	LED, Pack-Based, 8 Watt BR30	Wisconsin Focus on Energy. Cost reflects bulk pricing cost to implementer.	$3.43

MMID	Measure Name	Source	Incremental Cost
4277	LED, Pack-Based, 9 Watt	Wisconsin Focus on Energy. The incremental measure cost for pack-based measures is the cost to the program, which is equivalent to the incentive.	$2.58
4278	LED, Pack-Based, 11 Watt		$4.85
4280	LED, Exterior Fixture, Low Output, <= 4,999 lumens	1000 Bulbs. Website. Accessed September 2017. www.1000bulbs.com E-conolight. Website. Accessed September 2017. www.e-conolight.com Amazon. Website. Accessed September 2017. www.amazon.com SPECTRUM. “SPECTRUM Lighting Participation Measure Participation Wattages.” January 2017–September 2017 application date ranges for Large Energy User Program, Business Incentive Program, Small Business Program, and Multifamily Energy Savings Program. MMIDs included 3108, 3099, 3100, 3101, 3102, 3103, 3104, 3106, 3107, 3109, 3110, and 3407.	$91.99
4281	LED, Exterior Fixture, Mid Output, 5,000-9,999 lumens		$192.94
4282	LED, Exterior Fixture, High Output, 10,000-29,999 lumens		$279.30
4283	LED, Exterior Fixture, Very High Output, >= 30,000 lumens		$415.38
4284	Permanent Magnet Synchronous (PMS) Evaporator Fan Motor, Refrigerated Case, Replacement	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 10 units over 2 projects in 2018.	$92.40
4286	Circulation Fan, HS/HE, 36”-47”, Ag	Illinois Energy Efficiency Stakeholder Advisory Group. “Illinois Technical Reference Manual.” Version 4.0. p. 62 referencing ‘Act on Energy Commercial Technical Reference Manual No. 2010-4.’ January 22, 2016. http://www.ilsag.info/il_trm_version_4.html	$150.00
4287	Circulation Fan, HS/HE, 36”-47”, Ag		
4288	Circulation Fan, HS/HE, 48”-52”, Ag		
4289	Circulation Fan, HS/HE, 48”-52”, Ag		
4290	Circulation Fan, HS/HE, ≥53”, Ag		
4291	Circulation Fan, HS/HE, ≥53”, Ag		
4292	Ventilation Fan, HS/HE, 36”-47”, Ag		

MMID	Measure Name	Source	Incremental Cost
4293	Ventilation Fan, HS/HE, 36”-47”, Ag	Illinois Energy Efficiency Stakeholder Advisory Group. “Illinois Technical Reference Manual.” Version 4.0. p. 62 referencing ‘Act on Energy Commercial Technical Reference Manual No. 2010-4.’ January 22, 2016. http://www.ilsag.info/il_trm_version_4.html	$150.00
4294	Ventilation Fan, HS/HE, 48”-52”, Ag		
4295	Ventilation Fan, HS/HE, 48”-52”, Ag		
4296	Ventilation Fan, HS/HE, ≥53”, Ag		
4297	Ventilation Fan, HS/HE, ≥53”, Ag		
4298	Communicating Thermostat, Existing Natural Gas Boiler	Average cost of communicating thermostats. Online retail research conducted February 2017. Minus the cost of a manual thermostat, which is $39.11 based on online lookups from July 2018.	$90.89
4299	Communicating Thermostat, Existing Natural Gas Furnace		
4300	Communicating Thermostat, Existing Natural Gas Boiler		
4301	Smart Thermostat, Existing Natural Gas Boiler	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. July 2017 to December 2017. Average actual measure cost of 2,585 smart thermostat measures incented by Focus on Energy is $213.00 (MMIDs 3609, 3610, and 3611). Minus the cost of a manual thermostat, which is $39.11 based on online lookups from July 2018.	$173.89
4302	Smart Thermostat, Existing Natural Gas Furnace		
4303	Smart Thermostat, Existing Air-Source Heat Pump		
4304	Smart Thermostat, Pack-Based	Energy Federation, Inc. December 2017. Incremental cost is the average incentive cost to the implementer providing the pack, plus the customer copay for higher-end smart thermostat models. The cost for a communicating thermostat is $115.21. The implementer cost for premium smart thermostats is $102.20, with customers opting for a $120 copay. The implementer cost for value smart thermostats is $135.04.	$222.20
4305	Communicating Thermostat, Pack-Based		$115.21

MMID	Measure Name	Source	Incremental Cost
4306	LED, Reflector, 12 Watt, Retail Store Markdown, Long Lifetime	August 2018 online lookups of 12 base and efficient models show an average efficient lamp price of $4.92 and base lamp price of $3.27, for an incremental cost of $1.65.	$1.65
4307	LED, Omnidirectional, 310-749 Lumens, Long Lifetime, Retail Store Markdown	August 2018 online lookups of 11 base and efficient models show an average efficient lamp price of $1.92 and base lamp price of $1.28, for an incremental cost of $0.64.	$0.64
4308	LED, Omnidirectional, 750-1,049 Lumens, Retail Store Markdown	August 2018 online lookups of 12 base and efficient models show an average efficient lamp price of $1.99 and base lamp price of $1.46, for an incremental cost of $0.53.	$0.53
4309	LED, Omnidirectional, 750-1,049 Lumens, Long Lifetime, Retail Store Markdown		
4310	LED, Omnidirectional, 1,050-1,489 Lumens, Retail Store Markdown	August 2018 online lookups of 11 base and efficient models show an average efficient lamp price of $5.25 and base lamp price of $1.63, for an incremental cost of $3.62.	$3.62
4311	LED, Omnidirectional, 1,050-1,489 Lumens, Long Lifetime, Retail Store Markdown	August 2018 online lookups of 11 base and efficient models show an average efficient lamp price of $5.25 and base lamp price of $1.63, for an incremental cost of $3.62.	$3.62
4312	LED, Omnidirectional, 1,490-2,600 Lumens, Retail Store Markdown	August 2018 online lookups of 12 base and efficient models show an average efficient lamp price of $6.42 and base lamp price of $2.93, for an incremental cost of $3.49.	$3.49
4313	LED, Omnidirectional, 1,490-2,600 Lumens, Long Lifetime, Retail Store Markdown		
4314	4FT Linear LED 2L, Replacing 8FT 1L T8 or T12	See below	$52.00
4315	4FT Linear LED 2L, Replacing 8FT 1L T8 or T12, Exterior		
4316	4FT Linear LED 2L, Replacing 8FT 1L T8 or T12, 24/7		

MMID	Measure Name	Source	Incremental Cost
4317	4FT Linear LED 2L, Replacing 8FT 1L T8HO or T12HO	Pricing was collected from online sources and distributors for lamps, ballasts, drivers, and 8-foot conversion kits used in MMIDs 3616 and 3617. Labor was estimated. Incremental costs were determined between a baseline conversion of 8-foot T12 lamps to T8 lamps with a new ballast and an improved conversion of 8-foot T12 lamps to 4-foot T8 LED lamps with a new ballast. Eight-foot, 2-lamp conversions to 4-foot, 2-lamp removes the incremental material cost of two 4-foot T8 LED lamps ($11.29 each from MMID 3512) and is added to the incremental cost of the 8-foot 2-lamp conversion.	$52.00
4318	4FT Linear LED 2L, Replacing 8FT 1L T8HO or T12HO, Exterior		
4319	4FT Linear LED 2L, Replacing 8FT 1L T8HO or T12HO, 24/7		
4320	4FT Linear LED 4L, Replacing 8FT 2L T8 or T12		
4321	4FT Linear LED 4L, Replacing 8FT 2L T8 or T12, Exterior		$103.00
4322	4FT Linear LED 4L, Replacing 8FT 2L T8 or T12, 24/7		
4323	4FT Linear LED 4L, Replacing 8FT 2L T8HO or T12HO		
4324	4FT Linear LED 4L, Replacing 8FT 2L T8HO or T12HO, Exterior		
4325	4FT Linear LED 4L, Replacing 8FT 2L T8HO or T12HO, 24/7		
4326	4FT Linear LED 2L, Replacing 8FT 2L T8 or T12		$125.58
4327	4FT Linear LED 2L, Replacing 8FT 2L T8 or T12, Exterior		
4328	4FT Linear LED 2L, Replacing 8FT 2L T8 or T12, 24/7		

MMID	Measure Name	Source	Incremental Cost
4329	4FT Linear LED 2L, Replacing 8FT 2L T8HO or T12HO	See above	$125.58
4330	4FT Linear LED 2L, Replacing 8FT 2L T8HO or T12HO, Exterior		
4331	4FT Linear LED 2L, Replacing 8FT 2L T8HO or T12HO, 24/7		
4332	LED Fixture, 2x2, Low Output w/LLLC, DLC Listed	August 2018 online lookups of 4 base and efficient models show an average efficient fixture price of $55.6 and base bulb price of $16.89, for an incremental cost of $38.71.	$38.71
4333	LED Fixture, 2x2, High Output w/LLLC, DLC Listed	August 2018 online lookups of 4 base and efficient models show an average efficient fixture price of $127.93 and base bulb price of $16.89, for an incremental cost of $111.04.	$111.04
4334	LED Troffer, 1x4, Replacing 4' 1-2 Lamp T8 Troffer w/LLLC	The incremental cost of $144.57 for MMID 4334 reflects the cost for MMID 3760 ($49.57) plus the cost for occupancy sensors ($70.00 per WESCO Distribution Pricing) and labor ($25.00).	$144.57
4335	LED Troffer, 2x4, Replacing 4' 3-4 Lamp T8 Troffer w/LLLC	Incremental cost of $144.24 for MMID 4335 reflects the cost for MMID 3111 plus the cost for occupancy sensors (MMID 2474), which according to WESCO Distribution Pricing is $70.00, plus $25.00 in labor.	$144.24
4336	Interior New Construction Lighting LPD ≥ 20% below code	Efficiency Vermont. Technical Reference User Manual. Lighting Power Density Measure. p. 89. March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf	$0.35
4337	Interior New Construction Lighting LPD ≥ 30% below code		$0.49
4338	Interior New Construction Lighting LPD ≥ 40% below code		$0.62
4339	ELO, LED, Fixture, Low Output, ≤4,999 lumens	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 207 units in 2018.	$129.76
4340	ELO, LED, Fixture, Low Output, ≤4,999 lumens w/NLC	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 207 units over 17 projects in 2018.	$370.76

MMID	Measure Name	Source	Incremental Cost
4341	ELO, LED, Fixture, Mid Output, 5,000-9,999 lumens	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 95 units over 20 projects in 2018.	$354.90
4342	ELO, LED, Fixture, Mid Output, 5,000-9,999 lumens w/NLC		$595.90
4343	ELO, LED, Fixture, High Output, 10,000-29,999 lumens	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 238 units over 16 projects in 2018.	$589.43
4344	ELO, LED, Fixture, High Output, 10,000-29,999 lumens w/NLC		$830.43
4345	ELO, LED, Fixture, Very High Output, ≥ 30,000 lumens	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 133 units over 7 projects in 2018.	$720.89
4346	ELO, LED, Fixture, Very High Output, ≥ 30,000 lumens w/NLC		$961.89
4347	LED Fixture, ≤250 Watts, Replacing 8-lamp T8 or 6-lamp T5HO, High Bay	Full fixture cost of $90.58 is derived from online lookups at www.warehouselighting.com , www.prolighting.com , www.amazon.com , and www.greenelectricalsupply.com . Base lamp cost of $12.75 derived from August 2018 online lookups at www.1000bulbs.com , www.bulbs.com , and www.lightbulbs.com . Incremental cost is $77.83.	$77.83
4348	LED Replacement of 4-Foot T8 Lamps Utilizing Existing Ballast, Exterior	August 2018 online lookups of 6 base and efficient models show an average efficient lamp price of $7.4 and base lamp price of $1.92, for an incremental cost of $5.48.	$5.48
4349	LED Replacement of 4-Foot T8 Lamps Utilizing Existing Ballast, Exterior, 24/7		
4350	LED Replacement of 4-Foot T8 Lamps, Direct Wire, Exterior	August 2018 online lookups of 6 base and efficient models show an average efficient lamp price of $8.21 and base lamp price of $1.92, for an incremental cost of $6.29.	$6.29
4351	LED Replacement of 4-Foot T8 Lamps, Direct Wire, Exterior, 24/7		

MMID	Measure Name	Source	Incremental Cost
4352	LED Replacement of 4-Foot T8 Lamps, w/External Driver, Exterior	Energy Avenue. Website. Philips Advance ICN-2P32-N. www.energyavenue.com ASL Supply. Website. Philips ICN-2P32-N. www.adlsupply.com The Lighting Spot. Website. GE-232-MV-N. http://www.lighting-spot.com Bulb America. Website. SKU 49853. www.bulbamerica.com 1000Bulbs. Website. Philips 281535. www.1000bulbs.com ALB. Website. Halco F32T8/835/ECO. www.atlantalightbulbs.com Bulbs.com. Website. SKU U3000100. www.bulbs.com Average baseline cost data from retail sources is $10.79. SPECTRUM measure participation from January 2017 through December 2017 shows that the average cost for participating products is $24.90 for MMID 3511. Therefore, the incremental cost is $14.11 ($24.90 - $10.79).	$24.90
4353	LED Replacement of 4-Foot T8 Lamps, w/External Driver, Exterior, 24/7		$24.90
4354	LED Fixture, Downlights, Interior	Full cost of $1.57 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 120,239 watts reduced over 84 projects, from 2016 to 2018. August 2018 online lookups of 12 baseline lamps on www.1000bulbs.com , www.topbulb.com , www.lowes.com , and www.homedepot.com show a baseline cost of $0.05 per watt for a halogen replacement bulb. The incremental cost is therefore $1.52.	$1.52
4355	LED Fixture, Downlights, In Unit	Full cost of $1.15 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 30,140 watts reduced over 17 projects, from 2016 to 2018. August 2018 online lookups of 12 baseline lamps on www.1000bulbs.com , www.topbulb.com , www.lowes.com , and www.homedepot.com show a baseline cost of $0.05 per watt for a halogen replacement bulb. The incremental cost is therefore $1.52.	$1.10

MMID	Measure Name	Source	Incremental Cost
4356	LED Fixture, Downlights, Exterior	Full cost of $1.57 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 11,460 watts reduced over 12 projects, from 2016 to 2018. August 2018 online lookups of 12 baseline lamps on www.1000bulbs.com , www.topbulb.com , www.lowes.com , and www.homedepot.com show a baseline cost of $0.05 per watt for a halogen replacement bulb. The incremental cost is therefore $1.52.	$1.29
4357	LED Fixture, Quantity Modification, Interior	SPECTRUM. Average cost of 12,093 interior fixture units and 4,692 exterior fixture units in Small Business Program. January 2017–December 2017 application date ranges.	$1.41
4358	LED Fixture, Quantity Modification, Exterior		$1.36
4359	Salamander Broiler, Infrared, Nautral Gas, Per input MBh	Nicor Gas Energy Efficiency Plan 2011–2014. “Revised Plan Filed Pursuant to Order Docket 10-0562.” May 27, 2011. https://www.icc.illinois.gov/downloads/public/edocket/295533.pdf	$1,000.00
4360	Floating Head Pressure Control- NEW	Based on size and similar design, assume same as compressor. $260 - Regional Technical Forum, UES Measures. "Commercial: Grocery - Compressor Head Fan Motor Retrofit to ECM." Measure Workbook 2.2, June 29, 2016. $260.00 for all "Compressor Head Fan Motor Retrofit to ECM" measures. http://rtf.nwcouncil.org/measures/measure.asp?id=106	$260.00
4361	VSD Vacuum Pump, Variable Torque, 4361	Evaluator and implementer consensus for setting cost on a per hp basis, instead of per motor. For variable torque VFDs, cost set at $210.52 per hp, based on 2016-2017 data of 1,069 projects.	$210.52
4362	VSD Vacuum Pump, Constant Torque	Evaluator and implementer consensus for setting cost on a per hp basis, instead of per motor. For constant torque VFDs, cost set at $122.48 per hp, based on 2016-2017 data of 111 projects.	$122.48
4363	Dew Point Controls for Desiccant Dryers	Compressed Air Challenge. Dessicant Air Dryer Control: Seeing Isn’t Always Believing. August 2015. http://www.compressedairchallenge.org/data/sites/1/media/library/articles/2015-08-CABP.pdf	$4,000.00

MMID	Measure Name	Source	Incremental Cost
4368	A/C Split or Packaged System, High Efficiency, ≥ 5.42 to < 11.25 tons	Northeast Energy Efficiency Partnerships and Navigant. NEEP Incremental Cost Study Phase Three Final Report. May 28, 2014. Table 10. http://www.neep.org/sites/default/files/resources/NEEP%20ICS3%20Report%20FINAL%202014%20June%2022_0.pdf Used CEE Tier 2 values. Historical Focus on Energy project data. SPECTRUM. January 1, 2018 to December 31, 2018. Business Incentive, Ag Schools and Government, and Large Energy User programs had 113 projects with 187 DX cooling units, of which 61 projects and 122 DX cooling units had capacity information entered in the Actual Capacity field in SPECTRUM.	$1,025.44
4369	A/C Split or Packaged System, High Efficiency, ≥ 11.25 to < 20.00 tons		$1,749.75
4370	A/C Split or Packaged System, High Efficiency, ≥ 20.00 to < 63.33 tons		$1,083.06
4371	A/C Split or Packaged System, High Efficiency, ≥ 63.33 tons		$2,742.68
4372	Communicating Thermostat, Natural Gas Boiler	Online retail research, February 2017. Average cost of communicating thermostats is $130. Minus the cost of a manual thermostat, which is $39.11 based on online lookups from July 2018.	$90.89
4373	Communicating Thermostat, Natural Gas Furnace with AC		
4374	Communicating Thermostat, Natural Gas Rooftop Unit with AC	Online retail research, February 2017. Average cost of communicating thermostats is $130. Minus the cost of a manual thermostat, which is $39.11 based on online lookups from July 2018.	$90.89
4375	Smart Thermostat, Natural Gas Boiler	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. July 2017 to December 2017. Average actual measure cost of 2,585 smart thermostat measures incented by Focus on Energy is $213.00 (MMIDs 3609, 3610, and 3611). Minus the cost of a manual thermostat, which is $39.11 based on online lookups from July 2018.	$173.89
4376	Smart Thermostat, Natural Gas Furnace with AC		
4377	Smart Thermostat, Natural Gas Rooftop Unit		
4379	Insulation, Attic, NG heat without Cooling, New Construction to R-50	California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” Revised Measure Cost Summary. June 2, 2008. http://www.deeresources.com/index.php/deer-versions/deer2008-for-09-11-planning-reporting	$0.85

MMID	Measure Name	Source	Incremental Cost
4380	Insulation, Attic, Electric heat with Cooling, New Construction to R-50	California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." Revised Measure Cost Summary. June 2, 2008. http://www.deeresources.com/index.php/deer-versions/deer2008-for-09-11-planning-reporting	$0.85
4381	Insulation, Attic, Electric heat without Cooling, New Construction to R-50		
4384	Faucet Aerator, 1.5 GPM, Kitchen, Electric	California Database for Energy Efficient Resources. 2015. $6.54 for materials. http://www.deeresources.com/index.php/ex-ante-database	$6.54
4385	Faucet Aerator, 1.5 GPM, Kitchen, NG		
4386	Faucet Aerator, 1.0 GPM, Kitchen, Electric		
4387	Faucet Aerator, 1.0 GPM, Kitchen, NG		
4388	Faucet Aerator, 0.5 GPM, Kitchen, Electric		
4389	Faucet Aerator, 0.5 GPM, Kitchen, NG		
4390	Faucet Aerator, 0.5/1.0/1.5 Variable GPM, Kitchen, Electric		
4391	Faucet Aerator, 0.5/1.0/1.5 Variable GPM, Kitchen, NG	California Database for Energy Efficient Resources. 2015. $6.54 for materials. http://www.deeresources.com/index.php/ex-ante-database	$6.54
4392	Faucet Aerator, 1.5 GPM, Bath, Electric	California Database for Energy Efficient Resources. 2015. $6.54 for materials. http://www.deeresources.com/index.php/ex-ante-database	$6.54
4393	Faucet Aerator, 1.5 GPM, Bath, NG		
4394	Faucet Aerator, 1.0 GPM, Bath, Electric		
4395	Faucet Aerator, 1.0 GPM, Bath, NG		
4396	Faucet Aerator, 0.5 GPM, Bath, Electric		

MMID	Measure Name	Source	Incremental Cost
4397	Faucet Aerator, 0.5 GPM, Bath, NG	California Database for Energy Efficient Resources. 2015. $6.54 for materials. http://www.deeresources.com/index.php/ex-ante-database	$6.54
4398	Showerhead, 1.5 GPM, Shower, Electric	$5.00 = WESCO Distribution Pricing ($3.11) + Labor ($1.89). Only included $3.11 in materials.	$3.11
4399	Showerhead, 1.5 GPM, Shower, NG		
4400	Showerhead, 1.25 GPM, Shower, Electric		
4401	Showerhead, 1.25 GPM, Shower, NG		
4403	Refrigeration System Tune-up, Agriculture	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 35 units over 31 projects, in 2018.	$194.05
4407	Schedule Optimization, Weekday Heating	Focus on Energy. Engineering Judgement. While RSMeans 2016 shows $59 per hour under 23 09 33.10 – Electronic Control System for HVAC, engineer stakeholders for Focus on Energy believe that $100 per hour is a more realistic rate, and that three hours is a realistic average time to complete.	$300.00
4408	Schedule Optimization, Weekday Cooling		
4409	Schedule Optimization, Weekend Heating		
4410	Schedule Optimization, Weekend Cooling		
4411	VFD, Agriculture Secondary Use Water System, Low HOU	Evaluator and implementer consensus for setting cost on a per hp basis, instead of per motor. For variable torque VFDs, cost set at $210.52 per hp, based on 2016-2017 data of 1,069 projects.	$210.52
4412	VFD, Constant Torque	Evaluator and implementer consensus for setting cost on a per hp basis, instead of per motor. For constant torque VFDs, cost set at $122.48 per hp, based on 2016-2017 data of 111 projects.	$122.48
4413	VFD, Ventilation/Circulation Fan, Low HOU	Evaluator and implementer consensus for setting cost on a per hp basis, instead of per motor. For variable torque VFDs, cost set at $210.52 per hp, based on 2016-2017 data of 1,069 projects.	$210.52

MMID	Measure Name	Source	Incremental Cost
4414	VFD Pump, Hybrid	Evaluator and implementer consensus for setting cost on a per hp basis, instead of per motor. For variable torque VFDs, cost set at $210.52 per hp, based on 2016-2017 data of 1,069 projects.	$210.52
4415	VFD, Irrigation Well Pump, Low HOU		
4419	Boiler Tune Up	Illinois Technical Reference Manual. p. 185. 2013. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf	$0.83
4432	Connected Lighting Pack, Hub-Based	Wisconsin Focus on Energy. Quote from Philips for two-bulb Hue kit.	$65.33
4433	Connected Lighting Pack, Non-Hub	Wisconsin Focus on Energy. Quote from LIFX for two A19 LIFX bulbs.	$79.98
4436	Smart Thermostat, Value, Pack-Based	Energy Federation, Inc. December 2017. Incremental cost is the average incentive cost to the implementer providing the pack, plus the customer copay for higher-end smart thermostat models. The cost for a communicating thermostat is $115.21. The implementer cost for premium smart thermostats is $102.20, with customers opting for a $120 copay. The implementer cost for value smart thermostats is $135.04.	$135.04
4441	LED, Exterior Fixture, Low Output, <= 4,999 lumens, SBP	1000 Bulbs. Website. Accessed September 2017. www.1000bulbs.com E-conolight. Website. Accessed September 2017. www.e-conolight.com Amazon. Website. Accessed September 2017. www.amazon.com SPECTRUM. “SPECTRUM Lighting Participation Measure Participation Wattages.” January 2017–September 2017 application date ranges for Large Energy User Program, Business Incentive Program, Small Business Program, and Multifamily Energy Savings Program. MMIDs included 3108, 3099, 3100, 3101, 3102, 3103, 3104, 3106, 3107, 3109, 3110, and 3407.	$31.65

MMID	Measure Name	Source	Incremental Cost
4442	LED, Exterior Fixture, Mid Output, 5,000-9,999 lumens, SBP	1000 Bulbs. Website. Accessed September 2017. www.1000bulbs.com E-conolight. Website. Accessed September 2017. www.e-conolight.com Amazon. Website. Accessed September 2017. www.amazon.com SPECTRUM. "SPECTRUM Lighting Participation Measure Participation Wattages." January 2017–September 2017 application date ranges for Large Energy User Program, Business Incentive Program, Small Business Program, and Multifamily Energy Savings Program. MMIDs included 3108, 3099, 3100, 3101, 3102, 3103, 3104, 3106, 3107, 3109, 3110, and 3407.	$192.94
4443	LED, Exterior Fixture, High Output, 10,000-29,999 lumens, SBP		$279.30
4444	LED, Exterior Fixture, Very High Output, >= 30,000 lumens, SBP		$415.38
4445	4FT Linear LED 2L, Replacing 8FT 1L T8 or T12, SBP	Pricing was collected from online sources and distributors for lamps, ballasts, drivers, and 8-foot conversion kits used in MMIDs 3616 and 3617. Labor was estimated. Incremental costs were determined between a baseline conversion of 8-foot T12 lamps to T8 lamps with a new ballast and an improved conversion of 8-foot T12 lamps to 4-foot T8 LED lamps with a new ballast. Eight-foot, 2-lamp conversions to 4-foot, 2-lamp removes the incremental material cost of two 4-foot T8 LED lamps ($11.29 each from MMID 3512) and is added to the incremental cost of the 8-foot 2-lamp conversion.	$52.00
4446	4FT Linear LED 2L, Replacing 8FT 1L T8 or T12, Exterior, SBP		
4447	4FT Linear LED 2L, Replacing 8FT 1L T8 or T12, 24/7, SBP		
4448	4FT Linear LED 2L, Replacing 8FT 1L T8HO or T12HO, SBP		
4449	4FT Linear LED 2L, Replacing 8FT 1L T8HO or T12HO, Exterior, SBP		
4450	4FT Linear LED 2L, Replacing 8FT 1L T8HO or T12HO, 24/7, SBP		
4451	4FT Linear LED 4L, Replacing 8FT 2L T8 or T12, SBP		
4452	4FT Linear LED 4L, Replacing 8FT 2L T8 or T12, Exterior, SBP		$103.00

MMID	Measure Name	Source	Incremental Cost
4453	4FT Linear LED 4L, Replacing 8FT 2L T8 or T12, 24/7, SBP	Pricing was collected from online sources and distributors for lamps, ballasts, drivers, and 8-foot conversion kits used in MMIDs 3616 and 3617. Labor was estimated. Incremental costs were determined between a baseline conversion of 8-foot T12 lamps to T8 lamps with a new ballast and an improved conversion of 8-foot T12 lamps to 4-foot T8 LED lamps with a new ballast. Eight-foot, 2-lamp conversions to 4-foot, 2-lamp removes the incremental material cost of two 4-foot T8 LED lamps ($11.29 each from MMID 3512) and is added to the incremental cost of the 8-foot 2-lamp conversion.	$103.00
4454	4FT Linear LED 4L, Replacing 8FT 2L T8HO or T12HO, SBP		
4455	4FT Linear LED 4L, Replacing 8FT 2L T8HO or T12HO, Exterior, SBP		
4456	4FT Linear LED 4L, Replacing 8FT 2L T8HO or T12HO, 24/7, SBP		
4457	4FT Linear LED 2L, Replacing 8FT 2L T8 or T12, SBP		$125.58
4458	4FT Linear LED 2L, Replacing 8FT 2L T8 or T12, Exterior, SBP		
4459	4FT Linear LED 2L, Replacing 8FT 2L T8 or T12, 24/7, SBP		
4460	4FT Linear LED 2L, Replacing 8FT 2L T8HO or T12HO, SBP		
4461	4FT Linear LED 2L, Replacing 8FT 2L T8HO or T12HO, Exterior, SBP		
4462	4FT Linear LED 2L, Replacing 8FT 2L T8HO or T12HO, 24/7, SBP		
4463	LED Fixture, 2x2, Low Output w/LLLC, DLC Listed, SBP	August 2018 online lookups of 4 base and efficient models show an average efficient fixture price of $55.6 and base bulb price of $16.89, for an incremental cost of $38.71.	$38.71
4464	LED Fixture, 2x2, High Output w/LLLC, DLC Listed, SBP	August 2018 online lookups of 4 base and efficient models show an average efficient fixture price of $127.93 and base bulb price of $16.89, for an incremental cost of $111.04.	$111.04

MMID	Measure Name	Source	Incremental Cost
4465	LED Troffer, 1x4, Replacing 4' 1-2 Lamp T8 Troffer w/LLLC, SBP	The incremental cost of $144.57 for MMID 4334 reflects the cost for MMID 3760 ($49.57) plus the cost for occupancy sensors ($70.00 per WESCO Distribution Pricing) and labor ($25.00).	$144.57
4466	LED Troffer, 2x4, Replacing 4' 3-4 Lamp T8 Troffer w/LLLC, SBP	Incremental cost of $144.24 for MMID 4335 reflects the cost for MMID 3111 plus the cost for occupancy sensors (MMID 2474), which according to WESCO Distribution Pricing is $70.00, plus $25.00 in labor.	$144.24
4467	LED Fixture,<=180 Watts, Replacing 4 lamp T5 or 6 lamp T8, High Bay, DLC Listed, SBP	August 2018 online lookups of 4 base and efficient models show an average efficient fixture price of $214.99 and base bulb price of $12.76, for an incremental cost of $202.23.	$202.23
4468	LED Fixture, ≤250 Watts, Replacing 8-lamp T8 or 6-lamp T5HO, High Bay, SBP	Full fixture cost of $90.58 is derived from online lookups at www.warehouselighting.com , www.prolighting.com , www.amazon.com , and www.greenelectricalsupply.com . Base lamp cost of $12.75 derived from August 2018 online lookups at www.1000bulbs.com , www.bulbs.com , and www.lightbulbs.com . Incremental cost is $77.83.	$77.83
4469	LED Replacement of 4-Foot T8 Lamps Utilizing Existing Ballast, Exterior, SBP	August 2018 online lookups of 6 base and efficient models show an average efficient lamp price of $7.4 and base lamp price of $1.92, for an incremental cost of $5.48.	$5.48
4470	LED Replacement of 4-Foot T8 Lamps Utilizing Existing Ballast, Exterior, 24/7, SBP		
4471	LED Replacement of 4-Foot T8 Lamps, Direct Wire, Exterior, SBP	August 2018 online lookups of 6 base and efficient models show an average efficient lamp price of $8.21 and base lamp price of $1.92, for an incremental cost of $6.29.	$6.29
4472	LED Replacement of 4-Foot T8 Lamps, Direct Wire, Exterior, 24/7, SBP		

MMID	Measure Name	Source	Incremental Cost
4473	LED Replacement of 4-Foot T8 Lamps, w/External Driver, Exterior, SBP	Energy Avenue. Website. Philips Advance ICN-2P32-N. www.energyavenue.com ASL Supply. Website. Philips ICN-2P32-N. www.adlsupply.com The Lighting Spot. Website. GE-232-MV-N. http://www.lighting-spot.com Bulb America. Website. SKU 49853. www.bulbamerica.com 1000Bulbs. Website. Philips 281535. www.1000bulbs.com ALB. Website. Halco F32T8/835/ECO. www.atlantalightbulbs.com Bulbs.com. Website. SKU U3000100. www.bulbs.com Average baseline cost data from retail sources is $10.79. SPECTRUM measure participation from January 2017 through December 2017 shows that the average cost for participating products is $24.90 for MMID 3511. Therefore, the incremental cost is $14.11 ($24.90 - $10.79).	$24.90
4474	LED Replacement of 4-Foot T8 Lamps, w/External Driver, Exterior, 24/7, SBP	Energy Avenue. Website. Philips Advance ICN-2P32-N. www.energyavenue.com ASL Supply. Website. Philips ICN-2P32-N. www.adlsupply.com The Lighting Spot. Website. GE-232-MV-N. http://www.lighting-spot.com Bulb America. Website. SKU 49853. www.bulbamerica.com 1000Bulbs. Website. Philips 281535. www.1000bulbs.com ALB. Website. Halco F32T8/835/ECO. www.atlantalightbulbs.com Bulbs.com. Website. SKU U3000100. www.bulbs.com Average baseline cost data from retail sources is $10.79. SPECTRUM measure participation from January 2017 through December 2017 shows that the average cost for participating products is $24.90 for MMID 3511. Therefore, the incremental cost is $14.11 ($24.90 - $10.79).	$24.90

MMID	Measure Name	Source	Incremental Cost
4475	LED Fixture, Downlights, Interior, SBP	Full cost of $1.57 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 2,701 watts reduced over 2 projects, from 2016 to 2018. August 2018 online lookups of 12 baseline lamps on www.1000bulbs.com , www.topbulb.com , www.lowes.com , and www.homedepot.com show a baseline cost of $0.05 per watt for a halogen replacement bulb. The incremental cost is therefore $1.52.	$0.85
4476	LED Fixture, Downlights, Exterior, SBP	Full cost of $1.57 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 390 watts reduced over 1 project, from 2016 to 2018. August 2018 online lookups of 12 baseline lamps on www.1000bulbs.com , www.topbulb.com , www.lowes.com , and www.homedepot.com show a baseline cost of $0.05 per watt for a halogen replacement bulb. The incremental cost is therefore $1.52.	$0.88
4477	LED Fixture, Quantity Modification, Interior, SBP	SPECTRUM. Average cost of 12,093 interior fixture units and 4,692 exterior fixture units in Small Business Program. January 2017–December 2017 application date ranges.	$1.41
4478	LED Fixture, Quantity Modification, Exterior, SBP		$1.36
4481	Dew Point Controls for Desiccant Dryers	Compressed Air Challenge. Dessicant Air Dryer Control: Seeing Isn't Always Believing. August 2015. http://www.compressedairchallenge.org/data/sites/1/media/library/articles/2015-08-CABP.pdf	$4,000.00
4483	Cycled Refrigeration Thermal Mass Air Dryers NEW	Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 5.0, Volume 2. (2016). Page 476. Available online: http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Final/IL-TRM_Effective_060116_v5.0_Vol_2_C_and_I_021116_Final.pdf	$6.00
4487	Case door, freezer, low heat	Price sheets for Styleline Classic II Plus and Hybridoor freezers, and Anthony 401, 101, and Infinity freezers. Sept 2016.	$548.67
4488	Case door, freezer, no heat	Price sheets for Styleline Classic II Plus freezer, and Anthony ELM, ELM 2, and 401 freezers. Sept 2016.	$121.00

MMID	Measure Name	Source	Incremental Cost
4489	Case door, refrigerated, no heat	Price sheets for Styleline Classic II Plus cooler, and Anthony ELM, ELM 2, 101, 101 No Heat, 401, Infinity, Vista C, and Vista B coolers. Sept 2016.	$208.83
4492	Compressed Air Condensate Drains, No Loss Drain	Historical project data from 2016 and 2017. Average cost for 118 projects is $448.93 per drain.	$448.93
4493	Pressure/Flow Controllers, NEW	Historical data of 71 projects since 2012, with average cost of $27.15 per horsepower.	$27.15
4494	Compressed Air Heat Recovery, Space Heating	Historical project data. 105 applications across 2015 and 2016.	$112.41
4495	Compressed Air Mist Eliminators, NEW	Actual Program Data, 2014-2015. 24 projects, average cost of $21.55 per hp installed.	$21.55
4496	Compressed Air Nozzles, Air Entraining	Focus on Energy Historical Project Data. 2013.	$35.49
4497	Dishwasher, Low Temp, Door Type, Energy Star, Energy Star, Electric, SBP	ENERGY STAR. “Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.” Calculator. 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx	$662.00
4498	Dishwasher, High Temp, Electric Booster, Door Type, Energy Star, Electric, SBP		$995.00
4499	Dishwasher, High Temp, Electric Booster, Door Type, Energy Star, NG, SBP		$995.00
4500	Dishwasher, High Temp, Electric Booster, Multi Tank Conveyor, Energy Star, Electric, SBP		$970.00

MMID	Measure Name	Source	Incremental Cost
4501	Dishwasher, High Temp, Electric Booster, Multi Tank Conveyor, Energy Star, NG, SBP	ENERGY STAR. "Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment." Calculator. 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx	$970.00
4502	Dishwasher, High Temp, Electric Booster, Single Tank Conveyor, Energy Star, Electric, SBP		
4503	Dishwasher, High Temp, Electric Booster, Single Tank Conveyor, Energy Star, NG, SBP		
4504	Dishwasher, High Temp, Electric Booster, Under Counter, Energy Star, Electric, SBP		$2,025.00
4506	Dishwasher, High Temp, Gas Booster, Door Type, Energy Star, NG, SBP		$995.00
4507	Dishwasher, High Temp, Gas Booster, Multi Tank Conveyor, Energy Star, NG, SBP		$970.00
4508	Dishwasher, High Temp, Gas Booster, Single Tank Conveyor, Energy Star, NG, SBP		$2,050.00
4509	Dishwasher, High Temp, Gas Heat, Gas Booster, Under Counter, Energy Star, NG, SBP		$2,025.00

MMID	Measure Name	Source	Incremental Cost
4510	Dishwasher, Low Temp, Door Type, Energy Star, NG, SBP	ENERGY STAR. "Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment." Calculator. 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx	$995.00
4511	Dishwasher, Low Temp, Multi Tank Conveyor, Energy Star, Electric, SBP		$970.00
4512	Dishwasher, Low Temp, Multi Tank Conveyor, Energy Star, NG, SBP		$970.00
4513	Dishwasher, Low Temp, Single Tank Conveyor, Energy Star, Electric, SBP		$0.00
4514	Dishwasher, Low Temp, Single Tank Conveyor, Energy Star, NG, SBP		$0.00
4515	Dishwasher, Low Temp, Under Counter, Energy Star, Electric, SBP		$234.00
4516	Dishwasher, Low Temp, Under Counter, Energy Star, NG, SBP		
4521	Energy Recovery Ventilator	Historical Focus on Energy project data, 2012-2013. 86 projects, excluded high cost per CFM that may be for complete AHU replacement, average cost of ERV is $6.14 per CFM.	$6.63
4522	Freezer, Chest, Glass Door, < 15 cu ft, Energy Star, SBP	ENERGY STAR. Program Calculator for Commercial Refrigerators and Freezers. October 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx	$1,240.00
4523	Freezer, Chest, Glass Door, 15-29 cu ft, Energy Star, SBP		
4524	Freezer, Chest, Glass Door, 30-49 cu ft, Energy Star, SBP		

MMID	Measure Name	Source	Incremental Cost
4525	Freezer, Chest, Glass Door, 50+ cu ft, Energy Star, SBP	ENERGY STAR. Program Calculator for Commercial Refrigerators and Freezers. October 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx	$1,240.00
4526	Freezer, Chest, Solid Door, < 15 cu ft, Energy Star, SBP		$0.00
4527	Freezer, Chest, Solid Door, 15-29 cu ft, Energy Star, SBP		
4528	Freezer, Chest, Solid Door, 30-49 cu ft, Energy Star, SBP		
4529	Freezer, Chest, Solid Door, 50+ cu ft, Energy Star, SBP		
4530	Freezer, Vertical, Glass Door, < 15 cu ft, Energy Star, SBP		$1,240.00
4531	Freezer, Vertical, Glass Door, 15-29 cu ft, Energy Star, SBP		$1,240.00
4532	Freezer, Vertical, Glass Door, 30-49 cu ft, Energy Star, SBP		
4533	Freezer, Vertical, Glass Door, 50+ cu ft,Energy Star, SBP		
4534	Freezer, Vertical, Solid Door, < 15 cu ft, Energy Star, SBP		$0.00
4535	Freezer, Vertical, Solid Door, 15-29 cu ft, Energy Star, SBP		
4536	Freezer, Vertical, Solid Door, 30-49 cu ft, Energy Star, SBP		

MMID	Measure Name	Source	Incremental Cost
4537	Freezer, Vertical, Solid Door, 50+ cu ft, Energy Star, SBP	ENERGY STAR. Program Calculator for Commercial Refrigerators and Freezers. October 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx	$0.00
4538	Fryer, Energy Star, NG, SBP	ENERGY STAR. "Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment." Calculator. October 2016 Version. www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx	$1,860.00
4539	Griddle, Energy Star, NG, SBP		$1,250.00
4543	Insulation, Steam Fitting, Removable, Natural Gas	Actual Program Data, 2015-2016. 20 projects with average actual cost of $37.63 per fitting	$37.63
4544	Insulation, Steam Piping, Natural Gas	Actual Program Data, 2015-2016. 18 projects with average actual cost of $8.40 per foot	$8.40
4545	Oven, Convection, Energy Star, Electric, SBP	ENERGY STAR. "Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment." Calculator. 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx	$388.00
4546	Oven, Convection, Energy Star, NG, SBP		$170.00
4547	Oven, Rack Type, Gas, Double Compartment, High Efficiency	ENERGY STAR® Commercial Kitchen Savings Calculator. Accessed March 11, 2016. All Rack Ovens Incremental Cost = $0.00. https://www.energystar.gov/products/commercial_food_service_equipment	$0.00
4548	Oven, Rack Type, Gas, Single Compartment, High Efficiency	ENERGY STAR® Commercial Kitchen Savings Calculator. Accessed March 11, 2016. All Rack Ovens Incremental Cost = $0.00. https://www.energystar.gov/products/commercial_food_service_equipment	$0.00
4551	Refrigerator, Chest, Glass Door, < 15 cu ft, Energy Star, SBP	ENERGY STAR® Calculator Commercial Kitchen Equipment. Accessed 03/2016. "Commercial refrigerator" incremental cost is $0.00 for all. Available online: https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx.	$470.00
4552	Refrigerator, Chest, Glass Door, 15-29 cu ft, Energy Star, SBP		
4553	Refrigerator, Chest, Glass Door, 30-49 cu ft, Energy Star, SBP		

MMID	Measure Name	Source	Incremental Cost
4554	Refrigerator, Chest, Glass Door, 50+ cu ft, Energy Star, SBP	ENERGY STAR® Calculator Commercial Kitchen Equipment. Accessed 03/2016. "Commercial refrigerator" incremental cost is $0.00 for all. Available online: https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx.	$470.00
4555	Refrigerator, Chest, Solid Door, < 15 cu ft, Energy Star, SBP		$1,440.00
4556	Refrigerator, Chest, Solid Door, 15-29 cu ft, Energy Star, SBP		
4557	Refrigerator, Chest, Solid Door, 30-49 cu ft, Energy Star, SBP		
4558	Refrigerator, Chest, Solid Door, 50+ cu ft, Energy Star, SBP		
4559	Refrigerator, Vertical, Glass Door, < 15 cu ft, Energy Star, SBP		$470.00
4560	Refrigerator, Vertical, Glass Door, 15-29 cu ft, Energy Star, SBP		
4561	Refrigerator, Vertical, Glass Door, 30-49 cu ft, Energy Star, SBP		
4562	Refrigerator, Vertical, Glass Door, 50+ cu ft, Energy Star, SBP		
4563	Refrigerator, Vertical, Solid Door, < 15 cu ft, Energy Star, SBP		$1,440.00
4564	Refrigerator, Vertical, Solid Door, 15-29 cu ft, Energy Star, SBP		
4565	Refrigerator, Vertical, Solid Door, 30-49 cu ft, Energy Star, SBP		

MMID	Measure Name	Source	Incremental Cost
4566	Refrigerator, Vertical, Solid Door, 50+ cu ft, Energy Star, SBP	ENERGY STAR® Calculator Commercial Kitchen Equipment. Accessed 03/2016. "Commercial refrigerator" incremental cost is $0.00 for all. Available online: https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx.	$1,440.00
4578	VFD, HVAC Fan	Evaluator and implementer consensus for setting cost on a per hp basis, instead of per motor. For variable torque VFDs, cost set at $210.52 per hp, based on 2016-2017 data of 1,069 projects.	$210.52
4579	VFD, HVAC Heating Pump		
4580	VFD, Pool Pump Motor		
4581	VFD, Process Fan		
4582	VFD Pump, Hybrid		
4583	Hot Food Holding Cabinet, V = 13-28 cu. ft., Energy Star, SBP	ENERGY STAR. Commercial Kitchen Equipment Calculator. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx Used for both incremental cost and calculation inputs (hours per day and days per year)	$902.00
4584	Hot Food Holding Cabinet, V < 13 cu. ft., Energy Star, SBP		
4585	Hot Food Holding Cabinet, V ≥ 28 cu. ft., Energy Star, SBP		
4594	Oven, Combination, Energy Star, Electric, SBP	ENERGY STAR® Commercial Kitchen Savings Calculator. Accessed March 11, 2016. All Rack Ovens Incremental Cost=$0.00. https://www.energystar.gov/products/commercial_food_service_equipment	$0.00
4595	Oven, Combination, Energy Star, NG, SBP		
4596	Dishwasher, High Temp, Electric Booster, Pots/Pans Type, Energy Star, Electric, SBP	ENERGY STAR. “Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.” Calculator. 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx	$1,710.00
4597	Dishwasher, High Temp, Electric Booster, Pots/Pans Type, Energy Star, NG, SBP		
4598	Dishwasher, High Temp, Gas Booster, Pots/Pans Type, Energy Star, NG, SBP		

MMID	Measure Name	Source	Incremental Cost
4599	Dishwasher, Low Temp, Pots/Pans Type, Energy Star, Electric, SBP	ENERGY STAR. "Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment." Calculator. 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx	$1,710.00
4600	Dishwasher, Low Temp, Pots/Pans Type, Energy Star, NG, SBP		
4601	VFD, Constant Torque	Evaluator and implementer consensus for setting cost on a per hp basis, instead of per motor. For constant torque VFDs, cost set at $122.48 per hp, based on 2016-2017 data of 111 projects.	$122.48
4602	Variable Speed ECM Pump, Domestic Hot Water Recirculation, < 100 Watts Max Input	Pricing research, Nov 2014. PSC and ECM pump motors from Viridian, Stratos, Star, Top, and other brands were examined across www.taco-hvac.com, www.wilo-usa.com, and www.nz.grundfos.com.	$690.79
4603	Variable Speed ECM Pump, Domestic Hot Water Recirculation, 100 - 500 Watts Max Input		$1,324.75
4604	Variable Speed ECM Pump, Domestic Hot Water Recirculation, > 500 Watts Max Input		$1,844.58
4605	Variable Speed ECM Pump, Heating Water Circulation, < 100 Watts Max Input		$690.79
4606	Variable Speed ECM Pump, Heating Water Circulation, 100 - 500 Watts Max Input		$1,324.75
4607	Variable Speed ECM Pump, Heating Water Circulation, > 500 Watts Max Input		$1,844.58

MMID	Measure Name	Source	Incremental Cost
4608	Variable Speed ECM Pump, Cooling Water Circulation, < 100 Watts Max Input	Pricing research, Nov 2014. PSC and ECM pump motors from Viridian, Stratos, Star, Top, and other brands were examined across www.taco-hvac.com, www.wilo-usa.com, and www.nz.grundfos.com.	$690.79
4609	Variable Speed ECM Pump, Cooling Water Circulation, 100 - 500 Watts Max Input		$1,324.75
4610	Variable Speed ECM Pump, Cooling Water Circulation, > 500 Watts Max Input		$1,844.58
4611	Variable Speed ECM Pump, Water Loop Heat Pump Circulation, < 100 Watts Max Input		$690.79
4612	Variable Speed ECM Pump, Water Loop Heat Pump Circulation, 100 - 500 Watts Max Input		$1,324.75
4613	Variable Speed ECM Pump, Water Loop Heat Pump Circulation, > 500 Watts Max Input		$1,844.58
4614	Spring-loaded Garage Door Hinge, 55 Degree Indoor Temperature Setpoint	2015 Vendor Feedback. The average installation cost is based on the average door size of 10 feet wide by 12 feet tall, with six panels and five sets of hinges at $28.00 per set (trade ally feedback /web quote) plus an estimated installation of $200.00 per door.	$228.00
4615	Spring-loaded Garage Door Hinge, 60 Degree Indoor Temperature Setpoint		
4616	Spring-loaded Garage Door Hinge, 65 Degree Indoor Temperature Setpoint		

MMID	Measure Name	Source	Incremental Cost
4617	Spring-loaded Garage Door Hinge, 70 Degree Indoor Temperature Setpoint	2015 Vendor Feedback. The average installation cost is based on the average door size of 10 feet wide by 12 feet tall, with six panels and five sets of hinges at $28.00 per set (trade ally feedback /web quote) plus an estimated installation of $200.00 per door.	$228.00
4618	LED Fixture, Linear Ambient, Replacing 1 or 2 T5 lamp(s) in Cross Section, SBP	1000 Bulbs. Website. Accessed July 2018. www.1000bulbs.com Top Bulb. Website. Accessed July 2018. www.topbulb.com Average efficient cost of $16.35 and base cost of $3.76 for MMIDs 3738, 4618, 4791, 4785, and 4786. Average efficient cost of $38.15 and base cost of $8.77 for MMIDs 3739, 4619, 4792, 4787, and 4788.	$12.59
4619	LED Fixture, Linear Ambient, Replacing 3 or 4 T5 lamps in Cross Section, SBP	1000 Bulbs. Website. Accessed July 2018. www.1000bulbs.com Top Bulb. Website. Accessed July 2018. www.topbulb.com Average efficient cost of $16.35 and base cost of $3.76 for MMIDs 3738, 4618, 4791, 4785, and 4786. Average efficient cost of $38.15 and base cost of $8.77 for MMIDs 3739, 4619, 4792, 4787, and 4788.	$29.38
4620	LED Fixture, Linear Ambient, Replacing 1 or 2 T8/T12 lamp(s) in Cross Section, SBP	August 2018 online lookups of 6 base and efficient models show an average efficient lamp price of $12.82 and base lamp price of $2.94, for an incremental cost of $9.89.	$9.89
4621	LED Fixture, Linear Ambient, Replacing 3 or 4 T8/12 lamps in Cross Section, SBP	August 2018 online lookups of 6 base and efficient models show an average efficient lamp price of $29.93 and base lamp price of $6.85, for an incremental cost of $23.08.	$23.08
4622	ENERGY STAR® Commercial Ice Machine, Ice Making Head, SBP	ENERGY STAR. "Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment." Calculator. 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx	$222.00
4623	ENERGY STAR® Commercial Ice Machine, Remote Condensing Unit, SBP		

MMID	Measure Name	Source	Incremental Cost
4624	ENERGY STAR® Commercial Ice Machine, Self-Contained Unit, SBP	ENERGY STAR. “Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.” Calculator. 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx	$222.00
4625	ECM HVAC Fan Motors, Heating	Navigant Consulting Inc. “Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment.” Table 2.1, p. 5, Section 2.4.3, p. 16, and Table 4.10, p. 49. Prepared for U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. December 4, 2013. http://energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf SP efficiency is the midpoint of 20 – 40% range listed in Table 2.1. PSC efficiency is the midpoint of 35 – 50% range listed in Section 2.4.3. ECM efficiency is the fractional horsepower efficiency of 70% listed in Section 2.4.3.	$120.00 per motor
4626	ECM HVAC Fan Motors, Cooling		
4627	ECM HVAC Fan Motors, Occupied Ventilation		
4628	ECM HVAC Fan Motors, 24/7 Ventilation	Navigant Consulting Inc. “Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment.” Table 2.1, p. 5, Section 2.4.3, p. 16, and Table 4.10, p. 49. Prepared for U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. December 4, 2013. http://energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf SP efficiency is the midpoint of 20 – 40% range listed in Table 2.1. PSC efficiency is the midpoint of 35 – 50% range listed in Section 2.4.3. ECM efficiency is the fractional horsepower efficiency of 70% listed in Section 2.4.3.	$120.00 per motor
4629	Vacuum Pump Heat Recovery, Space Heating	Historical project data. 105 applications across 2015 and 2016.	$112.41

MMID	Measure Name	Source	Incremental Cost
4630	LED Lamp, ENERGY STAR, Replacing Exterior Directional CFL, ≥ 23W CFL, SBP	Cost data obtained in November 2016 through various online lighting retailers. A full list can be provided upon request.	$3.83
4631	LED Lamp, ENERGY STAR, Replacing Exterior Directional CFL, 14W-22W CFL, SBP		$9.49
4632	LED Lamp, ENERGY STAR, Replacing Exterior Directional CFL, ≤ 13W, SBP		$2.14
4633	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, 120W – 250W Incandescent, SBP	1000 Bulbs. Website. Accessed November 2016. www.1000bulbs.com Home Depot. Website. Accessed November 2016. www.homedepot.com Lowes. Website. Accessed November 2016. www.lowes.com Lightology. Website. Accessed November 2016. www.lightology.com	$0.37
4634	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, 100W – 119W Incandescent, SBP		$2.85
4635	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, 75W – 99W Incandescent, SBP	1000 Bulbs. Website. Accessed November 2016. www.1000bulbs.com Home Depot. Website. Accessed November 2016. www.homedepot.com Lowes. Website. Accessed November 2016. www.lowes.com Lightology. Website. Accessed November 2016. www.lightology.com	$3.56
4636	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, 55W – 74W Incandescent, SBP		$4.57

MMID	Measure Name	Source	Incremental Cost
4637	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, 36W – 54W Incandescent, SBP	1000 Bulbs. Website. Accessed November 2016. www.1000bulbs.com Home Depot. Website. Accessed November 2016. www.homedepot.com Lowes. Website. Accessed November 2016. www.lowes.com Lightology. Website. Accessed November 2016. www.lightology.com	$3.34
4638	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent, ≤ 35W Incandescent, SBP		$4.93
4639	LED Lamp, ENERGY STAR, 1,600 – 1,999 Lumens, Exterior, SBP		$11.40
4640	LED Lamp, ENERGY STAR, 1,100 – 1,599 Lumens, Exterior, SBP		$8.66
4641	LED Lamp, ENERGY STAR, 800 – 1,099 Lumens, Exterior, SBP		$3.61
4642	LED Lamp, ENERGY STAR, 450 – 799 Lumens, Exterior, SBP		$3.73
4643	LED Lamp, ENERGY STAR, 250 – 449 Lumens, Exterior, SBP		$5.87
4644	LED Lamp, DLC, High/Low-Bay Mogul Screw-Base (E39), SBP		$66.05
4645	LED Lamp, DLC, Mogul Screw-Base (E39), Exterior, SBP		$66.05

MMID	Measure Name	Source	Incremental Cost
4646	Advanced Rooftop Unit Controller	Average historic project cost for MMID 3651 completed under special offer for advanced rooftop unit controllers in 2015, plus historical project cost under MMID 3964 for projects completed in 2017 and January through March 2018 (35 applications for a total of 68 rooftop units; total of 1,500 tons). Note that no measures were completed under MMID 3650 for the advanced rooftop unit controller special offer, so that MMID was excluded.	$530.10
4648	Steam Trap Repair, <10 psig, General Heating, Prescriptive: 7/32" or Smaller	Average measure cost of five projects (Radiator Measure MMID 2772) from 2012 to 2014 for low-pressure heating measures, with extrapolated industrial costs.	$50.89
4649	Steam Trap Repair, <10 psig, General Heating, Prescriptive: 1/4"		
4650	Steam Trap Repair, <10 psig, General Heating, Prescriptive: 5/16"		
4651	Steam Trap Repair, <10 psig, General Heating, Prescriptive: 3/8" or Larger		
4652	Permanent Magnet Synchronous (PMS) Evaporator Fan Motor, Refrigerated Case, Replacement	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 10 units over 2 projects in 2018.	$92.40
4653	VFD, Boiler Draft Fan	Evaluator and implementer consensus for setting cost on a per hp basis, instead of per motor. For variable torque VFDs, cost set at $210.52 per hp, based on 2016-2017 data of 1,069 projects.	$210.52
4654	VFD, Cooling Tower Fan		
4655	VFD, Chilled Water Distribution Pump		
4659	Boiler Tune-Up, Single Family	CLEAResult. Informal survey of four Wisconsin Trade Allies. December 2017.	$150.00
4660	Furnace Tune-Up, Single Family		

MMID	Measure Name	Source	Incremental Cost
4661	Salamander Broiler, Infrared, Nautral Gas, Per input MBh	Nicor Gas Energy Efficiency Plan 2011–2014. "Revised Plan Filed Pursuant to Order Docket 10-0562." May 27, 2011. https://www.icc.illinois.gov/downloads/public/edocket/295533.pdf	$1,000.00
4666	Smart Thermostat, Existing Natural Gas Boiler	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. July 2017 to December 2017. Average actual measure cost of 2,585 smart thermostat measures incented by Focus on Energy is $213.00 (MMIDs 3609, 3610, and 3611). Minus the cost of a manual thermostat, which is $39.11 based on online lookups from July 2018.	$173.89
4667	Smart Thermostat, Existing Natural Gas Furnace		
4668	Smart Thermostat, Existing Air-Source Heat Pump		
4681	Low-E Storm Window, Single Family	See Assumptions	$126.00
4682	Low-E Storm Window, Multifamily	See Assumptions	$160.00
4684	7 Outlet Advanced Power Strip, Business, Pack Based	Quote from Resource Action Programs, January 16, 2018.	$13.50
4685	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent, BR30, Pack-Based	AM Conservation Group. Price quote for Focus on Energy program. March 2018.	$4.15
4686	LED Lamp, ENERGY STAR, Replacing Omnidirectional and Decorative Incand. or CFL, 800 Lumens, Pack-Based	Quote from Resource Action Programs.	$2.75
4687	LED Exit Sign, Retrofit, Pack-Based	Quote from Resource Action Programs. March 2018.	$10.49
4688	Kitchen Aerator, 1.5 GPM, Small Office, Electric or Natural Gas, Pack Based	Resource Action Programs. Quote for Focus on Energy program. March 2018.	$1.44

MMID	Measure Name	Source	Incremental Cost
4689	Kitchen Aerator, 1.5 GPM, Restaurant, Electric or Natural Gas, Pack Based	Resource Action Programs. Quote for Focus on Energy program. March 2018.	$1.44
4690	Bathroom Aerator, 1.0 GPM, Small Office, Electric or Natural Gas, Pack Based	Resource Action Programs. Quote for Focus on Energy program. March 2018.	$1.46
4691	Bathroom Aerator, 1.0 GPM, Restaurant, Electric or Natural Gas, Pack Based		
4692	Bathroom Aerator, 1.0 GPM, Retail, Electric or Natural Gas, Pack Based		
4693	Pre-Rinse Sprayer, 1.1 GPM, Electric or Natural Gas, Pack Based		$26.25
4710	Steamer, ENERGY STAR, Electric	ENERGY STAR. "Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment." Calculator. October 2016 version. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx	$755.56
4711	Steamer, ENERGY STAR, NG		$504.44
4712	Chiller, Air Cooled, < 150 tons, Path A	Northeast Energy Efficiency Partnerships. Incremental Cost Study Phase Two Final Report: A Report on 12 Energy Efficiency Measure Incremental Costs in Six Northeast and Mid-Atlantic Markets. January 2013. http://www.neep.org/incremental-cost-study-phase-2	$354.00
4713	Chiller, Air Cooled, ≥ 150 tons, Path A		$101.00
4714	Chiller, Air Cooled, < 150 tons, Path B		$354.00
4715	Chiller, Air Cooled, ≥ 150 tons, Path B		$101.00
4716	Chiller, Water Cooled, Positive Displacement, < 75 tons, Path A		$57.00

MMID	Measure Name	Source	Incremental Cost
4717	Chiller, Water Cooled, Positive Displacement, ≥ 75 and < 150 tons, Path A	Northeast Energy Efficiency Partnerships. Incremental Cost Study Phase Two Final Report: A Report on 12 Energy Efficiency Measure Incremental Costs in Six Northeast and Mid-Atlantic Markets. January 2013. http://www.neep.org/incremental-cost-study-phase-2	$25.00
4718	Chiller, Water Cooled, Positive Displacement, ≥ 150 and < 300 tons, Path A		$61.00
4719	Chiller, Water Cooled, Positive Displacement, ≥ 300 and < 600 tons, Path A		$31.00
4720	Chiller, Water Cooled, Positive Displacement, ≥ 600 tons, Path A		$31.00
4721	Chiller, Water Cooled, Positive Displacement, < 75 tons, Path B		$57.00
4722	Chiller, Water Cooled, Positive Displacement, ≥ 75 and < 150 tons, Path B		$25.00
4723	Chiller, Water Cooled, Positive Displacement, ≥ 150 and < 300 tons, Path B		$61.00
4724	Chiller, Water Cooled, Positive Displacement, ≥ 300 and < 600 tons, Path B		$31.00
4725	Chiller, Water Cooled, Positive Displacement, ≥ 600 tons, Path B		$31.00
4726	Chiller, Water Cooled, Centrifugal, < 150 tons, Path A		$37.00

MMID	Measure Name	Source	Incremental Cost
4727	Chiller, Water Cooled, Centrifugal, ≥ 150 and < 300 tons, Path A	Northeast Energy Efficiency Partnerships. Incremental Cost Study Phase Two Final Report: A Report on 12 Energy Efficiency Measure Incremental Costs in Six Northeast and Mid-Atlantic Markets. January 2013. http://www.neep.org/incremental-cost-study-phase-2	$21.00
4728	Chiller, Water Cooled, Centrifugal, ≥ 300 and < 400 tons, Path A		$61.00
4729	Chiller, Water Cooled, Centrifugal, ≥ 400 and < 600 tons, Path A		$30.00
4730	Chiller, Water Cooled, Centrifugal, ≥ 600 tons, Path A		$30.00
4731	Chiller, Water Cooled, Centrifugal, < 150 tons, Path B		$37.00
4732	Chiller, Water Cooled, Centrifugal, ≥ 150 and < 300 tons, Path B		$21.00
4733	Chiller, Water Cooled, Centrifugal, ≥ 300 and < 400 tons, Path B		$61.00
4734	Chiller, Water Cooled, Centrifugal, ≥ 400 and < 600 tons, Path B		$30.00
4735	Chiller, Water Cooled, Centrifugal, ≥ 600 tons, Path B		$30.00
4736	A/C Split System, ≤ 65 MBh, SEER 15	Itron. Ex Ante Measure Cost Study results Matrix, Volume I: Hedonic Model Estimates, Version 1.7. Spreadsheet “NR HW Heater WA017 MCS Results Matrix Volume I August 2016.” https://energy.mo.gov/about/trm/supporting-documents Equipment + Labor tab, rows 152 through 175 for split system costs and rows 224 through 235 for packaged system costs.	$184.25
4737	A/C Split System, ≤ 65 MBh, SEER 16		$276.38
4738	A/C Split System, ≤ 65 MBh, SEER 17		$368.51
4739	A/C Split System, ≤ 65 MBh, SEER 18+		$460.63
4740	A/C Single Package, ≤ 65 MBh, SEER 15		$725.37

MMID	Measure Name	Source	Incremental Cost
4741	A/C Single Package, ≤ 65 MBh, SEER 16	Itron. Ex Ante Measure Cost Study results Matrix, Volume I: Hedonic Model Estimates, Version 1.7. Spreadsheet "NR HW Heater WA017 MCS Results Matrix Volume I August 2016." https://energy.mo.gov/about/trm/supporting-documents Equipment + Labor tab, rows 152 through 175 for split system costs and rows 224 through 235 for packaged system costs.	$1,257.35
4742	A/C Single Package, ≤ 65 MBh, SEER 17		$1,789.32
4743	A/C Single Package, ≤ 65 MBh, SEER 18+		$2,321.29
4744	Air-Source Heat Pump, ≤ 65 MBh, SEER 15 and 9.0 HSPF	Itron. Ex Ante Measure Cost Study results Matrix, Volume I: Hedonic Model Estimates, Version 1.7. Spreadsheet "NR HW Heater WA017 MCS Results Matrix Volume I August 2016." https://energy.mo.gov/about/trm/supporting-documents Equipment + Labor tab, rows 134–150 for split heat pump costs, and rows 291–303 for packaged heat pump costs.	$308.16
4745	Air-Source Heat Pump, ≤ 65 MBh, SEER 16 and 9.0 HSPF		$432.82
4746	Air-Source Heat Pump, ≤ 65 MBh, SEER 17 and 9.0 HSPF		$576.00
4747	Air-Source Heat Pump, ≤ 65 MBh, SEER 18 and 9.0 HSPF		$719.75
4748	Guest Room Energy Management Controls, PTHP Systems	Illinois Statewide Technical Reference Manual for Energy Efficiency. Version 6.0. p. 158. February 8, 2017. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/ILTRM_Version_6.0_dated_February_8_2017_Final_Volumes_1-4_Compiled.pdf	$260.00
4749	Air Sealing, Natural Gas Heat with Cooling	Energy House LLC. Personal communication with Doug McFee on April 10, 2019 suggests $0.27 per square foot.	$0.27
4750	Air Sealing, Natural Gas Heat without Cooling	Energy House LLC. Personal communication with Doug McFee on April 10, 2019 suggests $0.27 per square foot.	$0.27
4751	Air Sealing, Electric Heat with Cooling	Energy House LLC. Personal communication with Doug McFee on April 10, 2019 suggests $0.27 per square foot.	$0.27
4752	Air Sealing, Electric Heat without Cooling	Energy House LLC. Personal communication with Doug McFee on April 10, 2019 suggests $0.27 per square foot.	$0.27

MMID	Measure Name	Source	Incremental Cost
4753	Unit Heater, ≥ 90% Thermal Efficiency, Heating Setpoint = 70°F	Historical Focus on Energy project data, 2015 to June 2018. Twenty-nine projects, 100 total unit heaters. Average unit heater cost is $22.64/MBh, less baseline unit heater cost of $7.08/MBh from review of www.supplyhouse.com pricing (Accessed June 2018) for Reznor and Modine unit heaters. See 2018 Focus on Energy Incremental Measure Cost study for details.	$15.56
4754	Unit Heater, ≥ 90% Thermal Efficiency, Heating Setpoint = 65°F		
4755	Unit Heater, ≥ 90% Thermal Efficiency, Heating Setpoint = 60°F		
4756	Unit Heater, ≥ 90% Thermal Efficiency, Heating Setpoint = 55°F		
4757	VFD, Domestic Water Pump	Evaluator and implementer consensus for setting cost on a per hp basis, instead of per motor. For variable torque VFDs, cost set at $210.52 per hp, based on 2016-2017 data of 1,069 projects.	$210.52
4758	Demand Defrost Controls	Grainger, Inc. Average Cost of Defrost Timer Controls (= $146; average of 23 relevant products). Baseline cost. Accessed September 2018. https://www.grainger.com/category/defrost-timer-control/	$619.00
4759	Evaporator Fan Control for Reach-in Cooler/Freezer	Regional Technical Forum. "Evaporator Fan Controls and Evaporator Fan Uniform Energy Savings Measures Calculations." 2010. https://nwcouncil.app.box.com/s/pt7getqkjxzmlvm5f87wn3eydvidvjb5 Cost adjusted from $141 in 2010 dollars to $155 in 2017 dollars based on http://www.usinflationcalculator.com/	$155.00
4760	Process Boiler Burner, 10:1 High Turn Down	Wisconsin Focus on Energy. Historical project data for MMID 2203 obtained from SPECTRUM. Average cost of 25 units over 19 projects from 2016 to 2018.	$65.22
4761	Process Boiler Control, Linkageless	Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 27 units over 21 projects from 2016 to 2018.	$79.61

MMID	Measure Name	Source	Incremental Cost
4762	Process Boiler, Oxygen Trim Combustion Controls	Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 459 units over 44 projects from 2012 to 2018.	$55.54
4763	High Efficiency Side Entry Agitator	Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. October 2016 through October 2018. Weighted average cost of three previous Process, Not Otherwise Specified projects involving this technology is $225.29/hp.	$225.29
4764	Spline Rotor Upgrade for Refiners	Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. December 2015 through July 2018. Weighted average cost of six previous process (not otherwise specified) projects involving this technology is $127.59/refiner hp.	$127.59
4765	Industrial High Frequency Battery Chargers	Pacific Gas & Electric. "Analysis of Standards Options for Battery Charger Systems." EUL: p. 43. Incremental cost: p. 45. Baseline wattages: p. 17. 2010. This report is cited in 2019 Illinois Statewide Technical Reference Manual for Energy Efficiency. Version 7.0, p. 581. September 28, 2018. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_1-4_Compiled_092818_Final.pdf	$400.00
4766	Compressed Air System Leak Survey and Repair	Historical Focus on Energy project data, January 1, 2016 to June 30, 2018. For 301 projects across previous compressed air leak survey and repair measures MMID 2261, MMID 2262, MMID 2263, and MMID 3598, the average cost is $4.83/hp.	$4.83
4767	Compressed Air System Leak Survey and Repair-Agriculture	Historical Focus on Energy project data, January 1, 2016 to June 30, 2018. For 301 projects across previous compressed air leak survey and repair measures MMID 2261, MMID 2262, MMID 2263, and MMID 3598, the average cost is $4.83/hp.	$4.83

MMID	Measure Name	Source	Incremental Cost
4768	Split System, SEER 15, <5.4 tons, Data Center/Telecom	Itron. Ex Ante Measure Cost Study results Matrix, Volume I: Hedonic Model Estimates, Version 1.7. Spreadsheet "NR HW Heater WA017 MCS Results Matrix Volume I August 2016." Equipment + Labor tab, rows 152–175 for split system costs and rows 224–135 for packaged system costs. https://energy.mo.gov/about/trm/supporting-documents	$184.25
4769	Split System, SEER 15, <5.4 tons, Data Center/Telecom		$276.38
4770	Split System, SEER 15, <5.4 tons, Data Center/Telecom		$368.51
4771	Split System, SEER 15, <5.4 tons, Data Center/Telecom		$460.63
4772	Single Package, SEER 15, <5.4 tons, Data Center/Telecom	Itron. Ex Ante Measure Cost Study results Matrix, Volume I: Hedonic Model Estimates, Version 1.7. Spreadsheet "NR HW Heater WA017 MCS Results Matrix Volume I August 2016." Equipment + Labor tab, rows 152–175 for split system costs and rows 224–135 for packaged system costs. https://energy.mo.gov/about/trm/supporting-documents	$725.37
4773	Single Package, SEER 15, <5.4 tons, Data Center/Telecom		$1,257.35
4774	Single Package, SEER 15, <5.4 tons, Data Center/Telecom		$1,789.32
4775	Single Package, SEER 15, <5.4 tons, Data Center/Telecom		$2,321.29
4776	Air-Side Economizer, Data Center/Telecom	RS Means. Facilities Construction Cost Data. 29th Edition. 2013. Assumed $54.00 per hour labor rate for work performed on air cooling equipment. Estimated 2 hours for completion based on project experience.	$108.00
4777	Efficient UPS	California Municipal Utilities Association. Savings Estimation Technical Reference Manual 2017, Third Edition. Section 8.12, p. 8–15. https://www.cmua.org/files/CMUA-POU-TRM_2017_FINAL_12-5-2017%20-%20Copy.pdf	$59.00
4778	Efficient Rectifier		

MMID	Measure Name	Source	Incremental Cost
4779	DLC Listed, Four Pin-Base Lamp Replacing CFL, Interior	1000 Bulbs. Accessed October 2018. www.1000bulbs.com Amazon. Accessed October 2018. www.amazon.com Bulbs. Accessed October 2018. www.bulbs.com Home Depot. Accessed October 2018. www.homedepot.com Grainger. Accessed October 2018. www.grainger.com	$0.84
4780	DLC Listed, Four Pin-Base Lamp Replacing CFL, Exterior		
4781	LED Fixture, Linear Ambient, Replacing 1 or 2 T8/T12 Lamp(s) in Cross Section, Exterior, 24 hour	1000 Bulbs. Website. Accessed July 2018. www.1000bulbs.com Average efficient cost of $12.82 and base cost of $2.94 for 1 or 2 T8/12 Lamp measures. Average efficient cost of $29.93 and base cost of $6.85 for 3 or 4 T8/12 Lamp measures.	$9.89
4782	LED Fixture, Linear Ambient, Replacing 1 or 2 T8/T12 Lamp(s) in Cross Section, Exterior, 12 hour		$9.89
4783	LED Fixture, Linear Ambient, Replacing 3 or 4 T8/T12 Lamps in Cross Section, Exterior, 24 hour		$23.08
4784	LED Fixture, Linear Ambient, Replacing 3 or 4 T8/T12 Lamps in Cross Section, Exterior, 12 hour	1000 Bulbs. Website. Accessed July 2018. www.1000bulbs.com Average efficient cost of $12.82 and base cost of $2.94 for 1 or 2 T8/12 Lamp measures. Average efficient cost of $29.93 and base cost of $6.85 for 3 or 4 T8/12 Lamp measures.	$23.08
4785	LED Fixture, Linear Ambient, Replacing 1 or 2 T5 Lamp(s) in Cross Section, Exterior, 24 hour	1000 Bulbs. Website. Accessed July 2018. www.1000bulbs.com Top Bulb. Website. Accessed July 2018. www.topbulb.com Average efficient cost of $16.35 and base cost of $3.76 for MMIDs 3738, 4618, 4791, 4785, and 4786. Average efficient cost of $38.15 and base cost of $8.77 for MMIDs 3739, 4619, 4792, 4787, and 4788.	$12.59

MMID	Measure Name	Source	Incremental Cost
4786	LED Fixture, Linear Ambient, Replacing 1 or 2 T5 Lamp(s) in Cross Section, Exterior, 12 hour	1000 Bulbs. Website. Accessed July 2018. www.1000bulbs.com Top Bulb. Website. Accessed July 2018. www.topbulb.com Average efficient cost of $16.35 and base cost of $3.76 for MMIDs 3738, 4618, 4791, 4785, and 4786. Average efficient cost of $38.15 and base cost of $8.77 for MMIDs 3739, 4619, 4792, 4787, and 4788.	$12.59
4787	LED Fixture, Linear Ambient, Replacing 3 or 4 T5 Lamps in Cross Section, Exterior, 24 hour		$29.38
4788	LED Fixture, Linear Ambient, Replacing 3 or 4 T5 Lamps in Cross Section, Exterior, 12 hour		$29.38
4789	LED Fixture, Linear Ambient, Replacing 1 or 2 T8/T12 Lamp(s) in Cross Section, In Unit	1000 Bulbs. Website. Accessed July 2018. www.1000bulbs.com Average efficient cost of $12.82 and base cost of $2.94 for 1 or 2 T8/12 Lamp measures. Average efficient cost of $29.93 and base cost of $6.85 for 3 or 4 T8/12 Lamp measures.	$9.89
4790	LED Fixture, Linear Ambient, Replacing 3 or 4 T8/T12 Lamps in Cross Section, In Unit		$23.08
4791	LED Fixture, Linear Ambient, Replacing 1 or 2 T5 Lamp(s) in Cross Section, In Unit	1000 Bulbs. Website. Accessed July 2018. www.1000bulbs.com Top Bulb. Website. Accessed July 2018. www.topbulb.com Average efficient cost of $16.35 and base cost of $3.76 for MMIDs 3738, 4618, 4791, 4785, and 4786. Average efficient cost of $38.15 and base cost of $8.77 for MMIDs 3739, 4619, 4792, 4787, and 4788.	$12.59
4792	LED Fixture, Linear Ambient, Replacing 3 or 4 T5 Lamps in Cross Section, In Unit		$29.38
4793	LED Troffer, 2x4, Replacing 4-Foot 1- or 2-Lamp T8 Troffer	The incremental cost is based on measure MMID 3111. Average baseline cost data was $78.15. SPECTRUM measure participation data from January through December 2017 shows that the average cost for participating products is $127.39 for MMID 3111. Therefore, the incremental cost is $49.24 ($127.39 - $78.15).	$49.24

MMID	Measure Name	Source	Incremental Cost
4794	LED Troffer, 2x4, Replacing 4-Foot 1- or 2-Lamp Troffer with Luminaire Level Lighting Controls	The incremental cost of $144.24 reflects the cost for MMID 3111 plus the cost for occupancy sensors ($70.00 per WESCO Distribution Pricing) and labor ($25.00).	$144.24
4795	LED Fixture, ≤ 300 Watts, Replacing 10 Lamp T8 or 8 Lamp T5HO, High Bay	Incremental cost based on MMID 4347.	$90.58
4796	LED Fixture, ≤ 350 Watts, Replacing 12 Lamp T8 or 10 Lamp T5HO, High Bay		
4797	LED Replacement of 2-Foot T8 Lamps w/ External Driver	1000bulbs. Website. Accessed September 2018. www.1000bulbs.com Warehouse-lighting. Website. Accessed September 2018. www.warehouse-lighting.com Atlantalightbulbs. Website. Accessed September 2018. www.atlantalightbulbs.com Prolighting. Website. Accessed September 2018. www.prolighting.com Bulbsdepot. Website. Accessed September 2018. www.bulbsdepot.com LEDt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Average 2-foot LED cost from retail sources. Baseline lamps cost $2.71. Efficient lamps cost $10.60. Efficient lamp driver cost $23.50. Therefore, the incremental cost is $31.39.	$31.39

MMID	Measure Name	Source	Incremental Cost
4798	LED Replacement of 2-Foot T8 Lamps, Direct Wire	1000bulbs. Website. Accessed September 2018. www.1000bulbs.com Warehouse-lighting. Website. Accessed September 2018. www.warehouse-lighting.com Atlantalightbulbs. Website. Accessed September 2018. www.atlantalightbulbs.com 1000bulbs. Website. Accessed September 2018. www.1000bulbs.com Atlantalightbulbs. Website. Accessed September 2018. www.atlantalightbulbs.com LEDt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Average 2-Foot LED cost from retail sources. Baseline lamps cost $2.71. Efficient lamps cost $10.11. Therefore, the incremental cost is $7.41.	$7.41
4799	LED Replacement of 2-Foot Lamps Using Existing Ballast	1000bulbs. Website. Accessed September 2018. www.1000bulbs.com Warehouse-lighting. Website. Accessed September 2018. www.warehouse-lighting.com Atlantalightbulbs. Website. Accessed September 2018. Wwww.atlantalightbulbs.com 1000bulbs. Website. Accessed September 2018. www.1000bulbs.com Warehouse-lighting. Website. Accessed September 2018. www.warehouse-lighting.com LEDt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Average 2-foot LED cost from retail sources. Baseline lamps cost $2.71. Efficient lamps cost $12.36. Therefore, the incremental cost is $9.66.	$9.66

MMID	Measure Name	Source	Incremental Cost
4800	LED Replacement of U-Bend T8 Lamps w/ External Driver	1000Bulbs. Website. Accessed September 2018. www.1000bulbs.com Warehouse-lighting. Website. Accessed September 2018. www.warehouse-lighting.com Atlantalightbulbs. Website. Accessed September 2018. www.atlantalightbulbs.com Prolighting. Website. Accessed September 2018. www.prolighting.com Bulbsdepot. Website. Accessed September 2018. www.bulbsdepot.com LEDt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Average U-bend LED cost from retail sources. Baseline lamps cost $7.31. Efficient lamps cost $17.88. Efficient lamp driver cost $28.95. Therefore, the incremental cost is $39.53.	$39.53
4801	LED Replacement of U-Bend T8 Lamps, Direct Wire	1000bulbs. Website. Accessed September 2018. www.1000bulbs.com Warehouse-lighting. Website. Accessed September 2018. www.warehouse-lighting.com Atlantalightbulbs. Website. Accessed September 2018. www.atlantalightbulbs.com 1000bulbs. Website. Accessed September 2018. www.1000bulbs.com Topbulb. Website. Accessed September 2018. topbulb.com LEDt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Average U-bend LED cost from retail sources. Baseline lamps cost $7.31. Efficient lamps cost $19.69. Therefore, the incremental cost is $12.39.	$12.39

MMID	Measure Name	Source	Incremental Cost
4802	LED Replacement of U-Bend T8 Lamps Using Existing Ballast	1000bulbs. Website. Accessed September 2018. www.1000bulbs.com Warehouse-lighting. Website. Accessed September 2018. www.warehouse-lighting.com Atlantalightbulbs. Website. Accessed September 2018. www.atlantalightbulbs.com 1000bulbs. Website. Accessed September 2018. www.1000bulbs.com Atlantalightbulbs. Website. Accessed September 2018. www.atlantalightbulbs.com LEDt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Average U-bend LED cost from retail sources. Baseline lamps cost \$7.31. Efficient lamps cost \$20.79. Therefore, the incremental cost is \$13.49.	\$13.49
4803	LED Replacement of 4-Foot T5 Lamps w/ External Driver	1000Bulbs. Website. Accessed September 2018. www.1000bulbs.com Warehouse-lighting. Website. Accessed September 2018. www.warehouse-lighting.com Payless-4-lighting. Website. Accessed September 2018. www.payless-4-lighting.com Ledt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Bulbsdepot. Website. Accessed September 2018. www.bulbsdepot.com Ledt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Average cost from retail sources. Baseline lamps cost \$3.26. Efficient lamps cost \$20.63. Efficient lamp driver cost \$31.95. Therefore, the incremental cost is \$49.32.	\$49.32

MMID	Measure Name	Source	Incremental Cost
4804	LED Replacement of 4-Foot T5HO Lamps w/ External Driver	1000Bulbs. Website. Accessed September 2018. www.1000bulbs.com Warehouse-lighting. Website. Accessed September 2018. www.warehouse-lighting.com Payless-4-lighting. Website. Accessed September 2018. www.payless-4-lighting.com Ledt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Bulbsdepot. Website. Accessed September 2018. www.bulbsdepot.com Ledt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Average cost from retail sources. Baseline lamps cost $3.26. Efficient lamps cost $20.63. Efficient lamp driver cost $31.95. Therefore, the incremental cost is $49.32.	$49.32
4805	LED Replacement of 4-Foot T5 Lamps, Direct Wire	1000bulbs. Website. Accessed September 2018. www.1000bulbs.com Warehouse-lighting. Website. Accessed September 2018. www.warehouse-lighting.com Payless-4-lighting. Website. Accessed September 2018. www.payless-4-lighting.com Ledt8bulbs. Website. Accessed September 2018. www.ledt8bulb.com Atlantalightbulbs. Website. Accessed September 2018. www.atlantalightbulbs.com Bulbs. Website. Accessed September 2018. bulbs.com Average cost from retail sources. Baseline lamps cost $3.26. Efficient lamps cost $13.91. Therefore, the incremental cost is $10.65.	$10.65

MMID	Measure Name	Source	Incremental Cost
4806	LED Replacement of 4-Foot T5HO Lamps, Direct Wire	1000bulbs. Website. Accessed September 2018. www.1000bulbs.com Warehouse-lighting. Website. Accessed September 2018. www.warehouse-lighting.com Payless-4-lighting. Website. Accessed September 2018. www.payless-4-lighting.com 1000bulbs. Website. Accessed September 2018. www.1000bulbs.com Bulbs. Website. Accessed September 2018. bulbs.com LEDt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Average cost from retail sources. Baseline lamps cost $3.26. Efficient lamps cost $13.38. Therefore, the incremental cost is $10.12.	$10.12
4807	LED Replacement of 4-Foot T5 Lamps Using Existing Ballast	1000bulbs. Website. Accessed September 2018. www.1000bulbs.com Warehouse-lighting. Website. Accessed September 2018. www.warehouse-lighting.com Payless-4-lighting. Website. Accessed September 2018. www.payless-4-lighting.com 1000bulbs. Website. Accessed September 2018. www.1000bulbs.com Bulbs. Website. Accessed September 2018. bulbs.com LEDt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Average cost from retail sources. Baseline lamps cost $3.26. Efficient lamps cost $13.38. Therefore, the incremental cost is $10.12.	$10.12
4808	LED Replacement of 4-Foot T5HO Lamps Using Existing Ballast		

MMID	Measure Name	Source	Incremental Cost
4809	LED Replacement of 8’ T8 or T12 Lamp w/ External Driver (UL Type C)	1000Bulbs. Website. Accessed September 2018. www.1000bulbs.com Bulbs. Website. Accessed September 2018. bulbs.com Ledt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Itsthyme. Website. Accessed September 2018. itsthyme.com Ledt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Ledt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Average cost from retail sources. Baseline lamps cost $10.37. Efficient lamps cost $36.10. Efficient lamp driver cost $31.95. Therefore, the incremental cost is $57.68.	$57.68
4810	LED Replacement of 8’ T8 or T12 Lamps, Direct Wire (UL Type B)	1000Bulbs. Website. Accessed September 2018. www.1000bulbs.com Bulbs. Website. Accessed September 2018. bulbs.com Ledt8bulb. Website. Accessed September 2018. www.ledt8bulb.com 1000bulbs. Website. Accessed September 2018. www.1000bulbs.com Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com LEDt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Average cost from retail sources. Baseline lamps cost $10.37. Efficient lamps cost $33.66. Therefore, the incremental cost is $23.29.	$23.29

MMID	Measure Name	Source	Incremental Cost
4811	LED Replacement of 8' T8 or T12 Lamp Utilizing Existing Ballast (UL Type A)	1000Bulbs. Website. Accessed September 2018. www.1000bulbs.com Bulbs. Website. Accessed September 2018. bulbs.com Ledt8bulb. Website. Accessed September 2018. www.ledt8bulb.com 1000bulbs. Website. Accessed September 2018. www.1000bulbs.com Greenelectricalsupply. Website. Accessed September 2018. www.greenelectricalsupply.com Lighting-spot. Website. Accessed September 2018. www.lighting-spot.com Average cost from retail sources. Baseline lamps cost $10.37. Efficient lamps cost $27.06. Therefore, the incremental cost is $16.69.	$16.69
4812	Non-High Bay Occupancy/Vacancy Sensor	Incremental cost based on similar MMID 3406. Actual cost from 2015 and 2016 program data, 21 applications.	$0.73
4813	LED Fixture, Track/Mono/Accent	SPECTRUM. Historical program data for MMIDs 3736 and 3737 based on 9,720 units from January 2015 to October 2018 applications.	$2.29
4814	LED Fixture, Track/Mono/Accent, In-Unit		
4824	Insulation, Attic, NG heat with Cooling, New Construction to R-49	California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." Revised Measure Cost Summary. June 2, 2008. http://www.deeresources.com/index.php/deer-versions/deer2008-for-09-11-planning-reporting	$0.85

MMID	Measure Name	Source	Incremental Cost
4830	LED Replacement of 8' T8 or T12 Lamp Utilizing Existing Ballast (UL Type A), Exterior	1000Bulbs. Website. Accessed September 2018. www.1000bulbs.com Bulbs. Website. Accessed September 2018. bulbs.com Ledt8bulb. Website. Accessed September 2018. www.ledt8bulb.com 1000bulbs. Website. Accessed September 2018. www.1000bulbs.com Greenelectricalsupply. Website. Accessed September 2018. www.greenelectricalsupply.com Lighting-spot. Website. Accessed September 2018. www.lighting-spot.com Average cost from retail sources. Baseline lamps cost $10.37. Efficient lamps cost $27.06. Therefore, the incremental cost is $16.69.	$16.69
4831	LED Replacement of 8' T8 or T12 Lamp w/ External Driver (UL Type C), Exterior	1000Bulbs. Website. Accessed September 2018. www.1000bulbs.com Bulbs. Website. Accessed September 2018. bulbs.com Ledt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Itsthyme. Website. Accessed September 2018. www.itsthyme.com Ledt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Ledt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Average cost from retail sources. Baseline lamps cost $10.37. Efficient lamps cost $36.10. Efficient lamp driver cost $31.95. Therefore, the incremental cost is $57.68.	$57.68

MMID	Measure Name	Source	Incremental Cost
4832	LED Replacement of 8' T8 or T12 Lamps, Direct Wire (UL Type B), Exterior	1000Bulbs. Website. Accessed September 2018. www.1000bulbs.com Bulbs. Website. Accessed September 2018. bulbs.com Ledt8bulb. Website. Accessed September 2018. www.ledt8bulb.com 1000bulbs. Website. Accessed September 2018. www.1000bulbs.com Atlantalightbulbs. Website. Accessed September 2018. www.atlantalightbulbs.com LEDt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Average cost from retail sources. Baseline lamps cost $10.37. Efficient lamps cost $33.66. Therefore, the incremental cost is $23.29.	$23.29
4833	LED Replacement of 8' T8 or T12 Lamp Utilizing Existing Ballast (UL Type A), Exterior 24/7	1000Bulbs. Website. Accessed September 2018. www.1000bulbs.com Bulbs. Website. Accessed September 2018. bulbs.com Ledt8bulb. Website. Accessed September 2018. www.ledt8bulb.com 1000bulbs. Website. Accessed September 2018. www.1000bulbs.com Greenelectricalsupply. Website. Accessed September 2018. www.greenelectricalsupply.com Lighting-spot. Website. Accessed September 2018. www.lighting-spot.com Average cost from retail sources. Baseline lamps cost $10.37. Efficient lamps cost $27.06. Therefore, the incremental cost is $16.69.	$16.69

MMID	Measure Name	Source	Incremental Cost
4834	LED Replacement of 8' T8 or T12 Lamp w/ External Driver (UL Type C) Exterior 24/7	1000Bulbs. Website. Accessed September 2018. www.1000bulbs.com Bulbs. Website. Accessed September 2018. bulbs.com Ledt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Itsthyme. Website. Accessed September 2018. www.itsthyme.com Ledt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Ledt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Average cost from retail sources. Baseline lamps cost $10.37. Efficient lamps cost $36.10. Efficient lamp driver cost $31.95. Therefore, the incremental cost is $57.68.	$57.68
4835	LED Replacement of 8' T8 or T12 Lamps, Direct Wire (UL Type B), Exterior 24/7	1000Bulbs. Website. Accessed September 2018. www.1000bulbs.com Bulbs. Website. Accessed September 2018. bulbs.com Ledt8bulb. Website. Accessed September 2018. www.ledt8bulb.com 1000bulbs. Website. Accessed September 2018. www.1000bulbs.com Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com LEDt8bulb. Website. Accessed September 2018. www.ledt8bulb.com Average cost from retail sources. Baseline lamps cost $10.37. Efficient lamps cost $33.66. Therefore, the incremental cost is $23.29.	$23.29
4836	Tankless Water Heater, NG, EF ≥ 0.90	Ohio Technical Reference Manual. p. 123. 2010. http://s3.amazonaws.com/zanran_storage/amppartners.org/ContentPages/2464316647.pdf Tankless DHW EF > 0.82 incremental cost is $605.00 per water heater.	$605.00
4838	Residential AC Tune-Up	Average cost based on responses from 12 residential HVAC contractors in Wisconsin. Costs ranged from $98 to $150. January 2019.	$122.48

MMID	Measure Name	Source	Incremental Cost
4841	Horticultural Lighting, Vertical Farming, Agriculture	Zoro. Website. Accessed February 2018. www.zoro.comWarehouse Lighting. Website. Accessed February 2018. www.warehouse-lighting.com LBC Lighting. Website. Accessed February 2018. www.lbclighting.com Access Fixtures. Website. Accessed February 2018. www.accessfixtures.com Direct-Lighting. Website. Accessed February 2018. www.direct-lighting.com Lightbulbs.com. Website. Accessed February 2018. www.lightbulbs.com Light Store USA. Website. Accessed February 2018. www.lightstoreusa.com Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. January 2017 through December 2017. Participation data for MMIDs 3091 through 3096 and online lookups performed in February 2018 show that the average costs of participating products are \$324.29 (3091), \$383.07 (3092), \$276.53 (3093), \$598.52 (3094), \$445.47 (3095), and \$631.73 (3096). The average of MMID 3093 and MMID 3095 were used for the horticultural lighting measure.	\$361.00
4842	Horticultural Lighting, Non-Stacked Indoor, Agriculture		\$361.00
4843	Horticultural Lighting, Supplemented Greenhouse, Agriculture		\$361.00
4852	Boiler, Hot Water, Modulating, ≥ 90% AFUE, < 300 MBh, Propane-Fueled	Wisconsin Focus on Energy historical project data obtained from SPECTRUM. January 1, 2016 to June 30, 2018. Average cost of 456 boilers over 237 projects is \$37.16/MBh. August 2018 online lookups of 18 baseline and 22 efficient boiler models less than 300 MBh on www.supplyhouse.com and www.grainger.com reveal an efficient cost that is 27.6% higher than the baseline cost. The incremental cost is therefore 27.6% * \$37.16 = \$10.26/MBh.	\$10.26
4866	Boiler, Condensing, ≥ 90% AFUE, ≥ 300 MBh, Propane-Fueled	Wisconsin Focus on Energy historical project data obtained from SPECTRUM. 2016 to 2018. Average cost of 90 boilers over 50 projects is \$23.06/MBh. August 2018 online lookups of four baseline and 19 efficient boiler models over 300 MBh on www.supplyhouse.com and www.grainger.com reveal an efficient cost that is 38.1% higher than the baseline cost. The incremental cost is therefore 38.1% * \$23.06 = \$8.79/MBh.	\$8.79

MMID	Measure Name	Source	Incremental Cost
4867	Boiler, Hot Water, Near Condensing, ≥ 85% AFUE, ≥ 300 MBh, Propane-Fueled	Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 67 boilers over 36 projects from 2016 to 2018 is \$11.96/MBh. August 2018 online lookups of four baseline and 19 efficient boiler models over 300 MBh on www.supplyhouse.com and www.grainger.com reveal an efficient cost that is 38.1% higher than the baseline cost. The incremental cost is therefore 38.1% * \$11.96 = \$4.56/MBh.	\$4.56
4868	Energy Efficient Grain Dryer, Propane-Fueled	Average of unit pricing values from Mathews Company Grain Dryer Price Book based on suggested base retail prices for their new grain dryer equipment offerings. Print.	\$179.00
4877	Propane Commercial Water Heater Storage	Full cost of \$5,248.13 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 6 units over 5 projects, from 2017 to 2018. August 2018 online lookups of 5 baseline models on www.homeperfect.com , www.afsupply.com , and www.homedepot.com show an average baseline price of \$1,726.21. Incremental cost is \$5,248.13 - \$1,726.21 = \$3,521.92.	\$3,521.92
4878	Unit Heater, ≥ 90% Thermal Efficiency, Propane-Fueled, Heating Setpoint = 70°F	Historical Focus on Energy project data, 2015 to June 2018. Twenty-nine projects, 100 total unit heaters. Average unit heater cost is \$22.64/MBh, less baseline unit heater cost of \$7.08/MBh from review of www.supplyhouse.com pricing (Accessed June 2018) for Reznor and Modine unit heaters. See 2018 Focus on Energy Incremental Measure Cost study for details.	\$15.56
4879	Unit Heater, ≥ 90% Thermal Efficiency, Propane-Fueled, Heating Setpoint = 65°F		
4880	Unit Heater, ≥ 90% Thermal Efficiency, Propane-Fueled, Heating Setpoint = 60°F		
4881	Unit Heater, ≥ 90% Thermal Efficiency, Propane-Fueled, Heating Setpoint = 55°F		
4883	Project Completion, Electric Heat		\$4,687.83

MMID	Measure Name	Source	Incremental Cost
4884	Project Completion, Natural Gas Heat	Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. January 2017 to December 2018. Average actual measure cost based on 2,819 projects.	$4,687.83
4885	Project Completion, Tier 2, Electric Heat		$4,745.14
4886	Project Completion, Tier 2, Natural Gas Heat		$4,745.14