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Wisconsin Focus on Energy 2024 Technical Reference Manual

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Public Service Commission of Wisconsin
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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 once per year. The present edition presents deemed savings and inputs effective beginning January 2024.

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[1] The Evaluation Team consists of Cadmus and Apex Analytics.

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.

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 TRM.

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 clear definition of the measure
- A clear description of how the measure saves energy
- 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
- 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:

- 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]

  - Residential single-family homes
  - Residential multifamily dwellings (such as apartment buildings and condominiums)
  - Commercial facilities
  - Industrial facilities
  - Agriculture facilities
  - 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 customer sectors. For example, research has confirmed that, on average, homeowners, commercial businesses, and industrial facilities use the same lighting product for 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.

amounts of time and at different times of the day, resulting in different annual electricity savings and demand reductions.

- 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:
  - *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.
  - *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.
  - *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.

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.

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 2:00 p.m. to 6:00 p.m., June through September . 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 effective useful life (EUL) of the measure. The **EUL** definition originates from the Focus on Energy Policy manual and it is described as the measure median number of years of expected operation, i.e. the time until half the units would be expected to have failed or been removed. 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. Electricity and natural gas savings are rounded to the nearest integer if their calculated value is 10 kWh or therms or greater, and rounded to two decimals if lower. Demand reduction in kilowatts is always rounded to four decimals.

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.

All factual statements and figures throughout the measure description include a superscript citation and respective sources are numerically listed at the end of each measure in the form of end-notes. 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 Mitch Horrie at the PSC, (608) 267-3206, mitch.horrie@wisconsin.gov.

The **Revision History** section has a table with all the revision dates for that TRM entry and briefly describes the changes.

Acknowledgements

Many individuals and companies have made valuable contributions to compiling and validating the TRM, as well as to preparing the measure write-ups and savings calculations that preceded the first edition. Special thanks go to:

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    - Franklin Energy Services – Zach Obert, Cory Clementz
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    - CESA 10 – Melissa Rickert, Tad Beeksma, and Todd Wanous
    - Leidos – Paul Olson and Tom Vermeulen
    - TechniArt – Jillian Deso

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

Agriculture Water Heaters

	Measure Details
Measure Master ID	Natural Gas to Natural Gas Commercial Water Heater Storage, 4937 Propane Commercial Water Heater Storage, 4938
Workpaper ID	W0029
Measure Unit	Per water heater
Measure Type	Hybrid
Measure Group	Agriculture
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
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Natural gas = $7,016.11 (MMIDs 4937)[2], Propane = $3,470.54 (MMIDs 4938)[3]

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, using less energy. Dairy farms require a commercial-sized water heater to meet the farming hot water needs. This does not include measures for switching to an electric tankless water heater. AHRI listings are 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 a commercial and industrial building. Per an ACEEE report,[4] 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 high-efficiency replacement water heaters are as follows:

- ***Gas Storage to High-Efficiency Gas Storage or 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 heater must have a thermal efficiency of ≥98% and a standby loss of ≤0.64% per hour as rated by AHRI.

Annual Energy-Savings Algorithm

Electric Water Heaters

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

Where:

Variable	Description	Units	Value
Btu_{SAVED}	Calculated as shown below for natural gas and propane water heaters	Btu	
3,412	Conversion factor	Btu/kWh	3,412

Natural Gas and Propane Water Heaters

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

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

Where:

Variable	Description	Units	Value
Gas_{SAVED}	Therms of natural gas or gallons of propane	Therms	
ConvF	Fuel conversion factor	MBtu/therm Mbtu/gallon	100 MBtu/therm 91.3 Mbtu/gallon propane[5]
GPY	Annual hot water usage	GPD	365
GPD	Average gallons of hot water usage per day	Gallons/day	2.75 gallons/cow/day * number of milking cows being served by water heater (as defined by user), or * maximum amount of hot water that can be supplied by total number of purchased water heaters during two one-hour milking sessions[2]; see Assumptions. Note that for hybrid calculations, use lesser of these two approaches to determine annual water usage.
365	Number of days in a year	Days/yr	365
ρ_{WATER}	Density of water	Lbs/gal	8.33
$C_{P,H2O}$	Specific heat of water	Btu/lb-°F	1

Variable	Description	Units	Value
ΔT	Change in temperature (= Temp_{HOT_H20} – Temp_{COLD_H20})	°F	Temp_{HOT_H20} = Average dairy farm water heater setpoint temperature (170°F)[2] Temp_{COLD_H20} = Assumed starting water temperature (103°F; see Assumptions)
$EF_{BASELINE}$	Efficiency metric for baseline water heater	%	0.90 EF for electric storage, 0.59 EF for natural gas storage;[4] see Assumptions

$$EF_{\text{EFFICIENT}} = M * CP,_{\text{H2O}} * \Delta T \,/\, Q_{\text{in}}$$

$$Q_{\text{in}} = GPD * \rho_{\text{WATER}} * CP, H2O * \Delta T \,/\, \eta_{\text{RE}} * (1 - SL \,/\, P_{\text{in}}) + 24 * SL)$$

Where:

Variable	Description	Units	Value
M	Mass of hot water being used per day	GPD	GPD * 8.34 lbs/gal
Q_{in}	Daily Btu consumption of water heater (= GPD * ρ_{WATER} * $C_{P,H2O}$ * ΔT / η_{RE} * (1 - Standby Loss / P_{in}) + 24 * Standby Loss)[4]	Btu/day	
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 (SL)	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)	Btu/hr	
P_{in}	AHRI-rated input power of water heater (for commercial electric resistance conversion)	Btu/hour	3,412 * element kilowatt rating
24	Number of hours in a day	Hrs/day	24

Summer Coincident Peak Savings Algorithm

There are no peak coincident savings for these measures.

Lifecycle Energy-Savings Algorithm

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

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 unknown. 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.
- Savings are based on 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 that well water to the main water heater. Preheated refrigeration heat recovery output water is around a conservative 120°F and average well water temperature is 52.3°F,[6] and a 75/25 split of those two temperatures is assumed to determine 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 engineering judgment, a realistic estimated average of 2.75 gallons of hot water per cow per day was used for this analysis. [2]
- 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,[7] 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.

Revision History

Version Number	Date	Description of Change
01	10/2016	Initial release
02	12/2018	Updated incremental cost
03	03/2019	Added propane measure
04	12/2019	Removed residential-type references, added new MMIDs for natural gas and propane measures
05	04/2021	Removed electric measures
06	08/2023	Updated IMC and minor algorithm update

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[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] “Cost Updates 072023.xls”
The Water Heater Costs tab shows historical SPECTRUM data of 25 agricultural water heater project costs. Project dates ranges from January 2020 through March 2023. Retrofit incremental cost is $8,584.90 - $1,568.79 = $7,016.11.

[3] “Cost Updates 072023.xls”
The Water Heater Costs tab shows historical SPECTRUM data of 91 agricultural water heater project costs. Project dates ranges from January 2020 through March 2023. Retrofit incremental cost is $5,381.41 - $1,910.86 = $3,470.54.

[4] Talbot, Jacob (American Council for an Energy-Efficient Economy). “Market Transformation Efforts for Water Heating Efficiency.” ACEEE Report A121. January 2012. http://aceee.org/sites/default/files/publications/researchreports/a121.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] 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] 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

Horticultural Lighting, Agriculture

	Measure Details
Measure Master ID	Horticultural Lighting, Non-Stacked Indoor, Agriculture: <700 W LED, Replacing 1,000 W HID, 5024 <400 W LED, Replacing 600 W HID, 5025 Horticultural Lighting, Supplemented Greenhouse, Agriculture: <700 W LED, Replacing 1,000 W HID, 5026 <400 W LED, Replacing 600 W HID, 5027 <250 W LED, Replacing 400 W HID, 5028
Workpaper ID	W0253
Measure Unit	Per unit
Measure Type	Prescriptive
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)	Non-Stacked = 10 (MMIDs 5024 and 5025), Supplemented = 20 (MMIDs 5026, 5027, and 5028)[1,2]
Incremental Cost ($/unit)	1,000 W Replacement = $700.58 (MMIDs 5024 and 5026), 600 W Replacement = $492.34 (MMIDs 5025 and 5027), 400 W Replacement = $513.69 (MMID 5028)[3]

Measure Description

These prescriptive measures, part of the horticultural lighting offerings developed in 2020, are replacing 400 watt to 1,000 watt HID lighting with LED horticultural lighting fixtures. A mix of non-stacked indoor and supplemented greenhouses is anticipated. 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. Non-stacked indoor greenhouses grow plants in a single layer along the floor, under ceiling-mounted lighting.[2]

Large-scale lighting upgrades, for new construction or existing buildings, are better suited to using the wattage-reduction-based hybrid measures (MMIDs 5032 and 5033).

Description of Baseline Condition

The baseline equipment is HID lighting ranging from 400 watts to 1,000 watts. [2]

Description of Efficient Condition

The efficient condition is a DLC–listed fixture in the Horticultural Lighting category or a fixture that meets three requirements:

- Fixture photosynthetic photon efficacy ≥2.0 µmol/J (DLC requirement is ≥1.9 µmol/J)[4]
- Five-year minimum warranty
- Appropriate Horticultural Lighting designation by OSHA NRTL or SCC-recognized body

Annual Energy-Savings Algorithm

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

Variable	Description	Units	Value
$Watts_{\text{BASE}}$	Power consumption of baseline equipment	Watts	1,079 watts for MMIDs 5024 and 5026; 663 watts for MMIDs 5025 and 5027; 455 watts for MMID 5028[5]
$Watts_{\text{EE}}$	Power consumption of efficient equipment	Watts	625 watts for MMIDs 5024 and 5026; 361 watts for MMIDs 5025 and 5027; 184 watts for MMID 5028[5]
HOU	Hours of use	Hrs	5,475 for non-stacked indoor (MMIDs 5024 and 5025); 2,120 for supplemented (MMIDs 5026, 5027, and 5028)[3]
1,000	Conversion factor	W/kW	

Summer Coincident Peak Savings Algorithm

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

Where:

CF = Coincidence factor (1.0 for non-stacked indoor [MMIDs 5024 and 5025], 0 for supplemented [MMIDs 5026, 5027, and 5028]; see Assumptions)

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (10 years for non-stacked indoor [MMIDs 5024 and 5025], 20 years for supplemented [MMIDs 5026, 5027, and 5028][1]

Deemed Savings

Average Annual Deemed Savings for Horticultural Lighting

Measure		MMID	Agriculture	
			kWh	kW
Non-Stacked Indoor	<700 watt LED, replacing 1,000 watt HID	5024	2,486	0.454
	<400 watt LED, replacing 600 watt HID	5025	1,653	0.302
Supplemented Greenhouse	<700 watt LED, replacing 1,000 watt HID	5026	962	0.000
	<400 watt LED, replacing 600 watt HID	5027	640	0.000
	<250 watt LED, replacing 400 watt HID	5028	575	0.000

Average Lifecycle Deemed Savings for Horticultural Lighting

Measure		MMID	Agriculture
Non-Stacked Indoor	<700 watt LED, replacing 1,000 watt HID	5024	24,860
	<400 watt LED, replacing 600 watt HID	5025	16,530
Supplemented Greenhouse	<700 watt LED, replacing 1,000 watt HID	5026	19,240
	<400 watt LED, replacing 600 watt HID	5027	12,800
	<250 watt LED, replacing 400 watt HID	5028	11,500

Assumptions

- The EUL for horticultural lighting fixtures is different than the EUL for non-horticultural lighting and is limited by the current test procedures. There are several methods for determining how many hours a fixture will remain viable for users.
  - The most common way to measure non-horticultural LED fixtures is the L_{70} measurement, which determines how many hours a fixture will maintain 70% of the total original lumen output.
  - For horticultural lighting, the industry standard is either the L_{90} or Q_{90} measurement, or the number of hours a fixture can maintain 90% of its original output.
- Since most horticultural lighting fixtures are relatively new to the market and it is generally not possible to complete a full lifecycle output test before bringing to market, the accepted method of calculating the L_{90} and Q_{90} values is the TM-21 test procedure.[4] This procedure requires a test period of up to 10,000 hours (and sometimes 12,000 hours) to predict the L_{90} and Q_{90} values, but with a maximum L_{90} and Q_{90} value of six times the test period. Horticultural lighting fixtures therefore may perform with outputs at higher than 90% of their original rate for much longer than established by the TM-21 test method, but the company can only list six times the test period as their L_{90} or Q_{90}.
- In determining the EUL for new LED horticultural measures per the TM-21 test procedure,[4] manufacturer specification sheets for numerous DLC-listed horticultural lighting fixtures were reviewed. Some manufacturers list that their fixtures maintain L_{90} or Q_{90} requirements for greater than the value listed because they could only project out to six times their testing period. For horticultural lighting, the Q_{90} values are a better indicator of fixture effectiveness,

but L_{90} were used when Q_{90} values were unavailable. (Only specification sheets for 600 watt and 1,000 watt replacement LED fixtures were available, so a similar average lifetime hours for the 400 watt replacement fixtures was assumed.)

- The coincidence factor for a supplemented greenhouse is assumed to be zero because incident light levels during peak demand periods are typically adequate aside from cloudy days. Non-stacked indoor greenhouses with 100% artificial lighting will use 100% of their lights during peak hours in the summer.
- The DLC list of products is expanding rapidly. At the time of this workpaper development, only five 400 watt replacement fixtures were listed to determine the incremental cost of MMID 5028. This workpaper will be reviewed in one year to update the incremental costs for all measures.

Revision History

Version Number	Date	Description of Change
01	03/2020	Initial release

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[1] MaxLite. Website. Accessed March 2020. https://www.maxlite.com/products/photonmax-horticulture-led-spot-light
Osram. Website. Accessed March 2020. https://fluence.science/
Illumitex. Website. Accessed March 2020. https://illumitex.com/products/neopar/
The average specification sheet rated a Q_{90} or L_{90} of 57,433 hours for 600 watt and 1,000 watt replacement LED fixtures. With an HOU of 5,475 for non-stacked indoor units, their EUL is 10 years. With an HOU of 2,120 for supplemented units, their EUL is capped at 20 years.

[2] 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

[3] HTG Supply. Website. Accessed March 2020. www.htgsupply.com
LEDlighting Wholesale Inc. Website. Accessed March 2020. www.ledlightingwholesaleinc.com
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Maxlite. Website. Accessed March 2020. www.maxlite.com

[4] DesignLights Consortium. "Technical Requirements for Horticultural Lighting." Accessed March 2020. https://www.designlights.org/horticultural-lighting/technical-requirements/

[5] Wisconsin Focus on Energy. "Hort Lighting Analysis 051120.xlsx."

Grow Light System, Agriculture

	Measure Details
Measure Master ID	Grow Light System, Single tier Indoor, Agriculture, 5032 Grow Light System, Supplemented Greenhouse, Agriculture, 5033
Workpaper ID	W0254
Measure Unit	Per system
Measure Type	Hybrid
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	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)	Single tier = 10 (MMID 5032), Supplemented = 20 (MMID 5033)[1,2]
Incremental Cost ($/unit)	Varies[3]

Measure Description

These hybrid measures, part of the horticultural lighting offerings developed in 2020, involve installing LED horticultural lighting either instead of (for new construction) or to replace (for retrofit) existing HID and/or fluorescent fixtures. A mix of single tier indoor and supplemented greenhouses is anticipated. Customer inputs and lighting design details will be used to calculate savings (see Assumptions). Single tier indoor greenhouses grow plants in a single layer on the floor under ceiling-mounted lighting. Supplemented greenhouses use electric lighting to extend the hours of daylight, to supplement low levels of sunlight on cloudy days, or to disrupt periods of darkness—all intended to alter plant growth. Multi-tier farms, which include shelving from floor to ceiling (and where lighting is typically mounted within the shelving units and is much closer to the plants), are not included in this offering.[2]

The design and baseline photosynthetic photon flux density must be comparable and established by a lighting design.

Smaller-scale lighting upgrades, in existing buildings only, are better-suited to using the one-for-one prescriptive measures (MMIDs 5024 through 5028).

Description of Baseline Condition

The baseline system is a lighting design using HID and/or fluorescent fixtures with typical wattages (400 watts to 1,000 watts) that result in an equivalent photosynthetic photon flux density to the proposed design system. The baseline design must be a practical and viable alternative for the customer.

Description of Efficient Condition

The efficient condition must be comprised of either DLC-listed horticultural lighting fixtures, in the Horticultural Lighting category, or fixtures that meet three requirements:

- Fixture photosynthetic photon efficacy ≥2.3 µmol/J[4]
- Five-year minimum warranty
- Appropriate Horticultural Lighting designation by OSHA NRTL or SCC-recognized body

Annual Energy-Savings Algorithm

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

Variable	Description	Units	Value
$Watts_{BASE}$	Power consumption of baseline lighting system	Watts	Customer input
$Watts_{BASE}$	Power consumption of efficient lighting system	Watts	Customer input
HOU	Hours of use	Hrs	Customer input
1,000	Conversion factor	W/kW	1,000

Summer Coincident Peak Savings Algorithm

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

Where:

CF = Coincidence factor (customer input; see Assumptions)

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (10 years for single tier [MMID 5032], = 20 years for supplemented [MMID 5033])[1,2]

Assumptions

- The EUL for horticultural lighting fixtures is different than the EUL for non-horticultural lighting and is limited by the current test procedures. There are several methods for determining how many hours a fixture will remain useful.
  - The most common way to measure non-horticultural LED fixtures is the L_{70} measurement, which determines how many hours a fixture will maintain 70% of the total original lumen output.
  - For horticultural lighting, the industry standard is either the L_{90} or Q_{90} measurement, or the number of hours a fixture can maintain 90% of its original output.
- Since most horticultural lighting fixtures are relatively new to the market and it is not possible to have completed a full life cycle output test, the accepted method of calculating the L_{90} and Q_{90} values is the TM-21 test procedure.[4] This test procedure requires that a test period of up to

10,000 hours (and sometimes 12,000 hours) to predict the L_{90} and Q_{90} values, but with a maximum L_{90} and Q_{90} value of six times the test period. Horticultural lighting fixtures therefore may perform with outputs at a higher than 90% of their original rate for much longer than established by the TM-21 test method, but the company can only list six times the test period as their L_{90} or Q_{90}.

- In determining the EUL for horticultural measures per the TM-21 test procedure,[4] manufacturer specification sheets for numerous DLC-listed horticultural lighting fixtures were reviewed. Some manufacturers list that their fixtures maintain L_{90} or Q_{90} requirements for greater than the value listed because they could only project out to six times their testing period. For horticultural lighting, the Q_{90} values are a better indicator of fixture effectiveness, but when Q_{90} values were unavailable, L_{90} values were used instead. (Only specification sheets for 600 watt and 1,000 watt replacement LED fixtures were available, so a similar average lifetime hours for the 400 watt replacement fixtures was assumed.)
- The hours of use will vary for each project based on customer input. Default hours of 5,475 for single tier indoor applications and 2,120 for supplemented greenhouses should be used.[2] With greater potential for energy savings in single tier indoor applications, more LED lighting upgrades in this type of facility are anticipated.
- The coincidence factor for a single tier indoor greenhouse with 100% artificial lighting will be 1.0, since it will use 100% of the lights during peak hours in the summer. A supplemented greenhouse that uses natural sunlight as their primary light source will use a fraction of their lights during peak hours (cloudy days only). For these cases, use the customer input regarding what percentage of the time the artificial lighting will be on during peak times.

Revision History

Version Number	Date	Description of Change
01	03/2020	Initial release
02	10/2023	Updated min efficiency; changed language from 'non-stacked/vertical' to 'single/multi-tier'

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[1] MaxLite. Website. Accessed March 2020. https://www.maxlite.com/products/photonmax-horticulture-led-spot-light
Osram. Website. Accessed March 2020. https://fluence.science/
Illumitex. Website. Accessed March 2020. https://illumitex.com/products/neopar/
Average specification sheet rated Q_{90} or L_{90} of 57,433 hours for 600 watt and 1,000 watt replacement LED fixtures. With an HOU of 5,475 for single tier indoor units, their EUL is 10 years. With an HOU of 2,120 for supplemented units, their EUL is capped at 20 years.

[2] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. "Energy Savings Potential of SSL in Horticultural Applications." p. ii (HOU) and 2 (definitions). December 2017. https://www.energy.gov/sites/prod/files/2017/12/f46/ssl_horticulture_dec2017.pdf

[3] Incremental measure costs to be manually calculated and entered for each project individually. The following information details how costs were derived for the related prescriptive measures (MMIDs 5024-5028) and can serve as a reference for these hybrid measures as well.
HTG Supply Website. Accessed March 2020. www.HTGsupply.com
LEDlighting Wholesale Inc. Website. Accessed March 2020. www.ledlightingwholesaleinc.com

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BGHydro. Website. Accessed March 2020. www.bghydro.com
Amazon. Website. Accessed March 2020. www.amazon.com
Illumitex. Website. Accessed March 2020. www.illumitex.com
Fluence. Website. Accessed March 2020. www.fluence.com
MaxLite. Website. Accessed March 2020. www.maxlite.com
A blended incremental cost is based on a 40/40/20 split of 1,000 watt/600 watt/400 watt fixtures for a baseline mix. 1,000-watt replacement = $700.58, 600-watt replacement = $492.34, 400-watt replacement = $366.68. Refer to supporting document 'Hort Lighting Analysis 031020'.

[4] DesignLights Consortium. "Technical Requirements for Horticultural Lighting." Accessed September 2023. https://www.designlights.org/horticultural-lighting/technical-requirements/

Agriculture High Volume Low Speed Fans

	Measure Details
Measure Master ID	Fans, High Volume Low Speed (HVLS), General, 3998
Workpaper ID	W0053
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

$$kWh_{\text{SAVED}} = \left(Watts_{\text{HIGH SPEED}} - Watts_{\text{HVLS}}\right) / 1{,}000 * HOU$$

Variable	Description	Units	Value
$Watts_{\text{HIGH SPEED}}$	Power consumption of baseline high speed fan system	Varies by fan diameter; see table below	
$Watts_{\text{HVLS}}$	Power consumption of HVLS fan	Varies by fan diameter; see table below	
1,000	Conversion factor	W/kW	1,000
HOU	Average annual run hours	Hs	3,864[4]

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]	$W_{\text{HIGH SPEED}}$*	W_{HVLS5}[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.[6] Therefore, a 16-foot HVLS fan has a $W_{\text{HIGH SPEED}}$ equivalent to 4.0 * 1,031 watts = 4,124 watts.

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

$$kW_{\text{SAVED}} = \left(Watts_{\text{HIGH SPEED}} - Watts_{\text{HVLS}}\right) / 1{,}000 * CF$$

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

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

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.

Revision History

Version Number	Date	Description of Change
01	10/2015	Initial TRM entry
02	10/2016	Changed measure unit from per fan to per fan diameter (foot) and updated deemed savings source
03	12/2018	Updated incremental cost

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[1] Cadmus. Database. March 2013.
PA Consulting Group. *Focus on Energy, 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] Appendix B: Common Variables, 'Outside Air Temperature Bin Analysis' average number of hours in Wisconsin at or above 50°F.

[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] Bioenvironmental and Structural System Laboratory at The University of Illinois at Urbana-Champaign. "Fan Database." http://bess.illinois.edu/

Agricultural Fans, Dairy

	Measure Details
Measure Master ID	Circulation Fan, HS/HE, Fixed Speed: 36-47 inches, Ag, Dairy, 5086 ≥ 48 inches, Ag, Dairy, 5087 Ventilation Fan, HS/HE, Fixed Speed: ≥ 48 inches, Ag, Dairy, 5088 Ventilation Fan, HS/HE, Variable Speed: ≥ 48 inches, Ag, Dairy, Variable Speed, 5089
Workpaper ID	W0265
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 5086-5087)[1] Ventilation fan = 10 (MMID 5088)[2] Ventilation fan with variable speed = 15 (MMID 5089)[2]
Incremental Cost ($/unit)	MMID 5086 = $657.10, MMID 5086 = $914.94, MMID 5088 = $1,627.53,[3] MMID 5089 = $2,728.65[4]

Measure Description

Agriculture ventilation and circulation fans are intended to provide minimum ventilation rates and maintain indoor air quality for dairy cows. Dairy circulation fans are designed to help provide animal comfort, control insects in summer, and maintain indoor air quality conditions. This measure is based on dairy barn fan installations and their operational characteristics, but can be applied to fan use in other livestock housing areas with similar uses as well.

Each fan grouping is divided into two levels of energy efficiency based on size and whether a variable speed drive (VSD) or other method of varying the speed such as an electronically commutated motor (ECM) is integral to the fan. Program incentives vary based on fan type, size, and capacity to vary speed.

Description of Baseline Condition

The baseline condition is a ventilation or circulation fan used within an agricultural building of standard efficiency without the ability to vary the speed of the motor. The baseline values for each fan grouping are based on a comparison of actual and certified fan performance information supplied from the BESS labs website as of August 27, 2020.[5]

The results of compiling the fan performance data were sorted into fan size groupings, with single- and three-phase fans combined. The fan baseline (standard) efficiency and energy consumption values are an average of all non-qualifying fans tested by BESS for each respective fan size grouping. The baseline comparison performance criteria for each of the fan size groupings is listed in the Fan Average Power Ratings table.

Description of Efficient Condition

To qualify for a prescriptive incentive, each circulation or ventilation fan must undergo third-party testing and be rated by BESS labs, an accredited Air Movement and Control Association testing facility, or other third-party lab in accordance with AMCA/ANSI 210 or 230 test procedures.

The 75th percentile or higher is used as the minimum energy efficiency qualifying standard. Minimum efficiency for fans are listed in the 75th Percentile Efficiency Threshold column of the Deemed Inputs and Savings table below.

Annual Energy-Savings Algorithm

Fixed Speed Fans (MMIDs 5086-5088):

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

Where:

Variable	Description	Units	Value
Fan_{kW_BASE}	Baseline efficiency fan average kilowatt rating for nonqualifying equipment	kW	See Fan Average Power Ratings table below[3]
Fan_{kW_BASE}	High-efficiency fan average kilowatt rating	kW	See Power Rating columns of Deemed Inputs and Savings table below[3]
HOURS	Annual hours of operation	Hrs	6,570 for ventilation fans;[4] 3,864 for circulation fans, see Assumptions

Circulation fan baseline power ratings are the average kilowatts for fans below minimum qualifying efficiencies reported from BESS lab tested fans in stated fan size groupings.[5] Circulation fan efficient power ratings are the average kilowatts at or above the minimum qualifying efficiencies, stated in the Fan Average Power Ratings tables above, from BESS lab tested fans in applicable fan size groupings.

Ventilation/exhaust fan power ratings are determined by the same method as circulation fans, but at 0.10 inches of static pressure, since this is a critical variable in rating ventilation/exhaust fans.

Variable Speed Fans (MMID 5089):

Energy savings for this measure are custom calculated using a spreadsheet tool,[6] which is based on an engineering bulletin[7] and savings calculators from two different VFD manufacturers.[8,9]

For the energy savings analysis, this tool uses power curves developed from data obtained by measuring the operating characteristics of various fans and pumps. The curves are representative of typical VFD operation.

The spreadsheet tool uses this equation:

Power at Design GPM [CFM] = Controlled Horsepower * Conversion Constant [kW/hp] * Motor Load at Design GPM [CFM] / Nameplate Efficiency

These equations determine energy usage for each capacity level:

$$\text{Percentage of Design kW} = A1 + (A2 * \text{Capacity}) + (A3 * (\text{Capacity})^2) + (A4 * (\text{Capacity})^3)$$

$$\text{Percentage of Design kW for VFD} = A1 + (A2 * \text{Capacity}) + (A3 * (\text{Capacity})^2) + (A4 * (\text{Capacity})^3)$$

In the equations above, A1, A2, A3, and A4 are variables unique to each “before VFD” control type that allows for 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
On/Off	100.00000	0.00000	0.00000	0.00000
VFD Fan	5.90000	-0.19567	0.00766	0.00004

Since this is a prescriptive measure with deemed savings, the following inputs were entered into the VFD hybrid calculator. Deemed savings are in the table below.

VFD Calculator Inputs:

Nameplate Horsepower = 1.8249 (see Assumptions)

Motor Nameplate Efficiency = 86.5% (see Assumptions)

Annual Operating Hours = 6,570

Type of Flow Control (Controls before VFD) = On/Off

Summer Coincident Peak Savings Algorithm

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

Where:

CF = Coincidence factor (= 1.0)

The coincidence factor for the fixed speed fans is based on the assumption that the outdoor air temperature is above the desired temperature in barns and therefore ventilation fans are running during an overwhelming majority of peak hours for cooling purposes.

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (15 years for circulation fans,[1] 10 years for ventilation/exhaust fans,[2] 10 years for variable speed fans[2])

Deemed Savings

Deemed Inputs and Savings

Fan Type	Diameter	MMID	75th Percentile Efficiency Threshold*	Power Rating (kW)[3]		Savings		
						Annual		Lifecycle kWh
				Base	Efficient	kWh	kW	
Circulation	36”-47”	5086	20.0	0.6050	0.5141	526	0.1362	7,894
	48”+	5087	24.5	1.1643	1.0034	621	0.1608	9,321
Ventilation / Exhaust	48”+	5088	21.0	1.4382	1.0821	2,340	0.3561	37,433
	Variable Speed 48”+	5089	N/A	N/A	N/A	6,054	0.9215	60,540

*Circulation fans have units of lbf/kW, ventilation fans have units of cfm/watt at 0.10” of static

Assumptions

The hours for ventilation fans are 8,760 * 0.75 = 6,570 hours.[10] This is based on the assumption that dairy farms require mechanical ventilation for about three-quarters of the year to meet the needs of the facility. This is a conservative approach to account for barns designed with tunnel ventilation, side-wall curtains, and typical control schedules that incorporate the numbers of fans, stages, and temperature setpoints throughout the year.

According to Agriculture, Schools, and Government program subject matter expert, Terry Laube, dairy farmers in Wisconsin typically turn their circulation fans on when it is 50°F or warmer to improve cow comfort; this equates to 3,864 hours per year. This HOU assumption holds most true for dairy barn applications, and is assumed to reasonably hold true for other uses and for controlling animal comfort.

The variable speed fan calculations were run using the approved VFD savings calculation spreadsheet and motor speed profiles for agricultural ventilation/exhaust fans. The variable speed ventilation/exhaust fan measure uses the average kilowatt fan power ratings for all fans in the fan diameter range as shown in the BESS lab reports which is 1.3614.[5] The constant 0.746 kW/HP is used to convert the average fan kW to HP. The standard motor efficiency rating for a 1.5 HP motor of 86.5% was used as a conservative estimate since the average motor size was fractionally larger than 1.5 HP (1.8249 HP).

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 fans are sold and used as tested.

For peak savings, it was assumed that the temperature is above 50°F and fans are running during the majority of peak demand hours although the savings algorithm accounts for the fans running at lower than peak speeds during those peak hours.

Revision History

Version Number	Date	Description of Change
01	01/2016	Initial version
02	08/2016	Corrected table headings and typos, added details to Assumptions
03	10/2017	Created tiered structure for multiple levels of efficiency
04	10/2019	Updated ventilation fan HOU, efficiencies, and savings figures; added new MMIDs to reflect the change in incentive structure from fan diameter (per inch) to a flat rate per fan
05	10/2020	Removed Tier structure, added variable-speed measure

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[1] Circulation fans: 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] Ventilation Fans – Fixed Speed/Variable speed:
California Energy Efficiency Measure Data . "Electric TRM Ventilation Fan, Agricultural Measure." https://www.caetrm.com/measure/SWPR001/01/value-table/171498/

[3] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. MMID 5086: Average cost of 9 projects from 1/1/2021 to 6/30/2023 is $657.10. MMID 5087: Average cost of 34 projects from 1/1/2021 to 6/30/2023 is $914.94. MMID 5088: Average cost of 8 projects from 1/1/2021 to 6/30/2023 is $1,627.53.10.

[4] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. MMID 5089: Average cost of 92 projects from 1/1/2021 to 6/30/2023 is $2,728.65.

[5] Bio-Environmental and Structural System Lab at the University of Illinois. "BESS Labs High Speed Fan Performance Criteria." Accessed August 27, 2020. http://bess.illinois.edu/
Penn State Extension. "Summer Ventilation: Fan Efficiency and Maintenance." June 19, 2012. http://extension.psu.edu/dauphin/news/2012/summer-ventilation-fan-efficiency-and-maintenance

[6] Focus on Energy. VFD calculation spreadsheet: "2020 VFD Calc-Business and Ag Measures"

[7] "Flow Control." Westinghouse publication, Bulletin B-851, F/86/Rev-CMS 8121.

[8] ABB energy saving spreadsheet tools. ABB Pump Save (version 4.4), previously available (http://www.abb.com/product/seitp322/5fcd62536739a42bc12574b70043c53a.aspx)
ABB Fan Save (version 4.4), previously available
(http://www.abb.com/product/seitp322/5b6810a0e20d157fc1256f2d00338395.aspx
ABB has replaced both Fan Save and Pump Save with EnergySave Calculator)

[9] Toshiba Cost Savings Estimator. https://www.toshiba.com/tic/motors-drives/low-voltage-adjustable-speed-drives/hvac
(Click "View Technical Downloads" button, then click "Software" tab in pop-up window, then look for "Cost Savings Estimator")

[10] University of Wisconsin-Madison. "Ventilation and Cooling in Adult Cattle Facilities." January 7, 2020. https://thedairylandinitiative.vetmed.wisc.edu/home/housing-module/adult-cow-housing/ventilation-and-heat-abatement/

Agricultural Fans, Other

	Measure Details
Measure Master ID	Circulation Fan, HS/HE, Fixed Speed: 24-35 inches, non-Dairy, 5090 36-47 inches, non-Dairy, 5091 ≥ 48 inches, non-Dairy, 5092 Ventilation Fan, HS/HE, Fixed Speed: 36-47 inches, non-Dairy, 5093 ≥ 48 inches, non-Dairy, 5094 Ventilation Fan, HS/HE, Variable Speed: ≥ 48 inches, non-Dairy, Variable Speed, 5095
Workpaper ID	W0266
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 Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Circulation Fan = 15 (MMIDs 5090-5092)[1] Ventilation Fan = 16 (MMID 5093-5094)[1] Ventilation Fan with Variable Speed Drive = 15 (MMID 5095)[2]
Incremental Cost ($/unit)	MMIDs 5090-5094 = $150.00[3] MMID 5095 = $210.52 per HP[4]

Measure Description

Agriculture ventilation and circulation fans are intended to provide minimum ventilation rates and maintain indoor air quality for a variety of applications including, but not limited to poultry, swine, greenhouses, and produce storage. Agricultural circulation fans are designed to help provide animal comfort, control insects in summer, maintain relative humidity levels and maintain indoor air quality conditions.

Each fan grouping is divided into three levels of energy efficiency based on size and whether a variable speed drive (VSD) or other method of varying the speed such as an ECM is integral to the fan. Program incentives vary based on fan type, size and capacity to vary speed.

Description of Baseline Condition

The baseline condition is a ventilation or circulation fan used within an agricultural building of standard efficiency and 4,000 or more hours of operation per year without the ability to vary the speed of the motor. The baseline values for each fan grouping are based on a comparison of actual and certified fan performance information supplied from the BESS labs website as of August 27, 2020.[5]

The results of compiling the fan performance data were sorted into fan size groupings, with single- and three-phase fans combined. The fan baseline (standard) efficiency and energy consumption values are an average of all non-qualifying fans tested by BESS for each respective fan size grouping. The baseline comparison performance criteria for each of the fan size groupings is listed in the Fan Average Power Ratings table.

Description of Efficient Condition

To qualify for a prescriptive incentive, each circulation or ventilation fan must undergo third-party testing and be rated by BESS labs, an accredited Air Movement and Control Association testing facility, or other tried party lab in accordance with AMCA/ANSI 210 or 230 test procedures.

The 75th percentile or higher is used as the minimum energy efficiency qualifying standard. Minimum efficiency for fans are listed in the 75th Percentile Efficiency Threshold column of the Deemed Inputs and Savings table below.

Annual Energy-Savings Algorithm

Fixed Speed Fans (MMIDs 5090 - 5094):

$$kWh_{\text{SAVED}} = (Fan_{\text{kW\_BASE}} - Fan_{\text{kW\_EFF}}) * HOU$$

Where:

Variable	Description	Units	Value
$\text{Fan}_{\text{kW\_BASE}}$	Baseline efficiency fan average kilowatt rating for non-qualifying equipment	kW	See Fan Average Power Ratings table below[3]
$\text{Fan}_{\text{kW\_EFF}}$	High-efficiency fan average kilowatt rating	kW	See Power Rating columns of Deemed Inputs and Savings table below[3]
HOU	Annual hours of operation	Hrs	4,000 minimum

Circulation fan baseline power ratings are the average kilowatts for fans below minimum qualifying efficiencies reported from BESS lab tested fans in stated fan size groupings.[5] Circulation fan efficient power ratings are the average kilowatts at or above the minimum qualifying efficiencies, stated in the Fan Average Power Ratings tables above, from BESS lab tested fans in applicable fan size groupings. [5]

Ventilation/Exhaust fan power ratings are determined by the same method as the circulation fans, but at 0.10-inches of static pressure, since this is a critical variable in rating ventilation/exhaust fans.

For Variable Speed Fans (MMID 5095):

- Energy savings for these measures are custom calculated using a spreadsheet tool,[6] which is based on an engineering bulletin[7] and savings calculators from two different VFD manufacturers.[8,9]

- For the energy savings analysis, this tool uses power curves developed from data obtained by measuring the operating characteristics of various fans and pumps. The curves are representative of typical VFD operation.

The spreadsheet tool uses this equation:

$$\text{Power at Design GPM [CFM]} = \text{Controlled Horsepower} * \text{Conversion Constant [kW/hp]} * \text{Motor Load at Design GPM [CFM]} / \text{Nameplate Efficiency}$$

These equations determine energy usage for each capacity level:

$$\text{Percentage of Design kW} = A1 + (A2 * \text{Capacity}) + (A3 * (\text{Capacity})^2) + (A4 * (\text{Capacity})^3)$$

$$\text{Percentage of Design kW for VFD} = A1 + (A2 * \text{Capacity}) + (A3 * (\text{Capacity})^2) + (A4 * (\text{Capacity})^3)$$

In the equations above, A1, A2, A3, and A4 are variables unique to each “before VFD” control type that allows for 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
On/Off	100.00000	0.00000	0.00000	0.00000
VFD Fan	5.90000	-0.19567	0.00766	0.00004

Since this is a prescriptive measure with deemed savings, the following inputs were entered into the VFH hybrid calculator. Deemed savings are in the table below.

VFD Calculator Inputs:

Nameplate Horsepower = 1.8249 (see assumptions)
Motor Nameplate Efficiency = 86.5% (see assumptions)

Annual Operating Hours = 4,000

Type of Flow Control (Controls before VFD) = On/Off

Summer Coincident Peak Savings Algorithm

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

Where:

CF = Coincidence factor (= 1.0)

The coincidence factor for the fixed speed fans is based on the assumption that the outdoor air temperature is above the desired temperature in barns, greenhouses, and crop storage areas and therefore ventilation fans are running during an overwhelming majority of peak hours for cooling purposes.

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (= 15 years for circulation fans[1], = 16 years for ventilation/exhaust fans[1], = 15 years for variable speed fans[2])

Deemed Savings

Deemed Inputs and Savings

Fan Type	Diameter	MMID	75th Percentile Efficiency Threshold*	Power Rating (kW)3		Savings		
				Base	Efficient	Annual		Lifecycle kWh
						kWh	kW	
Circulation	24”-35”	5090	15.8	0.479460	0.397576	328	0.0819	4,913
	36”-47”	5091	20.0	0.650350	0.514149	545	0.1362	8,172
	48”+	5092	24.5	1.164257	1.003434	643	0.1608	9,649
Ventilation / Exhaust	36”-47”	5093	17.0	0.793860	0.549116	979	0.2447	15,664
	48”+	5094	21.0	1.438194	1.082097	1,424	0.3561	22,790
	Variable Speed 48”+	5095	N/A	N/A	N/A	3,686	0.9215	55,288

*Circulation fans have units of lbf/kW, ventilation fans have units of cfm/watt at 0.10” of static

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 fans are sold and used as tested.
- The variable speed fan calculations were run using the approved VFD savings calculation spreadsheet and motor speed profiles for agricultural ventilation/exhaust fans. The variable speed ventilation/exhaust fan measure uses the average kilowatt fan power ratings for all fans in the fan diameter range as shown in the BESS lab reports which is 1.3614.[5] The constant 0.746 kW/HP is used to convert the average fan kW to HP. The standard motor efficiency rating for a 1.5 HP motor of 86.5% was used as a conservative estimate since the average motor size was fractionally larger than 1.5 HP (1.8249 HP).
- For peak savings, it was assumed that the temperature is above 50°F and fans are running during the majority of peak demand hours although the savings algorithm accounts for the fans running at lower than peak speeds during those peak hours.

Revision History

Version Number	Date	Description of Change
01	10/2020	Initial TRM entry

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[1] Circulation fans: 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
Ventilation Fans: Average of two sources.
California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com/
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] California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." February 2014. http://www.deeresources.com/

[3] 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

[4] Evaluator and implementer consensus for setting cost on a per horsepower basis, instead of per motor. For variable torque VFDs, cost set at $210.52 per horsepower based on 2016 and 2017 data of 1,069 projects.

[5] Bio-Environmental and Structural System Lab at the University of Illinois. "BESS Labs High Speed Fan Performance Criteria." Accessed August 27, 2020. http://bess.illinois.edu/
Penn State Extension. "Summer Ventilation: Fan Efficiency and Maintenance." June 19, 2012. http://extension.psu.edu/dauphin/news/2012/summer-ventilation-fan-efficiency-and-maintenance

[6] Focus on Energy. VFD calculation spreadsheet: "2020 VFD Calc-Business and Ag Measures"

[7] "Flow Control." Westinghouse publication, Bulletin B-851, F/86/Rev-CMS 8121.

[8] ABB energy saving spreadsheet tools. ABB Pump Save (version 4.4), previously available (http://www.abb.com/product/seitp322/5fcd62536739a42bc12574b70043c53a.aspx)
ABB Fan Save (version 4.4), previously available (http://www.abb.com/product/seitp322/5b6810a0e20d157fc1256f2d00338395.aspx
ABB has replaced both Fan Save and Pump Save with EnergySave Calculator)

[9] Toshiba Cost Savings Estimator. https://www.toshiba.com/tic/motors-drives/low-voltage-adjustable-speed-drives/hvac

Agriculture, VFD, Milk Pump

	Measure Details
Measure Master ID	VFD, Dairy Milk Pump, Agriculture, 3988
Workpaper ID	W0153
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]

$$kWh_{\text{SAVED}} = lbs\ of\ Milk * C_{\text{P,MILK}} * \Delta T_{\text{MILK}} * 365 / AEER_{\text{COMP}} / 1{,}000$$

Where:

Variable	Description	Units	Value
lbs of Milk	Estimated daily pounds of milk produced by dairy farm that needs to be cooled through use of a milk pre-cooler	Lb.	68 pounds of milk per cow;[4] with the number of milking cows being user defined
$C_{\text{P,MILK}}$	Specific heat of milk	Btu/(lb-°F)	0.94 Btu/(lb-°F))[5]
ΔT_{MILK}	Temperature difference of output of plate cooler milk before and after use of variable speed control on milk pump to slow milk pump and increase heat removed from milk through plate cooler prior to mechanical refrigeration. VFD control on milk pump can help decrease milk temperature in plate cooler to within around 4°F of well water temperature.[3]	°F	Average plate cooler milk temperature without VFD control is 70°F (see Assumptions). 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[6]	Yrs	365
$AEER_{\text{COMP}}$	Annual energy efficiency ratio of refrigeration compressor[7]	Btu/watt * hr	15.39
1,000	Conversion factor	W/kW	1,000

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

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

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.[7]
- 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.[8] 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.[9] 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.[10] 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.[8]
- 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.

Revision History

Version Number	Date	Description of Change
01	09/2015	Initial TRM entry
02	10/2016	Updated measure to be based on number of milking cows. Updated algorithm inputs. Replaced MMID 3797 with MMID 3988.

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[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 User Manual*. p. 24. August 9, 2013.

[3] EnSave. “Milk Pump Variable Speed Drive.” 2011. http://www.usdairy.com/~/media/usd/public/ensavemilkpumpvariablespeeddrive.pdf

[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] Wisconsin Milk Marketing Board. “Did You Know? Website: Milking Every Day.” Accessed December 21, 2015. http://www.dairydoingmore.org/economicimpact/dairyfacts

[7] “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.

[8] 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

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[9] "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.

[10] 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.

Agriculture, VFD, Vacuum Pump

	Measure Details
Measure Master ID	VFD, Dairy Vacuum Pump, Small, Agriculture, 5231 VFD, Dairy Vacuum Pump, Large, Agriculture, 5232
Workpaper ID	W0154
Measure Unit	Per milking cow
Measure Type	Prescriptive
Measure Group	Motors & Drives
Measure Category	VFD
Sector(s)	Agriculture
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 ($/VFD)	Varies by measure[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.

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

kWh savings are based on herd size. The Small measure includes pumps serving < 500 milking cows, and the Large measure includes pumps serving 500 - 2,000 milking cows. Based on historical project data, the average number of cows is 232 for a small herd and 864 for a large herd.[3] It is noted below where assumptions vary based on equipment used for small and large milking operations.

$$kWh_{\text{SAVED}} = kWh_{\text{BASE}} - kWh_{\text{VFD}}$$

$$kWh_{\text{BASE}} = hp * 0.746 * Motor\ Load\ /\ Motor\ Eff * (HOURS_{\text{MILK}} + HOURS_{\text{WASH}})$$

$HOURS_{MILK}$ = 365 * MD * HPM

$HOURS_{WASH}$ = 365 * MD * HPW

$$kWh_{\text{VFD}} = kW_{\text{MILKING}} * HOURS_{\text{MILK}} + kW_{\text{WASH}} * HOURS_{\text{WASH}}$$

$kW_{MILKING}$ = 0.05 * %CFM_{MIN} * CFM_{TOT} + 1.7729 (see Assumptions)

kW_{WASH} = 0.05 * CFM_{TOT} + 1.7729 (see Assumptions)

Variable	Description	Units	Value
hp	Motor horsepower of the pump	hp	9.8 hp for Small, 13.6 hp for Large[3]
0.746	Conversion factor	kW/hp	0.746
Motor Load	Estimated percentage of full load motor runs at		90%
Motor Eff	Based on motor horsepower and NEMA Premium TEFC 1800 RPM full load motor efficiency ratings		91.7%
365	Days per year	Days/yr	365
MD	Milkings per day	Milkings/day	2.39 for Small,[4] 3 for Large, see Assumptions
HPM	Hours per milking	Hrs/milking	4.73 for Small, 4.85 for Large[4]
HPW	Hours per washing	Hrs/washing	0.75[4]
0.05	Formula constant (see Assumptions)[5]		0.05
$\%CFM_{MIN}$	Minimum percent speed required for constant torque vacuum pump to not overheat	% CFM	35% for Small, 20% for Large, see Assumptions
CFM_{TOT}	Total required suction for milking and washing needs	CFM	79 CFM for Small, 119 CFM for Large, see Assumptions
1.7729	Formula constant (see Assumptions)[5]		1.7729

Summer Coincident Peak Savings Algorithm

Small herd size will not have any kW savings because milkings are not likely to occur during peak hours.

For Large herd size:

$$kW_{SAVED} = kWh_{\text{SAVED}} / (HOURS_{\text{MILK}} + HOURS_{\text{WASH}}) / 864$$

Where:

864 = Number of cows for the large herd size (see above)

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 hours of 12:00 p.m. to 4:00 p.m. every day.

Lifecycle Energy-Savings Algorithm

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

Where:

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

Deemed Savings

Deemed Inputs and Savings

Description	MMID	kWh/cow		kW/cow	$/VFD
		Annual	Lifecycle		
VFD, Dairy Vacuum Pump, Small	5231	85	1,275	0	$2,803.81
VFD, Dairy Vacuum Pump, Large	5232	54	810	0.0074	$8,517.73

Assumptions

- For Small herd sizes (< 500 milking cows), 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.[6] Milking operations need a minimum CFM for kick offs and/or system leaks. For Large herd sizes (500 - 2,000 milking cows), it is assumed the motor speed can be reduced down to the point at which it will overheat (20%) and still have adequate CFM capacity.
- Large farms milk three times a day for maximum production and milking will take place during peak hours.
- Number of milking units for Small herds is based on an average of SPECTRUM project data (14.57).[3] For Large herds, a 2 x 14 milking parlor (28 milking units) was estimated to correspond to the average cow herd size by an industry expert.
- 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. Sizing in UW publication states 3 CFM per milking unit + 35 CFM reserve up to a maximum of 120 CFM. For Small herds, (14.57 milking units * 3 CFM) + 35 CFM = 78 CFM. For Large herds, (28 milking units * 3 CFM) + 35 CFM = 119 CFM.[6,5]
- It is assumed that a correct-sized VFD is installed to control the vacuum pump properly across its operating range.
- A 2003 paper measured energy usage for variable speed vacuum pumps at four farms with 12 to 32 milking cows each.[5] The measured usage was [pump kW] = 0.0018 * [liters per minute air flow] + 1.7729. Converting liters to cubic feet yields [pump kW] = 0.05 * CFM + 1.7729.
- Savings based on 365 days per year of milking operations.
- User defined input provided for milking units is assumed to be the average number of cows being milked daily.

Revision History

Version Number	Date	Description of Change
01	09/2015	Initial TRM entry
02	10/2016	Updated to be based on number of milking cows using new sources and replaced MMID 3798 with MMID 3987
03	12/2020	Updated cost
04	10/2021	Restructured measure into small and large herd size and updated costs, replacing MMID 3987 with MMIDs 5231 and 5232.
05	08/2022	Updated cost
06	10/2023	Clarified *milking cow* definition.

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[1] California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." February 2014. http://www.deeresources.com/

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Small: average VFD cost for 40 projects, 56 VFDs, from December 2020 to June 2022 is $2,803.81. Large: average VFD cost for 14 projects, 19 VFDs, from January 2021 to June 2022 is $8,517.73.

[3] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM (March 2019 – May 2021). 38 Small farms and 28 Large farms.

[4] Wisconsin Focus on Energy. Historical project data. Sample data of 78 hybrid vacuum pump projects entered in SPECTRUM from January 2013 through May 2015. 70 Small farms and eight Large farms.

[5] Sanford, Scott. University of Wisconsin–Madison. *Milking System Air Consumption When Using a Variable Speed Vacuum Pump*. Presented at the ASAE Annual International Meeting, Las Vegas, Nevada, July 27–30, 2003.

[6] Sanford, Scott. University of Wisconsin–Madison. *Energy Conservation in Agriculture: Vacuum Systems*. 2003.

Swine Farrowing Crate Heater

	Measure Details
Measure Master ID	Swine Farrowing Crate Heater w/Controls, Single, 4939 Swine Farrowing Crate Heater w/Controls, Double, 4940
Workpaper ID	W0249
Measure Unit	Per heater
Measure Type	Prescriptive
Measure Group	Agriculture
Measure Category	Controls
Sector(s)	Agriculture
Annual Energy Savings (kWh)	828 kWh for MMID 4939, 1,656 kWh for MMID 4940
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	4,140 kWh for MMID 4939, 8,280 kWh for MMID 4940
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1,2]
Incremental Cost ($/unit)	Single Farrowing Crate Heater = $205.00 (MMID 4939), Double Farrowing Crate Heater = $360.00 (MMID 4940)[3]

Measure Description

This measure involves installing a swine farrowing crate heater with controls to keep piglets warm after birth. The use of heaters reduces mortality rates and increases piglet growth rates. Heaters are designed to keep the piglets at around 100°F while the sow, adjacent to the piglets, is kept at around 70°F to maximize comfort and milk production.

The heaters come in a few different styles: one type consists of mats with heating elements. When placed under the piglets, these mats allow for better control of heating temperatures and more precise placement of heat. Other models have the heaters placed above the piglets, mounted on the crate wall. These incorporate a plastic curtain to create a microclimate within that can be controlled at a set temperature. As they grow or as the ambient air temperature rises, the piglets need less heat. The heating controls modulate to lower the electrical consumption of the heating elements due to this reduced need for heat.

Description of Baseline Condition

The baseline condition is heat lamps or ceramic heaters that generate radiant heat and only adjust due to changes in ambient air temperature. The electrical usage for a baseline single crate unit is typically 175 watts to 250 watts[4,5] and for a baseline double crate unit is typically 350 watts to 500 watts.[4,5]

Description of Efficient Condition

The efficient condition is an energy-efficient swine farrowing heater that is in a farrowing crate directly under or over the piglets. Qualifying farrowing crate heaters have thermostatic controls. Studies have shown the average energy consumption per crate for both mats and overarching microclimate heaters, such as the FarrPro Haven units, is 60 watts[6,5] for a single crate and 120 watts[6, 5] for a double crate when used with a controller that automatically varies the heat output according to piglet needs.

Annual Energy-Savings Algorithm

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

Where:

Variable	Description	Units	Value
$Watts_{\text{BASE}}$	Average power consumption of baseline heat lamp per crate	Watts	Single crate = 175 watts, double crate = 350 watts[4,5]
$Watts_{\text{EE}}$	Average power consumption of energy-efficient measure equipment retrofit per crate	Watts	Single crate = 60 watts, double crate = 120 watts[6, 5]
1,000	Conversion factor	W/kW	1,000
HOU	Average annual run hours of farrowing heater	Hrs	7,200[7]

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (= 5 years)[1,2]

Deemed Savings

Average Annual Deemed Savings

Type	MMID	Annual kWh	Lifecycle kWh
Single Farrowing Crate Heater	4939	828	4,140
Double Farrowing Crate Heater	4940	1,656	8,280

Assumptions

- No peak demand reduction is associated with this measure because farrowing heaters are not guaranteed to be operating during peak demand times.
- All costs were gathered from the manufacturers' (Kane and Osborne-Stanfield) websites[3] and are assumed to be representative of industry-wide costs. FarrPro Haven costs are very similar to Kane and Osborne-Stanfield costs for both single crate and double crate heaters.
- Annual operation estimates for the number of hours are based on a 20-day average farrowing cycle and an average of 15 turns (litters of piglets per year) per farrowing stall.[7] This is a conservative estimate of the number of turns per stall compared with other published farm data.

- The Internal Revenue Service methodology for depreciation of assets that fit the swine farrowing crate heater[1] were assumed to be conservative estimates of the equipment EUL. The manufacturer also recommended five years as a conservative estimate for the EUL of equipment included in this measure.[2]

Revision History

Version Number	Date	Description of Change
01	12/2019	Initial TRM entry
02	02/2020	Added to TRM

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[1] U.S. Internal Revenue Service. *Tax Reform Changes to Depreciation Deduction Affect Farmers Bottom Line: IRS Tax Reform Tax Tip 2018-170.* November 1, 2018. https://www.irs.gov/newsroom/tax-reform-changes-to-depreciation-deduction-affect-farmers-bottom-line

[2] Chris Hanson, Co-Founder and Vice President of Business Development, FarrPro. Personal communication. October 2, 2019.

[3] Kane Manufacturing. Website. Accessed June 2019. https://kanemfg.com/products/livestock/hogs/heat-mats-thermostats/
Osborne-Stanfield Livestock and Equipment. Website. Accessed June 2019. https://osbornelivestockequipment.com/products/stanfield-heat-pads/

[4] Michael Glos, Cornell University. “Managing Risk: Using Heat Lamps on the Farm.” April 7, 2014. https://smallfarms.cornell.edu/2014/04/managing-risk-using-heat-lamps-on-the-farm/

[5] Department of Agricultural and Biosystems Engineering, Iowa State University. “Pilot-Scale Assessment of a Novel Farrowing Creep Area Supplementary Heat Source.” October 25, 2019. https://www.mdpi.com/2076-2615/9/11/996

[6] Romtek Services. *Hog Hearth Heat Mat vs. Heat Lamp Comparison.* November 17, 2014. http://hoghearth.com/wp-content/uploads/2019/09/Hog-Hearth-vs-Heat-Lamps-Test-Report-2014.pdf

[7] Department of Agricultural and Biosystems Engineering, Iowa State University. “Pilot-Scale Assessment of a Novel Farrowing Creep Area Supplementary Heat Source.” October 25, 2019. https://www.mdpi.com/2076-2615/9/11/996

Energy Efficient Grain Dryer

	Measure Details
Measure Master ID	Energy Efficient Grain Dryer, 3386 Energy Efficient Grain Dryer, Propane-Fueled, 4868
Workpaper ID	W0004
Measure Unit	Bushels per hour
Measure Type	Hybrid
Measure Group	Agriculture
Measure Category	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[1,2,3]
Measure Incremental Cost ($/unit)	$160.78[4]

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. 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.

While this measure can apply to all types of grain, the 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.

Agricultural customers will provide the number of acres planted for the upcoming harvest season and Industrial customers will provide the bushels/year estimated to be dried to calculate the energy savings.

Description of Baseline Condition

The grain dryer’s baseline efficiency (in Btu per pound of water removed) is a default value that is based on USDA literature[2] (refer to Baseline Grain Dryer Efficiency and Energy Savings Splits Table).

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.

Description of Efficient Condition

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 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)
- Advanced grain dryer operation controls

Annual Energy-Savings Algorithm

Energy-Savings Calculations:

$$kWh_{\text{SAVED}}, Agr = Acres * Bsh/Acre * Lbs_{\text{BUSHEL}} * MS\% * (Eff_{\text{BASE}} - Eff_{\text{EE}}) \ / \ 3{,}412 * \%Elec$$

OR

$$kWh_{\text{SAVED,Ind}} = Bsh/Year * Lbs_{\text{BUSHEL}} * MS\% * (Eff_{\text{BASE}} - Eff_{\text{EE}}) \ / \ 3{,}412 * \%Elec$$

$$Gas_{\text{SAVED}} = Acres * Bsh/Acre * Lbs_{\text{BUSHEL}} * MS\% * (Eff_{\text{BASE}} - Eff_{\text{EE}}) \ / \ ConvF * \%Gas$$

MS% = Moisture shrink percent, % weight reduction of wet grain as it is dried
= $(MC_{\text{INIT}} - MC_{\text{FINAL}}) / (100\% - MC_{\text{FINAL}})$
= 9.51% (see inputs below)

Eff_{EE} = Proposed grain dryer efficiency in Btu per pound of water removed[5]

$$= [CAP / Eff_{BURN} + (hp * 0.746 * LF / Eff_{MOT} * 3{,}412)] / [Bsh/h * (Lbs_{H20,\ INIT} – Lbs_{H2O,\ FINAL})]$$

$$CAP = \text{Grain dryer burner capacity, Btu/h}^{5}$$

$$= 1.08 * CFM * (T_P - T_A)$$

Where:

Variable	Description	Units	Value
Acres	Number of acres planted per year that will be dried using the proposed grain dryer	Acres	User-defined input
Bsh/Acre	Average number of bushels per acre based on crop type	Bsh/acre	175.2[3]
Bsh/Year	Average number of bushels per year to be dried	Bsh	Customer input
Lbs_{BUSHEL}	Bushel weight of corn determined from agricultural standards	Bsh weight	56[6]
MC_{INIT}	Harvested grain moisture content percentage	% harvested moisture	22.9%[7]
MC_{FINAL}	Dried grain moisture content percentage	% dried moisture	14.8%[7]
Eff_{BASE}	Existing grain dryer efficiency, Btu per pound of water removed	Btu/lb	Deemed by dryer type, see Grain Dryer Type Efficiency and Energy Savings Splits table below
1.08	Constant for sensible heat load equation	Btu/CFM-°F-hr	1.08
CFM	Rated blower CFM	CFM	Derived from dryer specification sheet or user-defined if spec sheet not available
T_P	Plenum temperature inside dryer at normal operation	°F	Derived from dryer specification sheet or user-defined if spec sheet not available
T_A	Average outside air temperature during typical drying times	°F	Varies by city; see Average Fall Ambient Temperatures table below
Eff_{BURN}	Combustion efficiency of grain dryer burner	%	Assumed to be 95%[5]
ConvF	Fuel conversion factor	Btu/therm Btu/gallon	100,000 Btu per therm, = 91,333 Btu per gallon of propane)[8]
hp	Main grain dryer blower fan horsepower rating	hp	Derived from dryer specification sheet or user-defined if spec sheet not available
0.746	Conversion factor	kW/hp	0.746
LF	Assumed load factor of blower fan		Estimated to be 85%
Eff_{MOT}	Efficiency of motor, derived from NEMA-rated fan efficiency tables based on motor horsepower[91]	hp	
3,412	Conversion factor	Btu/kWh	3,412
Bsh/hr	Bushels per hour of dryer capacity at 100% operation based on manufacturer rated capacities for a 5% moisture removal and a 10% moisture removal, with a finishing moisture of 15%	Bsh/hr	User-defined, or derived from dryer specification sheet
$Lbs_{H2O,\ INIT}$	Initial water weight in a bushel of corn determined by initial moisture content	lbs	$MC_{INIT} * Lbs_{BUSHEL}$

Variable	Description	Units	Value
$Lbs_{H2O,\ FINAL}$	Final water weight of a bushel of corn determined by final moisture content	lbs	MC_{FINAL} * Lbs_{BUSHEL}
%Elec	Percentage of total energy consumed that is electric	%	See Grain Dryer Type Efficiency and Energy Savings Splits table below
%Gas	Percentage of total energy consumed that is gas	%	See Grain Dryer Type Efficiency and Energy Savings Splits table below

Grain Dryer Type Efficiency and Energy Savings Splits[2]

Dryer Type	Eff_{BASE}*	$Gas_{\%}$	$Electric_{\%}$
Continuous Cross Flow Dryer (Tower Dryer)	2,800	98%	2%
Combination High/Low Temperature	1,475	75%	25%
Ambient-Air Bin Dryer (No Heat)	1,500	0%	100%
Low Temperature Bin Dryer	1,650	0%	100%
Continuous Flow In-Bin Dryer	2,000	98%	2%
Mixed Flow Dryer	2,050	98%	2%
Recirculating Cross-Flow Batch Dryer	2,200	98%	2%
High Temperature Batch Bin Dryer	2,430	98%	2%
Batch Cross Flow Dryer	2,450	98%	2%

* Assuming 10% moisture removed

Average Fall Ambient Temperatures[10]

City	October	November	Total
Eau Claire	46°F	33°F	40°F
Green Bay	47°F	34°F	41°F
La Crosse	48°F	36°F	42°F
Madison	47°F	34°F	40.5°F
Milwaukee	50°F	38°F	44°F

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

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

Where:

EUL = Effective useful life (= 20 years, see Assumptions)[2,3]

Assumptions

- The amount of energy savings from grain dryers is based on production; 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 acres planted for the upcoming harvest is collected on the application for agricultural customers and will be used along with Wisconsin historical crop yields per acre to determine future grain drying output. The average bushels to be dried per year will be used for industrial customers where grain is grown off-site.

- The measure assumes that all grain drying takes place in the late fall months after grain harvest, typically around October and November.[113] 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. This is accounted for in the Energy Savings Split Between Gas and Electric table. 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 an 10% moisture content reduction for corn.

- 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, etc., are equal for both fuel types. Any infrastructure or maintenance costs unique to each fuel are ignored.
- Sources for EUL list a measure life of 30 years[1] and 10 to 12 years.[2,3] An EUL of 20 years is deemed.

Revision History

Version Number	Date	Description of Change
01	10/2015	Initial TRM entry
02	03/2018	Added propane measure
03	11/2019	Minor changes to requirements
04	11/2020	Updated cost
05	07/2021	Added baseline efficiencies table for various dryers, updated moisture content reference, replaced input value of annual bushels with annual acres dried, removed reference to utility bill method for determining baseline efficiency
06	08/2022	Updated the bushel definition and Bsh/Acre value. Algorithm re-worked as a result of the change to bushel definition. Removed trade ally input option for baseline efficiency and added language regarding industrial dryers.

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[1] Shapiro and Moran. *Fundamentals of Engineering Thermodynamics*. Washington DC: McGraw Hill, 1995. 815. Print.

[2] U.S. Department of Agriculture. "Grain Dryer Energy Self-Assessment information, (Grain Drying) Energy Efficiency and Energy Cost (graph)." http://www.ruralenergy.wisc.edu/conservation/grain_drying/prequalify_graindrying.aspx

[3] US Department of Agriculture. National Agricultural Statistics Services Quick Stats Ad-hoc Query Tool. Pulled bushels per acre of corn yields for Wisconsin from 1981 to present (2022). Updated the average of the last five years' production. https://quickstats.nass.usda.gov/results/09BA59EA-3FF1-37AB-9280-E8E180B2A336

[4] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 15 projects and 15 units from July 2018 to July 2020 is $160.78.

[5] Maier, Dirk, and Fred Bakker-Arkema. "Grain Drying Systems." Paper presented at the Facility Design Conference of the Grain Elevator & Processing Society, St. Charles, Illinois, July 28–31, 2002. https://fyi.extension.wisc.edu/energy/files/2016/09/Grain-drying-Systems-GEAPS-2002-secured.pdf

[6] In the US, the bushel unit for individual grains are defined by weight, not volumetrically. This was confirmed by industry personnel involved in Focus on Energy. Bushels, Test Weights, and Calculations, Ohio State University. December 26, 2018. https://ohioline.osu.edu/factsheet/agf-503#:~:text=Corn%20was%20assigned%20a%20bushel,and%20fescue%20at%2032%2C%20etc.

[7] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Moisture shrink of 9.51% is derived from the average grain moisture content percentage (initial and final) from 34 projects with values from 2014 to 2020 is 22.9% and 14.8% respectively.

[8] U.S. Energy Information Administration. "Energy Units and Calculators Explained." Accessed December 2018. https://www.eia.gov/energyexplained/?page=about_energy_units

[9] Baldor. "The Energy Independence and Security Act of 2007: The Law's Requirements for 1 to 500 Horsepower AC Motors Effective December 19, 2010." January 23, 2009. p. 11. https://www.dekkervacuum.com/assets/1/6/Baldor_Reliance_EISA1.pdf NEMA nominal full load efficiencies for 4 Pole 3PH Energy Efficient Motors shown as a table of typical motor efficiencies used in the energy savings calculations on a per-hp basis.

[10] Average Wisconsin air temperatures by city using TMY3 data found from https://www.nrel.gov/grid/solar-resource/renewable-resource-data.html.Accessed January 15, 2016.

[11] Iowa's Corn Production. Website. March 10, 2013. http://www.iowacorn.org/en/corn_use_education/faq

[12] 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

Grain Dryer Tune-Up

	Measure Details
Measure Master ID	Grain Dryer Tune-Up, 5564 Grain Dryer Tune-Up, Propane-Fueled, 5565
Workpaper ID	W0248
Measure Unit	Per grain dryer
Measure Type	Hybrid
Measure Group	Agriculture
Measure Category	Tune-Up / Repair / Commissioning
Sector(s)	Agriculture
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	Varies
Water Savings (gal/year)	0
Effective Useful Life (years)	1[1]
Incremental Cost ($/unit)	Standard = $276.18 (MMID 5564); Propane-Fueled = $355.40 (MMID 5565)[2]

Measure Description

This incentive offering is for agricultural operations that service their existing grain drying systems to improve energy efficiency. Although still operational, the efficiency of grain drying equipment drops as its components become clogged, dirty, or out of calibration. Cleaning all fans and screens to allow for increased airflow will effectively reduce the annual hours of operation by allowing for faster process of grain and increased capacity.[3] All temperature and moisture sensors will also need to be cleaned and calibrated to ensure that the equipment controls are functioning properly and at peak efficiencies.[1] This incentive will be provided annually as a hybrid measure with a fixed incentive rate and savings based on the number of acres planted that will be dried in the grain dryer receiving a tune-up.

While this measure can apply to all types of grain, the focus of this workpaper is on corn, which is the main use of grain dryers in the state of Wisconsin. Also, certain types of grain dryers will benefit more from the listed tune-up items than others. For this reason, only grain dryers with the highest potential for savings have been included: tower-style continuous flow dryers, mixed flow dryers, high-temperature batch dryers, and other styles of dryers with heat recovery capabilities. Low temperature bin style dryers are not eligible for this incentive.

This measure is not eligible for new construction.

Description of Baseline Condition

The baseline condition is grain drying equipment associated with a commercial-grade farm facility that has not been inspected or tuned up by a trade ally in the current calendar year.

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 grain dryer efficiencies used for this measure are estimates made using normal weather temperature and humidity data at the location of grain dryer installation during the time of harvest and drying. Baseline conditions and efficiencies were established using USDA literature[4] as well as an industry fact sheet:[5] the analysis also states that the overall efficiency of grain dryers does not change with increases in the capacity of the dryer.

Grain dryer capacities vary considerably from a few hundred bushels per hour up to 10,000 bushels per hour for the largest units. Since the corn harvest season only lasts a few weeks in the fall, run time on the grain dryers can be from a few hundred hours up to almost 1,000 hours depending on the total amount of corn that needs to be dried and the starting moisture content. Many dryers will handle a few hundred thousand bushels of corn each year.

Description of Efficient Condition

The efficient condition is grain drying equipment associated with a commercial-grade farm facility that has been inspected, cleaned, and tuned up by a Focus on Energy trade ally. The trade ally must abide by all rules and regulations related to grain dryer testing and safety protocols and must conduct the following tasks: inspect and clean screens, inspect and clean fans, clean and calibrate all temperature sensors, clean and calibrate moisture sensors if applicable, inspect and adjust grain dryer controls including temperature setpoint for maximum efficiency, and lubricate bearings.

These tune-up items are low-cost activities that will improve the grain drying equipment efficiency and performance[1,6] and are useful system checks, as regular maintenance keeps the equipment operating as specified.[3]

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = Acres * Bsh/Acre * Lbs_{\text{BUSHEL}} * MS\% * Eff_{\text{GD}} / 3{,}412 * \%Elec * SF$$

$$Gas_{\text{SAVED}} = Acres * Bsh/Acre * Lbs_{\text{BUSHEL}} * MS\% * Eff_{\text{GD}} / ConvF * \%Gas * SF$$

MS% = Moisture shrink percent, % weight reduction of wet grain as it is dried
= $(MC_{\text{INIT}} - MC_{\text{FINAL}}) / (100\% - MC_{\text{FINAL}})$
= 9.51% (see inputs below)

Where:

Variable	Description	Units	Value
Acres	Number of acres planted that will be dried using the grain dryer	Acres	User defined input
Bsh/Acre	Average number of bushels of corn per acre	Bsh/acre	172.8[7]
Lbs_{BUSHEL}	Initial bushel weight determined from grain moisture content percentage and weight per bushel reference tables	Lbs	61.37[8]
MC_{INIT}	Harvested grain moisture content percentage	%	22.9%[9]
MC_{FINAL}	Dried grain moisture content percentage	%	14.8%[9]
Eff_{GD}	Existing grain dryer efficiency, Btu per pounds water removed	Btu/lbs	Varies by type of dryer; see Grain Dryer Table – Common Types below
3,412	Conversion factor	Btu/kWh	3,412
%Elec	Percentage of total energy consumed that is electric	%	Varies by type of dryer; see Grain Dryer Table – Common Types below
ConvF	Fuel conversion factor	Btu/therm Btu/gallon	100,000 Btu per therm, 91,333 Btu per gallon propane[10]
Gas%	Existing natural gas usage	%	1 - Elec%
SF	Savings factor	None	0.05; see Assumptions

Grain Dryer Table – Common Types

Grain Dryer Type	Eff_{GD}* (Btu/Lbs_{H2O})[4,5]	kWh%[11]	kWh_{SAVED}/ Acre	$Therm_{SAVED}$/ Acre (MMID 5564)	$Gallons_{SAVED}$/ Acre (MMID 5565)
Continuous Cross Flow Dryer (includes Tower Dryers)	2,800	2%	0.83	1.38	1.51
Continuous Flow In-Bin Dryer	2,000	2%	0.59	1.00	1.08
Mixed Flow Dryer	2,050	2%	0.61	1.01	1.11
Recirculating Cross-Flow Batch Dryer	2,200	2%	0.65	1.09	1.19
High Temperature Batch Bin Dryer	2,430	2%	0.72	1.20	1.31
Batch Cross Flow Dryer	2,450	2%	0.72	1.21	1.32

* Assuming 10% moisture removed

After two years of implementation using the savings algorithm above, the measure has been simplified to deemed savings per acre. Below is the grain dryer type breakdown and average savings based on 69 natural gas grain dryer tune-ups (MMID 5564) and 66 propane grain dryer tune-ups (MMID 5565)[12]

Grain Dryer Historical Dryer Mix and Deemed Savings

Grain Dryer Type	Natural Gas (MMID 4901)[12]	Propane (MMID 5085)[12]	kWh_{SAVED}/ Acre (MMID 5564)	$Therm_{SAVED}$/ Acre (MMID 5564)	kWh_{SAVED}/ Acre (MMID 5565)	$Gallons_{SAVED}$/ Acre (MMID 5565)
Continuous Cross Flow Dryer (includes Tower Dryers)	65%	41%	0.78	1.30	0.75	1.37
Continuous Flow In-Bin Dryer	10%	11%				
Mixed Flow Dryer	0%	0%				
Recirculating Cross-Flow Batch Dryer	0%	0%				
High Temperature Batch Bin Dryer	17%	27%				
Batch Cross Flow Dryer	7%	21%				

Summer Coincident Peak Savings Algorithm

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

Lifecycle Energy-Savings Algorithm

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

Where:

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

Assumptions

- The savings factor of 5% is a conservative estimate based on a whole grain dryer equipment and controls tune up according to Kerry Hartwig, the Sukup dryer sales director.[6] Mr. Hartwig made two notable comments:
  - Dirty screens essentially reduce airflow through the dryer. This means it is burning the same amount of electricity but accomplishing less, which significantly decreases the dryer's capacity by generally well over 5%.
  - Moisture sensor cleaning and calibration can make a big difference. If a customer is over-drying grain because of a dirty or uncalibrated sensor, they are wasting a lot of energy (both heating fuel and electricity) and costing themselves grain weight they can sell. A potential gain of 5% or more would be very reasonable here.
- 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 number of planted acres serviced by the grain dryer is a user input, and is multiplied by the Wisconsin state average yield for bushels of corn harvested per acre from the last five years to produce the bushels per year dried by the dryer. This accounts for the variability of productivity based on weather from

year to year, and is a change from the previous approach for this measure which required users to estimate upcoming bushels per year.

- The measure assumes that all grain drying takes place in the late fall months after grain harvest, typically around October and November. While latent heat effects the grain drying process, for purposes of simplification, the air sensible heat transfer formula is used for grain dryer efficiency calculations. The measure assumes that blower/dryer fans are running at their full rated speed throughout the entire drying period. It also assumes that the dryer rated capacity is decreased as screens and fans build up with debris due to a reduction in airflow and constant burner plenum temperatures. Specific electric use for grain dryer conveyors or augers/stirrers is not included in the calculation.

Revision History

Version Number	Date	Description of Change
01	07/2019	Initial TRM entry
02	09/2020	Added propane measure and removed low temperature bin style dryers
03	09/2021	Replaced input value of annual bushels with annual acres dried, updated dryer efficiencies, moisture content references, and lbs water removed
04	05/2023	Changed measures from Hybrid to Prescriptive with deemed savings/acre and updated incremental cost values

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[1] University of Wisconsin-Madison Extension. “Low Cost Energy Conservation: Grain Drying (A3784-10).” https://learningstore.uwex.edu/Assets/pdfs/A3784-10.pdf

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average measure cost of 69 projects from July 2021 to October 2022 is $224.92 for natural gas dryers (MMID 5564). Average measure cost of 66 projects from August 2021 to October 2022 is $258.74 for propane dryers (MMID 5565).

[3] Iowa State University, MidWest Plan Service. “Grain Drying, Handling, and Storage Handbook.” MWPS-13, Third Edition. 2017. Chapter 4 for fan and screen clearing reference, Chapter 6 for maintenance reference. https://www-mwps.sws.iastate.edu/catalog/grain-handling-storage/grain-drying-handling-and-storage-handbook

[4] U.S. Department of Agriculture. “Energy Self-Assessment, Step 2: Informational Section.” Grain Drying Energy Efficiency and Energy Cost graph. Accessed May 2019.
See Grain Dryer Tune Up Supporting Document for referenced graph:
http://www.ruralenergy.wisc.edu/conservation/grain_drying/prequalify_graindrying.aspx

[5] University of Wisconsin–Madison, Extension. Wisconsin Energy Efficiency and Renewable Energy “Improving Energy Efficiency in Grain Drying: Fact Sheet.” December 2012. https://fyi.extension.wisc.edu/energy/files/2016/09/FS_FlowDryers.pdf

[6] Hartwig, Kerry (Sukup dryer sales director). June 2019.

[7] US Department of Agriculture. National Agricultural Statistics Services Quick Stats Ad-hoc Query Tool. Pulled bushels per acre of corn yields for Wisconsin from 1981 to 2020 data in July 2021. https://quickstats.nass.usda.gov/results/09BA59EA-3FF1-37AB-9280-E8E180B2A336

[8] Tables for Weights and Measurement: Crops, Provides table of weights, in lbs, per bushel of corn at various moisture contents http://courses.missouristate.edu/WestonWalker/AGA375_Forages/Forage%20Mgmt/References/1Guides/Equip/MUG4020TablesWeightsMeasurementsCrops.htm

[9] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Moisture shrink of 9.51% is derived from the average grain moisture content percentage (initial and final) from 34 projects with values from 2014 to 2020 is 22.9% and 14.8% respectively.

[10] U.S. Energy Information Administration. “Energy Units and Calculators Explained.” Accessed December 2018. https://www.eia.gov/energyexplained/?page=about_energy_units

[11] The National Corn Handbook. “Energy Conservation and Alternative Sources for Corn Drying.” NCH-14, page 3, Table 4. http://corn.agronomy.wisc.edu/Management/NCH.aspx

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[12] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM from July 2021 to October 2022. Grain dryer type breakdown (natural gas and propane) from 69 and 66 projects respectively. Average first year savings of 0.78 kWh/acre and 1.30 Therms/acre for natural gas dryer tune-ups (MMID 5564) and 0.75 kWh/acre and 1.37 Gallons Propane/acre for propane dryer tune-ups (MMID 5565).

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

	Measure Details
Measure Master ID	Refrigeration Heat Recovery, NG WH, Ag, 10032 Refrigeration Heat Recovery, Electric WH, Ag, 10033 Refrigeration Heat Recovery, Propane WH, Ag, 10034
Workpaper ID	W0002
Measure Unit	Per milking cow
Measure Type	Hybrid
Measure Group	Domestic Hot Water
Measure Category	Energy Recovery
Sector(s)	Agriculture
Annual Energy Savings (kWh)	Varies by number of milking cows and tank size
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Annual Propane Savings (Gallons)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by number of milking cows and tank size
Lifecycle Propane Savings (Gallons)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	4,044.74[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 preheats groundwater 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. Historical project data has been evaluated to determine the weighted average of RHRs used in combination with or without a milk pump VFD control and milk plate cooler.

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 groundwater.

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 groundwater, 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 groundwater.

Annual Energy-Savings Algorithm

The kWh savings are for MMID 10033 (RHR unit paired with electric water heater). The therm savings are for MMID10034 (RHR unit paired with natural gas water heater). The propane savings are for MMID 10035 (RHR unit paired with propane water heater).

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

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

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

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

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

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

Where:

Variable	Description	Units	Value
3,412	Btu per kWh conversion factor	Btu/kWh	3,412
ConvF	Fuel conversion factor	MBtu/therm MBtu/gallon	100 MBtu/therm, 91.3 MBtu/gallon propane[4]
365	Days of milking per year[5]	Days/yr	365
EF	Energy factor	%	90% for electric standard water heater; 59% for natural gas standard water heater[6]
Lbs of Milk	Daily, per-cow milk production that needs to be cooled	Lbs/cow/day	68 lbs of milk per cow; note: number of milking cows is user-defined[7]
$C_{\text{P,MILK}}$	Specific heat of milk	Btu/(lb-°F)	0.94[8]

Variable	Description	Units	Value
ΔT_{MILK}	Change in milk temperature (°F_{IN} - °F_{FINAL}) °F_{IN} = Temperature of supplied milk that needs to be mechanically cooled °F_{FINAL} = Final stored temperature of cooled milk = 38°F[9]	°F	28.3°F (10033); 41.5°F (10034); 27.7°F (10035)[2]; see Assumptions
SF	Savings factor, percentage of energy able to be captured from milk cooling process	%	50%; see Assumptions[9]
RHR tank size	Size in gallons the RHR tank(s) can hold preheated water per wash cycle	Gallons	Customer-provided input found on project invoice; default of 100 gallons should be used if RHR tank size cannot be determined from invoice
# of milkings per day	Number of times cows milked per day based on 11.25% of Wisconsin farms milking more than twice per day.[10] Note: number of milkings typically equals number of equipment wash cycles	Milkings/day	2.1125
$C_{P,H2O}$	Specific heat of water	Btu/(lb-°F)	1.0
P_{WATER}	Density of water	Lbs/gallon	8.34
ΔT_{H20}	Temperature difference ($Temp_{WARM\_H20}$ – $Temp_{COLD\_H20}$)	°F	$Temp_{WARM\_H20}$ = Expected temperature an RHR unit can preheat well water up to (120 °F)[9] $Temp_{COLD\_H20}$ = Average well water temperature (52.3 °F)[11]
8,760	Hours per year	Hours/year	8,760; see Assumptions

Summer Coincident Peak Savings Algorithm

$$kW_{SAVED} = \frac{kWh_{SAVED}}{8{,}760} * CF$$

Where:

CF = Coincidence factor (= 1.0; see Assumptions)

Lifecycle Energy-Savings Algorithm

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

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

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

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,[7] 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]).
- 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]
- Prior to 2024, there were different measures based on if the RHR was installed in combination with a milk pre-cooler and milk pump VFD, milk pre-cooler only, or without a milk pre-cooler. $°F_{IN}$ = 98°F[9] average temperature of milk coming from cow without precooler; 67°F average temperature of milk coming from cow with precooler (98°F - 31°F); 56.3°F average temperature of milk coming from cow with precooler and VFD milk pump (see above). 38°F is the final desired milk storage temperature. The calculation was simplified using the weighted average of these measures to determine a single ΔT_{MILK} for each type of water heater the RHR is paired with (NG, Electric, or Propane).[2]
- 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 user-defined input provided for the number of milking cows is assumed to be the average number of cows being milked daily.
- Since the temperature of the milk and the temperature of well water is relatively constant, the demand savings is assumed to be relatively constant throughout the year. As such, the demand savings is estimated by dividing the annual electric savings evenly throughout the year which equates to a coincidence factor of 1.0. There is no apparent data to inform the times of water heater cycling in this application. The aforementioned approach is fairly conservative in that it

treats the peak period as any other period. If additional information on this is found, the demand algorithm will be updated in a future TRM.

Revision History

Version Number	Date	Description of Change
01	10/2015	Initial release
02	10/2016	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
04	02/2021	Added propane measures
05	10/2023	Consolidated measures and updated cost based on new historical data. Updated demand savings algorithm. Updated ‘milking cow’ definition.

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[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 223 units over 190 projects from 2019 to 2023.

[3] U.S. Department of Agriculture, Natural Resources Conservation Service. “Energy Self-Assessment: Refrigeration Heat Recovery.” Accessed December 8, 2015. http://www.ruralenergy.wisc.edu/Information.aspx?Q=AM&Def=IMGHR_D_P2

[4] U.S. Energy Information Administration. “Energy Units and Calculators Explained.” https://www.eia.gov/energyexplained/?page=about_energy_units

[5] Wisconsin Milk Marketing Board. “Did You Know? Website: Milking Every Day.” Accessed December 21, 2015. http://www.dairydoingmore.org/economicimpact/dairyfacts

[6] Talbot, Jacob (American Council for an Energy-Efficient Economy). *ACEEE Report A121: Market Transformation Efforts for Water Heating Efficiency.* January 2012. http://aceee.org/sites/default/files/publications/researchreports/a121.pdf

[7] “Ag Heat Recovery Tank Supplemental 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
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 the project inputs of these 86 sample projects.

[8] 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).

[9] DeLaval. “Dairy Farm Energy Efficiency.” April 20, 2011. Accessed July 28, 2016. http://www.milkproduction.com/Library/Scientific-articles/Management/Dairy-farm-energy-efficiency/

[10] U.S. Department of Agriculture Economic Research Service. “Milk Cost of Production Estimates.” Accessed August 5, 2016. http://www.ers.usda.gov/data-products/milk-cost-of-production-estimates.aspx

[11] 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.

[12] Sanford, Scott (University of Wisconsin–Madison). “Energy Efficiency for Dairy Enterprises.” Presentation to Agricultural and Life Sciences Program staff. Slide 21. December 2014. http://farmenergymedia.extension.org/sites/default/files/Dairy%20Energy%20Conservation-2013.pdf

[13] EnSave. “Milk Pump Variable Speed Drive.” Brochure. 2009. http://www.usdairy.com/~/media/usd/public/ensavemilkpumpvariablespeeddrive.pdf

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
Workpaper ID	W0005
Measure Unit	Per milking cow
Measure Type	Prescriptive
Measure Group	Refrigeration
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)	$12.10[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

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

Where:

Variable	Description	Units	Value
lbs of Milk	Estimated daily pounds of milk produced by dairy farm that needs to be cooled through use of a milk pre-cooler	Lbs milk/day/ cow	# milking cows * 68 lbs of milk/day/cow[2,3] /365 days
$C_{\text{P,MILK}}$	Specific heat of milk	Btu/(lb-°F)	0.94[4]
ΔT_{MILK}	Temperature difference between warm milk incoming into plate cooler and cooled milk leaving plate cooler	°F	31°F; see Assumptions
Milking Days per year	Number of milking days per year	Milking days/yr	365[5]
$AEER_{\text{COMPRESSOR}}$	Annual energy efficiency ratio of compressor	Btu/watt-hr	15.39 Btu/watt-hr; see Assumptions[6]
1,000	Conversion factor	W/kW	1,000

Summer Coincident Peak Savings Algorithm

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

Lifecycle Energy-Savings Algorithm

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

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.

Revision History

Version Number	Date	Description of Change
01	09/2015	Initial TRM entry
02	10/2016	Added additional assumptions, updated sources, changed to prescriptive based on number of milking cows
03	12/2020	Updated cost
04	08/2022	Updated cost

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[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 unit cost of 59 projects and 59 units for MMIDs 3982 and 3983 from February 2021 to July 2022 is $12.10.

[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

Energy Efficient or Energy Free Livestock Waterer

	Measure Details
Measure Master ID	Waterer, Livestock: < 250 Watts, 2660 Energy Free, 3018
Workpaper ID	W0006
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 = $468.74 for retrofit, $475.16 for new construction (MMID 2660);[2] Energy free = $640.50 (MMID 3018)[3]

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

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

Where:

Variable	Description	Units	Value
$Watts_{BASE}$	Power consumption of baseline measure equipment	Watts	1,100 watts for retrofit; 500 watts for new installation[4]
$Watts_{EE}$	Power consumption of efficient measure equipment	Watts	250 watts for energy-efficient retrofit; 0 watts for energy-free installation
1,000	Conversion factor	W/kW	1,000
HOU	Average annual run hours of heater	Hrs	3,040; annual operation is used as a conservative estimate of number of hours below 32°F annually throughout state of Wisconsin, consistent with TMY3 bin data

Summer Coincident Peak Savings Algorithm

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

Where:

CF = Coincidence factor (= 0)

Lifecycle Energy-Savings Algorithm

$$kWh_{\text{LIFECYCLE}} = kWh_{\text{SAVED}} * \; EUL$$

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 used only during winter months.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	12/2018	Updated cost based on historical program data
03	08/2023	Updated cost based on historical program data

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[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 88 units over 42 projects from 2020 to 2023 is $687.22. Retrofit baseline cost of $218.48 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 $687.22 - $218.48 = $468.74. New construction baseline cost of $212.48 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 $687.22 - $212.48 = $475.16.

[3] Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 620 units over 123 projects from 2020 to 2023 is $978.98. Baseline cost of $338.48 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 $978.98 - $338.48 = $640.50.

[4] EnSave. Energy Efficient Stock Waterers. http://www.usdairy.com/~/media/usd/public/ensaveenergyefficientstockwaterers.pdf

Dairy Refrigeration Tune-Up

	Measure Details
Measure Master ID	Refrigeration System Tune-Up, Agriculture, 4403
Workpaper ID	W0008
Measure Unit	Per milking cow
Measure Type	Prescriptive
Measure Group	Refrigeration
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%.[3]

$$kWh_{\text{SAVED}} = kWh_{\text{SAVED}}/day * 365\ days$$

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

Where:

Variable	Description	Units	Value
365	Number of days per year cows are milked[4]	Days/year	365
lbs milk/day	Pounds of milk produced at farm facility per day	Lbs milk/day	68 lbs of milk per cow;[5, 4] number of milking cows is user-defined input
$C_{P,MILK}$	Specific heat of milk	Btu/lb-°F	0.94 Btu/lb-°F[6]
$°F_{IN}$	Temperature of supplied milk that needs to be mechanically cooled	°F	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	°F	38°F
$AEER_{COMPRESSOR}$	Annual energy efficiency ratio of refrigeration compressor	Btu/watt-hour	15.39 Btu/watt-hour;[3] see Assumptions
1,000	Conversion factor	W/kW	1,000
SF	Energy savings factor		0.05

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.[3] 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.[8] 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]).[3]

- The AEER value is based on an even 50/50 split of farms using scroll versus reciprocating compressors to drive the milk cooling process.[3]
- The savings are based on a well water temperature of 52.3°F being used as milk coolant.[3] 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).[9] 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.[3]
- The 2017 Focus on Energy Potential Study Site Surveys[3] 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.

Revision History

Version Number	Date	Description of Change
01	10/2015	Initial TRM entry
02	10/2016	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	10/2017	Combined three measures into one using Potential Study[3] results to weight existing milking equipment scenarios
05	12/2018	Updated Incremental cost

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[1] Engineering judgment. 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] 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.

[4] Wisconsin Milk Marketing Board. "Did You Know? Milking Every Day." Accessed December 21, 2015. http://www.dairydoingmore.org/economicimpact/dairyfacts

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[5] 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

[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 P3recoolers." Publication A3784-3. October 2003. http://learningstore.uwex.edu/Assets/pdfs/A3784-03.pdf

[8] 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.

[9] EnSave. "Milk Pump Variable Speed Drive." Brochure. 2009. http://www.usdairy.com/~/media/usd/public/ensavemilkpumpvariablespeeddrive.pdf

Irrigation Pressure Reduction

	Measure Details
Measure Master ID	Irrigation Pressure Reduction, Nozzle Installation & Motor Downsizing, 2434
Workpaper ID	W0289
Measure Unit	Per horsepower reduced
Measure Type	Hybrid
Measure Group	Agriculture
Measure Category	Irrigation
Sector(s)	Agriculture
Annual Electricity Savings (kWh)	Varies by horsepower, load factor, hours, efficiency
Peak Demand Reduction (kW)	Varies by horsepower, load factor, hours, efficiency
Annual Natural Gas Savings (therms)	0
Lifecycle Electricity Savings (kWh)	Varies by horsepower, load factor, hours, efficiency
Lifecycle Natural Gas Savings (therms)	0
Annual Water Savings (gallons)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	$379.29 per hp reduced[2]

Measure Description

This measure is about motor HP reduction of irrigation well pumps which can be achieved by retrofit of existing pump systems through re-nozzling and simultaneously replacing existing motor with a lesser motor HP.

The input parameters such as hours of use of pumps for irrigation, coincidence factor, and HP downsizing from current irrigation systems will be provided by the agricultural customers on separate supplemental sheet. This information will be used to calculate the energy savings.

Description of Baseline Condition

The baseline condition is irrigation pumping system where the HP of the motor is not optimized considering end use and flow requirements.

Description of Efficient Condition

The efficient condition is the irrigation system where the HP of the motor is downsized significantly after performing re-nozzling of the irrigation system, which leads to a reduction in water pressure optimized for the end use.

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = kWh_{\text{BASE}} - kWh_{\text{EE}}$$

$$kWh_{\text{BASE}} = n_{\text{BASE}} * hp_{\text{BASE}} * 0.746 * LF_{\text{BASE}} * HOU_{\text{BASE}} / Eff_{\text{BASE}}$$

$$kWh_{\text{EE}} = n_{\text{EE}} * hp_{\text{EE}} * 0.746 * LF_{\text{EE}} * HOU_{\text{EE}} / Eff_{\text{EE}}$$

Where:

Variable	Description	Units	Value
n_{BASE}	Number of motors	Motors	User input
hp_{BASE}	Baseline motor horsepower	hp	User input
0.746	Kilowatts per horsepower	kW/hp	
LF_{BASE}	Baseline motor load factor	%	User input, or assume 79%[3]
HOU_{BASEv}	Hours of use	Hours	User input
Eff_{BASE}	Baseline pump motor efficiency		User input
n_{EE}	Number of motors	Motors	User input
hp_{EE}	Efficient case motor horsepower	hp	User input
LF_{EE}	Efficient case motor load factor	%	User input, or assume 79%[3]
HOU_{EE}	Hours of use	Hours	User input
Eff_{EEv}	Efficient case pump motor efficiency		User input

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = [(n_{\text{BASE}} * hp_{\text{BASE}} * 0.746 * LF_{\text{BASE}} / Eff_{\text{BASE}}) - (n_{\text{EE}} * hp_{\text{EE}} * 0.746 * LF_{\text{EE}} / Eff_{\text{EE}})] * CF$$

Where:

CF = Coincidence factor (= user input)

Lifecycle Energy-Savings Algorithm

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

Where:

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

Assumptions

- The downsized motor HP (Efficient case motor horsepower) is assumed to be adequately sized for the end use after performing analysis of the existing system by the trade ally. It is assumed that the trade ally working with the customer on a specific project recommends an optimized irrigation systems based on the flow requirements.

Revision History

Version Number	Date	Description of Change
01	12/2022	Initial TRM entry

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[1] US DOE. Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Electric Motors. Table 8.3.4. February 2022. https://downloads.regulations.gov/EERE-2020-BT-STD-0007-0010/attachment_1.pdf

[2] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 4 projects from May 2017 through September 2021 is $379.29 per horsepower.

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[3] Cascade Energy. *Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors.* Table 6. November 5, 2012.

BOILERS AND BURNERS

Boiler, Condensing, ≥90% Efficiency

	Measure Details
Measure Master ID	Boiler, Hot Water, Modulating: ≥90% AFUE, <300 MBh, 2218 ≥90% AFUE, <300 MBh, Propane-Fueled, 4852 Boiler, Condensing: ≥90% Thermal Efficiency, ≥300 MBh, 3276 ≥90% Thermal Efficiency, ≥300 MBh, Propane-Fueled, 4866
Workpaper ID	W0009
Measure Unit	Per MBh
Measure Type	Prescriptive
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)	25[1]
Incremental Cost ($/unit)	$10.98 for modulating (MMIDs 2218 and 4852),[2] $6.07 for condensing (MMIDs 3276 and 4866)[3]

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 84% AFUE boiler[4] for MMID 2218 and 4852, and is an 84%[5] thermal efficiency boiler for MMID 3276 and 4866.

Description of Efficient Condition

The efficient measure meets several requirements:

- Boiler must be ≥90% AFUE (for <300 MBh) or ≥90% thermal efficiency(for ≥300 MBh)
- 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)
- 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 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 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
  - MMID 4866 is only for when the existing boiler uses propane

Annual Energy-Savings Algorithm

$$Gas_{\text{SAVED}} = BC * OF * EFLH * (1 / EFF_{\text{BASE}} - 1 / EFF_{\text{EE}}) / ConvF$$

Where:

Variable	Description	Units	Value
BC	Boiler rated capacity	MBtu/hr	
OF	Oversizing factor		Varies by measure; see Oversize Factor table below
EFLH	Equivalent full-load hours	Hours	1,890[6]
EFF_{BASE}	Boiler baseline efficiency	%	84% [5]
EFF_{EE}	Boiler proposed efficiency	%	95%[7]
ConvF	Conversion factor	MBtu/therm MBtu/gallon	100 MBtu per therm, 91.3 MBtu per gallon propane[8]

Oversize Factor by Measure

Description	MMIDs	Sectors	Oversize Factor[6]
Boiler, Hot Water, Modulating, ≥90% AFUE, ≤300 MBh	2218	Residential- multifamily	174%
Boiler, Hot Water, Modulating, ≥90% AFUE, <300 MBh	2218, 4852	Agriculture, Commercial, Industrial, Schools & Government	217%
Boiler, Condensing, ≥90% AFUE, ≥300 MBh	3276	Residential- multifamily, Agriculture, Commercial, Industrial, Schools & Government	120%
Boiler, Condensing, ≥90% AFUE, ≥300 MBh	4866	Agriculture	119%

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (= 25 years)[1]

Deemed Savings

Natural Gas Savings (per MBh)

Description	MMID	Sector	therms		Gallons Propane	
			Annual	Lifecycle	Annual	Lifecycle
Boiler, Hot Water, Modulating						
≥90% AFUE, ≤300 MBh	2218	Residential- multifamily	4.53	113.3	-	-
≥90% AFUE, <300 MBh	2218	Agriculture, Commercial, Industrial, Schools & Government	5.65	141.3	-	-
≥90% AFUE, <300 MBh, Propane-Fueled	4852	Agriculture	-	-	6.19	154.8
Boiler, Condensing						
≥90% AFUE, ≥300 MBh	3276	Residential- multifamily, Agriculture, Commercial, Industrial, Schools & Government	3.13	78.16	-	-
≥90% AFUE, ≥300 MBh, Propane-Fueled	4866	Agriculture	-	-	3.40	84.9

Assumptions

- This entry includes measures for gas-fired equipment eligible to both natural gas and propane customers. The Code of Federal Regulations,[9] 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 co*sts unique to each particular fuel are ignored.

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.
06	02/2020	Revised to move multifamily MMID 2743 savings to multifamily sector savings under MMID 2218. Updated cost.
07	11/2020	Revised values of oversize factors, updated cost
08	07/2022	Updated ISR to 100% for MMIDs 3276 and 4866. See Huddle comments
09	09/2022	Update baseline boiler efficiency to 84%, clarify when to use AFUE and when to use thermal efficiency

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[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 unit cost of 321 projects, 440 boilers, and 109,151 MBh for MMIDs 2218, 4852 from January 2018 to July 2020 is $39.80. 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% * $39.80 = $10.98 per MBh.

[3] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 400 projects, 741 boilers, and 1,017,865 MBh for MMIDs 3276, 4866 from January 2018 to July 2020 is $21.99. 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% * $21.99 = $6.07 per MBh.

[4] U.S. Code of Federal Regulations. 10 CFR 432(e)(3). https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32.

[5] U.S. Code of Federal Regulations. 10CFR 431, Table I.1. https://www.regulations.gov/document/EERE-2013-BT-STD-0030-0099

[6] 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 have 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.

[7] 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 through 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.

[8] U.S. Energy Information Administration. “Energy Units and Calculators Explained.” Accessed December 2018. https://www.eia.gov/energyexplained/?page=about_energy_units

[9] 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

Boiler Plant Retrofit

	Measure Details
Measure Master ID	Boiler Plant Retrofit, Hybrid Plant, ≥1 MMBh, 3275
Workpaper ID	W0011
Measure Unit	Per MBh
Measure Type	Prescriptive
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

$$Therm_{\text{SAVED}} = BC * OF * EFLH * (AFUE_{\text{EE}} / AFUE_{\text{BASE}} - 1)/ 100$$

Where:

Variable	Description	Units	Value
BC	Boiler rated capacity	MBtu/hr	
OF	Oversizing factor	%	124%[4]
EFLH	Equivalent full-load hours	Hrs	1,890[5]
$AFUE_{\text{BASE}}$	Boiler baseline thermal efficiency	%	82%[3]
$AFUE_{\text{EFF}}$	Boiler proposed thermal efficiency	%	87%
100	Conversion factor	Mbtu/therm	100

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$$Therm_{\text{LIFECYCLE}} = DS * EUL$$

Where:

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

Revision History

Version Number	Date	Description of Change
01	01/2013	Updated baseline efficiency from 80% to 82% (MMID 2743)
02	08/2016	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

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[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 were 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.

Boiler Control, Outside Air Temperature Reset/Cutout Control

	Measure Details
Measure Master ID	Boiler, Outside Temperature Reset/Cutout Control, 2221
Workpaper ID	W0012
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

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

Where:

Variable	Description	Units	Value
BC	Boiler input capacity in MBh	MBh	1
$EFLH_{\text{HEAT}}$	Equivalent full-load heating hours	Hrs	1,890
Eff	Combustion efficiency of the boiler	%	84%[3]
100	Conversion factor from therm to MBtu	therm to MBtu	100
SF	Savings factor	%	8%[4]

Equivalent Full-Load Heating and Cooling Hours by City

City	$EFLH_{\text{HEAT}}$[5]
Green Bay	1,852
La Crosse	1,966
Madison	1,934
Milwaukee	1,883
Wisconsin Average	1,909
Weighted Average	**1,890**

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

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

Where:

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

Deemed Savings

Evaluated Therm Savings

Measure Name	MMID	Sector, City	Energy Savings (therms per MBh)	
			Annual	Lifetime
Boiler, Outside Temperature Reset/Cutout Control	2221	Commercial Industrial Agriculture Schools & Gov Multifamily	1.800	9.000

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
05	12/2020	Corrected EFLH text and sectors

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[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] 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.

[4] Michigan Energy Measures Database. http://www.michigan.gov/mpsc/0,1607,7-159-52495_55129---,00.html

[5] 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.

Boiler Burner, 10:1 High Turndown

	Measure Details
Measure Master ID	HVAC Boiler Burner, Retrofit, 10:1 High Turndown, 2203 HVAC Boiler Burner, New Boiler, 10:1 High Turndown, 5237 Process Boiler Burner, Retrofit, 10:1 High Turndown, 4760 Process Boiler Burner, New Boiler, 10:1 High Turndown, 5238
Workpaper ID	W0013
Measure Unit	Per boiler horsepower
Measure Type	2203, 5237: Prescriptive 4760, 5238: Hybrid
Measure Group	Boilers & Burners
Measure Category	Controls
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
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	Install on New Boilers = 21 (MMIDs 5237, 5238)[1] Retrofit on Existing Boiler = 15 (MMIDs 2203, 4760)[2]
Incremental Cost ($/unit)	$65.22[3]

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. Boilers ≤ 1,000 horsepower are eligible; larger boilers may be eligible for a custom incentive.

Description of Baseline Condition

The baseline condition is a boiler burner that is ≤ 1,000 boiler horsepower (BHP) and has standard (code efficient) turndown capability. IECC 2015 requirements for boiler turndown are based on the complete system, meaning having multiple boilers counts towards the system turndown ratio:

Boiler System Input Capacity (Btu/hr)	Boiler System Input Capacity (BHP)	Minimum Turndown Ratio
≥ 1,000,000 and ≤ 5,000,000	≥ 29.87 and ≤ 149.36	3:1
> 5,000,000 and ≤ 10,000,000	> 149.36 and ≤ 298.72	4:1
> 10,000,000	> 298.72	5:1

Description of Efficient Condition

The efficient condition is a burner system with 10:1 turndown capability. High turndown burners may be paired with linkageless and oxygen trim controls in order to further improve the boiler system efficiency.

Annual Energy-Savings Algorithm

Process boilers:

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

HVAC boilers:

$$Therm_{\text{SAVED}} = \Sigma_{\text{TEMPBIN-HOU}} [BHP * 33{,}476 * LF * HOU_{\text{BIN}} / 100{,}000 * (1 / Eff_{\text{BASE}} - 1 / Eff_{\text{PROP}})]$$

$$Therm_{\text{SAVED}} = \Sigma_{\text{TEMPBIN-HOU}} [BHP * 33{,}476 * LF * HOU_{\text{BIN}} / 100{,}000 * (1 / Eff_{\text{BASE}} - 1 / Eff_{\text{PROP}})]$$

Where:

Variable	Description	Units	Value
BHP	Boiler horsepower	hp	User input
33,476	Conversion factor	Btuh/BHP	33,476
LF	Boiler load factor		Single user input for process boilers, see Assumptions for HVAC boilers
HOU	Annual hours of operation	Hrs	Single user input for process boilers, see Assumptions for HVAC boilers
100,000	Conversion factor	Btu/therm	100,000
Eff_{BASE}	Boiler efficiency baseline	%	User input for process boilers, 85%[4] for HVAC boilers, see Assumptions
Eff_{PROP}	Boiler efficiency with proposed burner	%	Scales across load factors based on user-specified Eff_{BASE}; see Assumptions
$\Sigma_{\text{TEMPBIN-HOU}}$	Summary of items across temperature bins		
HOU_{BIN}	Hours of use within that temperature bin	Hrs	

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for this measure.

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (= 21 years for install on new boilers, = 15 years for retrofit on existing boilers)[1,2]

Deemed Savings

For process boilers (MMIDs 4760 and 5238), savings vary by application. These hybrid measures use inputs from the application that are then entered into the savings algorithm above to generate the therm savings.

For HVAC boilers (MMIDs 2203 and 5237), savings are prescriptive (on a per-boiler horsepower basis) since HVAC boilers use average Wisconsin weather data. See the table below.

Annual Savings (per BHP) for High Turndown Burners for HVAC Boilers

Measure	MMID	Sector	Annual Therms	Lifecycle Therms
HVAC Boiler Burner, 10:1 High Turndown	2203	Commercial	13	195
		Industrial	13	195
		Agriculture	13	195
		Schools & Government	13	195
		Multifamily	13	195
HVAC Boiler Burner, 10:1 High Turndown	5237	Commercial	13	273
		Industrial	13	273
		Agriculture	13	273
		Schools & Government	13	273
		Multifamily	13	273

Assumptions

- The boiler efficiency baseline uses the combustion efficiency provided by the end user on the application form (MMIDs 4760 and 5238) or 85% (MMIDs 2203 and 5237).[4] Based on a bulletin from Cleaver Brooks,[5] the calculations assume that boiler efficiency will remain at this baseline 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% load and 10% load.
- Boiler manufacturers claim that a high turndown burner can add savings of 2% to 3%.[5,6,7] 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.[5]
- 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%.
- For high turndown burners for HVAC boilers (MMIDs 2203 and 5237), a linear load profile was used with the boiler operating at 100% load at the design outside air temperature of -15°F[8] and ramping down to 10% load at a cut-out temperature of 55°F. A cut-out temperature of 55°F was used to get the estimated equivalent full load hours to closely match the 1,890 hours used for other heating measures.
- Boiler horsepower, boiler load factor, and operating hours are all provided by the end user on the application form for MMIDs 4760 and 5238. 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.

Revision History

Version Number	Date	Description of Change
01	02/2019	Initial TRM entry
02	11/2020	Added HVAC high turndown burners
03	10/2022	Updated algorithm for boilers > 1,000 hp

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[1] American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc. ASHRAE Handbook, HVAC Applications. Chapter 38 "Owning and Operating Costs," Table 4. 2019.

[2] Engineering judgment. A burner retrofit on an existing boiler should have a shorter EUL than a burner on a new boiler. A 15-year EUL also matches the EUL for linkageless controls (W0014).

[3] 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.

[4] Cadmus. Focus on Energy Evaluated Deemed Savings Changes. p. 34. August 31, 2017. www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf

[5] 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

[6] 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

[7] Missouri Division of Energy. *The Missouri Technical Reference Manua*l. *Volume 2: Commercial and Industrial Measures*. p. 110 and 111. March 31, 2017. https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdf

[8] PA Consulting Group. 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

Boiler Control, Linkageless

	Measure Details
Measure Master ID	Boiler Control, Linkageless, 2205 Process Boiler Control, Linkageless, 4761
Workpaper ID	W0014
Measure Unit	Per boiler horsepower
Measure Type	Boiler Control = Prescriptive (MMID 2205) Process Boiler Control = Hybrid (MMID 4761)
Measure Group	Boilers & 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)	$85.42[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

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

Where:

Variable	Description	Units	Value
BHP	Boiler horsepower	hp	User input
33,476	Conversion factor	Btuh/BHP	33,476
LF	Boiler load factor	%	100% for MMID 2205, see Assumptions; actual for MMID 4761
HOU	Annual hours of operation	Hrs	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	Btu/therm	100,000
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

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

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 judgment 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.

Revision History

Version Number	Date	Description of Change
01	02/2019	Initial TRM entry
02	01/2021	Updated cost

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[1] California Utilities Statewide Codes and Standards Team. *Codes and Standards Enhancement Initiative, Commercial Boilers*. p. 16. October 2011. http://title24stakeholders.com/wp-content/uploads/2017/10/2013_CASE-Report_Commercial-Boilers.pdf

[2] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 41 boilers and 30,484 BHP over 28 projects from January 2020 to July 2021.

[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. http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_ASHP.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. *Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

[6] Cellucci, G. *Removing Guesswork*. Hydronics. September/October 2005. http://www.bizlink.com/HPAC_articles/September2005/38.pdf

[7] Steven Winter Associates. *Linkageless Boiler Retrofits for Steam Boilers: Going Beyond Carburetor Technology in a Large Segment of the NYS Market*. December 2017. https://www.swinter.com/wp-content/uploads/Linkageless-Burner-Retrofits-for-Steam-Boilers-46932-SWA-Final-Report.pdf

[8] Carpenter, K., C. Schmidt, and K. Kissock. *Common Boiler Excess Air Trends and Strategies to Optimize Efficiency*. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. https://aceee.org/files/proceedings/2008/data/papers/3_349.pdf

Boiler Oxygen Trim Controls

	Measure Details
Measure Master ID	Boiler Oxygen Trim Controls, 2206 Process Boiler, Oxygen Trim Combustion Controls, 4762
Workpaper ID	W0015
Measure Unit	Per boiler horsepower
Measure Type	Oxygen Trim Controls = Prescriptive (MMID 2206) Oxygen Trim Combustion Controls = Hybrid (MMID 4762)
Measure Group	Boilers & 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)	$79.95[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

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

Where:

Variable	Description	Units	Value
BHP	Boiler horsepower	hp	User input
33,476	Conversion factor from BHP to Btu/h	BHP to MBh	33,476
LF	Boiler load factor	%	100% for MMID 2206, see Assumptions; actual for MMID 4762

Variable	Description	Units	Value
HOU	Annual hours of operation	Hrs	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	Btu/therm	100,000
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

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

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.

Revision History

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

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[1] PA Consulting Group. *Focus on Energy, 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 30 boilers and 27,536 BHP over 19 projects from January 2020 to July 2021.

[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. http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_ASHP.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. *Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

[6] Oak Ridge National Laboratory. *Steam Survey Guide*. ORNL/TM-2001/263. May 2002. https://www.energy.gov/sites/prod/files/2014/04/f15/steam_survey_guide.pdf

[7] United States Environmental Protection Agency. *Guide to Industrial Assessments for Pollution Prevention and Energy Efficiency*. EPA/625/R-99/003. June 2001. https://p2infohouse.org/ref/19/18351.pdf

[8] United States Environmental Protection Agency. *Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Industrial, Commercial, and Institutional Boilers*. p. 15. October 2010. https://www.epa.gov/sites/production/files/2015-12/documents/iciboilers.pdf

[9] Carpenter, K., C. Schmidt, and K. Kissock. *Common Boiler Excess Air Trends and Strategies to Optimize Efficiency*. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. https://aceee.org/files/proceedings/2008/data/papers/3_349.pdf

[10] Cooperative Extension Washington State University Energy Program. *Boiler Combustion Monitoring & Oxygen Trim Systems*. 2010. http://controltrends.org/wp-content/uploads/2010/11/boiler_comb.pdf

Steam Fittings and Pipe Insulation

	Measure Details
Measure Master ID	Insulation, Steam Fitting, Removable, Natural Gas, 2429 Insulation, Steam Piping, Natural Gas, 2430
Workpaper ID	W0017
Measure Unit	Per fitting (fitting insulation) Per linear foot (pipe insulation)
Measure Type	Prescriptive
Measure Group	Boilers & Burners
Measure Category	Insulation
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government Residential- Multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	37.56 (per fitting insulation) 10.58 (per linear foot pipe insulation)
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	158.7 (per fitting insulation) 563.4 (per linear foot pipe insulation)
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Steam fitting = $37.63 (MMID 2429)[2] Steam piping = $8.40 (MMID 2430)[3]

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,[4] as outlined in section 5.3.2.8. For steam pipe with a 1.5-inch normal pipe size (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[4] * °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 v4.1 software, distributed by NAIMA (North American Insulation Manufacturers Association).[5] 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.

$$Therm_{\text{SAVED\_PIPE}} = PipeInsul_{\text{SAVED}} * LF$$

$$PipeInsul_{\text{SAVED}} = Pipe_{\text{BARE}} - Pipe_{\text{INSUL}}$$

Where:

Variable	Description	Units	Value
PipeInsul$_{\text{SAVED}}$	Annual energy savings through insulating in therms per linear foot of pipe	Therms/linear ft	10.58
LF	Total linear feet of pipe	Linear ft	1
Pipe$_{\text{BARE}}$	Annual energy consumption for uninsulated pipe calculated with 3E Plus software		
Pipe$_{\text{INSUL}}$	Annual energy consumption for insulated pipe calculated with 3E Plus software		

$$Therm_{\text{SAVED\_FITTING}} = FittingInsul_{\text{SAVED}} * NF$$

$$FittingInsul_{\text{SAVED}} = Fitting_{\text{BARE}} - Fitting_{\text{INSUL}}$$

Where:

Variable	Description	Units	Value
FittingInsul$_{\text{SAVED}}$	Annual energy savings through insulating in therms per fitting	therm/fitting	37.56, see Assumptions
NF	Number of fittings		1
Fitting$_{\text{BARE}}$	Annual energy consumption for uninsulated fitting calculated with 3E Plus software		
Fitting$_{\text{INSUL}}$	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

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

Where:

EUL = Effective useful life (15 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, with the dimensional standard of ASTM C 585 Rigid/Flexible. The insulation is 850F Mineral Fiber PIPE, Type 1, C547-15. The wind speed is zero, process temperature is 227.1°F (5 PSIG steam), and the ambient temperature is 75°F.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	10/2016	Cost update
03	12/2020	Added multifamily sector, removed SBP MMIDs
04	07/2023	Detailed assumptions.

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[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] Actual Program Data, 2015-2016. 20 projects with average actual cost of $37.63 per fitting

[3] Actual Program Data, 2015-2016. 18 projects with average actual cost of $8.40 per foot.

[4] 2009 IECC standards.

[5] This program is available through NAIMA (North American Insulation Manufacturers Association) at http://www.pipeinsulation.org/

Boiler Tune-Up

	Measure Details
Measure Master ID	Boiler Tune-Up, 2744, 4419
Workpaper ID	W0018
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

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

Where:

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

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

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

Where:

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

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

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[1] PA Consulting Group. "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. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. 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.

BUILDING SHELL

Spring-Loaded Garage Door Hinge

	Measure Details
Measure Master ID	Spring-Loaded Garage Door Hinge, 5438
Workpaper ID	W0019
Measure Unit	Per garage door
Measure Type	Prescriptive
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)	161
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	3,228
Water Savings (gal/Year)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	$195.52[2]

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

$$Therm_{SAVED} = [AL * ((Cs * \Delta T) + (Cw * Ws2))0.5] * 60 * 0.08 * 0.24 * \Delta T / (HtgEff * 100{,}000) * HOU_{HT}$$

Where:

Variable	Description	Units	Value
A_L	Effective leakage area reduced	Sq in	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	cfm/(in * °F)	0.0299 $CFM^3/(in^4$ * °F; determined from building height in stories, with average of 2 stories assumed)[5]
ΔT	Indoor temperature setpoint minus average outside temperature during heating season	°F	Indoor setpoint = 62.56 °F - 35°F average outside temperature across Wisconsin during heating season for four locations = 27.56 °F, see assumptions[4]
C_w	Wind coefficient	cfm/in miles/hr	0.0086 CFM^3/in^4 mph^3; determined from how sheltered building is from wind)[6]
Ws	Average heating season wind speed	Miles/hr	11 mph[3,7]
60	Minutes per hour conversion	Minutes/hr	60
0.08	Average heating season air density in Wisconsin	lb/CF[8]	0.08
0.24	Specific heat of air	Btu/lb[9]	0.24
HtgEff	Typical non-condensing heating efficiency		0.80[2]
100,000	Conversion factor	Btu/therm	100,000
HOU_{HT}	Hours in typical September to April heating season	Hrs	5,840

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 (0 years)[1]

Assumptions

- The average indoor setpoint temperature is based on historical participation from 2016 thru September of 2022 for measures 3680 to 3683:

Historical Participation

MMID	Indoor Setpoint (°F)	# of Doors	% of Participation
3680	55	87	9.0%
3681	60	361	37.2%
3682	65	461	47.5%
3683	70	62	6.4%
Total	**62.56**	**971**	**100%**

- 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 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.

Revision History

Version Number	Date	Description of Change
01	08/2016	Initial TRM entry
02	10/2022	Combine measures for separate setpoints into one measure based on historical data. Update incremental cost.

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[1] Focus on Energy. Evaluation – Business Program: Measure Life Study. 2009.

[2] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Data for MMIDs 3680 to 3683, the previous version of this measure. From January 2018 thru September 2022, there were a total of 524 doors that had spring loaded hinges installed for an average cost of $195.52.

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[3] 2009 ASHRAE Handbook – Fundamentals. p. 16.23.

[4] U.S. Climate Data. "U.S. climate data." Last updated 2016. http://www.usclimatedata.com.

[5] 2001 ASHRAE Handbook – Fundamentals. p. 26.21 (40).

[6] Graphiq Inc. "Find Average Wind Speed for US Cities." Last updated 2016. http://average-wind-speed.findthebest.com/

[7] The Engineering ToolBox. "Air Density and Specific Weight." http://www.engineeringtoolbox.com/air-density-specific-weight-d_600.html

[8] The Engineering ToolBox. "Properties of Air - temperatures ranging -100 to 1000 °F." http://www.engineeringtoolbox.com/air-properties-viscosity-conductivity-heat-capacity-d_1509.html

[9] The Engineering Toolbox. http://www.engineeringtoolbox.com/specific-heat-capacity-gases-d_159.html

Loading Dock Door and Pit/Ramp Seals

	Measure Details
Measure Master ID	Dock Door Infiltration Reduction, New Install, 2300 Dock Door Infiltration Reduction, Replace Existing, 2301 Dock Pit/Ramp External Seal, Added to Existing “Brush” Barrier, 2302 Dock Pit/Ramp External Seal, No Brush Barrier Present, 2303
Workpaper ID	W0281
Measure Unit	Per door or pit sealed
Measure Type	Prescriptive
Measure Group	Building Shell
Measure Category	Air Sealing
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Electricity Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Natural Gas Savings (therms)	Varies by measure
Lifecycle Electricity Savings (kWh)	0
Lifecycle Natural Gas Savings (therms)	Varies by measure
Annual Water Savings (gallons)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	Varies by measure, see Incremental Cost table below[2]

Measure Description

Loading dock seals, also known as loading dock shelters, stop outside air from leaking into the building while the loading dock door is open to load or unload semi-trailers. Without a seal, there is a roughly 4-to-6-inch gap between the semi and the dock door opening. Adding seals, which are typically made of compressible foam and rubber, seals the gap between the semi and dock door and significantly reduced the amount of infiltration.

Additionally, facilities often have a built-in pit ramp that adjusts (up or down) to meet the height of the semi-trailer to allow access for a forklift. The pits below these ramps typically remain open, or just have a basic “brush” type barrier that allows year-round infiltration. Ramp pit seals can be added to fill these gaps.

Description of Baseline Condition

The baseline condition is a loading dock door or ramp that does not have seals (MMIDs 2300, 2303) or that has degraded or minimal seals (MMIDs 2301, 2302).

Description of Efficient Condition

The efficient condition is a dock door with a loading dock door seal (MMIDs 2300 and 2301) and/or a ramp with a pit seal (MMIDs 2302, 2303).

Annual Energy-Savings Algorithm

$$Therm_{\text{SAVED}} = 1.08 * CFMI_{\text{NF}} * HDD * 24 * HrsPerWk / (168 * EFF_{\text{HEAT}} * 100{,}000)$$

$$CFM_{\mathrm{INF}} = Area_{LEAKS} * \sqrt{C_{STACK} * (T_{IN} - T_{OUT}) + C_{WIND} * V_{WIND}^2}$$

$$\text{For dock doors: } Area_{LEAKS} = GapSize * (2 * Height + 2 * Width)$$

$$\text{For pit seals: } Area_{LEAKS} = GapSize * (2 * Length + 2 * Width)$$

Where:

Variable	Description	Units	Value
1.08	Sensible heat load constant	Btu/cfm - °F-hr	1.08
HDD	Heating degree days	Days	7,616[3]
24	Conversion factor	Hrs/day	24
HrsPerWk	Hours per week that infiltration occurs	Hrs/wk	10 for dock doors,[4] 168 for leveler seals, see Assumptions
168	Conversion factor	Hrs/wk	168
EFF_{HEAT}	Heating efficiency	%	80%, see Assumptions
100,000	Conversion factor	Btu/therm	100,000
C_{STACK}	Stack coefficient		0.0225[5]
T_{IN}	Indoor temperature setpoint	°F	55°F, see Assumptions
T_{OUT}	Average outdoor temperature during heating season of October through April	°F	33.0°F[6]
C_{WIND}	Wind coefficient		0.006[5]
V_{WIND}	Average winter wind speed	Miles/hr	9.6 mph[7]
GapSize	Refer to Gap Size by MMID table below		Refer to Gap Size by MMID table below
Height	Height of the dock door	Feet	9 feet[8]
Width	Width of the dock door or leveler ramp	Feet	8 feet[8]
Length	Length of leveler ramp	Feet	8 feet, see Assumptions

Gap Size by MMID

Measure	MMID	Gap (inches)	Source
Dock Door Infiltration Reduction:			
New Install	2300	4.21	8
Replace Existing	2301	2.105	8, see Assumptions
Dock/Pit Ramp External Seal:			
Added to Existing “Brush” Barrier	2302	0.1	see Assumptions
No Brush Barrier Present	2303	0.5	see Assumptions

Summer Coincident Peak Savings Algorithm

There are no peak coincident savings for these measures.

Lifecycle Energy-Savings Algorithm

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

Where:

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

Deemed Savings

Savings for Loading Dock Door & Pit Seals

Measure	MMID	Annual Therms	Lifecycle Therms
Dock Door Infiltration Reduction:			
New Install	2300	258	2,580
Replace Existing	2301	129	1,290
Dock/Pit Ramp External Seal:			
Added to Existing “Brush” Barrier	2302	97	970
No Brush Barrier Present	2303	485	4,850

Assumptions

- Heating systems for loading dock areas are assumed to primarily be unit heaters and infrared heaters, which typically have an efficiency of 80%.
- The width of the leveler ramp was assumed to be the same as the dock door width (8 feet). Many manufacturer photos and spec sheets show the leveler ramp as square, so the length of the leveler ramp was assumed to be 8 feet.
- The hours for leveler ramps are set to 168 hours per week, as these air leaks occur all the time, regardless of whether a truck is being loaded/unloaded or not.
- The indoor temperature setpoint is assumed to be 55°F as the loading dock area would be minimally heated.
- A wind coefficient[5] of 0.0138 would be appropriate if there were no sheltering. A 1.5 story building with typical sheltering would have a wind coefficient of 0.0076, or 0.0045 in a more urban environment. A wind coefficient of 0.006 is selected for this measure.
- The gap size for replacing an existing loading dock seal (MMID 2301) is assumed to be 50% of the gap size for a new installation (MMID 2300), or 50% x 4.21 inches = 2.105 inches. The gap size for dock pit/ramp seals with an existing brush type barrier is assumed to be 0.1 inches and the gap for pit/ramp seals without a brush type barrier is assumed to be 0.5 inches, both of which are based on a historical Focus on Energy calculation derived from a manufacturer’s calculator.

Incremental Cost

Efficient costs are derived from historical project data.[2] Baseline cost is zero (continue without a dock / pit seal).

Incremental Costs

Measure Name	MMID	SPECTRUM Data			Base Cost	Incremental Cost
		Projects	Units (each)	Average Unit Cost		
Dock Door Infiltration Reduction:						
New Install	2300	9	38	$3,947.41	$0	$3,947.41
Replace Existing	2301	45	243	$2,722.43	$0	$2,722.43
Dock/Pit Ramp External Seal:						
Added to Existing “Brush” Barrier	2302	9	30	$1,176.29	$0	$1,176.29
No Brush Barrier Present	2303	10	234	$624.47	$0	$624.47

Revision History

Version Number	Date	Description of Change
01	12/2021	Initial TRM entry

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[1] Michaels Energy, "Final Report: Custom Measure Life Review (Michaels No.:O6717AAN)," Ontario Energy Board, Toronto, May 10, 2018. www.oeb.ca/sites/default/files/OEB-DSM-Custom-Measure-Life-Review.pdf

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. January 2018 through July 2021.

[3] 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.

[4] Minnesota Department of Commerce Division of Energy Resources. *State of Minnesota Technical Reference Manual for Energy Conservation Improvement Programs*. Version 3.2. https://mn.gov/commerce-stat/pdfs/20210201_trm_cip_vers3.2.pdf

[5] American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc. *ASHRAE Handbook – Fundamentals*. Chapter 16 “Ventilation and Infiltration,” Tables 2 and 4, page 16.16. 2021. Both stack coefficient and wind coefficient are the averages of the values for one-story and two-story buildings. Wind coefficient is the average of typical shielding and urban environment.

[6] National Renewable Energy Laboratory. “National Solar Radiation Data Base, 1991- 2005 Update: Typical Meteorological Year 3.” https://nsrdb.nrel.gov/data-sets/archives.html. Average temperature for Eau Claire, La Crosse, Madison, Milwaukee, and Green Bay for October to April from 6:00 a.m. to 6:00 p.m.

[7] NOAA-National Centers for Environmental Information-Comparative Climate Data, 1981-2015, Wind – Average Speed (MPH) http://www1.ncdc.noaa.gov/pub/data/ccd-data/wndspd15.dat, accessed December, 2021. Average monthly wind speeds for October-April for Madison, Milwaukee, La Crosse, and Green Bay = 9.6 MPH. Eau Claire data not available.

[8] Material Handling Industry (MHI), “Frequently Asked Questions”, accessed December 2021. www.mhi.org/media/members/49652/129999849700821430.pdf
Most common side of door is 8 foot wide by 9 foot tall. This aligns well (on the conservative side) of the door size options listed in the Ontario Natural Gas DSM TRM of 8x8, 8x9, 8x10, and 10x10.

COMPRESSED AIR, VACUUM PUMPS

Air Compressor, Variable Speed Drive

	Measure Details
Measure Master ID	Air Compressor, Variable Speed Drive, Constant Speed Replacement, 2196
Workpaper ID	W0264
Measure Unit	Per horsepower
Measure Type	Hybrid
Measure Group	Compressed Air, Vacuum Pumps
Measure Category	Compressor
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Electricity Savings (kWh)	Varies
Peak Demand Reduction (kW)	Varies
Annual Natural Gas Savings (therms)	0
Lifecycle Electricity Savings (kWh)	Varies
Lifecycle Natural Gas Savings (therms)	0
Annual Water Savings (gallons)	0
Effective Useful Life (years)	13[1]
Incremental Cost ($/unit)	$100.93[2]

Measure Description

This measure is for replacing a fixed-speed air compressor with a variable speed drive (VSD) equipped air compressor, or for installing a VSD instead of a fixed-speed compressor in new construction applications. The VSD allows the air compressor to match the actual load within the plant, which varies throughout the day. VSD air compressors are best suited for single compressor systems with varying loads and for trim compressor operation in multiple compressor systems, as they provide efficient part-load performance but, due to the VSD efficiency, are slightly less efficient at 100% speed.

Description of Baseline Condition

The baseline is one or more fixed-speed compressors with load/no load, inlet air modulation, or variable displacement controls.

Description of Efficient Condition

The efficient condition is one or more VSD compressors. It is allowable to use more than one VSD compressor when pre-approval is obtained and both compressors are needed to satisfy the load (and one VSD is not a backup). Typically, two compressors allow for widely varying maximum versus minimum airflow during operation, where, for example, two 50 hp compressors can provide a better turndown ratio than one 100 hp compressor.

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = kWh_{\text{BASE}} - kWh_{\text{EE}}$$

$$kWh_{\text{BASE}} = \sum_{\text{SHIFTS}} \left[\sum_{\text{BASECOMPS}} (0.892 * HP_{\text{BASE}} * HOU * Weeks * LF_{\text{BASE}} * PresAdjust_{\text{BASE}} * Runtime\%)\right]$$

$$kWh_{EE} = \sum_{SHIFTS} [\sum_{EFFCOMPS} (0.892 * HP_{EE} * HOU * Weeks * LF_{EE} * PresAdjust_{EE} * Runtime\%)]$$

Where:

Variable	Description	Units	Value
$\sum_{SHIFTS}$	Summary across shift 1, shift 2, shift 3, and weekends		
$\sum_{BASECOMPS}$	Summary across each baseline compressor		
0.892	Compressor motor nominal hp to full load kW conversion factor[3]	hp to full load kW	0.892
HP_{BASE}	Horsepower of baseline air compressor	hp	User input
HOU	Hours of use per week for given shift	Hrs/wk	User input for shift 1, shift 2, shift 3, and weekends, as applicable
Weeks	Weeks of operation per year	Wks/yr	52 unless lower value provided by user
Runtime%	Percentage of time that given compressor runs	%	100% for baseload compressor and VSD compressor, user input for baseline trim compressors
$\sum_{EFFCOMPS}$	Summary across each VSD compressor		
HP_{EE}	Horsepower of VSD air compressor	hp	User input
LF_{EE}	Percentage of load	%	For VSD controls
$PresAdjust_{EE}$	$1 + 0.01 * (PSI_{OPERATING} - PSI_{RATED,EE}) / 2$		See Assumptions
$PSI_{RATED, EE}$	Pressure for performance data of VSD air compressor		User input

LF_{BASE} = Load factor; varies as follows based on base compressor control method[4]
= -0.4513 * %Load^2 + 1.1965 * %load + 0.2631 (for load/no load controls)
= 0.3 * %Load + 0.7 (for inlet modulation controls)
= 0.7164 * %Load + 0.2782 (for variable displacement controls)

where:

%Load = CFM_{SHIFT} / CFM_{MAX}

CFM_{SHIFT} = The CFM assigned to the compressor for the given shift (see Assumptions)

CFM_{MAX} = Maximum CFM for the given compressor capability (= user input if existing compressor, = 4.55 CFM/hp[5] * HP_{EE} if no existing compressor)

$PresAdjust_{BASE}$ = $1 + 0.01 * (PSI_{OPERATING} - PSI_{RATED,BASE}) / 2$ (see Assumptions)

where:

$PSI_{OPERATING}$ = Actual operating pressure of air compressor (= user input)

$PSI_{RATED,BASE}$ = Pressure for performance data of baseline air compressor (= user input)

Summer Coincident Peak Savings Algorithm

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

Where:

kW_{BASE} = $\sum_{BASECOMPS}$ (0.892 * HP_{BASE} * LF_{BASE} * $PresAdjust_{BASE}$ * Runtime%)

kW_{EE} = $\sum_{EFFCOMPS}$ (0.892 * HP_{EE} * LF_{EE} * $PresAdjust_{EE}$ * Runtime%)

CF = Coincidence factor (= 1.0; see Assumptions)

Lifecycle Energy-Savings Algorithm

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

Where:

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

Assumptions

- The average CFM per shift provided on the incentive application is split between the various existing compressors. The lead compressor is assigned up to 60% of its maximum CFM (this is CFM_{SHIFT} in the savings algorithm above). If there is a second existing compressor, it is then assigned the remaining average CFM per shift up to 60% of its maximum, and similarly for the third existing compressor. This process is repeated for shift 1, shift 2, shift 3, and weekends (which encompasses all weekend hours on Saturday and Sunday). The 60% limit is based on engineering judgment to provide conservative savings since, over the course of one year, most compressors will run at well under 100% capacity.
- Existing air compressor performance data, new VSD air compressor performance, and actual operating pressure are often provided at different pressures. In order to try to match the performance data to the actual operating pressure, an assumption that power changes by 1% for every 2 PSI pressure change is used.[6]
- Shift 1 operation is assumed to occur during the Focus on Energy definition of on-peak (2:00 p.m. to 6:00 p.m., Monday to Friday from June through September). Therefore, the demand reduction is based on the average first shift CFM (user input). Since the kilowatt demand is already based on actual average airflow during first shift operation, the coincidence factor is assumed to be 1.0.

Revision History

Version Number	Date	Description of Change
01	12/2020	Initial TRM entry
02	10/2022	Updated hp to kW coefficient based on Focus data

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[1] U.S. Department of Energy. Technical Support Document: Energy Efficiency Program For Consumer Products and Commercial and Industrial Equipment: Air Compressors. December 2016. Page 8-12. http://www.energy.gov/sites/prod/files/2019/09/f66/crac-doas-noda-tsd.pdf

[2] Wisconsin Focus on Energy historical project data obtained from SPECTRUM. Average cost of 175 VSD air compressors over 169 projects from January 2019 to November 2020 was $403.93.
November 2020 online lookups of 34 models from 20 hp to 200 hp on www.northerntool.com, www.aircompressorsdirect.com,

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www.compressorworld.com, and www.store.industrialairpower.com show an average baseline price of $303.77 per horsepower.

[3] Conversion factor based on a review of CAGI data sheets for 230 different air compressors. See "Air Compressor Conversion Factor Data.xlsx" for more information.

[4] Compressed Air Challenge. "Best Practices for Compressed Air Systems - Second Edition." www.airbestpractices.com/article/best-practices-compressed-air-systems
Appendix 2, Figures A.2.o., A.2.p., A.2.q., and A2.r used to determine the average percentage power. Table A.2.o, 2 gallons per CFM receiver volume curve is used. Typical compressed air systems are in the 1 to 3 gallons per CFM range.

[5] U.S. Department of Energy, Office of Industrial Technologies. "Compressed Air Systems Fact Sheet #8: Packaged Compressor Efficiency Ratings." p. 2. April 1998. www.compressedairchallenge.org/data/sites/1/media/library/factsheets/factsheet08.pdf
This reference shows 22 bhp/100acfm, making the inverse (cfm per hp) equal to 4.55 cfm/hp.

[6] U.S. Department of Energy, Office of Industrial Technologies. "Compressed Air Systems Fact Sheet #4: Pressure Drop and Controlling System Pressure."p. 1. April 1998.
www.compressedairchallenge.org/data/sites/1/media/library/factsheets/factsheet04.pdf

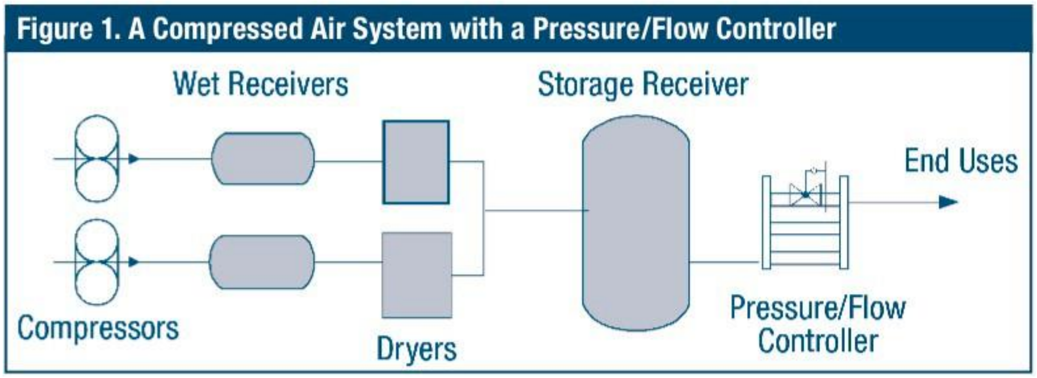
Compressed Air Controller, Pressure/Flow Controller

	Measure Details
Measure Master ID	Compressed Air Controller, Pressure/Flow Controller, 2255
Workpaper ID	W0020
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)	226 per hp
Peak Demand Reduction (kW)	0.040 per hp
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	3,390 per hp
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$26.46/hp[2]

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[3]



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

$$kWh_{\text{SAVED}} = hp * 0.892 * LF * HOU * \%\, decrease$$

Where:

Variable	Description	Units	Value
hp	Compressor motor size in horsepower	hp	
0.892	Compressor motor nominal hp to full load kW conversion factor[4]	hp to full load kW	0.892
LF	Average load on compressor motor	%	89%[5]
HOU	Average annual run hours	Hours	5,702[6]
% decrease	Percentage decrease in power input	%	5%[7]

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = hp * 0.892 * LF * \%\, decrease * CF$$

Where:

CF = Coincidence factor (= 1)[8]

Lifecycle Energy-Savings Algorithm

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

Where:

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

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
04	10/2022	Updated hp to kW coefficient based on Focus data

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[1] Estimate from product representative.

[2] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 309 units over 31 projects from 2016 to 2018.

[3] Industrial Technologies Program. *Compressed Air Tip Sheet #9.* August 2004.

[4] Conversion factor based on a review of CAGI data sheets for 230 different air compressors. See "Air Compressor Conversion Factor Data.xlsx" for more information.

[5] Cascade Energy. *Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors.* November 5, 2012.

[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. Department of Energy. *Improving Compressed Air System Performance: A Sourcebook for Industry.* P. 20. November 2003.

[8] U.S. 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. https://apps.dtic.mil/sti/pdfs/ADA419142.pdf

Compressed Air, Cycling Thermal Mass Air Dryers

	Measure Details
Measure Master ID	Compressed Air, Cycling Thermal Mass Air Dryers, 2264
Workpaper ID	W0021
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)	28.11 per CFM
Peak Demand Reduction (kW)	0.0049 per CFM
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	421.65 per CFM
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$6.00[2]

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,[3] 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

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

Where:

Variable	Description	Units	Value
SF	Savings factor	kW/cfm	0.00554[4]
LF	Load factor	%	89%[5]
CFM	Actual rated capacity of air dryer	cfm	
HOU	Average annual run hours	Hrs/yr	5,702[6]

Summer Coincident Peak Savings Algorithm

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

Where:

CF = Coincidence factor (= 1)[7]

Lifecycle Energy-Savings Algorithm

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

Where:

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

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	05/2018	Updated HOU
03	12/2020	Updated Savings Factor value and reference to root source. Updated savings to per cfm.

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[1] Energy and Resource Solutions. *Measure Life Study.* Prepared for The Massachusetts Joint Utilities. 2005. http://rtf.nwcouncil.org/subcommittees/nonreslighting/Measure%20Life%20Study_MA%20Joint%20Utilities_2005_ERS-1.pdf

[2] 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

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

[4] DNV GL. *Impact Evaluation of Prescriptive Chiller and Compressed Air Installations.* October 26, 2015. Table 1-10. https://ma-eeac.org/wp-content/uploads/MA30-Prescriptive-Chiller-and-CAIR-Report_FINAL_151026.pdf

[5] Cascade Energy. *Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors*. November 5, 2012.

[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] 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. https://apps.dtic.mil/sti/pdfs/ADA419142.pdf

Dew Point Controls for Desiccant Dryers

	Measure Details
Measure Master ID	Dew Point Controls for Desiccant Dryers, 4363
Workpaper ID	W0022
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)	$26.91 per CFM[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°F to 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

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

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

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

Where:

Variable	Description	Units	Value
CFM	Rated capacity of dryer	cfm	
PR_{BASE}	Power requirement of baseline system	kW/cfm	
PR_{EE}	Power consumption of efficient dew-point sensor controlled system	kW/cfm	
HOURS	Average annual run hours	Hrs/yr	5,702[4]
Eff	Efficiency of standard air compressor		Varies by air compressor type; see table below[5]
$\%Power_{\mathrm{BASE}}$	Percentage of rated power at baseline condition	%	Varies by air compressor control type and dryer type; see table below
HD_{BASE}	Heater demand of dryer at baseline condition		Varies by dryer type; see table below
BD_{BASE}	Blower demand of dryer at baseline condition		Varies by dryer type; see table below
$\%Power_{\mathrm{EE}}$	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 dryer with dew point control		Varies by dryer type; see table below
BD_{EE}	Blower demand of 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[6,7]

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

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

Where:

CF = Coincidence factor (= 1)[8]

Lifecycle Energy-Savings Algorithm

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

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.

Revision History

Version Number	Date	Description of Change
01	10/2017	Initial TRM entry
02	08/2022	Cost update

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[1] Energy and Resource Solutions. *Measure Life Study*. Prepared for the Massachusetts Joint Utilities. 2005. https://nwcouncil.app.box.com/s/f9mjj6ji9fvg4mmal3l1wjp6mdmj1hc4

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 19 projects and 15 units from January 2021 to July 2022 is $26.91.

[3] Sustainability Victoria. *Energy Efficiency Best Practices Guide Compressed Air Systems*. 2009. http://www.caps.com.au/docs/resources/best-practices-manual.pdf

[4] Illinois Energy Efficiency Statewide Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency Version 12.0.* Volume 2. September 22, 2023. Page 845. https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_2_C_and_I_09222023_FINAL_clean.pdf

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[5] United States Department of Energy. *Improving Compressed Air System Performance*. Pages. 48-49. https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/compressed_air_sourcebook.pdf

[6] Franklin Energy Services. *Michigan Energy Measures Database (MEMD).* Workpaper FES-I31 Dew Point Controls for Desiccant Dryers.

[7] Compressed Air Challenge. *Improving Compressed Air System Performance: A Sourcebook for Industry*. November 2003.

[8] Army Corps of Engineers (Mike C.J. Lin, Ahmad R. Ganji, Shy-Sheng Liou, and Bryan Hackett). *Compressed Air System Survey at Sierra Army Depot, CA.* November 2000. http://www.dtic.mil/docs/citations/ADA419142

[9] Efficiency, Energy, and Renewable Energy. “Improving Compressed Air System Performance.” https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/compressed_air_sourcebook.pdf

Compressed Air and Vacuum Pump Heat Recovery, Space Heating

	Measure Details
Measure Master ID	Compressed Air Heat Recovery, Space Heating, 2257 Compressed Air Heat Recovery, Space Heating, Propane, 4853 Vacuum Pump Heat Recovery, Space Heating, 3928
Workpaper ID	W0023
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 Electricity Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Natural Gas Savings (therms)	76
Annual Propane Savings (Gallons)	83
Lifecycle Electricity Savings (kWh)	0
Lifecycle Natural Gas Savings (therms)	988
Lifecycle Propane Savings (Gallons)	1,079
Annual Water Savings (gallons)	0
Effective Useful Life (years)	13[1]
Incremental Cost ($/unit)	$141.56[2]

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 or propane space heating.

Description of Efficient Condition

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

Annual Energy-Savings Algorithm

$$Gas_{\text{SAVED}} = hp * Load\ Factor * 2{,}545 * HR * HOU \ / \ (ConvF * EFF_{\text{HEAT}})$$

Where:

Variable	Description	Units	Value
Gas_{SAVED}	Therms of natural gas or gallons of propane saved	Therms natural gas/gallons propane	
hp	Compressor or vacuum pump motor horsepower size	hp	
Load Factor	Average load on compressor or vacuum pump motor	%	89%[3]
2,545	Conversion factor	hp to Btu/hr	2,545
HR	Heat recoverable as percentage of brake horsepower	% brake hp	70%, see Assumptions
HOU	Average annual run hours of compressor or vacuum pump	Hrs/yr	3,812[4]
ConvF	Fuel conversion factor	Btu/therm, Btu/gallon	100,000 Btu/therm, 91,300 Btu/gallon propane[5]
EFF_{HEAT}	Efficiency of building heating system	%	80%, see Assumptions[6]

Summer Coincident Peak Savings Algorithm

There are no peak coincident savings for this measure.

Lifecycle Energy-Savings Algorithm

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

Where:

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

Assumptions

- Historical project data for Focus on Energy indicates that all or nearly all heat recovery projects have been for air-cooled air compressors. Several references claim differing amounts of heat are recoverable from air cooled air compressors. One reference from the Compressed Air Challenge[7] claims 80% to 90%, but another[8] claims 50% to 90%. A research paper review[9] claims 50% to 80%. A conservative estimate of 70% is used here.
- Based on engineering judgment, the heating season is assumed to be October through March, which is six months or 50% of the year.
- The heating system efficiency is deemed to be 80%. This reflect data for rooftop units from the 2016 Potential study[6] and the 80% value assumed for unit heaters in workpaper W0048.

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
05	09/2020	Heat recovery fraction updated, updated cost
06	10/2021	Added propane measure, building heating efficiency factor

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[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
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

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 74 projects and 77 units from January 2018 to July 2020 is $141.56.

[3] Cascade Energy. "Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors." Table 6: Load Factor by Nameplate hp and End Use. November 5, 2012. https://rtf.nwcouncil.org/meeting/rtf-meeting-november-14-2012

[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] U.S. Energy Information Administration. "Energy Units and Calculators Explained." Accessed December 2018. https://www.eia.gov/energyexplained/?page=about_energy_units

[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. 80.3% value observed for 121 rooftop units.

[7] Moskowitz, Frank. "Compressed Air Challenge™, Heat Recovery and Compressed Air Systems." September 2010. www.compressedairchallenge.org/library/articles/2010-09-CABP.pdf

[8] Compressed Air Challenge. *Heat Recovery with Compressed Air Systems*. *Fact Sheet #10*. https://www.compressedairchallenge.org/data/sites/1/media/library/factsheets/factsheet10.pdf

[9] R. Saidur, N.A. Rahim, and M. Hasanuzzaman. *A review on compressed-air energy use and energy savings*. Renewable and Sustainable Energy Reviews. Volume 14, Issue 4, page 1135-1153. May 2010. https://www.sciencedirect.com/science/article/abs/pii/S1364032109002755

Compressed Air Mist Eliminators

	Measure Details
Measure Master ID	Compressed Air Mist Eliminators, 2258
Workpaper ID	W0024
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)	91
Peak Demand Reduction (kW)	0.0159
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	910
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$27.30[2]

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 pounds per square inch gauge (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.[3] 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.

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = hp * 0.892 * LF * HOU * \%\,Savings$$

$$\%\,Savings = Total_{\text{PR}} * RS$$

Where:

Variable	Description	Units	Value
hp	Compressor motor size in horsepower	hp	
0.892	Compressor motor nominal hp to full load kW conversion factor[4]	hp to full load kW	0.892
LF	Average load on compressor motor	%	89%[3]
HOU	Average annual run hours	Hrs/yr	5,702[5]
% Savings	Percentage of energy saved	%	2%[6]
$Total_{\text{PR}}$	Total pressure reduction from replacing filter	psig	4 psig[6]
RS	Percentage of energy saved for each psig reduced	%/psig	0.5%[7]

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = hp * 0.892 * LF * \%\,Savings * CF$$

Where:

CF = Coincidence factor (= 1; compressed air systems run during peak demand)[8]

Lifecycle Energy-Savings Algorithm

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

Where:

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

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
04	07/2022	Updated EUL and Incremental Cost
05	10/2022	Updated hp to kW coefficient based on Focus data

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[1] Beals, Chris. *An Auditor's Notes on Compressed Air Dryer Installations – Part I*. https://www.airbestpractices.com/system-assessments/air-treatmentn2/auditor%e2%80%99s-notes-compressed-air-dryer-installations-%e2%80%94-part-i. Accessed July 2022.

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 21 units over 21 projects from 2019 to 2021.

[3] Cascade Energy. *Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors.* November 5, 2012.

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[4] Conversion factor based on a review of CAGI data sheets for 230 different air compressors. See “Air Compressor Conversion Factor Data.xlsx” for more information.

[5] 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

[6] Sullair Corporation. *Compressed Air Filtration and Mist Eliminators Datasheet*. http://www.amcompair.com/products/brochures/sullair_brochures/_Sullair%20filtration.pdf.

[7] U.S. Department of Energy. *Improving Compressed Air System Performance: A Sourcebook for Industry*. p. 20. November 2003.

[8] U.S. 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. https://apps.dtic.mil/sti/pdfs/ADA419142.pdf

Compressed Air Nozzles, Air Entraining

	Measure Details
Measure Master ID	Compressed Air Nozzles, Air Entraining, 2259
Workpaper ID	W0025
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[2]

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[3] for a minimum of 2,000 hours per year.[4] Compressed air pipe flow rates are standard.[5]

Description of Efficient Condition

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

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = Eff * (Open\ Flow - Eng.Flow) * HOU$$

Where:

Variable	Description	Units	Value
Eff	Efficiency of standard air compressor	kW/scfm	0.16
Open Flow	Flow of copper pipe nozzle	scfm	21
Eng. Flow	Flow of engineered nozzle	scfm	6
HOU	Average annual run hours	Hrs/yr	2,000

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = Eff * (Open\ Flow - Eng.Flow) * CF$$

Where:

CF = Coincidence factor (= 0.75)[6]

Lifecycle Energy-Savings Algorithm

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

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.[5]

Revision History

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

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[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 228 units over 16 projects from 2012 to 2017.

[3] United States Department of Energy. *Improving Compressed Air System Performance*. Pgs. 48-49.

[4] 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.

[5] Franklin Energy Services, LLC. Personal communications regarding engineering approximation based on field observation.

[6] Technical Reference Manual for Ohio Senate Bill 221 Energy Efficiency and Conservation Program and 09-512-GE-UNC. October 15, 2009.

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
Workpaper ID	W0026
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

$$kWh_{\text{SAVED}} = CFM\ Reduction\ /\ (CFM/BHP) * 0.892 * HOU$$

Where:

Variable	Description	Units	Value
CFM Reduction	Total CFM reduction in entire compressed air system	cfm	Directly from leak log survey (preferred) or estimated using other reported leak log data (see table below)
CFM/BHP	Average amount of CFM per brake horsepower	cfm/hp	4.2[3]
0.892	Compressor motor nominal hp to full load kW conversion factor[4]	hp to full load kW	0.892
HOU	Average annual compressor run hours	Hrs/yr	User input

CFM Discharge Rates by Leak Decibel Readings and Pressure Levels[3,5]

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

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = CFM\ Reduction\ /\ (CFM/BHP) * 0.892$$

Lifecycle Energy-Savings Algorithm

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

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.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	10/2016	Updated savings algorithm
03	10/2018	Updated to one measure rather than separate measures for years 1 through 4
04	10/2022	Updated hp to kW coefficient based on Focus data

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[1] PA Consulting Group. *Focus on Energy, 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*. https://elmainstruments.no/Admin/Public/Download.aspx?file=%2Ffiles%2Ffiles%2Fdocuments%2Fecom%2FManuals%2F5706445331031_compressed_air_guide.pdf

[4] Conversion factor based on a review of CAGI data sheets for 230 different air compressors. See “Air Compressor Conversion Factor Data.xlsx” for more information.

[5] UE Systems, Inc. “Compressed Air Loss Guesstimator for Digital Ultraprobes.” Accessed January 30, 2017.

Compressed Air Condensate Drains, No Loss Drain

	Measure Details
Measure Master ID	Compressed Air Condensate Drains, No Loss Drain, 2254
Workpaper ID	W0027
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)	17,110
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$392.41[2]

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

$$kWh_{\text{SAVED}} = SF * HOU$$

Where:

Variable	Description	Units	Value
SF	Saving factor in kilowatts per drain	kW/drain	0.3[3]
HOU	Average annual run hours	Hrs/yr	5,702[4]

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = SF * CF$$

Where:

CF = Coincidence factor (= 0.80)[3]

Lifecycle Energy-Savings Algorithm

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

Where:

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

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	05/2018	Updated HOU
03	07/2023	Updated Incremental Cost and EUL

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[1] Based on survey of manufacturer claims (Zeks, Van Air, Quincy), as recommended in Navigant *ComEd Effective Useful Life Research Report*, May 2018.

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 111 units over 55 projects from 1/1/2021 to 6/30/2023 is $392.41.

[3] TecMarket Works. *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs*. pp. 193 and 194. October 15, 2010.

[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

Compressed Air Process Load Shifting

	Measure Details
Measure Master ID	Compressed Air Process Load Shifting, 2848
Workpaper ID	W0282
Measure Unit	Per horsepower of load shifted
Measure Type	Hybrid
Measure Group	Compressed Air, Vacuum Pumps
Measure Category	Reconfigure Equipment
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
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)	15[1]
Incremental Cost ($/unit)	$330.94 per horsepower of load shifted[2]

Measure Description

Compressed air is a necessary operation for most industrial facilities, but it may not be the most effective or efficient use of energy for a certain process. For example, to run a 1 hp air motor, 7 hp at the air compressor is needed.[3] Many applications that use air motors, open blowing, etc. can also be accomplished using an electric motor or a blower with considerably less energy use.

Description of Baseline Condition

The baseline condition is using compressed air when a less energy-intensive solution could be used instead. Potentially inappropriate uses of compressed air can be identified from a walk-through or a system audit performed by a compressed air specialist, the customer themselves, or an energy advisor. These audits will typically identify the amount of compressed air, in CFM, needed to perform the end use function. During the audit, the efficiency of the air compressor (in CFM/hp) is noted.

Description of Efficient Condition

The efficient solution involves installing an electric motor or a blower to accomplish the task that the compressed air was performing, and uses considerably less horsepower. The horsepower for the efficient condition is based on the specification sheet for the equipment being installed. The use of technologies other than a blower or electric motor are not covered by this measure and would need to be evaluated for a custom incentive.

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = [(CFM_{\text{BASE}} / (CFM_{\text{COMP}} / HP_{\text{COMP}}) * 0.892) - (HP_{\text{EFF}} * 0.746 / Eff_{\text{EE}})] * HOURS$$

Where:

Variable	Description	Units	Value
CFM_{BASE}	Baseline CFM of compressed air use that is being shifted	cfm	User input
CFM_{COMP}	Maximum CFM of air compressor	cfm	User input, see Assumptions
HP_{COMP}	Horsepower of air compressor	hp	User input, see Assumptions
0.892	Compressor motor nominal hp to full load kW conversion factor[4]	hp to full load kW	0.892
HP_{EE}	Horsepower of the efficient technology, i.e., electric motor or blower	hp	User input
0.746	Conversion factor	kW/hp	0.746
Eff_{EE}	Motor efficiency of efficient technology	hp	NEMA Premium efficiency[4] for HP_{EE}
HOURS	Average annual run hours	Hrs/yr	User input

Summer Coincident Peak Savings Algorithm

$$kW_{SAVED} = [(CFM_{BASE} / (CFM_{COMP} / HP_{COMP}) * 0.892) - (HP_{EFF} * 0.746 / Eff_{EE})] * CF$$

Where:

CF = Coincidence factor (= 1.0)[5]

Lifecycle Energy-Savings Algorithm

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

Where:

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

Assumptions

If the air compressor hp and CFM are not known, use 4.55 CFM/HP[6] in place of CFM_{COMP} / HP_{COMP} in the kWh_{SAVED} equation.

Revision History

Version Number	Date	Description of Change
01	12/2021	Initial TRM entry
02	10/2022	Updated hp to kW coefficient based on Focus data

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[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.
Used EUL for NEMA Premium motor (similar to efficient technology).
https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

[2] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 16 projects from January 1, 2018 to November 30, 2021 = $330.94/hp shifted. Excludes two outlier projects with costs of $2.10/hp shifted and $2,646.81/hp shifted.

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[3] Zolkowski, Jerry. "Pneumatic vs. Electric Tool Calculations and Considerations", *Compressed Air Best Practices*. Accessed December 2021. www.airbestpractices.com/technology/pneumatics/pneumatic-vs-electric-tool-calculations-and-considerations

[4] Conversion factor based on a review of CAGI data sheets for 230 different air compressors. See "Air Compressor Conversion Factor Data.xlsx" for more information.

[5] U.S. 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. https://apps.dtic.mil/sti/pdfs/ADA419142.pdf

[6] U.S. Department of Energy, Office of Industrial Technologies. "Compressed Air Systems Fact Sheet #8: Packaged Compressor Efficiency Ratings." p. 2. April 1998. www.compressedairchallenge.org/data/sites/1/media/library/factsheets/factsheet08.pdf This reference shows 22 bhp/100acfm, making the inverse (cfm per hp) equal to 4.55 cfm/hp.

Compressed Air Storage

	Measure Details
Measure Master ID	Compressed Air Storage, Increase from ≤ 1 Gal/CFM to ≥ 3 Gal/CFM, 5444
Workpaper ID	W0303
Measure Unit	Per HP
Measure Type	Hybrid
Measure Group	Compressed Air, Vacuum Pumps
Measure Category	Other
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by horsepower
Peak Demand Reduction (kW)	Varies by horsepower
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by horsepower
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	$49.33[2]

Measure Description

Compressed air storage is necessary to address brief spikes in demand and to reduce cycling when fixed speed compressors are used. Due to a focus on first cost or gradual expansion of the compressed air system over time, some compressed air systems may not have optimimal amounts of storage available.

Description of Baseline Condition

The baseline for this measure is a load/no load or modulating with blowdown compressed air system with less than or equal to 1 gallon/CFM of storage. This provides a minimal amount of storage, but for highly variable compressed air usage profiles additional storage can provide additional energy savings and reduce compressor cycling.

Description of Efficient Condition

The efficient case is adding compressed air storage so that the system has 3 gallons/CFM of storage. The additional storage can be a combination of wet (before the dryer) and dry (after the dryer) storage.

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = HP * 0.892 * (LF_{\text{BASELINE}} - LF_{\text{EFFICIENT}}) * HOU$$

Where:

Variable	Description	Units	Value
HP	Horsepower of the air compressor	hp	User input
0.892	Compressor motor nominal hp to full load kW conversion factor[3]	hp to full load kW	0.892
$LF_{BASELINE}$	Average load factor of compressed air system with baseline amount of storage		See table below
$LF_{EFFICIENT}$	Average load factor of compressed air system with efficient amount of storage		See table below
HOU	Average annual run hours	Hrs/yr	User input, or 5,702 if unknown[4]

Average Compressor Load Factor

Control Type & Storage Level	Avg Load Factor (≤40 hp)[4]	Avg Load Factor (>40 hp)[4]
Modulating with Blowdown	0.890	0.863
Load/No Load with 1 gallon/CFM	0.909	0.887
Load/No Load with 3 gallon/CFM	0.831	0.811
Load/No Load with 4 gallon/CFM	0.812	0.792
Load/No Load with 5 gallon/CFM	0.806	0.786

Summer Coincident Peak Savings Algorithm

$$kW_{SAVED} = HP * 0.892 * (LF_{BASELINE} - LF_{EFFICIENT}) * CF$$

Where:

CF = Coincidence factor (= 1)[5]

Lifecycle Energy-Savings Algorithm

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

Where:

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

Revision History

Version Number	Date	Description of Change
01	09/2022	Initial TRM entry

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[1] Michigan Public Service Commission. Michigan Energy Measure Database. 2022. www.michigan.gov/mpsc/regulatory/ewr/michigan-energy-measures-database. Refer to "Compressed Air Storage Tank (≤1 gal/cfm baseline)" measure.
PA Consulting Group. Focus on Energy, Business Programs: Measure Life Study Final Report. Appendix B. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

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Michigan Energy Measure Database EUL = 25 years, PA Consulting Group Measure Life Study EUL = 15 years, so used midpoint of 20 years.

[2] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Of 112 VSD air compressor measures from 1/1/2021 to 6/30/2022, 20 of them also included compressed air storage tanks with itemized costs on the project invoice, for an average cost of $5.42/gal. Using a 2 gal/CFM improvement in storage (measure definition) and 4.55 CFM/hp (www.compressedairchallenge.org/data/sites/1/media/library/factsheets/factsheet04.pdf) results in a cost of $49.33/hp.

[3] Conversion factor based on a review of CAGI data sheets for 230 different air compressors. See "Air Compressor Conversion Factor Data.xlsx" for more information.

[4] Illinois Stakeholder Advisory Group. 2022 Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 10.0. Volume 3. Pgs. 711-714. www.ilsag.info/technical-reference-manual/il-statewide-technical-reference-manual-version-10-0/

[5] U.s. 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. https://apps.dtic.mil/sti/pdfs/ADA384166.pdf

Desiccant Compressed Air Dryer

	Measure Details
Measure Master ID	Desiccant Compressed Air Dryer: Heated, 5441 Blower Purge, 5442 Zero Purge, 5443
Workpaper ID	W0306
Measure Unit	Per CFM
Measure Type	Hybrid
Measure Group	Compressed Air
Measure Category	Dryer
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
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)	15[1]
Incremental Cost ($/unit)	$3/CFM (heated); $12/CFM (blower/zero purge)[2]

Measure Description

Compressed air is dried to reduce or eliminate condensation within the compressed air system. Refrigerated air dryers are used to dry air where a dew point of 35-40°F is required, while desiccant air dryers are typically used where dew points down to -40°F are required.

Desiccant dryers generally consist of two towers (or vertical tanks) filled with porous desiccant media. "Wet" compressed air flows through one tower, exiting as dried compressed air, while the other tower is regenerated (i.e., dried out). The dryer alternates this process between towers to prevent compressed air flowing through saturated towers and damaging downstream equipment. The means of regeneration distinguishes the different types of desiccant dryer.

- **Heatless desiccant dryer:** Uses compressed air ("purge air") to dry out the regenerating tower. The amount of purge air is typically between 15-20% of the dryer's rated capacity (CFM), regardless of the flow rate that the compressor is supplying.[3] This type of dryer alternates tower regeneration approximately every 5 minutes.[4]
- **Heated desiccant dryer:** Uses a combination of compressed purge air and heat for regeneration. The amount of purge air is typically 5-10% of the dryer's rate flow (CFM), regardless of the flow rate that the compressor is supplying.[5] This type of dryer alternates tower regeneration approximately every 8 hours.[4]
- **Externally heated blower purge dryer:** Uses an external blower and heat source for regeneration. This type of dryer requires a small amount (2%) of compressed purge air or ambient air to cool the tower after heating. This type of dryer alternates tower regeneration approximately every 8 hours.[4]

- **Zero purge dryer:** There is a variant of blower purge dryer called a zero purge dryer that eliminates all compressed purge air.

Standard dryers come equipped with a fixed, timer regeneration control. However, the actual load on the dryer is variable. Optional dew point demand controls (DPDC) adjust the amount of regeneration to the moisture load on the dryer, reducing unnecessary purge energy. This workpaper (W0306) is intended to be additive to the Dew Point Demand Controls (DPDCs) measure (W0022), should the efficient dryer be equipped with DPDCs.

Description of Baseline Condition

The baseline equipment is a heatless desiccant dryer without dew point demand controls.

Description of Efficient Condition

The efficient equipment is heated desiccant dryer or externally heated, blower purge desiccant dryer without dew point demand controls.

Annual Energy-Savings Algorithm[2]

$$kWh_{\text{SAVED}} = CFM_{\text{DRYER}} * ((PF_{\text{HEATLESS}} * Eff) - (PF_{\text{EE}} * Eff + kW_{\text{HEATER}} + kW_{\text{BLOWER}})) * Hours$$

Where:

Variable	Description	Units	Value
CFM_{DRYER}	Rated capacity of the dryer in cubic feet per minute	cfm	User input
$PF_{HEATLESS}$	Purge flow of heatless model	%	15%[2]
Eff	Efficiency of standard air compressor	kW/cfm	See table below[6]
PF_{EE}	Purge flow by type of efficient model	%	7.5% heated; 2% blower purge; 0% zero purge[3]
kW_{HEATER}	Average power of heater, kW	kW	0.007 for heated; 0.013 for blower/zero purge[2]
kW_{BLOWER}	Average power of blower, kW	kW	0 for heated; 0.003 for blower/zero purge[2]
Hours	Average annual run hours	Hrs/yr	User input; if unknown, use 5,702[2]

Efficiency per Air Compressor Type

Air Compressor Type	Eff (kW/CFM)
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

Summer Coincident Peak Savings Algorithm

$$kW_{\text{PEAK}} = kWh_{\text{SAVED}} \, / \, HOURS \, * \, CF$$

Where:

CF = Coincidence factor (= 1)[7]

Lifecycle Energy-Savings Algorithm

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

Where:

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

Revision History

Version Number	Date	Description of Change
01	11/2022	Initial TRM entry

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[1] Focus on Energy Evaluation Business Programs: Measure Life Study, p. 91-92. PA Consulting Group. August 25, 2009. https://s3.us-east-1.amazonaws.com/focusonenergy/staging/bpmeasurelifestudyfinal_evaluationreport.pdf

[2] The algorithm format is largely borrowed from the IL TRM, v11. Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 11.0.* Volume 2: Commercial & Industrial Measures. Measure 4.7.7 https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010123_v11.0_Vol_2_C_and_I_092222_FINAL.pdf, accessed October 25, 2022.

[3] Lessons Learned: Saving Energy Costs with Heated Blower Purge Desiccant Dryers. Marshall, Ron. https://www.airbestpractices.com/system-assessments/air-treatmentn2/lessons-learned-saving-energy-costs-heated-blower-desiccant-dry-0

[4] Regenerative Desiccant Compressed Air Dryers. White, Donald. https://www.airbestpractices.com/technology/air-treatmentn2/regenerative-desiccant-compressed-air-dryers

[5] Types of Compressed Air Dryers 2: Refrigerant and Regenerative Desiccant, Compressed Air and Gas Institute (CAGI). https://www.airbestpractices.com/technology/air-treatment/n2/types-compressed-air-dryers-refrigerant-and-regenerative-desiccant

[6] United States Department of Energy. Improving Compressed Air System Performance. Pages. 48- 49. https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/compressed_air_sourcebook.pdf

[7] Consistent with other compressed air measures. Army Corps of Engineers (Mike C.J. Lin, Ahmad R. Ganji, Shy-Sheng Liou, and Bryan Hackett). Compressed Air System Survey at Sierra Army Depot, CA. November 2000. https://apps.dtic.mil/sti/pdfs/ADA419142.pdf

DOMESTIC HOT WATER

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

	Measure Details
Measure Master ID	Water Heater, High Usage: ≥95% TE, K-12 School, Natural Gas, 5083 ≥90% TE, Natu1ral Gas, 3045 ≥90% TE, Indirect, Natural Gas, 5084 ≥90% TE, Tankless, Natural Gas, 4942 ≥2.0 COP, Heat Pump Storage, Electric, 4941
Workpaper ID	W0030
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)	Varies by measure, see EUL and Incremental Costs by Measure table
Incremental Cost ($/unit)	Varies by measure, see EUL and Incremental Costs by Measure table

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 resistance or natural gas storage water heater intended for service in a commercial or industrial building (as new DHW heaters are only installed when the existing unit has failed or has reached its end of life). The fuel type is the same as the water heater being replaced.

Water heaters defined as commercial have certain input capacities:[1]

- >75 MBh for storage natural gas
- >300 MBh for indirect natural gas
- >200 MBh for tankless natural gas
- ≥12 kW for electric resistance and heat pump with supplemental electric resistance heaters (hybrid)

Several efficiency ratings are assumed:

- Natural gas storage DHW heater: 80% thermal efficiency[2]
- Natural gas indirect DHW heater: 80% thermal efficiency[2]
- Natural gas tankless DHW heater: ≥80% thermal efficiency[2]
- Electric DHW heater: 0.95 COP[3]

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)
Fitness	Fitness Center	≥300	Sq Ft (≥3,000)
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	≥250	Students/Building (≥600)
Prisons	Housing	≥200	Housed Inmates (≥50)
Multifamily	Housing	≥300	Mutifamily Units (≥10)

Description of Efficient Condition

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

Qualifying Natural Gas Equipment

- ***95% Thermal Efficiency Condensing Natural Gas Storage Water Heaters (K-12 School)***
- ***90% Thermal Efficiency 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 (meaning 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.
- ***90% Thermal Efficiency Condensing Natural Gas Indirect Water Heaters:*** These operate similarly to natural gas storage water heaters but are heated by a separate hot water supply boiler and storage tank. This allows for different combinations of heat source capacity versus storage capacity and is often used to have the same heat source serve both space heating and water heating needs.

- ***90% Thermal Efficiency Condensing Natural Gas Tankless Water Heaters:*** To be able to heat water to 70°F or higher virtually instantaneously, most natural gas tankless water heaters have an input of 200,000 Btu/hour or higher. Their major advantage is having no standby heat losses, in which the heater fires whenever the water temperature drops below a set temperature. 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.

Qualifying Electric Equipment

- ***Minimum 2.0 COP Heat Pump Water Heaters***

Heat pump water heaters may have supplemental electric resistance heating elements (hybrid heat pump water heater).

Annual Energy-Savings Algorithm

For a new natural gas water heater replacing a natural gas water heater:

$$\text{Therms}_{\text{SAVED}} = \frac{GPY * 8.33 * C_P * (T_{OUT} - T_{IN}) * \left(\frac{1}{TE_{BASE}} - \frac{1}{TE_{EE}}\right) + (Q_{LOSS\text{-}BASE} - Q_{LOSS\text{-}EE}) * 24 * 365}{100{,}000}$$

Where:

Variable	Description	Units	Value
GPY	Gallons per year of DHW usage	Gallons/yr	Derived from days/year of operation and gallons/day shown in Average Daily Gallons by Facility Type table below
8.33	Density of water in pounds per gallon	Lbs/gallon	8.33
C_P	Specific heat of water	Btu/(lb * °F)	1.0
T_{OUT}	Water temperature leaving DHW heater	°F	User input, or 130°F as default[4]
T_{IN}	Water temperature entering DHW heater	°F	52.3°F[5]
TE_{BASE}	Thermal efficiency for baseline DHW heater	%	80%[2]
TE_{EE}	Thermal efficiency for efficient DHW heater	%	User input
$Q_{LOSS\text{-}BASE}$	Standby heat losses for baseline DHW heater	Btu/h	1,292 Btu/h for storage water heaters, $Q_{LOSS\text{-}INDIRECT}$ for indirect water heaters, 0 for tankless water heaters; see Assumptions
$Q_{LOSS\text{-}EE}$	Standby heat losses for efficient DHW heater	Btu/h	User input or if unknown 1,089 Btu/h for storage water heaters, $Q_{LOSS\text{-}INDIRECT}$ for indirect water heaters, 0 for tankless water heaters; see Assumptions
24	Number of hours per day	Hrs/day	24
365	Number of days per year	Days/yr	365
100,000	Conversion factor for Btu per therm	Btu/therm	100,000

For indirect water heaters:

$$Q_{\text{LOSS-BASE}} = Q_{LOSS-INDIRECT} = [(\pi * D * H) + (2 * \pi * D2 / 4)] / R * (T_{\text{OUT}} - T_{\text{ROOM}})$$

Where:

Variable	Description	Units	Value
D	Diameter of storage tank	Feet	User input
H	Height of storage tank	Feet	User input
R	R-value of tank insulation		12.5 for baseline, actual for efficient storage tank
T_{ROOM}	Ambient temperature surrounding tank	°F	75°F; see Assumptions

For a new heat pump water heater replacing electric resistance water heater:

$$kWh_{\text{SAVED}} = GPY * 8.33 * 1.0 * (T_{\text{OUT}} - Tj) * [1 / COP_{\text{BASE}} - (1 + ERF) / COP_{\text{EE}}] / 3{,}412$$

Where:

Variable	Description	Units	Value
COP_{BASE}	Coefficient of performance for baseline DHW heater		0.95[3]
ERF	Electric reistance fraction, or fraction of electrical energy of hybrid heat pump water heaters attributed to electric resistance heater	%	0% for heat pump water heaters without supplemental electric resistance heating elements (not hybrid), 14.6% for heat pump water heaters with supplemental electric resistance heating elements (hybrid); see Assumptions
COP_{EE}	Coefficient of performance for efficient DHW heater		User input
3,412	Conversion factor for Btu per kilowatt-hour	Btu/kWh	3,412

Average Daily Gallons by Facility Type

Facility Type	Average Daily Gallons	Source
Schools Elementary School Junior/Senior High School	0.6 gal/student 1.8 gal/student	ASHRAE HVAC Applications 2019, Chapter 51, Table 6[6]
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 2019, Chapter 51, Table 6[6]
Dormitories	12.7 per student	ASHRAE HVAC Applications 2019, Chapter 51, Table 6[6] (average of 13.1 for male dormitory and 12.3 for female dormitory)
Prison Housing	12.7 per housed inmate	ASHRAE HVAC Applications 2019, Chapter 51, Table 6[6] (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	Sacremento Municipal Utility District[7] (lists a range of 25 to 90 gallons per day per bed; this workpaper used 50, which is conservative of 57.5 midpoint)[7]

Facility Type	Average Daily Gallons	Source
Nursing Homes	18.4 per bed	ASHRAE HVAC Applications 2019, Chapter 51, Table 6[6]
Food Service Full Service Restaurant or Cafeteria Fast Food	2.4 per meal 350 per day	Full service and cafeteria: ASHRAE HVAC Applications 2019, Chapter 51, Table 6[6] Fast food: ASHRAE HVAC Applications 2019, Chapter 51, page 51.15 (lists range of 250 to 500, used 350 as under midpoint of the range)[6]
Supermarket	650 per day	ASHRAE HVAC Applications 2019, Chapter 51, page 51.15 (lists range of 300 to 1,000, used average of 650)[6]
Fitness Center	0.1387 per sq ft per day	Calculated using data from eQuest Schematic Design Wizard, including: 13.1 gal/person/day (per ASHRAE HVAC Applications 2019, Chapter 51, Table 6 for male dormitories), sq ft per person (80% of space at 50 sq ft per person, 15% of space at 100 sq ft per person, and 5% of space at 333.3 sq ft per person) and average occupancy % (60%) as defined in eQuest.[6]
Laundry	21 per wash	ASHRAE HVAC Applications 2019, Chapter 51, page 51.13, Table 3 (for low-flow clothes washer) [6]
Multifamily	34.14 per unit	Florida Solar Energy Center. *Estimating Daily Domestic Hot-Water Use in North American Homes.* June 30, 2015.[7] and U.S. Energy Information Administration. *Residential Energy Consumption Survey*. 2009.[8]

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for a natural gas water heater.

For a heat pump water heater:

$$kW_{\text{SAVED}} = CF * FUF * kW_{\text{BASE}} * [1 / COP_{\text{BASE}} - (1 + EF) / COP_{\text{EE}}]$$

Where:

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

FUF = Facility utilization factor, or ratio of facility usage at the time of utility peak system demand to the maximum facility usage as 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 set of typical FUF values shown in Coincidence Factors and Facility Utilization Factors table below)

kW_{BASE} = Power rating of the baseline DHW heater

Coincidence Factors and Facility Utilization Factors[9]

Facility Type	CF	FUF
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
Food Service	0.40	1.00
Apartment Houses	0.25	0.90
Supermarkets	0.15	1.00
Fitness Center**	0.25	1.00
Laundry	0.50	1.00

* Excludes restaurants, kitchens, and laundries.

** Matches dormitories

Lifecycle Energy-Savings Algorithm

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

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

Where:

EUL = Effective useful life (= See EUL and Incremental Costs by Measure table below)[10]

Assumptions

- For heat pump water heaters, the effect of room temperature on COP and on heating and cooling energy are assumed to be small and are neglected. Program history shows installations in commercial kitchens, where the year-round cooling was beneficial.
- The electric resistance factor was determined from a U.S. Department of Energy study on hybrid heat pump water heaters.[11] The study measured the percentage of the kilowatt-hour consumption that was attributed to the water heater's electric resistance heater instead of the heat pump. For three models across 14 units and sites, the average of the values (32.7%, 5.6%, and 5.5%) is 14.6%.
- The default standby heat loss values for the natural gas baseline storage water heaters were calculated using the formulas from the federal standard for commercial water heaters.[12]

  $$Q_{\text{LOSS-BASE}} = (Rated\ Btu\ /\ h\ Input)\ /\ 800\ +\ 110\ *\ \sqrt{}(Rated\ Gallons)$$

  Based on an 90-gallon water heater with 199,000 Btu/h input:

  $$Q_{\text{LOSS-BASE}} = 199{,}000\ /\ 800\ +\ 110\ *\ \sqrt{90}\ =\ 1{,}292\ Btu/h$$

- The default standby heat loss value for the efficient storage water heater is the average standby loss of AHRI-rated commercial water heaters[13] with 80 to 100 gallon storage tanks, a thermal efficiency of at least 90%, and heating capacities less than or equal to 300 MBh. Based on data available in October 2019, there are 153 water heaters that meet the above criteria. However, 26 of those water heaters have a very low standby loss (<700 Btu/hr) compared to what Focus on Energy historical data has observed on actual projects (typically around 1,000 Btu/hr). Therefore, water heaters with a 700 Btu/hr or less standby loss were excluded, leaving 127 water heaters with an average standby loss of 1,089 Btu/hr.
- To determine the standby heat loss for the baseline storage water heater, 90 gallons was used as the storage capacity (midpoint of the 80 to 100 gallon range used for the efficient water heater) and 199 MBh was used as the heating capacity (data for efficient water heater standby loss was limited to a heating capacity of 300 MBh, and the minimum size in the AHRI data was about 100 MBh).
- Indirect water heater storage tanks are required to have R-12.5 insulation.[1] The heat loss in Btus per hour is calculated based on known or estimated storage tank dimensions and applying a U * A * ΔT heat loss formula with R-12.5 insulation for the baseline and actual insulation for the proposed. When calculating the heat loss, the average annual mechanical room temperature where the storage tank is located was assumed to be 75°F. Residential water heater MMID 4271 uses 65°F, but assumes the water heater is in a semi-conditioned space like a basement: this workpaper uses 75°F for commercial settings where the water heater is likely to be located in a warm mechanical room.

EUL and Incremental Costs by Measure

Measure	MMID	EUL[1]	Incremental Cost
≥95% TE, K-12 School, Natural Gas	5083	10	$1,660.25[14]
≥90% TE, Natural Gas	3045	10	$1,176.21[15]
≥90% TE, Indirect, Natural Gas	5084	25	$988.50[16]
≥90% TE, Tankless, Natural Gas	4942	17	$605.00[17]
≥2.0 COP, Heat Pump Storage, Electric	4941	12	$2,253.00[18]

Revision History

Version Number	Date	Description of Change
01	01/2013	Revised measure
02	11/2014	Added building categories
03	09/2015	Added categories for K-12 schools and prisons
04	12/2015	Updated incremental cost data
05	10/2017	Updated EUL for MMIDs 3045 and 3046
06	10/2017	Updated EUL for MMID 3047
07	05/2018	Updated based on Potential Study data
08	12/2018	Updated costs for MMIDs 3045 and 3047
09	10/2019	Added factor for hybrid heat pump water heaters and changed efficiency units and EUL for MMID 3046
10	12/2019	Add multifamily eligibility and retired MMID 2760 for only multifamily properties
11	02/2020	Revised baseline COP
12	09/2020	Removed MMID 3684 for K-12 schools, added indirect natural gas water heater
13	11/2021	Add fitness centers as an eligible building type
14	07/2022	Updated EUL

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[1] Code of Federal Regulations, Title 10, Chapter II, Subchapter D, Part 431, Subpart G. "Commercial Water Heaters, Hot Water Supply Boilers and Unfired Hot Water Storage Tanks." https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=cc520035f63ecd64fbaec49dadb361de&mc=true&n=sp10.3.431.g&r=SUBPART&ty=HTML

[2] International Code Council. *2015 International Energy Conservation Code.* Table C404.2. https://codes.iccsafe.org/content/IECC2015/chapter-4-ce-commercial-energy-efficiency?site_type=public

[3] National Institute of Standards and Technology. U.S. Department of Commerce. "An Assessment of Efficient Water Heating Options for an All-Electric Single Family Residence in a Mixed-Humid Climate." Energy and Buildings. Version 133 (2016) 371-380. www.nist.gov/publications/assessment-efficient-water-heating-options-all-electric-single-family-residence-mixed

[4] Cadmus. *2016 Potential Study for Focus on Energy.* Data maintained by Cadmus and Wisconsin Public Service Commission. Average water heater setpoint recorded at 132 school, office, restaurant, and retail sites.

[5] 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.

[6] American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc. *ASHRAE Handbook, HVAC Applications.* Chapter 51 "Service Water Heating." 2019.

[7] Sacramento Municipal Utility District. "Energy Library / Facility Types / Healthcare / Hospitals." Accessed November 12, 2014. http://smud.apogee.net/comsuite/content/ces/?id=971

[8] U.S. Energy Information Administration. *Residential Energy Consumption Survey*. 2009. https://www.eia.gov/consumption/residential/index.php

[9] Coincidence factors and facility use factors were developed by seeking consensus among seven engineers who have experience performing energy audits in commercial and industrial facilities.

[10] U.S. Department of Energy. Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment. p. 299; 8-22. https://downloads.regulations.gov/EERE-2014-BT-STD-0042-0016/attachment_1.pdf

[11] U.S. Department of Energy. "Field Performance of Heat Pump Water Heaters in the Northeast." October 2019. p. 3. Table 5. https://www.nrel.gov/docs/fy16osti/64904.pdf

[12] Code of Federal Regulations, Title 10, Chapter II, Subchapter D, Part 431, Subpart G. "Commercial Water Heaters, Hot Water Supply Boilers and Unfired Hot Water Storage Tanks." Section 431.110. https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=cc520035f63ecd64fbaec49dadb361de&mc=true&n=sp10.3.431.g&r=SUBPART&ty=HTML

[13] Air-Conditioning, Heating & Refrigeration Institute. Accessed October 2019. www.ahridirectory.org

[14] Wisconsin Focus on Energy historical project data for MMID 3684 obtained from SPECTRUM. Average cost of 61 water heaters ≥95% TE in over 31 projects from January 2018 to September 2020 was $10,185.59. 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

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MBh for baseline and efficient models. This fit was applied to the spread of water heater sizes in Focus on Energy program data, revealing an efficient cost that was 16.3% higher than the baseline cost. Therefore, the incremental cost is 16.3% * $10,185.59 = $1,660.25.

[15] Wisconsin Focus on Energy historical project data for MMID 3045 obtained from SPECTRUM. Average cost of 179 water heaters over 93 projects from 2016 to 2018 was $7,230.27. 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 spread of water heater sizes in Focus on Energy program data, revealing an efficient cost that was 16.3% higher than the baseline cost. Therefore, the incremental cost is 16.3% * $7,230.27 = $1,176.58.

[16] Opinion Dynamics. *New York Statewide Residential Gas High Efficiency Heating Equipment Programs: Evaluation of 2009-2011 Programs.* August 5, 2014. Average of mean and median costs using both approaches, Table 1-4. https://www.fuelingtomorrowtoday.com/wp-content/uploads/2018/03/August-2014-New-York-Statewide-Residential-Gas-High-Efficiency-Heating-Equipment-and-National-Fuel-Gas-Distribution-Corporations-Residential-Rebate-Program-Impact-Evaluation.pdf

[17] *Ohio Technical Reference Manual.* p. 123. 2010. https://docplayer.net/15339585-State-of-ohio-energy-efficiency-technical-reference-manual.html
Tankless DHW EF >0.82 incremental cost is $605.00 per water heater.

[18] 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

Natural Gas Storage Water Heater

	Measure Details
Measure Master ID	Water Heater, NG, ≤55 gal, UEF of 0.68 or Greater, 4943
Workpaper ID	W0250
Measure Unit	Per water heater
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Water Heater
Sector(s)	Commercial, Industrial, Schools & Government, 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 (years)	13[1]
Incremental Cost ($/unit)	$400.00[2]

Measure Description

This measure is residential-sized (55 gallons or smaller) tank-type storage domestic water heaters, defined as equipment with an input rating ≤75,000 Btuh and a storage volume from 20 gallons to 50 gallons. The measure is an upgrade from a water heater with a minimum allowed UEF to 0.68 UEF or greater.

Description of Baseline Condition

The base case is a natural gas–fueled residential-duty commercial storage water heater with a 0.58 UEF (see the Assumptions section for more details).

Description of Efficient Condition

The efficient condition is a natural gas–fueled residential-duty commercial storage water heater that is 55 gallons or smaller with a ≥0.68 UEF.

Annual Energy-Savings Algorithm

$$Therm_{\text{SAVED}} = [(GPD * 365 * 8.33 * C_{\text{P,WATER}} * \Delta Tw) / 100{,}000] * [(1 / UEF_{\text{BASE}}) - (1 / UEF_{\text{EE}})]$$

Where:

Variable	Description	Units	Value
GPD	Average daily hot water consumption	Gallons/day	55 gallons/day for business,[3] 34.14 gallons/day for multifamily[4,5]
365	Days per year	Days/yr	365
8.33	Specific heat of water	Lbs/gallon	8.33
$C_{P,WATER}$	Specific heat of water	Btu/lb °F	1
ΔT_w	Difference between the average cold water inlet temperature and the hot water delivery temperature (= T_{OUT} - T_{IN})	°F	T_{IN} = Average cold water inlet temperature (52.3°F)[6] T_{OUT} = Hot water delivery temperature (130°F for business,[7] 125°F for multifamily[8])
100,000	Conversion factor	Btu/therm	100,000
UEF_{BASE}	Energy factor of baseline water heater		0.58; see Assumptions
UEF_{EE}	Energy factor of efficient water heater		0.68; see Assumptions[9]

Summer Coincident Peak Savings Algorithm

Natural gas–fired storage water heaters consume no electrical energy, aside from a combustion air fan; therefore, they have a negligible impact on demand reduction.

Lifecycle Energy-Savings Algorithm

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

Where:

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

Deemed Savings

Deemed Natural Gas Savings

Measure	MMID	Sector	Annual Therms	Lifecycle Therms
Water Heater, NG, ≤55 gal, UEF of 0.68 or Greater	4943	Multifamily	19	247
		Commercial, Industrial, School and Government	33	429

Assumptions

- Based on data of available products and as defined in the federal standard,[10] water heaters are assumed to have a medium or high draw pattern. Reviewing water heater models with a tank size ≤55 gallons in the AHRI database[11] shows 12 low-use models, 435 medium-use models, and 583 high-use models. It also shows a majority of units between 40 gallons and 50 gallons. For simplicity and to match with the previously available measure, the UEF for the high draw pattern

(0.68) was selected as the efficient condition (which is slightly higher than the medium draw pattern requirement of 0.64 UEF). However, to be conservative, the 24-hour water usage for the medium draw pattern test was used for business sectors.

- The baseline efficiency was derived from federal standard for water heaters[10] and generally follows the form UEF = 0.6597 – (0.0009 * V), where V is the tank size volume. Several sets of coefficients exist across water heater types, tank size ranges, and draw patterns, as shown in the Baseline UEF Values table below. Therefore, for the baseline UEF, a value of 0.58—which is the average for medium and high draw for 50 gallons—was chosen. This reflects an average of 40 gallons to 50 gallons, with medium- and high-draw pattern values.

Baseline UEF Values

Tank Size	Fuel	Draw Pattern	UEF Formula	UEF Value for Tank Size (Gallons)			
				30	40	50	55
≥20 gallons and ≤55 gallons	Natural gas	Very Small	0.2674 – (0.0009 * V)	0.2404	0.2314	0.2224	0.2179
		Low	0.5362 – (0.0012 * V)	0.5002	0.4882	0.4762	0.4702
		Medium	0.6002 – (0.0011 * V)	0.5672	0.5562	0.5452	0.5397
		High	0.6597 – (0.0009 * V)	0.6327	0.6237	0.6147	0.6102

The gallons per day for multifamily use was calculated by fitting a polynomial equation to data from Table 3 of the Florida Solar Energy Center study.[4] An average value of 1.9 occupants per home was used for Wisconsin, based on 2009 RECS 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.

Revision History

Version Number	Date	Description of Change
01	12/2019	Initial TRM entry
02	02/2020	Added to TRM

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[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. *Water Heater Test Procedure Rulemaking: Development Testing Preliminary Report Energy Conservation Program for Consumer Products and Certain Industrial Equipment: Residential and Light Commercial Water Heaters.* November 2013. p. 10. Table 3. High Draw Pattern. https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/water_heater_test_report_111413.pdf

[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. Energy Information Administration. *Residential Energy Consumption Survey*. 2009. https://www.eia.gov/consumption/residential/index.php

[6] United States Department of Energy. *DHW Scheduler*.
Average water main temperature for all Wisconsin locations as measured by scheduler and weighted by city population.

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[7] Cadmus. *2016 Potential Study for Focus on Energy.* Data maintained by Cadmus and Wisconsin PSC. Average water heater setpoint recorded at 132°F for uses in schools, offices, restaurants, and retail sites.

[8] 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 leads 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 those are using unsourced engineering assumptions.

[9] *ENERGY STAR Program Requirements for Residential Water Heaters.* Appendix A. Table 2. https://www.energystar.gov/sites/default/files/Water%20Heaters%20Final%20Version%203.2_Program%20Requirements_0.pdf

[10] Federal standard for water heaters. *2016-12-29 Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters; Final Rule.* https://www.regulations.gov/document?D=EERE-2015-bt-tp-0007-0042

[11] Air-Conditioning, Heating, & Refrigeration Institute. *AHRI Directory of Certified Product Performance*. Accessed December 2019. https://www.ahridirectory.org/Search/SearchHome

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
Workpaper ID	W0032
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

$$kWh_{\text{SAVED}} = Gallons_{\text{SAVED}} * ((8.33 * C * (T_{\text{POU}} - T_{\text{ENTERING}}) * WFS_{\text{ELEC}} / (EF_{\text{ELEC}} * 3{,}412)) + (kWh_{\text{WATER}} / 1{,}000))$$

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

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

Where:

Variable	Description	Units	Value
$\text{Gallons}_{\text{SAVED}}$	First-year water savings	Gallons	
8.33	Density of water	Lbs/gal	8.33
C	Specific heat of water	Btu/lb °F	1.0
T_{POU}	Temperature of water at point of use	°F	86°F for bathrooms,[5] 93°F for office and retail kitchens,[6] 101°F for restaurant kitchens;[7] see Assumptions
$\text{T}_{\text{ENTERING}}$	Temperature of water entering water heater	°F	52.3°F[8]
WFS_{ELEC}	Assumed fraction of participating sites with electric hot water	%	60%[9]
EF_{ELEC}	Energy factor of electric water heater	%	93%[10]
3,412	Conversion factor	Btu/kWh	3,412
$\text{kWh}_{\text{WATER}}$	Energy saved from water and wastewater utilities	kWh/kgal	3.89 kWh/kgal[11]
1,000	Conversion factor	Gal/kgal	1,000
EF_{GAS}	Energy factor of natural gas water heater	%	77%[9]
100,000	Conversion factor	Btu/therm	100,000
WFS_{GAS}	Assumed fraction of participating sites with natural gas hot water	%	40%[8]
$\text{GPM}_{\text{EXISTING}}$	Baseline flow rate	gpm	2.2 gpm[3]
GPM_{NEW}	Efficient flow rate	gpm	1.5 gpm for kitchens, 1.0 gpm for bathrooms[4]
Usage	Estimated usage of mixed water	Gal/yr	2,500 gallons/year for small office, 3,650 gallons/year for retail, 12,675 gallons/year for restaurants; see Assumptions[11]
ISR	In-service rate	%	Varies, see table below

Aerator In-Service Rates

Facility Type	In-Service Rate[12]	
	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

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

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

Where:

EUL = Effective useful life (= 10 years)[11]

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	32	320	0.82	8.2
	Kitchen	4688	310	3,100	21	210	0.55	5.5
Restaurants	Bathroom	4691	5,634	56,340	321	3,210	8.22	82.2
	Kitchen	4689	3,287	32,870	265	2,650	6.93	69.3
Retail	Bathroom	4692	1,374	13,740	78	780	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.[6] 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.[7]
- For restaurant usage, a 50/50 average of sit-down and fast food values, from the Illinois TRM,[11] is used (the average of 9,581 and 15,768 is 12,675).

Revision History

Version Number	Date	Description of Change
01	03/2018	Initial TRM entry
02	06/2022	Added annual energy savings from water and WWTP utilities
03	10/2023	Updated energy saved from water and waste water utilities

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[1] Navigant. “ComEd Effective Useful Life Research Report.”May 2018. https://www.icc.illinois.gov/docket/P2017-0312/documents/287811/files/501915.pdf

[2] Resource Action Programs. Quote for Focus on Energy program. March 2018.

[3] Alliance Water Efficiency. *National Efficiency Standards and Specifications for Residential and Commercial Water-Using Fixtures and Appliances*. August 2011. https://www.nwf.org/~/media/PDFs/Eco-schools/matrix508.ashx

[4] AM Conservation Website. Accessed August 10, 2022. Kitchen aerator: https://amconservationgroup.canto.com/v/AMConservationClientPortal/library?keyword=N3115P&viewIndex=2&column=document&id=5brqi67oah0gp5epqfm7igun2e
Bathroom Aerator: https://amconservationgroup.canto.com/v/AMConservationClientPortal/library?keyword=N3210B-PC&viewIndex=2&column=document&id=b0lbrqb9e50531u94ng4irvo2u

[5] Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 6.0, Volume 2*. Estimated Water Usage Per Building Type, p. 92. February 8, 2017.

[6] Cadmus. “Showerhead and Faucet Aerator Meter Study.” Memo to Michigan Evaluation Working Group. June 2013.

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[7] SBW Consulting. *Impact and Process Evaluation Final Report for California Urban Water Conservation Council 2004-5 Pre-Rinse Spray Valve Installation Program (Phase2)*. Table 3-5. February 21, 2007. https://p2infohouse.org/ref/50/49026.pdf

[8] National Renewable Energy Laboratory. "Tool for Generating Realistic Residential Hot Water Event Schedules ." https://www.nrel.gov/docs/fy10osti/47685.pdf Average water main temperature of all locations measured in Wisconsin by scheduler, weighted by city populations.

[9] Cadmus. *Focus on Energy 2016 Energy Efficiency Potential Study*. Prepared for Public Service Commission of Wisconsin. Appendix A – Baseline Data, Tables A-5 and A-7, average of values for Restaurant, Small Retail, and Small Office Segments. https://focusonenergy.com/sites/default/files/Focus%20Potential%20Study%20Appendices_0_0.pdf

[10] 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 revealed an average of 93% electric water heater efficiency (101 sites) and 77% natural gas water heater efficiency (98 sites).

[11] Water-Related Energy Savings using updated CMAR (2016-2020) and WI Water Utility databases (2015-2022). A weighted average was used for the calculation of the water energy savings factor for groundwater/surface water, and for facilities with 0-1 MGD/ >1 MGD. Calculations and data provided in Huddle folder of this workpaper.

[12] Navigant. *ComEd Rural Small Business Energy Efficiency Kits IPA Program Impact Evaluation Report*. August 1, 2018. Tables 7-3 and 7-4. https://www.ilsag.info/wp-content/uploads/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

FOOD SERVICE

Salamander Broiler, Infrared

	Measure Details
Measure Master ID	Salamander Broiler, Infrared, Nautral Gas, Per input MBh, 4359
Workpaper ID	W0033
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

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

Where:

Variable	Description	Units	Value
MBh_{INPUT}	Input capacity in MBh of efficient salamander broiler	MBh	Actual capacity of efficient salamander broiler
EffRatio	Ratio of radiant to infrared broiler efficiency	%	75%, see Assumptions
DC	Duty cycle	%	70%[3]
HOU	Annual hours of use based on eight hours/day, six days/week, 52 weeks/year	Hrs/yr	2,496 hours[3]
100	Conversion factor	MBtu/therm	100

Lifecycle Energy-Savings Algorithm

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

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,[4] 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."

Revision History

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

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[1] California Energy Commission and California Public Utilities Commission. *Database for Energy Efficient Resources*. 2014. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx Consistent with other food service equipment lifetimes.

[2] 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

[3] Food Service Technology Center. "Commercial Cooking Appliance Technology Assessment." FSTC Report 5011.02.26. 2002. Table 4-3, p. 4-16. https://fishnick.com/equipment/techassessment/Appliance_Tech_Assessment.pdf

[4] Missouri Technical Reference Manual, Volume 2: Commercial and Industrial Measures. 2017. p. 63-64. https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdf

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[5] Food Service Technology Center. “Gas Broiler Life-Cycle Cost Calculator.” https://fishnick.com/saveenergy/tools/calculators/gbroilercalc.php

[6] Arnold, David. “Hotter than Hell.” *Food Arts Magazine*. June 2005. http://www.foodarts.com/tools/kitchen-features/706/hotter-than-hell

Dishwasher, ENERGY STAR Commercial

	Measure Details
Measure Master ID	Dishwasher: Low Temp: Door Type, ENERGY STAR, 2280 (Electric) and 2293 (Natural Gas) Multi Tank Conveyor, ENERGY STAR, 2294 (Electric), 2295 (Natural Gas) Single Tank Conveyor, ENERGY STAR, 2296 (Electric), 2297 (Natural Gas) Under Counter, ENERGY STAR, 2298 (Electric) and 2299 (Natural Gas) High Temp, Electric Booster: Door Type, ENERGY STAR, 2281 (Electric) and 2282 (Natural Gas) Multi Tank Conveyor, ENERGY STAR, 2283 (Electric) and 2284 (Natural Gas) Single Tank Conveyor, ENERGY STAR, 2285 (Electric) and 2286 (Natural Gas) Under Counter, ENERGY STAR, 2287 (Electric) and 2288 (Natural Gas) Pots/Pans Type, ENERGY STAR, 3136 (Electric) and 3137 (Natural Gas) High Temp, Natural Gas Booster: Door Type, ENERGY STAR, 2289 (Natural Gas) Multi Tank Conveyor, ENERGY STAR, 2290 (Natural Gas) Single Tank Conveyor, ENERGY STAR, 2291 (Natural Gas) Under Counter, ENERGY STAR, 2292, (Natural Gas) Pots/Pans Type, ENERGY STAR, 3138, (Natural Gas)
Workpaper ID	W0034
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, volume of water consumed per rack, and washing energy 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 v3.0 *Requirements for Commercial Dishwashers*.[4]

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = \Delta kWh_{\text{WH}} + \Delta kWh_{\text{BH}} + \Delta kWh_{\text{IDLE}} + \Delta kWh_{\text{WASH}} + \Delta kWh_{\text{WATER}}$$

$$Therm_{\text{SAVED}} = \Delta Therms_{\text{WH}} + \Delta Therms_{\text{BH}}$$

$$Gallons_{\text{SAVED}} = GPY_{\text{BASE}} - GPY_{\text{EE}}$$

Energy-Savings Algorithms by Fuel and Machine Type

Fuel Type	Machine Type	Algorithm
Electric	Water Heater	ΔkWh/yr$_{\text{WH}}$ = Gallons$_{\text{SAVED}}$* kWh/gallon$_{\text{WH}}$
	Booster Heater	ΔkWh/yr$_{\text{BH}}$ = Gallons$_{\text{SAVED}}$ * kWh/gallon$_{\text{BH}}$
Natural Gas	Water Heater	ΔTherms/yr$_{\text{WH}}$ = Gallons$_{\text{SAVED}}$ * Therms/gallon$_{\text{WH}}$
	Booster Heater	ΔTherms/yr$_{\text{BH}}$ = Gallons$_{\text{SAVED}}$ * Therms/gallon$_{\text{BH}}$

Energy Usage by Fuel and Machine Type

Fuel Type	Machine Type	Energy Use
Electric	Water Heater	kWh/gallon$_{\text{WH}}$ = ΔT$_{\text{WH}}$ * C$_{\text{WATER}}$ * ρ_{WATER} / η_{ELECTRIC} / 3,412
	Booster Heater	kWh/gallon$_{\text{BH}}$ = ΔT$_{\text{BH}}$ * C$_{\text{WATER}}$ * ρ_{WATER} / η_{ELECTRIC} / 3,412
Natural Gas	Water Heater	Therms/gallon$_{\text{WH}}$ = ΔT$_{\text{WH}}$ * C$_{\text{WATER}}$ * ρ_{WATER} / η_{GAS} / 100,000
	Booster Heater	Therms/gallon$_{\text{BH}}$ = ΔT$_{\text{BH}}$ * C$_{\text{WATER}}$ * ρ_{WATER} / η_{GAS} / 100,000

Where:

Variable	Description	Units	Value
ΔT_{WH}	Temperature rise delivered by water heater	°F	70°F[2]
C_{WATER}	Specific heat of water	Btu/lb-°F	1.0
ρ_{WATER}	Density of water	lbs/gal	8.33
$\eta_{ELECTRIC}$	Electric conversion efficiency	%	98%[5]
3,412	Conversion factor	Btu/kWh	3,412
ΔT_{BH}	Temperature rise delivered by booster heater	°F	40°F[2]
η_{GAS}	Natural gas conversion efficiency	%	76%[5]
100,000	Conversion factor, Btu/therm	Btu/therm	100,000

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

$$\Delta kWh_{WASH} = (WE_{BASE} - WE_{EE}) * RD * DY$$

Where:

Variable	Description	Units	Value
WE_{BASE}	Baseline washing energy, kWh/rack	kWh/rack	See table below; see Assumptions[2]
WE_{EE}	Efficient washing energy, kWh/rack	kWh/rack	See table below[3]
RD	Number of racks of dishes washed each day	Racks/day	See table below[2]
DY	Days per year of dishwasher operation	Days/yr	365[2]

$$\Delta kWh_{WATER} = (GPY_{BASE} - GPY_{EE}) * kWh_{WATER} / 1{,}000$$

$$GPY_{BASE} = GPR_{BASE} * DY * RD$$

$$GPY_{EE} = GPR_{EE} * DY * RD$$

Where:

Variable	Description	Units	Value
$kW_{BASE\ IDLE}$	Baseline consumption when on but not in wash cycle	kW	See table below[2]
HD	Hours per day of dishwasher operation	Hrs/day	18[2]
WT_{BASE}	Wash time, min/cycle	Min/cycle	See table below[2]
60	Conversion factor, min/hr	Min/hr	60
$kW_{EE\ IDLE}$	Efficient equipment consumption when on but not in wash cycle	kW	See table below[3]
WT_{EE}	Wash time efficient equipment		See table below
kWh_{WATER}	Energy saved from water and wastewater utilities	kWh/kgal	3.89[6]
1,000	Conversion factor, gal/kgal	Gal/kgal	1,000
GPR_{BASE}	Gallons per rack of baseline equipment	Gal/rack	See table below[2]
GPR_{EE}	Gallons per rack of ENERGY STAR equipment	Gal/rack	See table below[3]

Variable Values by Measure Type

Measure Type	GPR_{BASE}	GPR_{EE}	$kW_{BASE\ IDLE}$	$kW_{EE\ IDLE}$	WT_{BASE}	WT_{EE}	WE_{BASE}	WE_{EE}	RD
Low Temperature									
Under Counter	1.73	1.19	0.50	0.25	2.0	2.0	0.21	0.15	75
Stationary Single-Tank Door	2.10	1.18	0.60	0.30	1.5	1.5	0.21	0.15	280
Single-Tank Conveyor	1.31	0.79	1.60	0.85	0.3	0.3	0.224	0.16	400
Multiple Tank Conveyor	1.04	0.54	2.00	1.00	0.3	0.3	0.308	0.22	600
High Temperature									
Under Counter	1.09	0.86	0.76	0.30	2.0	2.0	0.49	0.35	75
Stationary Single-Tank Door	1.29	0.89	0.87	0.55	1.0	1.0	0.49	0.35	280
Single-Tank Conveyor	0.87	0.70	1.93	1.20	0.3	0.3	0.77	0.55	400
Multiple Tank Conveyor	0.97	0.54	2.59	1.85	0.2	0.2	0.504	0.36	600
Pot, Pan, and Utensil	0.70	0.58	1.20	0.90	3.0	3.0	0.504	0.36	280

Summer Coincident Peak Savings Algorithm

$$kW_{SAVED} = (kWh_{SAVED} * CF) / (DY * HD)$$

Where:

kWh_{SAVED} = Total kWh saved per year, as calculated above

CF = Coincidence factor (= 0.32, see Assumptions)[7]

Lifecycle Energy-Savings Algorithm

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

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

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

Where:

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

Deemed Savings

Savings with Electric Water Heater

Measure Type	MMIDs	Baseline		ENERGY STAR		Savings		
		kWh	Therms	kWh	Therms	kWh	Therms	kW
Low Temperature								
Under Counter	2298	17,020	-	11,328	-	5,692	0	0.2772
Stationary Single-Tank Door	2280	62,132	-	38,034	-	24,099	0	1.1738
Single-Tank Conveyor	2296	76,145	-	48,886	-	27,259	0	1.3277
Multitank Conveyor	2294	119,006	-	74,738	-	44,268	0	2.1561
High Temperature (with electric booster heater)								
Under Counter	2287	23,033	-	15,476	-	7,557	0	0.3681
Stationary Single-Tank Door	2281	77,815	-	54,662	-	23,153	0	1.1277
Pot, Pan, and Utensil	3136	98,719	-	72,231	-	26,488	0	1.2901
Single-Tank Conveyor	2285	107,500	-	77,788	-	29,712	0	1.4472
Multitank Conveyor	2283	163,372	-	110,727	-	52,646	0	2.5642

Savings with Natural Gas Water Heater

Measure Type	MMIDs	Baseline		ENERGY STAR		Savings		
		kWh	Therms	kWh	Therms	kWh	Therms	kW
Low Temperature								
Under Counter	2299	8,762	363	5,647	250	3,114	113	0.1517
Stationary Single-Tank Door	2293	24,706	1,647	17,004	925	7,702	721	0.3751
Single-Tank Conveyor	2297	42,792	1,467	28,773	885	14,019	582	0.6828
Multitank Conveyor	2295	79,288	1,747	54,115	907	25,173	840	1.2261
High Temperature (with electric booster heater)								
Under Counter	2288	20,803	229	11,997	181	8,805	48	0.4289
Stationary Single-Tank Door	2282	67,962	1,012	42,874	698	25,088	314	1.2220
Pot, Pan, and Utensil	3137	93,372	549	63,116	455	30,256	94	1.4737
Single-Tank Conveyor	2286	98,007	975	62,439	784	35,568	190	1.7324
Multitank Conveyor	2284	147,496	1,630	99,488	907	48,008	723	2.3383
High Temperature (with natural gas booster heater)								
Under Counter	2292	17,830	360	11,370	284	6,459	76	0.3146
Stationary Single-Tank Door	2289	54,825	1,590	38,800	1,097	16,024	493	0.7805
Pot, Pan, and Utensil	3138	86,243	863	61,894	715	24,349	148	1.1860
Single-Tank Conveyor	2291	85,349	1,531	59,966	1,232	25,384	299	1.2363
Multitank Conveyor	2290	126,328	2,561	90,104	1,426	36,224	1,135	1.7643

Annual Water Savings

Measure Type	MMIDs	Baseline (Gallons/yr)	ENERGY STAR (Gallons/yr)	Savings (Gallons/yr)
Low Temperature				
Under Counter	2298, 2299	47,359	32,576	14,783
Stationary Single-Tank Door	2280, 2293	214,620	120,596	94,024
Single-Tank Conveyor	2296, 2297	191,260	115,340	75,920
Multitank Conveyor	2294, 2295	227,760	118,260	109,500
High Temperature				
Under Counter	2287, 2288, 2292	29,839	23,543	6,296
Stationary Single-Tank Door	2281, 2282, 2289	131,838	90,958	40,880
Pot, Pan, and Utensil	3136, 3137, 3138	71,540	59,276	12,264
Single-Tank Conveyor	2285, 2286, 2291	127,020	102,200	24,820
Multitank Conveyor	2283, 2284, 2290	212,430	118,260	94,170

Assumptions

- The coincidence factor comes from estimates found in a 1985 research paper.[7] Coincidence factors derived from this paper are used for ovens in the Minnesota TRM[8] and applied to dishwashers in the Illinois TRM.[9] They vary based on building type, ranging from 0.32 to 0.51. A conservative value of 0.32 is used here.
- While the efficient washing energy (WE_{EE}) is specified by ENERGY STAR requirements, the baseline washing energy (WE_{BASE}) has not yet been estimated by ENERGY STAR in an updated food service calculation tool. To estimate WE_{BASE}, the WE_{EE} is multiplied by 140% based on ENERGY STAR claims that qualified units are 40% more efficient than non-ENERGY STAR units.[10]

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	01/2019	Removed MMIDs 2295, 2297, 3139, and 3140
03	02/2020	Altered demand savings, removed deactivated MMIDs, added previously missing MMIDs
04	06/2022	Added annual energy savings from water and WWTP utilities, updated EE baseline referencing v3 specifications
05	10/2023	Updated water-energy factor

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[1] PA Consulting Group. *Focus on Energy, 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. "ENERGY STAR Commercial Kitchens Calculator." www.energystar.gov.

[3] United State Environmental Protection Agency, Food Service Technology Center. http://www.fishnick.com/

[4] ENERGY STAR. Program Requirements for Commercial Dishwashers. Version 3.0. https://www.energystar.gov/sites/default/files/Commercial%20Dishwashers%20Final%20Version%203.0%20Specification.pdf

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[5] Air Conditioning, Heating, and Refrigeration Institute. RWH research. Most common RE for non-heat pump water heaters: http://www.ahridirectory.org/ahridirectory/pages/rwh/defaultSearch.aspx

[6] Water-Related Energy Savings using updated CMAR (2016-2020) and WI Water Utility databases (2015-2022). A weighted average was used for the calculation of the water energy savings factor for groundwater/surface water, and for facilities with 0-1 MGD/ >1 MGD. Calculations and data provided in Huddle folder of this workpaper.

[7] Claar, et al. "Project on Restaurant Energy Performance-End-Use Monitoring and Analysis", Appendixes I and II. May 1985. https://digital.library.unt.edu/ark:/67531/metadc1093753/m1/.

[8] Minnesota Department of Commerce Division of Energy Resources. *State of Minnesota Technical Reference Manual for Energy Conservation Improvement Programs*. Version 3.0. January 10, 2019. Page 465. http://mn.gov/commerce-stat/pdfs/mn-trm-v3.0.pdf

[9] Illinois Stakeholder Advisory Group. *2019 Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 7*.0. Volume 3. Page 38. https://s3.amazonaws.com/ilsag/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf

[10] "About 40 percent more energy efficient and 50 percent more water efficient than standard models" ENERGY STAR. Accessed November 1, 2022. https://www.energystar.gov/products/commercial_dishwashers

Fryer, ENERGY STAR

	Measure Details
Measure Master ID	Fryer, ENERGY STAR, Electric, 2337 Fryer, ENERGY STAR, NG, 2338
Workpaper ID	W0035
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: $1,500[2] MMID 2338: $1,000[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.

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

Where:

Variable	Description	Units	Value
E_{DAY}	Daily energy consumption per fry pot	kWh for electric Btu for natural gas	Calculated
LB_{FOOD}	Pounds of food cooked per day	Lb/day	150[3,4,5]
E_{FOOD}	ASTM energy	kWh/lb for electric Btu/lb for natural gas	0.167 kWh/lb for electric; 570 Btu/lb for natural 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	kWh for electric Btu for natural gas	See table in Assumptions section[4,5]
OpHrs	Operating hours per day	Hrs/day	12 hours for commercial, industrial, and agriculture sectors;[3] 9 hours for schools/ government sector; see Assumptions section[7]
PC	Production capacity in lb/hr	Lb/hr	Varies by measure and sector; see table in Assumptions section[4,5]
T_{PreHt}	Preheat time	Minutes	15[6]
60	Minute to hour conversion factor	Minute to hour	60
E_{PreHt}	Preheat energy in kWh for electric and in Btu for natural gas	kWh for electric 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.

$$kWh_{\mathrm{SAVED}} = (E_{\mathrm{DAY,B}} - E_{\mathrm{DAY,Q}}) * OpDay$$

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

Where:

Variable	Description	Units	Value
$E_{DAY,B}$	Daily energy use of a baseline unit in kWh or Btu	kWh or Btu	
$E_{DAY,Q}$	Daily energy use of a qualifying unit in kWh or Btu	kWh or Btu	
OpDay	Number of operating days per year	Operating days/yr	365 days for commercial, industrial, and agriculture sectors;[3,4,5] 282.5 days for schools/government sector; see Assumptions section[7]
100,000	Conversion factor	Btu/therm	100,000

Summer Coincident Peak Savings Algorithm

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

Where:

CF = Coincidence factor (=0.9)[8]

Lifecycle Energy-Savings Algorithm

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

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

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)[7] and days per year (200 days).[7] 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 prefheat 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]

Revision History

Version Number	Date	Description of Change
01	09/2017	Initial TRM entry

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[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 Commercial Food Service (CFS) Products.” Calculator. March 2021 Version. https://www.energystar.gov/sites/default/files/asset/document/CFS_calculator_03-02-2021.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] Engineering judgment from AgSG program for typical school operating hours per day (6 hours) and days per year (200 days).

[8] *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

Griddle, ENERGY STAR

	Measure Details
Measure Master ID	Griddle, ENERGY STAR, Electric, 2371 Griddle, ENERGY STAR, NG, 2372
Workpaper ID	W0036
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:

Variable	Description	Units	Value
E_{DAY}	Daily energy consumption in kWh/linear ft or Btu/linear ft	kWh/linear ft or Btu/linear ft	
LB_{FOOD}	Pounds of food cooked per day per linear foot	Lbs/day/linear ft	Varies by sector; see table in the Assumptions section
E_{FOOD}	ASTM energy to food in kWh/lb or Btu/lb	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	kW/ft or Btu/hr/ft	Varies by sector; see table in the Assumptions section
OpHrs	Operating hours per day	Hrs/day	Varies by sector; see Operating Schedule by Sector table below
PC	Production capacity per linear foot in lb/hr/ft	lb/hr/ft	Varies by sector; see table in the Assumptions section
T_{PREHT}	Preheat time	Minutes	15 minutes; see Assumptions section
60	Minute to hour conversion	Minute to hour	60
E_{PREHT}	Preheat energy per linear foot in kWh/ft or Btu/ft	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:

Variable	Description	Units	Value
$E_{DAY,B}$	Daily energy use of baseline unit per linear foot in kWh/ft or Btu/ft	kWh/ft or Btu/ft	
$E_{DAY,Q}$	Daily energy use of qualifying unit per linear foot in kWh/ft or Btu/ft	kWh/ft or Btu/ft	
OpDay	Number of operating days per year	Days/yr	See Operating Schedule by Sector table below

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

Where:

Variable	Description	Units	Value
$E_{Day,B}$	Daily energy use of baseline unit per linear foot in kWh/ft or Btu/ft	kWh/ft or Btu/ft	
$E_{Day,Q}$	Daily energy use of qualifying unit per linear foot in kWh/ft or Btu/ft	kWh/ft or Btu/ft	
OpDay	Number of operating days per year	Days/yr	Varies by sector; see Operating Schedule by Sector table below
100,000	Conversion factor	Btu/therm	100,000

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[6] (see Assumptions)	9	282.5

Summer Coincident Peak Savings Algorithm

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

Where:

CF = Coincidence factor (0.9)[7]

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

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

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

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.[8] 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*.[9]
- ***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.[10]
- ***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.

- ***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 2:00 p.m. to 6:00 p.m., Monday to Friday from June through September. 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) 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

Revision History

Version Number	Date	Description of Change
01	09/2017	Initial TRM entry
02	11/2017	Updated to address comments from other implementers

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[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] Engineering judgment from AgSG program for typical school operating hours per day (six hours) and days per year (200 days).

[7] *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

[8] ENERGY STAR. "Commercial Griddles Key Product Criteria." Products. Accessed September 5, 2017. https://www.energystar.gov/index.cfm?c=griddles.pr_crit_comm_griddles

[9] "ENERGY STAR Commercial Griddles Qualified Product List." Accessed January 19, 2018. https://www.energystar.gov/productfinder/product/certified-commercial-griddles/results

[10] Pacific Gas and Electric. "Commercial Griddle – Electric and Gas." Food Service Equipment Workpaper PGECOFST103 R7. 2016. http://deeresources.net/workpapers

Hot Food Holding Cabinets

	Measure Details
Measure Master ID	Hot Food Holding Cabinet, V = 13-28 cu. ft., ENERGY STAR, 2677 Hot Food Holding Cabinet, V < 13 cu. ft., ENERGY STAR, 2678 Hot Food Holding Cabinet, V ≥ 28 cu. ft., ENERGY STAR, 2679
Workpaper ID	W0037
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

$$kWh_{\text{SAVED}} = (Watts = - Watts_{\text{EE}}) * OpHrs * OpDays \,/\, 1{,}000$$

Where:

Variable	Description	Units	Value
$Watts_{BASE}$	Power consumption of baseline cabinet	Watts	Varies by volume; see table below
$Watts_{EE}$	Power consumption of efficient cabinet	Watts	Varies by volume; see table below
OpHrs	Average hours of operation per day	Hrs/day	Varies by sector; see table below
OpDays	Average days of operation per year	Days/yr	Varies by sector; see table below
1,000	Conversion factor	W/kW	1,000

$Watts_{BASE}$ 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*.[3] 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.[4]

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.[5]

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	$13 \leq V < 28$	21.14	$\leq 2.0 * V_{AVG} + 254.0$
2678	½ Size	$0 < V < 13$	7.78	$\leq 21.5 * V_{AVG}$
2679	Full Size	$28 \leq V$	53.40	$\leq 3.8 * V_{AVG} + 203.5$

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

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

Where:

CF = Coincidence factor (= 0.9)[6]

Lifecycle Energy-Savings Algorithm

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

Where:

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

Assumptions

Schools operate for fewer hours per day (six hours) and fewer days per year (200 days) than other sectors.[7] 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

Revision History

Version Number	Date	Description of Change
01	09/2017	Initial TRM entry
02	11/2017	Updated to address comments from other implementers

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[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

[3] “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

[4] Pacific Gas & Electric. *Insulated Holding Cabinet*. Food Service Equipment Workpaper PGECOFST105 R5. 2016. http://deeresources.net/workpapers

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[5] ENERGY STAR Commercial Hot Food Holding Cabinets. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_hot_food_holding_cabinets

[6] *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

[7] Engineering judgment from AgSG program for typical school operating hours per day (six hours) and days per year (200 days).

ENERGY STAR Commercial Combination Ovens (Natural Gas or Electric)

	Measure Details
Measure Master ID	Oven, Combination, ENERGY STAR, Electric, 3118 Oven, Combination, ENERGY STAR, Natural Gas, 3119
Workpaper ID	W0038
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 (electric), 0 (gas)
Peak Demand Reduction (kW)	3.446 (electric), 0 (gas)
Annual Therm Savings (Therms)	0 (electric), 1,103 (gas)
Lifecycle Energy Savings (kWh)	181,146 (electric), 0 (gas)
Lifecycle Therm Savings (Therms)	0 (electric), 13,237 (gas)
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	$0.00[2]

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,[3] per the ENERGY STAR v2.0 performance specifications for natural gas and electric combination ovens.[3]

Annual Energy-Savings Algorithms

<u>Electric Combination Oven:</u>

$$kWh_{\text{SAVED}} = (Wh/day_{\text{BASELINE}} - Wh/day_{\text{EE}}) * DPY / 1{,}000$$

$$Wh/day_{\text{BASELINE}} = Wh/day_{\text{CONVECTION, BASELINE}} + Wh/day_{\text{STEAM, BASELINE}} + Wh/day_{\text{PREHEAT, BASELINE}}$$

$$Wh/day_{\text{CONVECTION, BASELINE}} = (1 - \%_{\text{STEAM}}) * \{(m * E_{\text{CONVECTION}}) / \eta_{\text{CONVECTION, BASELINE}} + [E_{\text{IDLE-CONVECTION, BASELINE}} * (t_{\text{DAY}} - m/PC_{\text{CONVECTION, BASELINE}} - nP * t_{\text{PREHEAT}}/60)]\}$$

$$Wh/day_{\text{STEAM, BASELINE}} = \%_{\text{STEAM}} * \{(m * E_{\text{STEAM}}) / \eta_{\text{STEAM,BASELINE}} + [E_{\text{IDLE-STEAM, BASELINE}} * (t_{\text{DAY}} - m/PC_{\text{STEAM,BASELINE}} - nP * t_{\text{PREHEAT}}/60)]\}$$

$$Wh/day_{\text{PREHEAT, BASELINE}} = E_{\text{PREHEAT, BASELINE}} * nP$$

$$Wh/day_{\text{EE}} = Wh/day_{\text{CONVECTION, EE}} + Wh/day_{\text{STEAM, EE}} + Wh/day_{\text{PREHEAT, EE}}$$

$$Wh/day_{\text{CONVECTION, EE}} = (1 - \%_{\text{STEAM}}) * \{(m * E_{\text{CONVECTION}}) / \eta_{\text{CONVECTION, EE}} + [E_{\text{IDLE-CONVECTION, EE}} * (t_{\text{DAY}} - m/PC_{\text{CONVECTION, EE}} - nP * t_{\text{PREHEAT}}/60)]\}$$

$$Wh/day_{\text{STEAM, EE}} = \%_{\text{STEAM}} * \{(m * E_{\text{STEAM}}) / \eta_{\text{STEAM,EE}} + [E_{\text{IDLE-STEAM, EE}} * (t_{\text{DAY}} - m/PC_{\text{STEAM, EE}} - nP * t_{\text{PREHEAT}}/60)]\}$$

$$Wh/day_{\text{PREHEAT, EE}} = E_{\text{PREHEAT, EE}} * nP$$

<u>Natural Gas Combination Oven:</u>

$$Therm_{\text{SAVED}} = (Btu/day_{\text{BASELINE}} - Btu/day_{\text{EE}}) * DPY / 100{,}000$$

$$Btu/day_{\text{BASELINE}} = Btu/day_{\text{CONVECTION, BASELINE}} + Btu/day_{\text{STEAM,BASELINE}} + Btu/day_{\text{PREHEAT, BASELINE}}$$

$$Btu/day_{\text{CONVECTION, BASELINE}} = (1 - \% =) * \{(m * E_{\text{CONVECTION}}) / \eta_{\text{CONVECTION, BASELINE}} + [E_{\text{IDLE-CONVECTION, BASELINE}} * (t_{\text{DAY}} - m/PC_{\text{CONVECTION, BASELINE}} - nP * t_{\text{PREHEAT}}/60)]\}$$

$$Btu/day_{\text{STEAM, BASELINE}} = \%_{\text{STEAM}} * \{(m * E_{\text{STEAM}}) / \eta_{\text{STEAM, BASELINE}} + [E_{\text{IDLE-STEAM, BASELINE}} * (t_{\text{DAY}} - m/PC_{\text{STEAM,BASELINE}} - nP * t_{\text{PREHEAT}}/60)]\}$$

$$Btu/day_{\text{PREHEAT, BASELINE}} = E_{\text{PREHEAT,BASELINE}} * nP$$

$$Btu/day_{\text{EE}} = Wh/day_{\text{CONVECTION, EE}} + Wh/day_{\text{STEAM, EE}} + Wh/day_{\text{PREHEAT, EE}}$$

$$Wh/day_{\text{CONVECTION, EE}} = (1 - \%_{\text{STEAM}}) * \{(m * E_{\text{CONVECTION}}) / \eta_{\text{CONVECTION, EE}} + [E_{\text{IDLE-CONVECTION, EE}} * (t_{\text{DAY}} - m/PC_{\text{CONVECTION, EE}} - nP * t_{\text{PREHEAT}}/60)]\}$$

$$Wh/day_{\text{STEAM, EE}} = \%_{\text{STEAM}} * \{(m * E_{\text{STEAM}}) / \eta_{\text{STEAM, EE}} + [E_{\text{IDLE-STEAM, EE}} * (t_{\text{DAY}} - m/PC_{\text{STEAM, EE}} - nP * t_{\text{PREHEAT}}/60)]\}$$

$$Wh/day_{\text{PREHEAT, EE}} = E_{\text{PREHEAT,EE}} * nP$$

Where:

Variable	Description	Units	Value
DPY	Days of operation per year	Days/yr	365[4]
1,000	Conversion factor	W/kW	1,0000
$\%_{STEAM}$	Percentage of time in steam mode	%	50%[4]
m	Mass of food cooked per day	Lbs	250[4]
$E_{CONVECTION}$	Energy absorbed by food product: cooking by convection	Wh/lb Btu/lb	73.2 Wh/lb; 250 Btu/lb[5]
$E_{IDLE\text{-}CONVECTION,\ BASELINE}$	Baseline idle energy rate		Varies by unit type; see table below[4]
t_{DAY}	Operating time per day	Hrs/day	12[4]
$PC_{CONVECTION,\ BASELINE}$	Baseline production capacity, convection	Lbs/hr	Varies by unit type; see table below[4]
nP	Number of daily preheats	#/day	1[4]
$t_{PREHEAT}$	Estimated preheat time per preheat	Minutes	15[4]
60	Minutes in an hour	Minutes/hr	60
E_{STEAM}	Energy absorbed by food product: cooking by steam	Btu/lb	30.8 Wh/lb; 105 Btu/lb[5]
100,000	Conversion factor	Btu/therm	100,000
$\eta_{STEAM,BASELINE}$	Baseline steam cooking efficiency		Varies by unit type; see table below[5]
$\eta_{CONVECTION,\ BASELINE}$	Baseline convection cooking efficiency		Varies by unit type; see table below [5]
$E_{IDLE\text{-}STEAM,\ BASELINE}$	Baseline energy absorbed by food product: cooking by steam		Varies by unit type; see table below[4]
$PC_{STEAM,BASELINE}$	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 [4]
$\eta_{CONVECTION,\ EE}$	Cooking energy efficiency of efficient unit		
$E_{IDLE\text{-}CONVECTION,\ EE}$	Efficient idle rate, by convection		Varies by unit type; see table below [5]
$PC_{CONVECTION,\ EE}$	Efficient production capacity	Lbs/hr	Varies by unit type; see table below [4]
$\eta_{STEAM,\ EE}$	Cooking energy efficiency of efficient unit, cooking by steam		Varies by unit type; see table below [5]
$E_{IDLE\text{-}STEAM,\ EE}$	Efficient idle rate, cooking by steam		Varies by unit type; see table below[5]
$PC_{STEAM,EE}$	Efficient production capacity, cooking by steam		
$E_{PREHEAT,\ EE}$	Measured energy used per preheat from efficient equipment		Varies by unit type; see table below [4]

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

Summary Coincident Peak Savings Algorithm

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

Where:

CF = Coincidence factor (= 1)[6]

HOU = Annual hours of use (= 4,380)[4]

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.

Revision History

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

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[1] Similar MMIDs 2485-2488. EUL derived from Food Service Technology Center. Gas Convection Oven Life-Cycle Cost Calculator.
[2] 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
[3] United States Department of Energy. ENERGY STAR Product Finder: Commercial Combination Ovens.
[4] United States Department of Energy. Version 2.0 ENERGY STAR Performance Specification for Gas and Electric Combination Ovens.
[5] Food Service Technology Center. "Life-Cycle & Energy Cost Calculator: Combination Ovens." http://www.fishnick.com/saveenergy/tools/calculators/
[6] 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.

Oven, Convection, ENERGY STAR, Electric

	Measure Details
Measure Master ID	Oven, Convection, ENERGY STAR, Electric, 2485
Workpaper ID	W0039
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[2]

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:[5]

$$kWh_{\text{SAVED}} = (E_{DAY,\,BASELINE} - E_{\text{DAY, ENERGY STAR}}) * OpDay$$

$$E_{\text{DAY}} = [(LB_{\text{FOOD}} * E_{\text{FOOD}})/Efficiency] + IdleRate * [OpHrs - (LB_{\text{FOOD}}/PC) - (T_{\text{PREHT}}/60)] + E_{\text{PREHT}}$$

Where:

Variable	Description	Units	Value
OpDay	Operating days per year	Days/yr	Varies by model and fuel type; see table below
EDAY	Daily energy consumption	kWh or Btu	
LBFOOD	Pounds of food cooked per day	Lbs/day	Varies by model and fuel type; see table below
EFOOD	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		Varies by model and fuel type; see table below
OpHrs	Operating hours per day	Hrs/day	Varies by model and fuel type; see table below
PC	Production capacity in pounds per hour	Lbs/hr	Varies by model and fuel type; see table below
TPREHT	Preheat time in minutes	Minutes	Varies by model and fuel type; see table below
60	Conversion factor	Min/hr	60
EPREHT	Preheat energy	Preheat energy	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

$$kW_{\text{SAVED}} = (E_{\text{DAY, BASELINE}} - E_{\text{DAY, ENERGY STAR}}) \,/\, OpHrs$$

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (= 12 years)[4]

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	12/2018	Updated incremental cost

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[1] Food Service Technology Center. Convection Oven Life-Cycle Cost Calculator.

[2] ENERGY STAR. “Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.” 2016. https://www.energystar.gov/sites/default/files/asset/

[3] ENERGY STAR Commercial Ovens Program Requirements, Version 2.1.

[4] ENERGY STAR Commercial Kitchen Equipment Calculator.

[5] PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3-2 Lighting Hours of Use in Commercial Applications. March 22, 2010. https://focusonenergy.com/ sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Oven, Convection, ENERGY STAR, Natural Gas

	Measure Details
Measure Master ID	Oven, Convection, ENERGY STAR, Natural Gas, 2486
Workpaper ID	W0040
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[2]

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.[3]

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.[3]

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = (E_{\text{DAY, BASELINE}} - E_{\text{DAY, ENERGY STAR}}) * OpDay * (1/100{,}000)$$

$$E_{\text{DAY}} = [(LB_{\text{FOOD}} * E_{\text{FOOD}})/Efficiency] + IdleRate * [OpHrs - (LB_{\text{FOOD}}/\text{PC}) - (T_{\text{PREHT}}/60)] + E_{\text{PREHT}}$$

Where:

Variable	Description	Units	Value
EDAY	Daily energy consumption	kWh/day or Btu/day	
OpDays	Operating days per year	Days/yr	Varies by model and fuel type; see table below
1/100,000	Conversion factor	therms/Btu	1/100,000
LBFOOD	Pounds of food cooked per day	Lbs/day	Varies by model and fuel type; see table below
EFOOD	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/hr or Btu/hr	Varies by model and fuel type, see table below
OpHrs	Operating hours per day	Hrs/day	Varies by model and fuel type; see table below
PC	Production capacity	Lbs/hr	Varies by model and fuel type, see table below
TPREHT	Preheat time in minutes	Minutes	Varies by model and fuel type, see table below
60	Conversion factor	Min/hr	60
EPREHT	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	3
	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	3
	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

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

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

Where:

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

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	12/2018	Updated incremental cost

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[1] Food Service Technology Center. Gas Convection Oven Life-Cycle Cost Calculator.

[2] ENERGY STAR. "Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment." 2016. https://www.energystar.gov/sites/default/files/asset/

[3] Food Service Technology Center. Electric Convection Oven Life-Cycle Cost Calculator.

[4] ENERGY STAR Commercial Kitchen Equipment Calculator.

Oven, Rack Type, ENERGY STAR, Natural Gas

	Measure Details
Measure Master ID	Oven, Rack Type, ENERGY STAR, Natural Gas: Single Compartment, 2488 Double Compartment, 2487
Workpaper ID	W0041
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

$$Therm_{\text{SAVED}} = (E_{\text{DAY, BASELINE}} - E_{DAY,\, ENERGY\, STAR}) * OpDay * (1/100{,}000)$$

$$E_{\text{DAY}} = [(LB_{\text{FOOD}} * E_{\text{FOOD}})/Efficiency] + GasIdleRate * [OpHrs - (LB_{\text{FOOD}}/PC) - (T_{\text{PREHT}}/60)] + E_{\text{PREHT}}$$

$$kWh_{\text{SAVED}} = kWh_{\text{ANNUAL, BASELINE}} - kWh_{\text{ANNUAL, ENERGY STAR}}$$

$$kWh_{\text{ANNUAL}} = ElecIdleRate * OpDay * [OpHrs - (LB_{\text{FOOD}}/\text{PC})]$$

Where:

Variable	Description	Units	Value
E_{DAY}	Daily energy consumption	Btu	
OpDays	Operating days per year	Days/yr	Varies by model; see table below
1/100,000	Conversion factor	therm/Btu	1/100,000
LB_{FOOD}	Pounds of food cooked per day	Lbs/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	Hrs/day	Varies by model; see table below
T_{PREHT}	Preheat time in minutes	Minutes	Varies by model; see table below
60	Conversion factor	Min/hr	60
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	Lbs/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

$$kW_{\text{SAVED}} = ElecIdleRate_{\text{BASELINE}} - ElecIdleRate_{\text{ENERGY STAR}}$$

Where:

$\text{ElecIdleRate}_{\text{BASELINE}}$ = Electric Idle energy rate (kW; = varies by model, see table above)

$\text{ElecIdleRate}_{\text{ENERGY STAR}}$ = Electric Idle energy rate (kW; = varies by model, see table above)

Lifecycle Energy-Savings Algorithm

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

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

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

Revision History

Version Number	Date	Description of Change
01	11/2015	Updated from Wisconsin Focus on Energy QPL to ENERGY STAR
02	01/2016	Updated per comments

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[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).

Commercial Freezers, ENERGY STAR

	Measure Details
Measure Master ID	Freezer, Chest, Glass Door: 15-29 cu ft, ENERGY STAR, 2322 30-49 cu ft, ENERGY STAR, 2323 50+ cu ft, ENERGY STAR, 2324 Freezer, Chest, Solid Door: < 15 cu ft, ENERGY STAR, 2325 15-29 cu ft, ENERGY STAR, 2326 30-49 cu ft, ENERGY STAR, 2327 Freezer, Vertical, Glass Door: 15-29 cu ft, ENERGY STAR, 2330 30-49 cu ft, ENERGY STAR, 2331 50+ cu ft, ENERGY STAR, 2332 Freezer, Vertical, Solid Door: < 15 cu ft, ENERGY STAR, 2333 15-29 cu ft, ENERGY STAR, 2334 30-49 cu ft, ENERGY STAR, 2335 50+ cu ft, ENERGY STAR, 2336
Workpaper ID	W0042
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 5.0 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 5.0, effective December 22, 2022, for vertical and horizontal closed-door freezers.[2]

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = (kWh_{\text{BASE}} - kWh_{\text{ES}}) * Days$$

Where:

Variable	Description	Units	Value
kWh_{BASE}	Daily baseline unit consumption	kWh	Varies by unit; see table below
kWh_{ES}	Daily qualifying unit consumption	kWh	Varies by unit; see table below
Days	Annual days of operation, deemed	Days	365

Parameter Values by Unit Type

Unit Type	Door Type	Size (cu. ft.)	Daily Baseline Consumption, DOE 2017 (kWh/day)[3]	Daily Qualifying Consumption, ENERGY STAR Specification 5.0 (kWh/day)[2]
Vertical Closed Freezers	Solid	$0 < V < 15$	0.22V + 1.38	0.21V + 0.9
		$15 \leq V < 30$		0.12V + 2.248
		$30 \leq V < 50$		0.2578V – 1.8864
		$50 \leq V$		0.14V + 4.0
	Transparent	$0 < V < 15$	0.29V + 2.95	0.232V + 2.36
		$15 \leq V < 30$		
		$30 \leq V < 50$		
		$50 \leq V$		
Horizontal Closed Freezers	Solid	All volumes	0.06V + 1.12	0.057V + 0.55
	Transparent		0.08V + 1.23	

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = kWh_{\text{SAVED}} / Hours$$

Where:

Hours = Annual hours of use, deemed (= 8,760)

Lifecycle Energy-Savings Algorithm

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

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[3]	Daily Qualifying Consumption, ENERGY STAR Specification 5.0[2]	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 + 2.24	486	5,832	0.055
30-49 cu ft, ENERGY STAR	2335	39.5	0.22V + 1.38	0.2578V – 1.88	647	7,764	0.074
50+ cu ft, ENERGY STAR	2336	65	0.22V + 1.38	0.14V + 4.0	942	11,304	0.108

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.

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
04	09/2022	Updated to ENERGY STAR Version 5.0 specifications

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[1] ENERGY STAR. *Program Calculator for Commercial Refrigerators and Freezers*. October 2016. https://www.energystar.gov/partner_resources/energy_star_training_center/commercial_food_service

[2] ENERGY STAR. *Program Requirements for Commercial Refrigerators and Freezers*. Version 5.0. Effective 22, 2022. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%205.0%20Commercial%20Refrigerators%20and%20Freezers%20Specification_1.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

Commercial Refrigerator, ENERGY STAR

	Measure Details
Measure Master ID	Refrigerator, Chest, Glass Door: 15-29 cu ft, ENERGY STAR, 2522 30-49 cu ft, ENERGY STAR, 2523 50+ cu ft, ENERGY STAR, 2524 Refrigerator, Chest, Solid Door: < 15 cu ft, ENERGY STAR, 2525 15-29 cu ft, ENERGY STAR, 2526 30-49 cu ft, ENERGY STAR, 2527 50+ cu ft, ENERGY STAR, 2528 Refrigerator, Vertical, Glass Door: < 15 cu ft, ENERGY STAR, 2529 15-29 cu ft, ENERGY STAR, 2530 30-49 cu ft, ENERGY STAR, 2531 50+ cu ft, ENERGY STAR, 2532 Refrigerator, Vertical, Solid Door: < 15 cu ft, ENERGY STAR, 2533 15-29 cu ft, ENERGY STAR, 2534 30-49 cu ft, ENERGY STAR, 2535 50+ cu ft, ENERGY STAR, 2536
Workpaper ID	W0043
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 5.0 performance specification, effective December 22, 2022.[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 5.0, effective December 22, 2022, for vertical and horizontal closed-door refrigerators.

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = (kWh_{\text{BASE}} - kWh_{\text{ES}}) * Days$$

Where:

Variable	Description	Units	Value
kWh_{BASE}	Daily baseline unit consumption	kWh	Varies by unit; see table below
kWh_{ES}	Daily qualifying unit consumption	kWh	Varies by unit; see table below
Days	Annual days of operation, deemed	Days	365

Parameter Values by Unit Type[2,3]

Unit Type	Door Type	Size (cu. ft.)	Daily Baseline Consumption, DOE 2017 (kWh/day)[3]	Daily Qualifying Consumption, ENERGY STAR Specification 5.0 (kWh/day)[2]
Vertical Closed Refrigerators	Solid	0 < V < 15	0.05V + 1.36	0.0267V + 0.8
		15 ≤ V < 30	0.05V + 1.36	0.05V + 0.45
		30 ≤ V < 50	0.05V + 1.36	0.05V + 0.45
		50 ≤ V	0.05V + 1.36	0.025V + 1.6991
	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

$$kW_{\text{SAVED}} = kWh_{\text{SAVED}} / HOU$$

Where:

HOU = Annual hours of use, deemed (= 8,760)

Lifecycle Energy-Savings Algorithm

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

Where:

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

Deemed Savings

Deemed Savings Values by Measure

Measure Master Name	MMID	Average Volume (cu. ft.)	Daily Baseline Consumption (kWh/day)[3]	Daily Qualifying Consumption (kWh/day)2	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 - 1.11	601	7,212	0.069
Refrigerator, Vertical, Solid Door							
< 15 cu ft, ENERGY STAR	2533	7.5	0.05V + 1.36	0.0267V + 0.8	268	3,216	0.031
15-29 cu ft, ENERGY STAR	2534	22	0.05V + 1.36	0.05V + 0.45	332	3,984	0.038
30-49 cu ft, ENERGY STAR	2535	39.5	0.05V + 1.36	0.05V + 0.45	332	3,984	0.038
50+ cu ft, ENERGY STAR	2536	65	0.05V + 1.36	0.025V + 1.67	469	5,628	0.054

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.

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
04	09/2023	Updated to reflect ENERGY STAR v5.0

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[1] ENERGY STAR. *Program Calculator for Commercial Refrigerators and Freezers*. October 2016. https://www.energystar.gov/partner_resources/energy_star_training_center/commercial_food_service

[2] ENERGY STAR. *Program Requirements for Commercial Refrigerators and Freezers*. Version 5.0. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%205.0%20Commercial%20Refrigerators%20and%20Freezers%20Specification_1.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

Steamer, ENERGY STAR

	Measure Details
Measure Master ID	Steamer, ENERGY STAR, Electric, 4710 Steamer, ENERGY STAR, NG, 4711
Workpaper ID	W0044
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:

Variable	Description	Units	Value
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	kWh/lb for electric; Btu/lb for natural gas	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	Hrs/day	12 for commercial, industrial, and agriculture sectors; [2] 9 for schools and government sector; [2,5] see Assumptions
PC	Production capacity	lb/hr	See table in Assumptions[2]
T_{PreHt}	Preheat time	Minutes	15[6]
60	Minute to hour conversion	Minutes/hr	60
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 plus energy saved from water and wastewater utilities[7]:

$$kWh_{SAVED} = (E_{DAY,B} - E_{DAY,Q}) * OpDay + Gallons_{SAVED} * kWh_{WATER} / 1000$$

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

$$Gallons_{SAVED} = (GPH_{BASE} - GPH_{Q}) * OpHrs * OpDay$$

Where:

Variable	Description	Units	Value
$E_{DAY,B}$	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	Days/yr	365 for commercial, industrial, and agriculture sectors; [2] 282.5 for schools and government sector; [2,5] see Assumptions)
kWh_{WATER}	Energy saved from water and wastewater utilities	kWh/kgal	3.89 kWh/kgal)[7]
1,000	Conversion factor	Gallons/kgal	1,000
100,000	Conversion factor	Btu/therm	100,000
GPH_{BASE}	Gallons per hour water use for a baseline unit	Gallons/hr	Varies by measure; see table below and Assumptions
GPH_{Q}	Gallons per hour water use for a qualifying unit	Gallons/hr	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)[8]	Average ENERGY STAR Model Water Consumption Per Pan (Gallons/Hour)[9]
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	2,863	-	23,783
	Schools & Government	4.34	1,684	-	13,806
Steamer, ENERGY STAR, Natural Gas					
4711	Agriculture, Commercial, Industrial	-	91	189	23,302
	Schools & Government	-	53	110	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

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

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

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	34,356	-	285,396
	Schools & Government	20,208	-	165,672
Steamer, ENERGY STAR, Natural Gas				
4711	Agriculture, Commercial, Industrial	1,092	2,268	279,624
	Schools & Government	636	1,320	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[3]
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[8] 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).

Revision History

Version Number	Date	Description of Change
01	09/2017	Initial TRM entry
02	09/2018	Updated unit of measure and condensed measures into two MMIDs
03	06/2022	Added annual energy savings from water and WWTP utilities
04	09/2023	Updated electric energy savings factor from W/WW utilities

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[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 Commercial Food Service (CFS) Products." Calculator. Accessed October 24, 2022. https://www.energystar.gov/sites/default/files/asset/document/CFS_calculator_07-15-2021.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 judgment 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] Water-Related Energy Savings using updated CMAR (2016-2020) and WI Water Utility databases (2015-2022). A weighted average was used for the calculation of the water energy savings factor for groundwater/surface water, and for facilities with 0-1 MGD/ >1 MGD. Calculations and data provided in Huddle folder of this workpaper.

[8] ENERGY STAR. "Best Practices – How to Achieve the Most Efficient Use of Water in Commercial Food Service Facilities." February 2005.

[9] ENERGY STAR. "Commercial Steam Cookers Qualified Products List." Accessed January 23, 2018. www.energystar.gov/productfinder/product/certified-commercial-steam-cookers/results

Demand Controlled Kitchen Ventilation

	Measure Details
Measure Master ID	Ventilation Controls, Kitchen Hood, Temp only, Adder for MUA, 2621 Ventilation Controls, Kitchen Hood, Temp only, Exhaust Only, 2623 Ventilation Controls, Kitchen Hood, with Optical, Adder for MUA, 2625 Ventilation Controls, Kitchen Hood, with Optical, Exhaust Only, 2627 Ventilation Controls, Kitchen Hood, Temp only, Exhaust Only, (fan savings only), 5433 Ventilation Controls, Kitchen Hood, with Optical, Exhaust Only, (fan savings only), 5434
Workpaper ID	W0287
Measure Unit	Per horsepower
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Electricity Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Natural Gas Savings (therms)	Varies by measure
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Natural Gas Savings (therms)	Varies by measure
Annual Water Savings (gallons)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	Varies by measure, see Incremental Cost table[2]

Measure Description

Traditional kitchen ventilation controls include a manual on/off switch for each hood, so that the exhaust and make-up air fans operate either at 100% speed or not at all. Cooking loads, and therefore exhaust requirements, vary throughout the day and typically peak at meal times. However, the fans are typically left on from open to close to accommodate customers at off times and food preparation. These measures add variable speed controls to the exhaust fan, with an option to also control the make-up air fan.

Description of Baseline Condition

The baseline condition is a kitchen hood with manual on/off controls for the kitchen exhaust and make-up air fans.

Description of Efficient Condition

The efficient condition is a kitchen hood where the exhaust fan is variable speed and is controlled based on effluent output from the cooking appliances under the hood. Two control options are available: temperature only sensing, and temperature plus optical sensing. Heating savings from reduced make-up air is captured under the exhaust fan measure.

Additional measures (MMIDs 2621 & 2625) are available to capture the fan energy savings from the make-up air (MUA) unit if it is also converted to variable speed.

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED, EXHAUST}} = kW_{\text{EXHAUST}} / hp_{\text{EXHAUST}} * SF_{\text{FAN}} * HOU$$

$$kWh_{\text{SAVED, MUA}} = kW_{\text{MUA}} / hp_{\text{MUA}} * SF_{\text{FAN}} * HOU$$

$$Therm_{\text{SAVED}} = (1 / SpecificPower) * HeatLoad * 1{,}000 * SF_{\text{CFM}} / (100{,}000 * Eff_{\text{HEAT}})$$

Where:

Variable	Description	Units	Value
kW_{EXHAUST}	Average measured kW of make-up air unit fan	kW	3.20 for MMID 2623 and 5433[3,4]; 6.47 for MMID 2627 and 5434[5,6]
kW_{MUA}	Average measured kW of make-up air unit fan	kW	4.32,[5,6] see assumptions
hp_{EXHAUST}	Average rated exhaust fan horsepower	hp	7.88 for MMID 2623 and 5433[3,4]; = 9.55 for MMID 2627 and 5434[5,6]
hp_{MUA}	Average rated exhaust fan horsepower	hp	12.5,[5,6] see assumptions
SF_{FAN}	Average fan power reduction	%	45.6% for MMIDs 2621, 2623, and 5433[3,4]; 59.2% for MMIDs 2625, 2627, and 5434[5,6]
SF_{CFM}	Average airflow reduction	%	20.5% for MMID 2623,[3,4] 31.9% for MMID 2627[5]
HOU	Annual hours of use	Hrs/yr	6,205, see Assumptions
SpecificPower	Fan HP per 1,000 CFM	cfm	1.11 for MMID 2623,[3,4] 0.586 for MMID 2627[5]
HeatLoad	Average annual heating load	MBtu/cfm	1,000 cfm, see table below

Annual Heating Load[7]

Wistonsin Region	Heating Load, MBtu / 1000 CFM
Eau Claire	124,586
Green Bay	113,551
La Crosse	109,020
Madison	112,108
Milwaukee	107,022
Average	**113,257**

1,000 = Conversion factor, Btu/MBtu

100,000 = Conversion factor, Btu/therm

Eff_{HEAT} = Heating efficiency of make-up air unit (= 80%, see assumptions)

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED, EXHAUST}} = kW_{\text{EXHAUST}} / HP_{\text{EXHAUST}} * SF_{\text{FAN}} * CF$$

$$kW_{\text{SAVED, MUA}} = kW_{\text{MUA}} / HP_{\text{MUA}} * SF_{\text{FAN}} * CF$$

Where:

CF = Coincidence factor (= 1.0, see Assumptions)

Lifecycle Energy-Savings Algorithm

$$kWh_{\text{LIFECYCLE, EXHAUST}} = kWh_{\text{SAVED, EXHAUST}} * EUL$$

$$kWh_{\text{LIFECYCLE, MUA}} = kWh_{\text{SAVED, MUA}} * EUL$$

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

Where:

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

Deemed Savings

Savings for Kitchen Demand Controlled Ventilation

Measure	MMID	kW	kWh Savings		Therm Savings	
			Annual	Lifecycle	Annual	Lifecycle
Ventilation Controls, Kitchen Hood:						
Temp only, Adder for MUA	2621	0.158	974	9,740	0	0
Temp only, Exhaust Only	2623	0.185	1,148	11,480	262	2,620
with Optical, Adder for MUA	2625	0.205	1,281	12,810	0	0
with Optical, Exhaust Only	2627	0.401	2,490	24,900	771	7,710
Temp only, Exhaust Only (fan savings only)	5433	0.185	1,148	11,480	0	0
with Optical, Exhaust Only (fan savings only)	5434	0.401	2,490	24,900	0	0

Assumptions

- The temperature only DCV measurement and verification reports provided an average of 16.9 hours per day and 365 days per year for a total of 6,178 hours per year,[3,4] while the temperature + optical DCV projects in the PG&E workpaper provided an average of 18 hours per day and 348 days per year for a total of 6,256 hours per year.[5,6] To standardize these values and for use in the annual heating load calculations, 17 hours per day for 365 days per year, or 6,205 hours per year, was used. This also eliminates the need to estimate average days off (holidays, 1 regular day closed per week, etc.) when performing the annual heating load calculation if less than 365 days per year is used.
- For kW_{MUA} and hp_{MUA}, only data for temperature + optical systems were available, so the same data were used for temperature only systems.
- For calculation of annual heating load, 17 hours of operation per day was assumed to occur between 5:00 a.m. and 10:00 p.m..
- Demand savings for kitchen demand control ventilation is calculated as an average savings over the course of the day. This technology will likely see less savings during peak meal times (such as

6 a.m. to 8 a.m., 11 a.m. to 1 p.m., and 5 p.m. to 7 p.m.) and more savings between typical meal times. Since the Focus definition for electric demand peak is 1 p.m. to 4 p.m. Monday to Friday which would be between typical meal times, savings should be at least equal to the average demand savings over the day. Therefore a coincidence factor of 1.0 was used.

- Existing make-up air units are assumed to be indirect fired units, which would have a heating efficiency of approximately 80%.

Incremental Cost

Efficient costs are derived from historical project data.[2] Baseline cost is zero (continue with the current fixed speed kitchen ventilation system).

Incremental Costs

Measure Name	MMID	SPECTRUM Data			Base Cost	Incremental Cost
		Projects	Units (hp)	Average Unit Cost		
Ventilation Controls, Kitchen Hood:						
Temp only, Adder for MUA	2621	75	167.25	$4,211.53	$0	$4,211.53
Temp only, Exhaust Only	2623, 5433	82	186.03	$2,035.85	$0	$2,035.85
with Optical, Adder for MUA	2625	6	218.00	$413.31	$0	$413.31
with Optical, Exhaust Only	2627, 5434	7	167.50	$2,183.92	$0	$2,183.92

Revision History

Version Number	Date	Description of Change
01	12/2021	Initial TRM entry
02	09/2022	Added measures to capture facilities with propane heat source.

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[1] PA Consulting Group Inc. *State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. January 2018 through November 2021.

[3] Wisconsin Focus on Energy. Measurement & Verification Final Report for Medical Center in Southern Wisconsin. December 2010.

[4] Wisconsin Focus on Energy. Measurement & Verification Final Report for Quick Service Restaurant in Central Wisconsin. December 2010.

[5] Pacific Gas & Electric Company. Workpaper PGECOFST116, Commercial Kitchen Demand Ventilation Controls. Table 1, Page 4. December 21, 2007. http://deeresources.net/workpapers

[6] Fisher, Don; Swierczyna, Rich; and Karas, Angelo. “Future of DCV for Commercial Kitchens”, *ASHRAE Journal*, Table 1. February 2013. http://www.espair.co.in/download/commercial-kitchen-ventilation/ASHRAE-journal-Article-2013.pdf

[7] Annual heating load calculated for the hours of 5 a.m. to 10 p.m., a 60°F heating setpoint for make-up air using TMY3 weather data from: 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

HVAC

Advanced Rooftop Unit Controller

	Measure Details
Measure Master ID	Advanced Rooftop Unit Controller, 3964
Workpaper ID	W0045
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)	$509.08[2]

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.[3] 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.[4,5]

$$kWh_{\text{SAVED}} = (FanEnergy_{\text{BASELINE}} + CoolingEnergy_{\text{BASELINE}} + ElecHeatingEnergy_{\text{BASELINE}}) - (FanEnergy_{\text{PROPOSED}} + CoolingEnergy_{\text{PROPOSED}} + ElecHeatingEnergy_{\text{PROPOSED}})$$

$$FanEnergy_{\text{BASELINE}} = \Sigma\,(hp * 0.746 * LoadFactor\,/\,MotorEff * OccStatus * 1\ hour)$$

$$CoolingEnergy_{\text{BASELINE}} = \Sigma\,(1.08 * CFM * \Delta T\,/\,(1{,}000 * EER) * OccStatus * 1\ hour)$$

$$ElecHeatingEnergy_{\text{BASELINE}} = \Sigma\,(1.08 * CFM * \Delta T\,/\,(ElecHtgEff * 3{,}412) * OccStatus * 1\ hour)$$

$$FanEnergy_{\text{PROPOSED}} = \Sigma\,([FanPower40\% + FanPower75\% + FanPower90\%] * OccStatus * 1\ hour)$$

$$CoolingEnergy_{\text{PROPOSED}} = \Sigma\,(1.08 * CFM * \Delta T\,/\,(1{,}000 * EER) * OccStatus * 1\ hour)$$

$$ElecHeatingEnergy_{\text{PROPOSED}} = \Sigma\,(1.08 * CFM * \Delta T\,/\,(ElecHtgEff * 3{,}412) * OccStatus * 1\ hour)$$

$$Therm_{\text{SAVED}} = HeatingEnergy_{\text{BASELINE}} - HeatingEnergy_{\text{PROPOSED}}$$

$$HeatingEnergy_{\text{BASELINE}} = \Sigma\,(1.08 * CFM * \Delta T \,/\, (HtgEff * 100{,}000) * OccStatus * 1\ hour)$$

$$HeatingEnergy_{\text{PROPOSED}} = \Sigma\,(1.08 * CFM * \Delta T \,/\, (HtgEff * 100{,}000) * OccStatus * 1\ hour)$$

Where:

Variable	Description	Units	Value
hp	Fan horsepower of the rooftop unit	hp	
0.746	Conversion factor	kW/hp	0.746
LoadFactor	Fan motor load factor	%	Actual if known, otherwise 75%)
MotorEff	Fan motor efficiency	%	Actual if known, otherwise 90%
OccStatus	Indicator of whether building is occupied at specific hour for calculation	0 or 1	0 if unoccupied, 1 if occupied
1.08	Constant for sensible heat load equation	Btu/cfm-°F-hr	1.08
CFM	Airflow in CFM of the rooftop unit	cfm	Actual if known, otherwise 400 CFM/ton cooling capacity
ΔT	Temperature difference (°F) between outside air and either building heating or cooling setpoint	°F	
1,000	Conversion factor	W/kW	1,000 (EER units are Btuh/watt)
EER	Cooling efficiency of rooftop unit	Btu/Wh	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 factor	Btuh/kW	3,412
FanPower40%	Fan power while operating at 40% load	%	Using fan laws with 2.5 exponent and $FanEnergy_{\text{BASELINE}}$
FanPower75%	Fan power while operating at 75% load	%	Using fan laws with 2.5 exponent and $FanEnergy_{\text{BASELINE}}$
FanPower90%	Fan power while operating at 90% load	%	Using fan laws with 2.5 exponent and $FanEnergy_{\text{BASELINE}}$
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 factor	Btu/therm	100,000

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.

$$kW_{\text{SAVED}} = hp * 0.746 * LoadFactor \,/\, MotorEff * (1 - 0.92.5)$$

Where:

0.9 = Maximum fan motor percentage of speed under the proposed conditions

2.5 = Fan affinity law exponent

Lifecycle Energy-Savings Algorithm

$$kWh_{\text{LIFECYCLE}} = kWh\text{SAVED} * EUL$$

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

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[6] 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[4] 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.
- The workbook for these measures previously included 180 kWh per ton of "soft savings" reflecting improved user behavior as a result of the control upgrades that are difficult to quantify. That value came from a Bonneville Power Administration Rooftop Unit Servicing Program Report. The deemed algorithm above does not incorporate these savings, and they are removed from the workbook starting in the 2020 Focus program year.

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
04	12/2019	Removed "soft" savings from workbook
05	02/2021	Updated cost

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[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] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 287 projects and 353 units for MMIDs 3964, 4646 from January 2018 to July 2020 is $509.08.

[3] 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

[4] Wisconsin Focus on Energy. "2018-Advanced RTU Controls.xltx."

[5] 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

[6] Cadmus. *Summer 2017 Rooftop Unit Metering Study*. Data maintained by Cadmus.

Demand Control Ventilation for Air Handling Units

Measure Master ID	Demand Control Ventilation for Air Handling Units, 2853
Workpaper ID	W0046
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)	$0.86/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

$$kWh_{\text{SAVED}} = (4.5 * CFM * \Delta h) * (EFLH_{\text{COOL}} * 12 / EER) * SF_{\text{COOL}} / 3{,}412 * (HOU / HOU_{\text{COOL}})$$

$$Therm_{\text{SAVED}} = (1.08 * CFM) * HOU * HDD / \eta / 100{,}000 * SF_{\text{HEAT}}$$

Where:

Variable	Description	Units	Value
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	cfm/minute	
Δh	Difference in enthalpy (Btu/lbm) between the design day outside air conditions and the return air conditions; lbm is pounds per mass	Btu/lbm	
$EFLH_{COOL}$	Equivalent full-load cooling hours	Hrs	Varies by building type; see table below)[3]
12	Conversion factor from EER to kW/ton	EER to kW/ton	12
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)[3]
3,412	Conversion factor	Btu/kWh	3,412
HOU	Hours of operation per day, provided by customer	Hrs/day	
HOU_{COOL}	Default hours of operation per day used in $EFLH_{COOL}$	Hrs/day	Varies by building type; see table below) [3]
1.08	Sensible heat load constant	Btu/cfm-°F-hr	1.08
HDD	Heating degree days	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) [3]

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

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

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

Where:

EUL = Effective useful life (= 10 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.

Revision History

Version Number	Date	Description of Change
01	01/2013	Initial TRM entry
02	12/2018	Updated incremental cost
03	11/2019	Corrected 15-year EUL in text to 10 years
04	08/2022	Updated cost

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[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 20 projects from 2019 to 2021.

[3] PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3-2 Lighting Hours of Use in Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Demand Control Ventilation, RTU Optimization

	Measure Details
Measure Master ID	Demand Control Ventilation, RTU Optimization, 3266
Workpaper ID	W0290
Measure Unit	Per RTU
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Rooftop Unit / Split System AC
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by area of conditioned space and number of occupants
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by area of conditioned space and number of occupants
Lifecycle Energy Savings (kWh)	Varies by area of conditioned space and number of occupants
Lifecycle Therm Savings (Therms)	Varies by area of conditioned space and number of occupants
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$2,130.68/AHU[2]

Measure Description

Commercial spaces are required to provide ventilation based on a minimum flow rate of outside air, 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 controls measure the carbon dioxide in the space as a proxy for the number of occupants and allow 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 RTU with an air side economizer and a fixed minimum ventilation rate.

Description of Efficient Condition

The efficient equipment includes a sensor that measures the carbon dioxide level of the space and an economizer that can adjust the ventilation rate to maintain carbon dioxide levels within the space according to code.

Annual Energy-Savings Algorithm

Savings are calculated using the Honeywell Savings Estimator[4] tool for RTUs, with inputs given in the following table.

Honeywell Savings Estimator Inputs

Data Input	Demand Controlled Ventilation
Outdoor CO_2 Level[3]	415 ppm
Building Type[4]	Small Office, Retail Store, School Classroom Wing, School Gymnasium, School Library, School Auditorium, Restaurant – Quick Serve, Restaurant – Casual Dining, Restaurant – Fine Dining, or Theater
Area[4]	Use actual building sq ft Saved modeling runs use 50%, 100%, 200%, 300%, 400%, and 800% of the Honeywell Savings Estimator default sq ft for the building type (which is on the small side)
Construction	Frame Construction
Thermal Envelope	ASHRAE Standard 90.1 - 2010 (Honeywell Savings Estimator default)
City	Nearest to site address[4] in Eau Claire, Green Bay, La Crosse, or Madison, Milwaukee
Equipment Type	Unitary AC and Gas Furnace[4]
Efficiency[5]	Cooling EER = 11.3 Heating Natural Gas EER = 0.82
Equipment Oversizing	10% cooling 20% heating (Honeywell Savings Estimator defaults)
Damper Leakage	3% (Honeywell Savings Estimator default)
Base Case Controls	Continuous Fan for Base Case = No Commercial Setback Thermostat as Base Case = No
Set Points Heating	Occupied 70°F Unoccupied 65°F (Honeywell Savings Estimator defaults)
Set Points Cooling	Occupied 75°F Unoccupied 80°F (Honeywell Savings Estimator default)
CO_2 Setpoint	1,100 ppm (Honeywell Savings Estimator default)
Occupancy	Honeywell Savings Estimator Default occupancy
Utility Rates	$1.00/therm; $0.10/kWh

Savings from Honeywell Estimator:

$$Therm_{\text{SAVED}} = Natural\ Gas\ Energy\ (DCV\ +\ DB) - Natural\ Gas\ Energy\ (Dry\ Bulb)$$

$$kWh_{\text{SAVED}} = Electric\ Energy\ (DCV\ +\ DB) - Electric\ Energy\ (Dry\ Bulb)$$

Where:

Variable	Description	Units	Value
Natural Gas Energy	Model output from Honeywell Savings Estimator in therms[6]	Therms	
DCV + DB	Demand control ventilation plus dry bulb economizer		
Dry Bulb	Dry bulb economizer controls		
Electric Energy	Model output from Honeywell Savings Estimator in kWh[6]	kWh	

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

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

$$kWh == kWh_{\text{SAVED}} * EUL$$

Where:

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

Assumptions

The minimum ventilation is based on ASHRAE 62.1-2010, which is representative for building stock addressed by measure.

Revision History

Version Number	Date	Description of Change
01	03/2013	Initial measure entry
02	12/2021	Re-activate workpaper, update EUL and incremental cost
03	10/2022	Update workpaper to be based off of Honeywell Savings Estimator V5.0.

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[1] Engineering judgment. Most CO_2 sensors have a 5-year warranty and need periodic cleaning and calibration. When they fail, they read high CO_2 levels so outdoor air is brought in and DCV ceases to function. An EUL of 10 years is deemed.

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 131 projects and 247 units from January 2018 to May 2020 is $2,130.68.

[3] Climate.gov website report that 2021 global average atmospheric carbon dioxide was 414.72 PPM. Accessed 10/19/2022. www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide

[4] Inputs collected from customer in Focus on Energy application.

[5] 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.

[6] Honeywell Savings Estimator Model located at: https://customer.honeywell.com/Documents/setupFullSE4_2_0_1.zip

Unit Heaters, ≥ 90% Thermal Efficiency

	Measure Details
Measure Master ID	Unit Heater, ≥ 90% Thermal Efficiency, 5436 Unit Heater, ≥ 90% Thermal Efficiency, Propane-Fueled, 5437
Workpaper ID	W0048
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)	2.79
Annual Propane Savings (Gallons)	3.06
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	41.9
Lifecycle Propane Savings (Gallons)	45.9
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$4.82[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 propane-fired heater.

Description of Efficient Condition

Qualified units must be condensing natural gas– or propane-fired unit heaters, with 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

$$Gas_{\text{SAVED}} = CAP_{\text{EE}} * LF * (Eff_{\text{EE}} / Eff_{\text{BASE}} - 1) * EFLH_{\text{HEAT}} / ConvF$$

Where:

Variable	Description	Units	Value
Gas_{SAVED}	Therms of natural gas or gallons of propane saved	Therms	
CAP_{EE}	Efficient unit heater input capacity in MBh	MBh	User input
LF	Load factor		= 0.7245; see Assumptions
Eff_{EE}	Thermal efficiency of new unit heaters		0.93[3]
Eff_{BASE}	Thermal efficiency of baseline unit heaters		0.80[4]
ConvF	Fuel conversion factor	MBtu/therm Mbtu/gallon	100 MBtu per therm, 91.3 MBtu per gallon propane)[5]

$$EFLH_{\text{HEAT}} = 24 * HDD / \Delta T \text{ in hours}$$

Where:

Variable	Description	Units	Value
24	Conversion factor from days to hours	Days to hrs	24
HDD	Heating degree days	Days	Varies by balance point inside temperature, see Assumptions

$$\Delta T = T_{\text{INSIDE}} - (T_{\text{OUTSIDE}} + TDR / 2)$$

Where:

Variable	Description	Units	Value
T_{INSIDE}	Design balance point inside temperature	°F	Varies with internal loads; see Assumptions
T_{OUTSIDE}	Design outside temperature	°F	Deemed; -15°F[5]
T_{DR}	Average winter diurnal temperature range	°F	18°F; see Assumptions

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

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

Where:

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

- Baseline equipment costs were obtained from an equipment supplier website that sells non-condensing unit heaters from multiple manufacturers.[2] Capacities ranged from 30 MBh to 400

MBh. The average baseline equipment cost was $12.634 per MBh for non-condensing unit heaters. Condensing unit heaters cost an average of $17.457 per MBh based on historical Focus on Energy project data from 2020 to September 2022. This resulted in an incremental cost of $4.82 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
La Crosse	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 $EFLH_{HEAT}$ of 1,890 hours at a 70°F setpoint. This is consistent with the average commercial $EFLH_{HEAT}$ used elsewhere in this technical manual.

Equivalent Full-Load Heating Hours by Thermostat Setpoint

Thermostat Setpoint Temperature	HDD Base Temperature, T_{INSIDE}	ΔT	HDD	$EFLH_{HEAT}$	$EFLH_{HEAT}$ * LF
66.1°F	61.1°F	67.1°F	6,629	2,371	1,718

This entry includes measures for natural gas–fired equipment eligible to both natural gas and propane customers. The Code of Federal Regulations,[3] 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.

Revision History

Version Number	Date	Description of Change
01	10/2018	Initial TRM entry
02	03/2019	Added propane measures
03	02/2020	Updated deemed savings to incorporate delivered efficiency
04	10/2022	Consolidate into one measure and use historical data to determine average heating setpoint. Update incremental cost.

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[1] PA Consulting Group. *Focus on Energy, 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. 2020 to September 2022. For 18 projects and 68 total unit heaters, the average unit heater cost is $17.46/MBh, less the baseline unit heater cost of $12.63/MBh from review of www.acwholesalers.com pricing (Accessed October 2022) for Reznor (UDX and UDZ series) and Modine (PDP and PTS series) unit heaters. $17.457 – $12.634 = $4.82/MBh.

[3] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average AFUE of 20 projects and 77 units from 1/2017 to 10/2019 is 93%.

[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] 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/

Infrared Heating Units, High or Low Intensity

	Measure Details
Measure Master ID	Infrared Heating Units, High or Low Intensity, 2422 Infrared Heating Units, High or Low Intensity, Propane, 4854
Workpaper ID	W0049
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)	Natural Gas = 3.34 (MMID 2422)
Annual Propane Savings (Gallons)	Propane = 3.65 (MMID 4854)
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Natural Gas = 50.1 (MMID 2422)
Lifecycle Propane Savings (Gallons)	Propane = 54.8 (MMID 4854)
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$8.01[2]

Measure Description

This measure applies to natural gas or propane–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 or propane–fired unit heater with a code minimum thermal efficiency of 80%.[3]

Description of Efficient Condition

The efficient condition is a natural gas or propane–fired infrared radiant heater with electronic ignition that uses non-conditioned air for combustion. Energy is saved in three possible ways:

- 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.
- 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.
- 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

$$Gas_{SAVED} = Gas_{BASE} - Gas_{EE}$$

$$Gas_{BASE} = Cap / RSF * EFLH / ConvF$$

$$Gas_{EE} = Cap * EFLH / ConvF$$

Where:

Variable	Description	Units	Value
Cap	Input capacity for new infrared heater	MBh	User input
RSF	Radiation Sizing Factor	%	0.85; see Assumptions
EFLH	Equivalent full-load heating hours	Hrs	1,890; see Assumptions
ConvF	Fuel conversion factor	MBtu/therm MBtu/gallon	100 (natural gas), 91.3 (propane)[4]

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

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

Where:

EUL = Effective useful life (= 15 years)

Assumptions

Radiation Sizing Factor suggested range of 0.80 to 0.85 in 2020 ASHRAE® Handbook. Value of 0.85 used for prescriptive measures for conservative deemed savings.[5]

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.

Supporting Inputs for Equivalent Full-Load Heating Hours by City for Business[6]

Location	$EFLH_{HEAT}$	Weighting by Participant
Green Bay	1,852	22%
La Crosse	1,966	3%
Madison	1,934	18%
Milwaukee	1,883	48%
Wisconsin Average	1,909	9%
Weighted Average	**1,890**	**100%**

Revision History

Version Number	Date	Description of Change
01	10/2018	Initial TRM entry
02	02/2021	Propane measure added
03	10/2023	New savings method. Updated IMC.

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[1] PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. Appendix B. August 25, 2009.

[2] Historical Focus on Energy project data. 2020 to July 2023.
Forty-three projects, 273 total unit heaters. Average unit heater cost is $15.09/MBh, minus the baseline unit heater cost of $7.08/MBh = $8.01/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] 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] U.S. Energy Information Administration. "Energy Units and Calculators Explained." https://www.eia.gov/energyexplained/?page=about_energy_units

[5] Radiant Heat Output (RSF) value determined by testing as per 2020 ASHRAE® HANDBOOK: Heating, Ventilating, and Air Conditioning SYSTEMS AND EQUIPMENT, Inch-Pound Edition, Chapter 16, pg. 16.1, "Energy Conservation," 2020, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. Atlanta, GA.

[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.

Direct-Fired Make-Up Air Units

	Measure Details
Measure Master ID	Direct Fired Make-Up Air Unit, Constant Volume, Natural Gas, 5081 Direct Fired Make-Up Air Unit, Variable Speed, Natural Gas, 10030 Direct Fired Make-Up Air Unit, Constant Volume, Propane, 5407 Direct Fired Make-Up Air Unit, Variable Speed, Propane, 10031
Workpaper ID	W0260
Measure Unit	Per CFM
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Direct Fired Heating
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
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)	$0.99[2]

Measure Description

This measure is installing a direct-fired make-up air unit in place of a standard efficiency, constant volume indirect-fired make-up air unit. Direct-fired make-up units heat with an open flame in the airstream, which sends the products of combustion into the space. As such, they are best used for spaces with high ventilation needs to ensure that products of combustion are vented to outdoors.

Constant volume direct-fired make-up air units operate at a constant speed when sending the heated airstream into the space. With no variable speed capabilities, electric savings will not be calculated for constant volume direct-fired make-up air units. Variable speed direct-fired make-up air units rely on variable frequency drives (VFDs) for energy savings by varying the fan speed that distributes the heated airstream. 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% in this example).

Description of Baseline Condition

The baseline condition is a constant volume make-up air unit with an indirect burner (flame separated from airstream), which is nominally 80% efficient.

Description of Efficient Condition

The efficient condition is either a constant volume or variable speed direct-fired make-up air unit, which is typically considered to have a 92% thermal efficiency rating.[3]

Annual Energy-Savings Algorithm

VFDs are responsible for the kWh savings for a variable speed direct-fired make-up air unit. The calculations use the same kWh savings calculation used for the other VFD measures and tools,[4] and uses the same HVAC Fan VFD energy savings algorithm that relies on data collected by Cadmus from 2014 through 2016.[5]

$$kWh_{SAVED} = \sum (kWh_{BASE} - kWh_{EE})$$

$$kWh_{BASE} = kWh_{HP,BASE} * HP_{FAN}$$

$$kWh_{EFF} = kWh_{HP,EE} * HP_{FAN}$$

Where:

Variable	Description	Units	Value
$kWh_{HP,BASE}$	Kilowatt- hours per horsepower without VFD	kWh/hp	Calc input
$kWh_{HP,EE}$	Kilowatt-hours per horsepower with VFD	kWh/hp	Calc input
HP_{FAN}	Supply fan horsepower	hp	User input

$$Therm_{SAVED} = \sum [[1.08 * CFM * (T_{SA} - T_{OA})] * (1 / Eff_{BASE} - 1 / Eff_{EE}) * ConvF * Hr] * Fan_{SPEED\%}$$

Where:

Variable	Description	Units	Value
1.08	Constant for sensible heat load equation	Btu/cfm-°F-hr	1.08
CFM	Outside airflow provided by make-up air unit	cfm	User input
T_{SA}	Supply air temperature from make-up air unit	°F	User input; use 65°F if unknown
T_{OA}	Outside air dry bulb from hourly TMY3 weather data file[6]	°F	
EFF_{BASE}	Thermal efficiency of indirect-fired make-up air unit	%	80%[7]
$EFFE_{EE}$	Thermal efficiency of direct-fired make-up air unit	%	92%[2]
ConvF	Fuel conversion factor	MBtu/therm MBtu/gallon	100 (natural gas) 91.3 (propane)[8]
Hr	Each hour of operation across a typical meteorological year	hrs	User input
$FAN_{SPEED\%}$	The % speed that the fan is operating at	%	100% (MMIDs 5081 & 5407); = Calc input (MMIDs 10030 & 10031)

Summer Coincident Peak Savings Algorithm

Peak savings vary per project based on whether the direct-fired make-up air unit is operating year-round, and operating during peak period hours. A direct-fired make-up air unit that only operates during the heating season will not realize peak savings. Because the calculation for the measure requires estimates of hour-by-hour energy savings for the entire year, the coincident peak savings can be directly calculated, rather than being determined using a coincidence factor.

$kW_{SAVED} = (kW_{BASE,PEAK} – kW_{EE,PEAK})$

$kW_{BASE,PEAK} = kWh_{BASE,PEAK} / Hrs_{PEAK}$

$kW_{EE,PEAK} = kWh_{EE,PEAK} / Hrs_{PEAK}$

Where:

Variable	Description	Units	Value
$kWh_{BASE,PEAK}$	Total baseline energy consumption during peak hours	kWh	Calc input
$kWh_{EE,PEAK}$	Total energy consumption with VFD during peak hours	kWh	Calc input
Hrs_{PEAK}	Total peak period hours	hrs	User input

Lifecycle Energy-Savings Algorithm

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

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

Where:

EUL = Effective useful life (18 years)[1]

Assumptions

- The hours of operation will be provided as a start/stop time for weekdays, Saturdays, and Sundays on the incentive application. A minimum of 500 hours annually are required. The constant volume calculation will assume that the operating schedule applies year-round without holidays unless specifically noted by the customer. The variable speed calculation will require user defined input to determine whether the schedule is year-round or heating season only. If the hourly dry bulb temperature in the weather data is below the make-up air unit supply air temperature and the operating schedule indicates that the building is occupied, heating savings will be calculated.
- A 92% Eff_{EE} value is used based on a reasonable estimate. After a year or more, this value will be updated based on actual application data.
- The electric savings calculations use pre-determined kilowatts per horsepower from a Cadmus HVAC fan VFD metering study (see workpaper W0155).

Revision History

Version Number	Date	Description of Change
01	11/2020	Initial TRM entry
02	10/2022	Added propane MMID
03	10/2023	Updated EUL ; Added variable speed measure and minimum hours value

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[1] The 18-year EUL estimate comes from a couple sources:
Navigant Consulting (Young, Jim). Field Demonstration of High Efficiency Gas Heaters. Prepared for Better Buildings Alliance and U.S. DOE. 2014. www.energy.gov/sites/prod/files/2014/11/f19/gas_heater_demo_report_2.pdf. EULs listed as approximately 15 to 20 years (18 years is the average value, rounded).

US DOE. Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Warm Air Furnaces. https://www.regulations.gov/document/EERE-2013-BT-STD-0021-0012. Table 8.2.16. January 2015. This document provides a median lifetime of 18.7 years. While direct-fired MUA aren't covered under this DOE definition, this is fairly similar to the technology and is also similar to RTUs in their components and their likely exterior location.

[2] Navigant Consulting (Young, Jim). Field Demonstration of High Efficiency Gas Heaters. Prepared for Better Buildings Alliance and U.S. DOE. 2014. www.energy.gov/sites/prod/files/2014/11/f19/gas_heater_demo_report_2.pdf. The field demonstration report lists a cost of $7.43 per MBh. Online lookups conducted in November 2019 of CFM and MBh from eight different manufacturers and 126 total models found a weighted average of 7.51 cfm per MBh, which results in an incremental cost of $0.99 per CFM.

[3] Boeckermann, Thomas, et al. "Direct-Fired Technology." ASHRAE Journal. September 2015. www.ruppair.com/documents/news/ASHRAE%20Direct%20Fired%20Heating%20Article.pdf

[4] Focus on Energy. “2020 VFD Calc-Business and Ag Measures.” VFD calculation spreadsheet.

[5] Cadmus. HVAC fan VFD metering study. July 2016. Monthly power consumption data for 56 HVAC fan VFD motors over one year and hourly power consumption data for 66 HVAC fan constant speed motors over one year.

[6] National Renewable Energy Laboratory. “National Solar Radiation Data Base, 1991- 2005 Update: Typical Meteorological Year 3.” https://nsrdb.nrel.gov/data-sets/archives.html

[7] International Code Council. *2015 International Energy Conservation Code*. Table 403.2.3(4). 2015. https://codes.iccsafe.org/public/document/IECC2015

[8] U.S. Energy Information Administration. “Energy Units and Calculators Explained.” https://www.eia.gov/energyexplained/?page=about_energy_units

Smart Thermostats for Business

	Measure Details
Measure Master ID	Smart Thermostat, Natural Gas Heat Source, 10041
Workpaper ID	W0050
Measure Unit	Per thermostat
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	465
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	113
Lifecycle Electricity Savings (kWh)	4,185
Lifecycle Therm Savings (Therms)	1,017
Water Savings (gal/year)	0
Effective Useful Life (years)	9[1]
Incremental Cost ($/unit)	Per-thermostat unit = $298.45[2]

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. 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 thermostat installed in a small business to replace the existing thermostat. Thermostat must control either boiler, furnace with A/C, rooftop unit, or unit heater with natural gas as the heat source.

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 includes 63 models from 17 manufacturers (as of September 14, 2020).

Annual Energy-Savings Algorithm

$$Therm_{\text{SAVED}} = EFLH_{\text{HEAT}} * CAP_{\text{HEAT}} / (EFF_{\text{HEAT}} * 100) * ESF_{\text{HEAT}}$$

$$kWh_{\text{SAVED}} = EFLH_{\text{COOL}} * CAP_{\text{COOL}} / EFF_{\text{COOL}} * RLF_{\text{COOL}} * ESF_{\text{COOL}}$$

Where:

Variable	Description	Units	Value
$EFLH_{HEAT}$	Equivalent full-load heating hours	Hrs	1,663 for unit heaters, see Assumptions; 1,890 average for other equipment in commercial buildings, see Equivalent Full-Load Heating Hours by City table below
CAP_{HEAT}	Heating system capacity	MBh	See Heating Capacity Info table in Assumptions section
EFF_{HEAT}	Efficiency of the heating system	%	89.6% for furnaces, 80.3% for rooftop units, 85.5% for boilers, 80% for unit heaters; see Efficiency Info table in Assumptions
100	Conversion factor	MBtu/therms	100
ESF_{HEAT}	Heating energy savings fraction	%	For smart thermostats: 4.6% for furnaces, rooftop units, and unit heaters; 3.9% for boilers, see Assumptions
$EFLH_{COOL}$	Equivalent full-load cooling hours	Hrs	599 average for Wisconsin commercial buildings, see Equivalent Full-Load Cooling Hours by Building Type table below
CAP_{COOL}	Cooling system capacity	MBh	See Cooling Capacity Info table in Assumptions section
EFF_{COOL}	Cooling system efficiency	Mbtu/kWh	0 for boilers, 13 SEER for furnaces with AC,[3] 11.4 EER for rooftop units;[4,5] see Efficiency Info table in Assumptions

Variable	Description	Units	Value
RLF_{COOL}	Rated load factor for cooling; peak cooling load/nameplate capacity. This factor compensates for oversizing air conditioning unit		0.90 for rooftop units, see Assumptions; 1.0 for all other
ESF_{COOL}	Cooling energy savings fraction	%	16.1% for furnace as heating system type and 11.3% for boiler as heating system type. See Assumptions

Equivalent Full-Load Heating Hours by City

Location	$EFLH_{HEAT}$[5]	Weighting by Participant
Green Bay	1,852	22%
La Crosse	1,966	3%
Madison	1,934	18%
Milwaukee	1,883	48%
Wisconsin Average	1,909	9%
Weighted Average	**1,890**	**100%**

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**

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

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

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

Where:

EUL = Effective useful life (= 9 years)[1]

Deemed Savings

Annual and Lifecycle Savings by Measure

Measure	MMID	Peak kW	Annual kWh	Lifecycle kWh	Annual therms	Lifecycle therms	Unit	Participation 2019-2023[7]
Smart Thermostat, Business Heated by								
Natural Gas Boiler	4375	0	0	0	0.86	7.76	Per MBh controlled	8%
Natural Gas Furnace with AC	4376	0	329	2,961	84	756	Per t-stat	67%
Natural Gas Rooftop Unit	4377	0	1,113	10,017	184	1,656	Per t-stat	22%
Natural Gas Unit Heater	5587	0	0	0	0.96	8.61	Per MBh controlled	3%
Natural Gas Heat Source	10041	0	465	4,185	113	1,017	Per t-stat	-

Assumptions

- For the 2022 Focus on Energy evaluation, Cadmus conducted a billing analysis to examine savings for participants who installed smart thermostats as part of the heating and cooling offering and the Online Marketplace Offering under the Direct to Customer Solutions. The 2022 *Focus on Energy Evaluation Report*[8] discusses these findings, and results from that billing analysis are analyzed further in the updated workpaper for these MMIDs.
- Energy savings factors for smart thermostats from the 2022 Cadmus billing analysis are shown in the table below.

Energy Savings Factors

Parameter	Thermostat Type	Furnace	Boiler
ESF_{HEAT}	Smart	4.6%	3.9%
ESF_{COOL}	Smart	16.1%	11.3%
ESF_{THERM}	Smart	17.1%	N/A

- Rooftop unit and unit heater energy savings factors are assumed to match furnace energy savings factors.
- For unit heaters (workpaper W0048), $EFLH_{HEAT}$ varies with the space temperature setpoint to account for unit heaters being used in lower temperature applications like parking garages and warehouses that are not heated to typical setpoints for offices, schools, retail, and similar. Using

historical project data[9] from Focus on Energy, the $EFLH_{HEAT}$ for unit heaters was determind to be 1,663. Details are shown in the table below.

Unit Heater Average EFLH

MMID	Setpoint Temperature (°F)	$EFLH_{HEAT}$ (including load factor adjustment)	MBh Participation	# of Projects	# of Unit Heaters
4753	70	1,890	735	2	5
4754	65	1,671	1,655	3	7
4755	60	1,464	900	3	5
4756	55	1,260	0	0	0
Weighted Average:		**1,663**			

- The heating and cooling efficiencies for boilers, furnaces, and rooftop units were obtained from *Potential Study* data,[5,6] 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 heating efficiencies for unit heaters were set to match the baseline and efficient condition values from workpaper W0048: 80%.[10]
- The cooling capacities for the furnace and rooftop unit measures were obtained by examining system sizes for an existing measure in historical project data.[11] 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. Boiler and unit heater systems were assumed to not have cooling capabililty.

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.[13] Heating capacity for rooftop units was obtained by examining common heating sizes matched to a cooling capacity of 146.2 MBh for three manufacturers.[12] 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
Unit Heater	5587	Unit heaters vary considerably in size, and large spaces may have multiple units controlled by a single 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

Revision History

Version Number	Date	Description of Change
01	05/2018	Initial TRM entry
02	12/2018	Added communicating thermostats, updated costs
03	09/2020	Removed communicating thermostats, added smart thermostat for unit heaters, updated cost
04	10/2023	MMID 5080 removed, measures consolidated into single MMID 10041 based on historical participation

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[1] GDS Associates. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*. Table 1, HVAC Controls. June 2007. https://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 6,350 projects and 7,163 units from May 2018 to July 2020 is $337.56 (MMIDs 3612 - 3615, 4054 - 4056, and 4301 - 4303, 4667, 4668, 4376, and 4377 in commercial and multifamily sectors). Minus the cost of a manual thermostat, which is $39.11 based on online lookups from July 2018.

[3] Appliance Standards Awareness Project. "Central Air Conditioners and Heat Pumps." http://www.appliance-standards.org/product/central-air-conditioners-and-heat-pumps

[4] 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.

[5] 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 TMY3 values.

[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] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. From January 2019 to August 2023. Average boiler capacity of 188 MBh from 23 projects. Average unit heater capacity of 129 MBh from 26 projects.

[8] Cadmus. *Focus on Energy Calendar Year 2022 Evaluation Report, Volume II*. May 22, 2023. https://assets.focusonenergy.com/production/inline-files/Evaluation_CY_2022-Vol-II.pdf

[9] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Eight projects and 17 heaters for MMIDs 4753, 4754, 4755, and 4756. January 1, 2019, to August 31, 2020.

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[10] 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

[11] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. January 1, 2016, through October 31, 2017.

[12] 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.

Energy Recovery Ventilator

	Measure Details
Measure Master ID	Energy Recovery Ventilator, 2314 Energy Recovery Ventilator, Sensible Only, 5082
Workpaper ID	W0052
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)	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)	15[1]
Incremental Cost ($/unit)	$6.70[2]

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 an HVAC system with the same facility operating hours, heating and cooling equipment efficiencies, and supply airflow CFM but without an energy recovery ventilator installed.

Description of Efficient Condition

The efficient condition is an ERV installed on the HVAC system. MMID 2314 is for ERVs that recover both sensible and latent heat, while MMID 5082 is for ERVs that only recover sensible heat. The system must both heat and cool the space, with minimum cooling hours from 2:00 p.m. to 6:00 p.m., June through September, and with heating occurring in the winter. Three additional specifications must be met:

- The leaving supply airflow matches (or is less than) AHRI standard 1060-2005. If the supply airflow is less than AHRI rated value, use the 75% airflow effectiveness ratings or interpolate between 75% and 100% as appropriate.
- Equipment is AHRI certified to standard 1060-2005 and bears 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:

$$kWh_{SAVED} = \Sigma\,(\Delta kWh_{\text{TEMP-INTERVAL}})$$

For sensible and latent energy recovery ventilators:

$$\Delta kWh_{\text{TEMP-INTERVAL}} = [\rho_{\text{AIR}} * 60 * CFM_{\text{SUPPLY}} * \eta_{\text{HX-SUMMER}} * (h_{\text{OUT}} - h_{\text{RETURN}}) / (EFF_{\text{COOL}} * 1{,}000) - kW_{\text{FAN}}] * t_{\text{TEMP-INTERVAL}}$$

For sensible only energy recovery ventilators:

$$\Delta kWh_{\text{TEMP-INTERVAL}} = [\rho_{\text{AIR}} * 60 * 0.24 * CFM_{\text{SUPPLY}} * \eta_{\text{HX-SUMMER}} * (T_{\text{COOLED}} - T_{\text{OUTSIDE}}) / (EFF_{\text{COOL}} * 1{,}000) - kW_{\text{FAN}}] * t_{\text{TEMP-INTERVAL}}$$

For sensible and latent energy recovery ventilators:

$$kW_{\text{FAN}} = CFM_{\text{SUPPLY}} * \Delta P_{\text{HX}} * 0.746 * 5.202 / (33{,}013 * \eta_{\text{FANMECH}} * \eta_{\text{FANMOTOR}})$$

When in heating, the savings for each temperature interval are calculated as:

$$Therm_{\text{SAVED}} = \Sigma\,(\Delta Therms_{\text{TEMP-INTERVAL}})$$

$$\Delta Therm_{\text{TEMP-INTERVAL}} = \rho_{\text{AIR}} * 60 * 0.24 * CFM_{\text{SUPPLY}} * \eta_{\text{HX-WINTER}} * (T_{\text{HEATED SPACE}} - T_{\text{OUTSIDE}}) / (100{,}000 * EFF_{\text{HEAT}}) * t_{\text{TEMP-INTERVAL}}$$

Where:

Variable	Description	Units	Value
ρ_{AIR}	Specific volume of air	Lb/ft^3	0.075 (at 1 atm and 68°F)
60	Conversion factor	min/hr	60
$\text{CFM}_{\text{SUPPLY}}$	Volume of supply air	$\text{ft}^3\text{/min}$	User input
$\eta_{\text{HX-SUMMER}}$	Efficiency of summer heat exchanger		User input from AHRI data sheet
h_{OUT}	Enthalpy of outside air	Btu/lb	Based on temperature interval
h_{RETURN}	Enthalpy of inside air at 75°F and 50% relative humidity	Btu/lb	28.3
EFF_{COOL}	Efficiency of cooling system	MBh/kW	User input, if unknown use 11.4 EER[3]
1,000	Conversion factor	Btu/MBtu	1,000
$t_{\text{TEMP-INTERVAL}}$	Number of hours the system operates in the particular temperature interval	Hrs	
0.24	Specfic heat of air	Btu/lb-°F	0.24
T_{COOLED}	Temperature inside cooled space	°F	74°F; see Assumptions
T_{OUTSIDE}	Midpoint of temperature interval outside	°F	
ΔP_{HX}	Pressure drop across heat exchanger		User input from AHRI data sheet, if unknown use 0.76 in of water; see Assumptions

Variable	Description	Units	Value
0.746	Conversion factor	kW/hp	0.746
5.202	Conversion factor from inches of water to pounds per square foot	Inches water to lbs/sq ft	5.202
33,013	Conversion factor from horsepower to foot pounds per minute	hp to ft lbs/ min	33,013
$\eta_{FANMECH}$	Fan mechanical efficiency	%	65%; see Assumptions
$\eta_{FANMOTOR}$	Fan motor efficiency	%	Actual, otherwise use default value of 89.5% for 5 hp fan motor; see Assumptions
$\eta_{HX\text{-}WINTER}$	Efficiency of summer heat exchanger		User input from AHRI data sheet
$T_{HEATED\ SPACE}$	Temperature inside heated space	°F	68°F; see Assumptions
100,000	Conversion factor	Btu/therm	100,000
EFF_{HEAT}	Efficiency of heating system as a percentage	%	User input, if unknown use 82.9%[4]

Summer Coincident Peak Savings Algorithm

$$kW_{SAVED} = kWh_{SAVED} / HOU_{COOLING}$$

Where:

$HOU_{COOLING}$ = Number of operating hours during cooling (= 1,258; see Assumptions)

Lifecycle Energy-Savings Algorithm

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

Where:

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

Assumptions

- The kilowatt-hour calculation may result in negative kilowatt-hour savings, as the fan pressure drop penalty is applied over all operating hours (in both heating and cooling mode), while the cooling savings from the ERV only apply to a small percentage of the annual hours of operation. A typical space heating temperature of 68°F and space cooling temperature of 74°F were selected, based on ASHRAE Standard 55-2017,[5] which recommends 67°F to 82°F to maintain thermal comfort, and based on values from ENERGY STAR,[6] which recommends 68°F to 78°F.
- A fan efficiency of 65% was selected based on engineering judgment and the ASHRAE Pocket Guide for Air Conditioning Heating Ventilation and Refrigeration recommending 55% to 60% for fan efficiency. Fan motors for ERVs are typically small (under 10 hp) and are intended to overcome the pressure drop of the heat exchange media. An average value of 5 hp was assumed, which corresponds to an efficiency of 89.5% for a NEMA Premium 1,800 RPM totally enclosed, fan-cooled motor.
- The default pressure drop across the heat exchanger was determind based on AHRI data for air-to-air energy recovery ventilators packages. The highest and lowest values (1.38 and 0.15 inches

of water) were excluded. The next highest and lowest values are 1.30 and 0.22 inches of water, with 0.76 as the midpoint.

- 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.[7]
- The weather intervals and corresponding operating hours in the following tables were used to calculate the deemed savings values.[7] The weather data bins identified as cooling mode in this table total 1,258 hours of operation in cooling mode. This value was used for calculating the kilowatt demand reduction.

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
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

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	12/2018	Updated incremental cost
03	10/2020	Added sensible-only ERV measure
04	08/2022	Cost update

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[1] PA Consulting Group. *Focus on Energy, 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 44 projects from January 2021 to July 2022.

[3] 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. Average installed roof-top unit efficiency is 11.4 EER.

[4] 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. Average installed boiler efficiency is 85.5% and average installed roof-top unit heating efficiency is 80.3%. The midpoint of these two efficiencies is 82.9%.

[5] American Society of Heating Refrigerating and Air-Cconditioning Engineers. *Standard 55: Thermal Environmental Conditions for Human Occupancy*. 2017. https://ashrae.iwrapper.com/ASHRAE_PREVIEW_ONLY_STANDARDS/STD_55_2017

[6] U.S. Department of Energy. “Energy Saver Thermostat.” Accessed November 20, 2020. https://www.energy.gov/energysaver/thermostats

[7] Franklin Energy. Focus on Energy Program Energy Recovery Ventilator Calculator.

ECM HVAC Fan Motors

	Measure Details
Measure Master ID	ECM HVAC Fan Motors, Heating, 3910 ECM HVAC Fan Motors, Cooling, 3911 ECM HVAC Fan Motors, Occupied Ventilation, 3912 ECM HVAC Fan Motors, 24/7 Ventilation, 3913
Workpaper ID	W0054
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)	21[1]
Incremental Cost ($/unit)	$120.00 per motor[2]

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.

$$kWh_{\text{SAVED}} = hp * 0.746 * (1/Eff_{\text{BASE}} - 1/Eff_{\text{EE}}) * HOU$$

Where:

Variable	Description	Units	Value
hp	Horsepower of motor being replaced	hp	Customer provided
0.746	Conversion factor	kW/hp	0.746
Eff_{BASE}	Motor efficiency of baseline technology	%	36.25%[2]
Eff_{EE}	Motor efficiency for ECM	%	70.0%[2]
HOU	Average annual hours of operation	Hrs/yr	Varies by motor application and sector; see table below

Hours of Use by Fan Type and Sector

MMID	Fan Type	Sector	Hours of Use
3910	Heating Fan[3]	All	2,285
3911	Cooling Fan[3]	All	678
3912	Occupied Ventilation	Commercial[4]	3,730
		Industrial[4]	4,745
		Agriculture[4]	4,698
		Schools and Government[4]	3,239
		Residential-Multifamily (common areas)[5]	5,950
3913	24/7 Ventilation	All	8,760

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = hp * 0.746 * (1/Eff_{\text{BASE}} - 1/Eff_{\text{EE}}) * CF$$

Where:

CF = Coincidence factor (varies by fan type; see table below)

Coincidence Factor by Fan Type

MMID	Fan Type	Coincidence Factor
3910	Heating Fan[6]	0.0
3911	Cooling Fan[5]	0.8
3912	Occupied Ventilation[7]	0.9
3913	24/7 Ventilation[8]	1.0

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (21 years)[1]

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 (MMID 3910)	Cooling Fan kW Reduced (MMID 3911)	Occupancy Vent kW Reduced (MMID 3912)	24/7 Vent kW Reduced (MMID 3913)
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 (MMID 3912)					24/7 Vent kWh Saved (MMID 3913)
		Heating (MMID 3910)	Cooling (MMID 3911)	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 (MMID 3912)					24/7 Vent kWh Saved (MMID 3913)
		Heating (MMID 3910)	Cooling (MMID 3911)	Comm	Indust	Ag	S&G	MF	
1.0	1.0	47,607	14,133	77,721	98,868	97,881	67,494	123,984	182,532

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.

Revision History

Version Number	Date	Description of Change
01	09/2016	Initial TRM entry
02	07/2022	EUL Update

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[1] U.S. Department of Energy. Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment. p. 310; 8-22. https://downloads.regulations.gov/EERE-2010-BT-STD-0011-0111/content.pdf

[2] 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.

[3] Appendix B: Common Variables, Heating and Cooling Degree Days. Converted HDD to hours using process for MMID 3275, and CDD to hours using process for MMIDs 3494 to 3505*.*

[4] PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use in Commercial Applications. 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.

[5] Tetra Tech. *ACES Deemed Savings Desk Review*. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf

[6] Engineering judgment. By definition of the measure, the motor only operates during the heating season, making the peak demand coincidence factor = 0.

[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] Engineering judgment. By definition of the measure, the motor operates continuously, making the peak demand coincidence factor = 1.0.

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
Workpaper ID	W0055
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)	18[1]
Incremental Cost ($/unit)	$1,025.44 (MMID 4368)[2,3] $1,749.75 (MMID 4369)[2,3] $1,083.06 (MMID 4370)[2,3] $2,742.68 (MMID 4371)[2,3]

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 is a standard efficiency packaged or split air conditioner that meets the energy efficiency requirements of 10 CFR Ch. 11, §431,97, Table 3, which covers equipment from ≥ 65 kBtu to < 760 kBtu. For equipment ≥ 760 kBtu, minimum efficiencies are defined by Wisconsin Commercial Building Code, which references IECC 2015. The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

Baseline Equipment Efficiency

Size of Standard AC Unit	Minimum Efficiency			
	Electric Resistance Heat		All Other Heat (including Natural Gas)	
≥ 65 and < 135 kBtu/hour (≥ 5.42 to < 11.25 tons)[4]	14.8 IEER		14.6 IEER	
≥ 135 and < 240 kBtu/hour (≥ 11.25 to < 20.00 tons)[4]	14.2 IEER		14.0 IEER	
≥ 240 and < 760 kBtu/hour (≥ 20.00 to < 63.33 tons)[4]	13.2 IEER		13.0 IEER	
≥ 760 kBtu/hour (≥ 63.33 tons)[5]	9.7 EER	11.2 IEER	9.5 EER	11.0 IEER

Description of Efficient Condition

The efficient equipment is a high-efficiency packaged air conditioner or variable refrigerant flow (VRF) system 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[6]
≥ 65 and < 135 kBtu/hour (≥ 5.42 to < 11.25 tons)	16.1 IEER
≥ 135 and < 240 kBtu/hour (≥ 11.25 to < 20.00 tons)	15.4 IEER
≥ 240 and < 760 kBtu/hour (≥ 20.00 to < 63.33 tons)	14.3 IEER
≥ 760 kBtu/hour (≥ 63.33 tons)	9.7 EER and 11.4 IEER

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = (CAP * 12) * (1 / IEER_{\text{BASE}} - 1 / IEER_{\text{EE}}) * EFLH_{\text{COOL}}$$

Where:

Variable	Description	Units	Value
CAP	Rated cooling capacity of the energy-efficient unit	Tons	
12	Conversion factor	MBh/ton	
$IEER_{BASE}$	Integrated energy efficiency ratio of standard efficiency code baseline unit	Btu/watt-hour	
$IEER_{EE}$	Integrated energy efficiency ratio of efficient unit in Btu/watt-hour	Btu/watt-hour	
$EFLH_{COOL}$	Equivalent full-load cooling hours	Hrs	410 for multifamily; 599 for commercial, industrial, agriculture, and schools and government; see tables below

Multifamily Equivalent Full-Load Cooling Hours by Location

Location	$EFLH_{COOL}$[7]	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	$EFLH_{COOL}$[8]
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%)[7]

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (= 18 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, Natural Gas Heat

Capacity (Btu/hour)	EER_{BASE}	EER_{EE}	$IEER_{BASE}$	$IEER_{EE}$	MMID	kW_{SAVED}	kWh_{SAVED}	$kWh_{LIFECYCLE}$
100,000	11.0	11.0	14.6	16.1	4368	0.00	262	4,716
187,000	10.8	10.8	14.0	15.4	4369	0.00	498	8,964
500,000	9.8	9.8	13.0	14.3	4370	0.00	1,434	25,812
800,000	9.5	9.7	11.0	11.4	4371	1.39	1,046	18,828

Reference Savings Values by Capacity:
Commercial, Industrial, Agriculture, and Schools & Government, Natural Gas Heat

Capacity (Btu/hour)	EER_{BASE}	EER_{EE}	$IEER_{BASE}$	$IEER_{EE}$	MMID	kW_{SAVED}	kWh_{SAVED}	$kWh_{LIFECYCLE}$
100,000	11.0	11.0	14.6	16.1	4368	0.00	382	6,876
187,000	10.8	10.8	14.0	15.4	4369	0.00	727	13,086
500,000	9.8	9.8	13.0	14.3	4370	0.00	2,094	37,692
800,000	9.5	9.7	11.0	11.4	4371	1.39	1,529	27,522

Assumptions

- The reference savings values were calculated for hypothetical units with capacities equal to the midpoint of each interval found in the IECC 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.[3] This results in the following incremental cost per DX Cooling unit:

Size Category	MMID	# of Applications	Average Capacity (tons)[3]	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

Revision History

Version Number	Date	Description of Change
01	10/2015	Initial TRM entry
02	12/2015	Revised per evaluator comments
03	11/2017	Updated to standardize offer across business and multifamily programs
04	01/2019	Updated efficient EER requirements, measure unit, costs
05	10/2020	Correct sources #3 and #4
06	08/2022	Updated EUL
07	10/2022	Update ≥ 65 kBtu to < 760 kBtu equipment to use new federal efficiency requirements that take effect January 2023.
08	10/2023	Added VRF language in efficient condition

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[1] Average between the State of Wisconsin Public Service Commission Measure Life Study and U.S. Department of Energy Technical Support Document sources was calculated.
PA Consulting Group. *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
Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment . p. 202; 8-24. https://downloads.regulations.gov/EERE-2013-BT-STD-0007-0105/attachment_1.pdf

[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] 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.

[4] U.S. Code of Federal Regulations. 10 CFR Ch. 11, §431,97, Table 3. www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431/subpart-F/subject-group-ECFR2640f6ad978e4e6/section-431.97

[5] International Code Council. *2015 International Energy Conservation Code*. Table C403.2.3(1). 2015. https://codes.iccsafe.org/content/IECC2015

[6] Consortium for Energy Efficiency. *High Efficiency Commercial Air Conditioning and Heat Pump Initiative*. Unitary AC Specifications for Tier 1. Copy for Public Review, November, 2022.
Values for "Heating Section Type" = "All Other."

[7] Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. November 14, 2014.
https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

[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.

A/C Split System or Single Package, ≤ 65 MBh, SEER2 16-20

	Measure Details
Measure Master ID	A/C Split System or Single Package, ≤ 65 MBh: SEER2 16, 5423 SEER2 17, 5424 SEER2 18, 5425 SEER2 19, 5426 SEER2 20, 5427
Workpaper ID	W0056
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 SEER2 level and application type
Peak Demand Reduction (kW)	Varies by SEER2 level and application type
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by SEER2 level and application type
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	18[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. Single package air conditioners (also referred to as unitary equipment or rooftop units) have the compressor and condenser packaged together in a common unit outside of the building, then connect ductwork to send the conditioned air inside the building. Energy savings result from installing a more efficient unit than the market standard.

Description of Baseline Condition

For both single package and split system air conditioners, the baseline condition is a SEER2 13.4 unit, both for new construction and for existing buildings.[3] For air conditioners that only have the old SEER and EER ratings, a conversion process is available, see the Assumptions section.

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 SEER2 16 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.[4]

Annual Energy-Savings Algorithm

$$kWh_{SAVED} = (CAP * 12) * (1 / SEER2_{BASE} - 1 / SEER2_{EE}) * EFLH_{COOL}$$

Where:

Variable	Description	Units	Value
CAP	Rated cooling capacity of the energy-efficient unit	Tons	
12	Conversion factor from tons to MBh	Tons to MBh	
$SEER2_{BASE}$	Seasonal energy efficiency rating of baseline unit		13.4 for both single package and split systems[3]
$SEER2_{EE}$	Seasonal energy efficiency rating of efficient unit		16, 17, 18, 19, or 20
$EFLH_{COOL}$	Equivalent full-load cooling hours	Hrs	410 for multifamily, 599 for business; see tables 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 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**

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = (CAP * 12) * (1 / EER2_{\text{BASE}} - 1 / EER2_{\text{EE}}) * CF$$

Where:

EER2$_{\text{BASE}}$ = Energy efficiency ratio of baseline unit (= 11.2 for 13.4 SEER2 unit, see assumptions)

EER2$_{\text{EE}}$ = Energy efficiency ratio of efficient unit (= 12.5 for 16 SEER2 unit, = 13.0 for 17 SEER2 unit, = 13.3 for 18 SEER2 unit, = 13.7 for 19 SEER2 unit, = 14.0 for 20 SEER2 unit)

CF = Coincidence factor (= 0.80)[5]

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (= 18 years)[1]

Deemed Savings

Deemed Savings per Ton by MMID and Sector

Sector	Equipment Type	SEER2	MMID	Savings (kW)	Annual Savings (kWh)	Lifecycle Savings (kWh)
Multifamily	Split System or Single Package	16	5423	0.089	60	1,080
		17	5424	0.114	78	1,404
		18	5425	0.135	94	1,692
		19	5426	0.153	108	1,944
		20	5427	0.168	121	2,178
Commercial, Industrial, Agriculture, Schools & Government	Split System or Single Package	16	5423	0.089	87	1,566
		17	5424	0.114	114	2,052
		18	5425	0.135	137	2,466
		19	5426	0.153	158	2,844
		20	5427	0.168	177	3,186

Assumptions

The new efficiency standards for < 65 Mbh equipment only specify a minimum SEER2 value for Wisconsin. To estimate EER2 for demand savings, the following conversions were used:

> SEER and EER values can be converted using SEER2 = Unit Type * SEER Conversion or EER2 = Unit Type * EER Conversion, where Unit Type is from the table below:

Converter Table[7]

Unit Type	SEER2 Conversion	EER2 Conversion	HSPF2 Conversion
Ducted	0.95	0.95	0.91
Ductless	1.00	1.00	0.95
Packaged	0.95	0.95	0.84

Additionally, SEER values were converted to EER (for calculating kilowatt savings) based on:

EER = (-0.02 * SEER^2) + 1.12 * SEER[8]

The following calculations show resulting EER2 using equations above for units with SEER baseline of 13.4:

Baseline SEER = 13.4 SEER2 baseline / 0.95 (assume most units are ducted or packaged) = 14.105 SEER

Baseline EER = (-0.02 x 14.1052) + 1.12 * 14.105 = 11.81 EER

Baseline EER2 = 11.819 EER * 0.95 = 11.2

Using equations above, EER2 are provided in table below for given SEER2 efficiencies.

SEER2 to EER2 Conversion[8]

SEER2	EER2
16	12.5
17	13.0
18	13.3
19	13.7
20	14.0

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 SEER2 levels. Incremental cost data was set using a weighted average of split system vs. single package historical program data from January 2020 to September 2022.

The following table shows incremental costs for each measure.

Incremental Costs by Measure

Measure	MMID	Historical % Split System[9]	Incremental Cost (per ton)[2]
A/C Split System or single package, ≤ 65 MBh, SEER2 16	5423	86%	$411.55
A/C Split System or single package, ≤ 65 MBh, SEER2 17	5424	46%	$1,141.68
A/C Split System or single package, ≤ 65 MBh, SEER2 18	5425	88%	$685.27
A/C Split System or single package, ≤ 65 MBh, SEER2 19	5426	77%	$1,084.00
A/C Split System or single package, ≤ 65 MBh, SEER2 20	5427	73%	$1,385.99

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.
04	10/2020	Retired SEER 15, added SEER 19 and 20
05	09/2022	Update for new SEER2 and EER2 requirements taking effect in 2023
06	09/2023	EUL Update

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[1] Average between the State of Wisconsin Public Service Comission Measure Life Study and U.S. Department of Energy Technical Support Document sources was calculated. PA Consulting Group. *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
Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment . p. 202; 8-24. https://www.regulations.gov/document/EERE-2013-BT-STD-0007-0105

[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] Electronic Code of Federal Regulations. Title 10, Chapter II, Subchapter D, Part 430, Subpart C, §430.32(c)(1). https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32

[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 were weather normalized for statewide use by population density.

[7] Consortium for Energy Efficiency (CEE) Testing, Testing, M1, 2, 3, Transitioning to New Federal Minimum Standards, CEE Summer Program Meeting, June 10, 2022.

[8] Robert Hendron and Cheryn Engebrecht, National Renewable Energy Lab. *Building America House Simulation Protocols.* October 2010. Page 7. https://www.nrel.gov/docs/fy11osti/49246.pdf

[9] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. For January 2021 through September 2022, there were a total of 274 split systems and 44 single package systems installed.

A/C Split System, Condensing Unit Only, High Efficiency

	Measure Details
Measure Master ID	A/C Split System, Condensing Unit Only, High Efficiency, 3909
Workpaper ID	W0057
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)	18[1]
Incremental Cost ($/unit)	$82.34[2]

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 are rated as “condensing unit only,” and generally appear 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 is a standard efficiency condensing unit that meets the 2015 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 = 10.5 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 10.5 EER / (1 – 0.09) = 11.5 EER.

Efficient air-cooled condensing unit ≥ 135,000 Btu/hr = 11.5 EER

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = Capacity * 12{,}000 * EFLH_{\text{C}} * (1 / 1{,}000) * (1/EER_{\text{BASE}} - 1/EER_{\text{EE}})$$

Where:

Variable	Description	Units	Value
Capacity	Capacity (size) of the condensing unit	Tons	
12,000	Conversion factor	Btu/ton	12,000
$EFLH_C$	Equivalent full-load cooling hours	Hrs	Varies by building type; see table below for default values
1,000	Conversion factor	W/kW	1,000
EER_{BASE}	Energy efficiency ratio of baseline condensing unit	Btu/watt-hour	10.5 EER
EER_{EE}	Energy efficiency ratio of efficient condensing unit	Btu/watt-hour	11.5 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

$$kW_{\text{SAVED}} = Capacity * (1 / 1{,}000) * CF * (1/EER_{\text{BASE}} - 1/EER_{\text{EE}})$$

Where:

CF = Coincidence factor (= 0.8)[6]

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (= 18 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}	kW_{BASE}	kW_{EE}	kW_{SAVED}	kWh_{BASE}	kWh_{EE}	kWh_{SAVED}	$kWh_{LIFECYCLE}$
187,000	10.5	11.5	14.25	13.01	1.24	10,668	9,740	928	16,704
500,000	10.5	11.5	38.10	34.78	3.31	28,524	26,043	2,480	44,640
800,000	10.5	11.5	60.95	55.65	5.30	45,638	41,670	3,969	71,442

Assumptions

- The average (mean) value for all building types was used to determine cooling EFLH.
- The deemed savings values were calculated for hypothetical units with capacities equal to the midpoint of each interval found in the IECC 2015 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.

Revision History

Version Number	Date	Description of Change
01	03/2017	Initial TRM entry
02	10/2020	Correct sources #2 and #3
03	10/2022	Update baseline and efficient condition to current state building code

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[1] PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

[2] 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)

[3] International Energy Conservation Code. Table C403.2.3(1). 2015. https://codes.iccsafe.org/content/IECC2015/chapter-4-ce-commercial-energy-efficiency

[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.

[6] PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. https://www.focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Commercial Air Source Heat Pumps

	Measure Details
Measure Master ID	Commercial Air Source Heat Pumps: ≥ 5.42 to < 11.25 tons, 10025 ≥ 11.25 to < 20.00 tons, 10026 ≥ 20.00 to < 63.33 tons, 10027
Workpaper ID	W0315
Measure Unit	Per Heat Pump
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Other
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)	$1,025.44 (MMID 10025) $1,749.75 (MMID10026) $1,083.06 (MMID 10027)

Measure Description

This measure is installing high-efficiency, unitary packaged or split system air source heat pump that is ≥ 65,000 Btu/hr (5.42 tons). Installed heat pumps are designed for full cooling load replacement described in workpaper W0055, but only offset a portion of a facility's main heating source due to limited operating temperature range. 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

For the cooling operation, the baseline condition is a standard efficiency packaged or split system heat pump that meets the energy efficiency code requirements of 10 CFR Ch. 11, §431,97, Tables 1, 3, and 4, which covers equipment ≥ 65 kBtu to < 760 kBtu.

For the heating operation in existing retrofits, the baseline condition can vary depending on the facility's current main heating source, either electric resistance or natural gas sourced. If a facility has not been previously heated, the baseline condition is a code minimum heat pump.

For the heating operation in new construction, the baseline condition is a code minimum heat pump.

Baseline Equipment Efficiency

Size of Standard HP Unit	Minimum Efficiency (Code Requirements)			
	Electric Resistance Heat[2,3]	All Other Heat (including NG)[2,3]	Average value (calc baseline)	COP[4]
≥ 65 and < 135 kBtu/hour (≥ 5.42 to < 11.25 tons)	11 EER 14.1 IEER	10.8 EER 13.9 IEER	10.9 EER 14.0 IEER	3.4
≥ 135 and < 240 kBtu/hour (≥ 11.25 to < 20.00 tons)	10.6 EER 13.5 IEER	10.4 EER 13.3 IEER	10.5 EER 13.4 IEER	3.3
≥ 240 and < 760 kBtu/hour (≥ 20.00 to < 63.33 tons)	9.5 EER 12.5 IEER	9.3 EER 12.3 IEER	9.4 EER 12.4 IEER	3.2

Description of Efficient Condition

The efficient equipment is a high-efficiency packaged or split system heat pump that meets or exceeds the energy efficiency requirements listed in the table below.

Efficient Equipment Requirements

Size of High-Efficiency Heat Pump	Minimum to Qualify	
	IEER	COP
≥ 65 and < 135 kBtu/hour (≥ 5.42 to < 11.25 tons)	15.1	3.4
≥ 135 and < 240 kBtu/hour (≥ 11.25 to < 20.00 tons)	14.5	3.3
≥ 240 and < 760 kBtu/hour (≥ 20.00 to < 63.33 tons)	13.5	3.2

Annual Energy-Savings Algorithm

$$kWh_{\text{COOL}} = (CAP_{COOL} * 12) * (1 / IEER_{\text{BASE}} - 1 / IEER_{\text{EE}}) * EFLH_{\text{COOL}}$$

$$kWh_{\text{HEAT}} = CAP_{HEAT} * (ELECTRIC_{BASE} / COP_{\text{BASE}} - 1 / COP_{\text{EE}}) * EFLH_{\text{HEAT}} / 3{,}412$$

$$kWh_{\text{SAVED}} = kWh_{\text{COOL}} + kWh_{\text{HEAT}}$$

$$Therm_{\text{SAVED}} = CAP_{HEAT} * EFLH_{HEAT} * NG_{BASE} / TE_{BASE} / 100{,}000$$ Where:

Variable	Description	Units	Value
CAP_{COOL}	Rated cooling capacity of the energy-efficient unit	Tons	User input
12	Conversion factor	MBh/ton	
$IEER_{BASE}$	Integrated energy efficiency ratio of standard efficiency baseline unit	Btu/watt-hour	See baseline efficiency table above
$IEER_{EE}$	Integrated energy efficiency ratio of efficient unit	Btu/watt-hour	User input
$EFLH_{COOL}$	Equivalent full-load cooling hours	Hrs	Per building type, see assumptions
CAP_{HEAT}	Rated heating capacity of the energy-efficient unit	Btu/h	
$ELECTRIC_{BASE}$	Factor indicating whether baseline case is heat pump or electric resistance heat		1 if baseline is heat pump or electric resistance heat, 0 if baseline is natural gas sourced heat
COP_{BASE}	Coefficient of performance of baseline equipment		1 if electric resistance; see baseline efficiency table

Variable	Description	Units	Value
COP_{EE}	Coefficient of performance of efficient equipment		User input
$EFLH_{HEAT}$	Equivalent full-load heating hours	Hrs	Per closest city, see assumptions
3,412	Conversion factor	Btu/kWh	3,412
GAS_{BASE}	Factor indicating whether the baseline case had natural gas heat		1 if natural gas heat source, otherwise 0
TE_{BASE}	Thermal Efficiency of offset heat source	%	82% assumed or user input if greater
100,000	Conversion factor	Btu/therm	100,000

Summer Coincident Peak Savings Algorithm

$$kW_{SAVED} = (CAP_{COOL} * 12) * (1 / EER_{BASE} - 1 / EER_{EE}) * CF$$

Where:

Variable	Description	Units	Value
EER_{BASE}	Energy efficiency ratio of standard efficiency baseline unit	Btu/watt-hour	See baseline efficiency table above
EER_{EE}	Energy efficiency ratio of efficient unit	Btu/watt-hour	User input
CF	Coincidence factor		0.80[5]

Lifecycle Energy-Savings Algorithm

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

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

Where:

EUL = Effective useful life (= 18 years[1])

Deemed Savings

The measure is hybrid and savings will vary.

Assumptions

- Incremental Costs reference workpaper W0055 and their equivalent measures. To be updated in the future per program participation.
- The baseline cooling performance criteria, both EER and IEER, were determined by averaging "All Other" Heat Type and Electric Resistance values respectively, even though majority are assumed to be rooftop units with gas heating.
- Thermal efficiency assumed to range from 80% to 82% for non-condensing rooftop units with natural gas heat.
- Determining the equivalent full-load cooling 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

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%
Weighted Average	**410**	**100%**

- Determining the equivalent full-load heating hours are presented in the tables below.

Supporting Inputs for Equivalent Full-Load Heating Hours by City

Location	$EFLH_{HEAT}$[7]	Adjusted $EFLH_{HEAT}$
Green Bay	1,852	1,137
La Crosse	1,966	1,207
Madison	1,934	1,187
Milwaukee	1,883	1,156
Wisconsin Average	1,909	1,172

- $EFLH_{HEAT}$ 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. 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.

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**	**61.4%**

Revision History

Version Number	Date	Description of Change
01	10/2023	Initial TRM entry

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[1] Average between the State of Wisconsin Public Service Commission Measure Life Study and U.S. Department of Energy Technical Support Document sources was calculated.
PA Consulting Group. *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
Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment . p. 202; 8-24. https://downloads.regulations.gov/EERE-2013-BT-STD-0007-0105/attachment_1.pdf

[2] U.S. Code of Federal Regulations. 10 CFR Ch. 11, §431,97, Table 1. www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431/subpart-F/subject-group-ECFR2640f6ad978e4e6/section-431.97

[3] U.S. Code of Federal Regulations. 10 CFR Ch. 11, §431,97, Table 3. www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431/subpart-F/subject-group-ECFR2640f6ad978e4e6/section-431.97

[4] U.S. Code of Federal Regulations. 10 CFR Ch. 11, §431,97, Table 4. www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431/subpart-F/subject-group-ECFR2640f6ad978e4e6/section-431.97

[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 were weather normalized for statewide use by population density.

[7] 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.

Air Source Heat Pump, Split System, ≤65 MBh

	Measure Details
Measure Master ID	Air-Source Heat Pump, Split System, ≤ 65 MBh: SEER2 16 and 8.5 HSPF2, 5428 SEER2 17 and 8.5 HSPF2, 5429 SEER2 18 and 8.5 HSPF2, 5430 SEER2 19 and 8.5 HSPF2, 5431 SEER2 20 and 8.5 HSPF2, 5432
Workpaper ID	W0058
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)	18[1]
Incremental Cost ($/ton)	Varies by measure, see Incremental Costs by Measure table[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. 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 split system heat pump with a cooling capacity of 5.42 tons or less, a cooling efficiency of 14.3 SEER2, and a heating efficiency of 7.5 HSPF2[3] for both new construction and retrofits.

Description of Efficient Condition

The efficient condition is an air cooled split system heat pump with a cooling capacity of 5.42 tons or less, a cooling efficiency of 16, 17, 18, 19, or 20 SEER2, and a heating efficiency of at least 8.5 HSPF2.

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

$$kWh_{\text{SAVED}} = kWh_{\text{COOL}} + kWh_{\text{HEAT}}$$

$$kWh_{\text{COOL}} = (CAP * 12) * [(1 / SEER2_{\text{BASE}}) - (1 / SEER2_{\text{EE}})] * EFLH_{\text{COOL}}$$

$$kWh_{\text{HEAT}} = (CAP * 12) * [(1 / HSPF2_{\text{BASE}}) - (1 / HSPF2_{\text{EE}})] * EFLH_{\text{HEAT}}$$

Where:

Variable	Description	Units	Value
CAP	Rated cooling capacity of the energy-efficient unit	Tons	
12	Conversion factor	MBh/ton	12
$SEER2_{BASE}$	Cooling seasonal energy efficiency rating of baseline unit	MBh/kW	14.3[3]
$SEER2_{EE}$	Seasonal energy-efficiency rating of efficient unit		16, 17, 18, 19, or 20
$EFLH_{COOL}$	Equivalent full-load hours in cooling mode	Hrs	410 average for Wisconsin multifamily buildings, 599 average for Wisconsin commercial buildings; see tables below
$HSPF2_{BASE}$	Heating seasonal performance factor of baseline unit	MBh/kW	7.5[3]
$HSPF2_{EE}$	Heating seasonal performance factor of efficient unit	MBh/kW	8.5
$EFLH_{HEAT}$	Equivalent full-load hours in heating mode	Hrs	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%
La Crosse	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

$$kW_{\text{SAVED}} = (CAP * 12) * [(1 / EER2_{\text{BASE}}) - (1 / EER2_{\text{EE}})] * CF$$

Where:

EER_{BASE} = Energy efficiency ratio of baseline unit (11.8 for 14.3 SEER2 unit, see assumptions)

EER_{EE} = Energy efficiency ratio of efficient unit (12.7 for 16 SEER2 unit, 13.1 for 17 SEER2 unit, 13.5 for 18 SEER2 unit, 13.9 for 19 SEER2 unit, 14.2 for 20 SEER2 unit, see assumptions)

CF = Coincidence factor (0.80)[8]

Lifecycle Energy-Savings Algorithm

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

Where:

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

Deemed Savings

Deemed Savings per Ton by MMID and Sector

Sector	SEER2	MMID	Savings (kW)	Annual Savings (kWh)	Lifecycle Savings (kWh)
Multifamily	16	5428	0.0543	255	4,590
	17	5429	0.0799	273	4,914
	18	5430	0.1017	289	5,202
	19	5431	0.1202	303	5,454
	20	5432	0.1358	316	5,688
Commercial, Industrial, Agriculture, Schools & Government	16	5428	0.0543	409	7,362
	17	5429	0.0799	436	7,848
	18	5430	0.1017	459	8,262
	19	5431	0.1202	480	8,640
	20	5432	0.1358	499	8,982

Assumptions

The new efficiency standards for < 65 MBh equipment only specify a minimum SEER2 value for Wisconsin. To estimate EER2 for demand savings, the following conversions were used:

> SEER and EER values can be converted using SEER2 = Unit Type * SEER Conversion or EER2 = Unit Type * EER Conversion, where Unit Type is from the table below:

Converter Table[9]

Unit Type	SEER2 Conversion	EER2 Conversion	HSPF2 Conversion
Ducted	0.95	0.95	0.91
Ductless	1.00	1.00	0.95
Packaged	0.95	0.95	0.84

Additionally, SEER values were converted to EER (for calculating kilowatt savings) based on:

$$EER = (-0.02 * SEER^2) + 1.12 * SEER$$ [10]

The following calculation shows resulting EER2 using equations above for units with SEER baseline of 14.3:

> Baseline SEER = 14.3 SEER2 baseline / 0.975 (average of ducted and ductless) = 14.667 SEER
>
> Baseline EER = $(-0.02 \times 14.667^2) + 1.12 * 14.667 = 12.12$ EER
>
> Baseline EER2 = 12.12 EER * 0.975 = 11.8

Using equations above, EER2 are provided in table below for given SEER2 efficiencies:

SEER2 to EER2 Conversion[10]

SEER2	EER2
16	12.7
17	13.1
18	13.5
19	13.9
20	14.2

Incremental costs per ton were determined by calculating incremental costs per ton for split systems across sizes specified in the Itron workbook.[2] Cost data were available up to 16 SEER for split systems. Costs for higher SEER units for each system type were determined by linear extrapolation.

Incremental Costs by Measure

Measure	MMID	Incremental Cost (per ton)[2]
Air-Source Heat Pump, ≤ 65 MBh, SEER2 16 and 8.5 HSPF2	5428	$325.23
Air-Source Heat Pump, ≤ 65 MBh, SEER2 17 and 8.5 HSPF2	5429	$498.60
Air-Source Heat Pump, ≤ 65 MBh, SEER2 18 and 8.5 HSPF2	5430	$671.96
Air-Source Heat Pump, ≤ 65 MBh, SEER2 19 and 8.5 HSPF2	5431	$845.32
Air-Source Heat Pump, ≤ 65 MBh, SEER2 20 and 8.5 HSPF2	5432	$1018.68

Revision History

Version Number	Date	Description of Change
01	12/2018	Initial TRM entry
02	10/2020	Removed 15 SEER, add 19 and 20 SEER
03	10/2022	Update for new SEER2, EER2, and HSPF2 requirements taking effect in 2023
04	9/2023	Updated EUL

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[1] Average between the State of Wisconsin Public Service Commission Measure Life Study and U.S. Department of Energy Technical Support Document sources was calculated.
PA Consulting Group. *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
Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment . p. 202; 8-24. https://www.regulations.gov/document/EERE-2013-BT-STD-0007-0105

[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://dnr.mo.gov/sites/dnr/files/media/file/2021/01/nr-hw-heater-wa017-mcs-results-matrix-volume-i-august-2016.xlsx
Equipment + Labor tab, rows 134–150 for split heat pump costs.

[3] Electronic Code of Federal Regulations. Title 10, Chapter II, Subchapter D, Part 430, Subpart C, §430.32(c)(5).
https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32

[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

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[6] California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” June 2, 2008.
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] PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. www.focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

[9] Consortium for Energy Efficiency (CEE) Testing, Testing, M1, 2, 3, Transitioning to New Federal Minimum Standards, CEE Summer Program Meeting, June 10, 2022.

[10] Robert Hendron and Cheryn Engebrecht, National Renewable Energy Lab. *Building America House Simulation Protocols.* October 2010. Page 7. https://www.nrel.gov/docs/fy11osti/49246.pdf

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
Workpaper ID	W0059
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
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Air Cooled and Water Cooled, Positive Displacement: 20[1] Water Cooled, Centrifugal = 23[2]
Incremental Cost ($/unit)	Varies by measure,[3] 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.[4] 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[4]

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

$$kWh_{SAVED} = (IPLV_{BASE} - IPLV_{EE}) * LF * Ton - hours$$

Where:

Variable	Description	Units	Value
$IPLV_{BASE}$	Integrated part-load value of baseline chiller	kW/ton	See Baseline Chiller Efficiency table above
$IPLV_{EE}$	Integrated part-load value of efficient chiller at AHRI conditions	kW/ton	User input
LF	Load factor		0.85[5]
Ton-hours	Annual chiller load	Hrs	Hours * efficient chiller capacity at AHRI conditions; see Assumptions

Summer Coincident Peak Savings Algorithm

$$kW_{SAVED} = (Full\ Load\ kW/ton_{BASE} - Full\ Load\ kW/ton_{EE}) * LF * Tons * CF$$

Where:

Full Load kW/ton_{BASE} = kW/ton full-load value of baseline chiller (see Baseline Chiller Efficiency table above)

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)[6]

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (= 20[1] years for air and water cooled positive displacement, = 23[2] years for water cooled centrifugal)

Assumptions

- The incremental measure cost was calculated in two steps. First, ratios of incremental costs to efficient costs are calculated from a 2013 incremental cost study from Northeast Energy Efficiency Partnership.[3] Second, these ratios are applied to actual costs recorded from historical Focus on Energy project data.Based on a 2021 benchmarking effort, the EUL is deemed to be 20 years for Air Cooled chillers and and Water Cooled, Positive Displacement chillers. A preponderance of sources listed centrifugal chiller EUL as 25 years, and there may be some merit to this because of their generally larger size. An EUL of 23 years, from the Illionois TRM,[2] is deemed for these.
- For developing the incremental to efficient cost ratios, 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 as that for Path A. Results can be seen in the Chiller Cost Ratios table.

Chiller Cost Ratios

Measure	Path A MMID	Path B MMID	Closest IC Information						Incremental / Efficient Cost Ratio
			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	67.3%
≥ 150	4713	4715	Avg 150, 200, 400	1.212	$49	1.141	$149	67.3%
Water Cooled, Positive Displacement								
< 75	4716	4721	Avg 50, 100	0.78	$0	0.720	$57	39.7%
≥ 75 to < 150	4717	4722	100	0.72	$38	0.680	$63	37.7%
≥ 150 to < 300	4718	4723	200	0.68	$61	0.640	$122	50.0%
≥ 300 to < 600	4719	4724	400	0.64	$61	0.600	$92	33.7%
≥ 600	4720	4725	400	0.64	$61	0.600	$92	33.7%

Measure	Path A MMID	Path B MMID	Closest IC Information					Incremental / Efficient Cost Ratio
			Tonnage of Chiller from Cost Source	Baseline kW/ton	Baseline $/ton	Efficient kW/ton	Efficient $/Ton	
Water Cooled, Centrifugal								
< 150	4726	4731	100	0.60	$73	0.580	$110	33.6%
≥ 150 to < 300	4727	4732	Avg 150, 200	0.60	$43	0.580	$64	32.8%
≥ 300 to < 400	4728	4733	300	0.58	$91	0.540	$152	40.1%
≥ 400 to < 600	4729	4734	600	0.58	$46	0.540	$76	39.5%
≥ 600	4730	4735	600	0.58	$46	0.540	$76	39.5%

- These ratios were then applied to Focus on Energy cost data from January 2018 through July 2020.[7] For measures that did not have usage in this time period, an overall ratio of costs was applied. Results can be seen in the Chiller Incremental Costs table.

Chiller Incremental Costs

Measure	Path A MMID	Path B MMID	Incremental / Efficient Cost Ratio	SPECTRUM Data, January 2018 - July 2020		Incremental Cost
				Total Tons	Cost / Ton	
Air Cooled						
< 150	4712	4714	67.3%	2,657	$673	$453.12
≥ 150	4713	4715	67.3%	4,883	$482	$323.56
Water Cooled, Positive Displacement						
< 75	4716	4721	39.7%	0*	0*	$164.29*
≥ 75 to < 150	4717	4722	37.7%	0*	0*	$70.62*
≥ 150 to < 300	4718	4723	50.0%	2,852	$479	$239.52
≥ 300 to < 600	4719	4724	33.7%	13,290	$368	$123.86
≥ 600	4720	4725	33.7%	13,290	$368	$123.86
Water Cooled, Centrifugal						
< 150	4726	4731	33.6%	0*	0*	$106.65*
≥ 150 to < 300	4727	4732	32.8%	559	$747	$245.06
≥ 300 to < 400	4728	4733	40.1%	2,852	$479	$239.52
≥ 400 to < 600	4729	4734	39.5%	600	$400	$157.89
≥ 600	4730	4735	39.5%	600	$400	$157.89

*Because no recent data was available for these measures, a ratio of the total updated incremental costs to the total previous incremental costs, 288%, was applied to the previous incremental costs for these measures.

- 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%
La Crosse	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[8]

Temperature Range	Green Bay	La Crosse	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**

Revision History

Version Number	Date	Description of Change
01	10/2018	Initial TRM entry
02	02/2021	Updated incremental costs

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[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] Illinois Stakeholder Advisory Group. *2022 Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 10.0, Volume 2: Commercial and Industrial Measures*. September 24, 2021. https://ilsag.s3.amazonaws.com/IL-TRM_Effective_010122_v10.0_Vol_2_C_and_I_09242021.pdf

[3] 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

[4] 2015 International Energy Conservation Code. Table C403.2.3(7). 2015. https://codes.iccsafe.org/public/document/IECC2015

[5] American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Standard 90.1-2013. Appendix G. Section G3.1.2.2 Equipment Capacities.

[6] Focus on Energy Business Programs Deemed Savings Manual V1.0. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

[7] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 153 projects, 9,681 chillers, and 1,762,983 tons for MMIDs 4712 through 4735 from January 2018 to July 2020.

[8] 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

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
Workpaper ID	W0060
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)	8[1]
Incremental Cost ($/unit)	<8,000 Btu/h = $58 (MMID 2699), 8,000–9,999 Btu/h = $92 (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

$$kWh_{\text{SAVED}} = kWh_{\text{COOL}} + kWh_{\text{HEAT}}$$

$$kWh_{\text{COOL}} = EFLH_{\text{COOL}} * (Cap_{\text{COOL}} / 1{,}000) * [(1 / EER_{\text{BASE}}) - (1 / EER_{\text{EE}})]$$

$$kWh_{\text{HEAT}} = EFLH\ Energy\ efficiency\ ratio\ of\ energy - effiient\ unit\ HEAT * Cap_{\text{COOL}} * [(1 / COP_{\text{BASE}}) - (1 / COP_{\text{EE}})] / 3{,}412$$

Where:

Variable	Description	Units	Value
$EFLH_{COOL}$	Equivalent full-load hours during cooling mode	Hrs	410 for multifamily,[4] 599 for business; see Assumptions
Cap_{COOL}	Nominal cooling capacity	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	Hrs	711 for multifamily, 1,161 for business; see Assumptions
COP_{BASE}	Coefficient of performance of baseline equipment		See Description of Efficient Condition
COP_{EE}	Coefficient of performance of energy-efficient equipment		See Description of Efficient Condition
3,412	Conversion factor	Btu/kWh	3,412

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 (8 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	8,200	0.0718	1,667	13,336
8,000–9,999 Btu/h	2702	0.1092	1,306	10,448	0.1092	2,123	16,984
10,000–12,999 Btu/h	2701	0.1808	1,731	13,848	0.1808	2,810	22,480
≥ 13,000 Btu/h	2700	0.2671	2,185	17,480	0.2671	3,543	28,344

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	8,024	0.0296	1,635	13,080
8,000–9,999 Btu/h	2702	0.0358	1,272	10,176	0.0421	2,072	16,576
10,000–12,999 Btu/h	2701	0.0360	1,660	13,280	0.0423	2,706	21,648
≥ 13,000 Btu/h	2700	0.0834	2,098	16,784	0.0981	3,416	27,328

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%
La Crosse	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%
La Crosse	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.

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.
02	07/2022	EUL update
03	08/2022	Cost update

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[1] U.S. Department of Energy. Technical Support Document: Energy Efficiency Program for Commercial and Industrial Equipment. p. 145; 8-18. https://downloads.regulations.gov/EERE-2012-BT-STD-0029-0040/attachment_1.pdf

[2] Grainger. Website. www.grainger.com. Accessed May 2022.
Total Home Supply. Website. www.totalhomesupply.com. Accessed May 2022.
Pricing lookups performed for baseline PTACs with electric heat, and efficient PTHPs. Amana, Friedrich, LG, and GE brands examined.

[3] Grainger. Website. www.grainger.com. Accessed May 2022.
Total Home Supply. Website. www.totalhomesupply.com. Accessed May 2022.
Pricing lookups performed for baseline PTACs with electric heat, and efficient PTHPs. Amana, Friedrich, LG, and GE brands examined

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[4] PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. www.focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

[5] Air-Conditioning, Heating, & Refrigeration Institute. Accessed May 2018. https://www.ahridirectory.org/Search/SearchHome?ReturnUrl=%2f

[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] Cadmus. *Focus on Energy Evaluated Deemed Savings Changes.* November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

[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

Data Center and Telecom Cooling, ≤65 MBh

	Measure Details
Measure Master ID	Split System: 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 SEER 19, <5.4 tons, Data Center/Telecom, 5075 SEER 20, <5.4 tons, Data Center/Telecom, 5076 Single Package: 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 SEER 19, <5.4 tons, Data Center/Telecom, 5077 SEER 20, <5.4 tons, Data Center/Telecom, 5078
Workpaper ID	W0061
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 16 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

$$kWh_{\text{SAVED}} = (CAP * 12) * LF * [(1 / SEER_{\text{BASE}}) - (1 / SEER_{\text{EE}})] * EFLH_{\text{COOL}}$$

Where:

Variable	Description	Units	Value
CAP	Rated cooling capacity of energy-efficient unit	Tons	User input
12	Conversion factor	Tons to MBh	12
LF	Load factor		0.65[6]
$SEER_{\text{BASE}}$	Cooling seasonal energy efficiency rating of baseline unit	MBh/kW	14 for single package new construction,[3] 13 for single package retrofits[4] and all split systems[3,4]
$SEER_{\text{EE}}$	Seasonal energy efficiency rating of efficient unit	MBh/kW	16 SEER for MMIDs 4769 and 4773, 17 SEER for MMIDs 4770 and 4774, 18 SEER for MMIDs 4771 and 4775, 19 SEER for MMIDs 5075 and 5077, 20 SEER for MMIDs 5076 and 5078
$EFLH_{\text{COOL}}$	Equivalent full-load cooling hours	Hrs	8760; see Assumptions

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = (CAP * 12) * LF * [(1 / EER_{\text{BASE}}) - (1 / EER_{\text{EE}})] * CF$$

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 (12.8 for 16 SEER, 13.1 for 17 SEER, 13.7 for 18 SEER, 14.1 for 19 SEER, 14.4 for 20 SEER; see Assumptions)

CF = Coincidence factor (1.0)

Lifecycle Energy-Savings Algorithm

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

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				
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
19 SEER	5075	0.1429	1,660	24,900
20 SEER	5076	0.1560	1,840	27,600
Packaged Systems, Existing Buildings				
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
19 SEER	5077	0.1429	1,660	24,900
20 SEER	5078	0.1560	1,840	27,600
Packaged Systems, New Construction				
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
19 SEER	5077	0.1085	1,284	19,260
20 SEER	5078	0.1216	1,464	21,960

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 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 Split System, ≤ 65 MBh, SEER 19	5075	$552.76
A/C Split System, ≤ 65 MBh, SEER 20	5076	$644.89
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
A/C Single Package, ≤ 65 MBh, SEER 19	5077	$2,853.26
A/C Single Package, ≤ 65 MBh, SEER 20	5078	$3,385.24

Revision History

Version Number	Date	Description of Change
01	12/2018	Initial TRM entry
02	10/2020	Retired 15 SEER measures, added 19 and 20 SEER measures.

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[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

[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. *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] Robert Hendron and Cheryn Engebrecht, National Renewable Energy Lab. *Building America House Simulation Protocols.* October 2010. Page 7. https://www.nrel.gov/docs/fy11osti/49246.pdf

Energy-Efficient Drycooler for Data Center

	Measure Details
Measure Master ID	Energy-Efficient Drycooler for Data Center, 2305
Workpaper ID	W0062
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

$$kWh_{\mathrm{SAVED}} = kWh_{\mathrm{BASE}} - kWh_{\mathrm{EE}}$$

$$kWh_{\mathrm{BASE}} = Cap * \Sigma[(LF * Eff_{\mathrm{COOL,BASE}} + P_{\mathrm{CRAC,BASE}}) * HOU]\ for\ each\ temperature\ bin$$

$$kWh_{\mathrm{EE}} = Cap * \Sigma[(LF * Eff_{\mathrm{COOL,EE}} + P_{\mathrm{CRAC,EE}} + P_{\mathrm{PUMP}} + P_{\mathrm{DC}}) * HOU]\ for\ each\ temperature\ bin$$

$P_{CRAC,BASE} = HP_{CRAC} * 0.746 * MLF_{CRAC,BASE} / Eff_{CRAC}$

$P_{CRAC,EE} = HP_{CRAC} * 0.746 * MLF_{CRAC,EE} / Eff_{CRAC}$

$P_{PUMP} = HP_{PUMP} * 0.746 * MLF_{PUMP} / Eff_{PUMP}$

$P_{DC} = HP_{DC} * 0.746 * MLF_{DC} / Eff_{DC}$

Where:

Variable	Description	Units	Value
Cap	Installed cooling capacity of DX split system serving CRAC unit	Tons	User input
LF	Average load factor on DX cooling system		0.65[3]
$Eff_{COOL,BASE}$	Air cooled condensing unit efficiency	kW/ton	User input; otherwise use 1.64 kW/ton per Assumptions
$P_{CRAC,BASE}$	CRAC unit fan power per ton without glycol coil	kW/ton	
HP_{CRAC}	CRAC fan horsepower per ton	hp/ton	User input; otherwise use 0.42 hp/ton per Assumptions
0.746	Conversion factor	kW/hp	0.746
$MLF_{CRAC,BASE}$	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	Hrs	Varies with temperature; see Assumptions
$P_{CRAC,EE}$	CRAC unit fan power per ton with glycol coil	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	kW/ton	
HP_{PUMP}	Glycol pump	hp/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	kW/ton	
HP_{DC}	Drycooler total fan horsepower per ton	hp/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

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

Where:

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

Assumptions

At temperatures other than rated condition, down to a minimum condenser temperature of 65°F,[4] the DX cooling system efficiency is calculated using standardized energy modeling equations published by COMNET,[5] 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 judgment.

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 were population weighted using the weighting factors shown in the following table.

Population Weighting Percentages

Location	Weighting by Location
Green Bay	22%
La Crosse	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	La Crosse	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**
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**

Revision History

Version Number	Date	Description of Change
01	02/28/2019	Initial TRM entry

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[1] California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." EUL Table. EUL ID "HVAC-WtrEcon" for waterside economizer. 2014. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx

[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

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[4] Daikin. *Chiller Application Guide*. p. 18. 2014. https://www.daikinapplied.com/o365/api/graphapi/GetDocument/Doc100/Daikin_AG_31-003_Chiller_Application_Guide.pdf/

[5] COMNET. Modelling Guidelines, Section 3.7.5 Cooling Systems. https://comnet.org/375-cooling-systems

[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.

[7] Vertiv. *Liebert PDX and PCW Thermal Management Systems Systems, System Design Catalog, 3 to 8 Ton (11 to 29 kW) Nominal Capacity, Upflow and Downflow, 60 Hz, Air-, Water-, Glycol- and Chilled-water-cooled Models*. 2018. https://www.vertivco.com/globalassets/products/thermal-management/room-cooling/liebert-pdx--liebert-pcw-system-design-manual_00.pdf

[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

[9] 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

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
Workpaper ID	W0063
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)	$102.28[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

$$Therm_{\text{SAVED}} = 1.9 * K * 60 * (\pi * D^2/4) * \sqrt{}([P_{\text{ABS}} - \{P_1 - P_2\}] * [P_1 - P_2]) * h_{\text{FG}} * HOU * DF \,/\, (100{,}000 * eff)$$

Where:

Variable	Description	Units	Value
1.9	Constant based on units and fluid flow equation[3]		1.9
K	Discharge coefficient		0.55[4]
60	Conversion factor	min/hr	60
D	Steam trap orifice diameter	Inches	7/32-inches, 1/4-inches, 5/16-inches, or 3/8-inches
P_{ABS}	System absolute pressure	psi	20.7 psia; steam gage pressure at trap inlet (6 psig) + atmospheric pressure at sea level (14.7 psi)[5]
P_1	Steam pressure at trap inlet	psig	6 psig[5]
P_2	Steam pressure at trap outlet, condensate tank pressure	psig	0 psig
h_{FG}	Latent heat of steam at system absolute pressure	Btu/lb	959 Btu/lb[6]
HOU	Annual hours of operation the boiler is on and system is at design pressure	Hrs	5,510[7]
DF	Derating factor to account for average percentage of time trap fails in open position and actual versus theoretical energy loss	%	5.9%[5]
100,000	Conversion factor	Btu/therm	100,000
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

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

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	516
Steam Trap Repair, < 10 psig, General Heating, 1/4-inches	4005	113	678
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	1,518

Revision History

Version Number	Date	Description of Change
01	01/2017	Initial TRM entry
02	05/2018	Adjusted derating factor to 5.9%
03	12/2020	Updated costs

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[1] PA Consulting Group. *Focus on Energy, 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 unit cost of 158 projects and 2,831 steam traps for MMIDs 4004, 4005, 4006, 4007, 4648, 4649, 4650, 4651 from March 2018 to July 2020 is $102.28.

[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: $1.9 * (\pi/4 * D^2) * K * \sqrt{}([P_1 – 0.42 * P_1] * 0.42 * P_1) * 60 = 24.24 * P_1 * D^2$. 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 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. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. 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.

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, >125psig, General Heating, Prescriptive: 7/32" or Smaller, 4944 1/4", 4945 5/16", 4946 3/8" or Larger, 4947
Workpaper ID	W0064
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.

There are several measure specifications:

- The 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 greater than or equal to 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 (greater than or equal to 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]

$$Therm_{\text{SAVED}} = 24.24 * P_{\text{ABS}} * D^2 * h_{\text{FG}} * HOU * DF / (100{,}000 * eff)$$

Where:

Variable	Description	Units	Value
24.24	Constant from Napier equation when units for absolute system pressure are in psia and units of diameter are in inches	psia and inches	
P_{ABS}	System absolute pressure	Lbs/sq in	Ssteam 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; input by implementers
D	Steam trap orifice diameter	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 Pressure, Latent Heat, and Savings Multipliers table below

Variable	Description	Units	Value
HOU	Annual hours of operation when boiler is on and system is at design pressure	Hrs	5,510[3]
DF	Derating factor to account for average percentage a trap fails in open position and to account for actual versus theoretical energy loss	%	5.9%[4]
100,000	Conversion factor	Btu/therm	100,000
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 Pressure, Latent Heat, and Savings Multipliers 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:

$$\begin{aligned} Therm_{\text{SAVED}} &= System\ Absolute\ Pressure\ *\ Annual\ Savings\ Multiplier \\ &= [System\ Gauge\ Pressure\ +\ 14.7]\ *\ Annual\ Savings\ Multiplier \end{aligned}$$

Pressure, Latent Heat, and Savings Multipliers

Measure Name	MMID	Assumed P_{ABS} for h_{FG}[4]	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	929.0	4.4	26.4
1/4"	4009		929.0	5.7	34.2
5/16"	4010		929.0	8.9	53.4
3/8" or Larger	4011		929.0	12.9	77.4
Steam Trap Repair, 50-124 psig, General Heating					
7/32" or Smaller	4012	102.2	887.5	4.2	25.2
1/4"	4013		887.5	5.5	33.0
5/16"	4014		887.5	8.5	51.0
3/8" or Larger	4015		887.5	12.3	73.8
Steam Trap Repair, >125 psig, General Heating					
7/32" or Smaller	4944	190.2	846.8	4.0	24.0
1/4"	4945		846.8	5.2	31.2
5/16"	4946		846.8	8.1	48.6
3/8" or Larger	4947		846.8	11.7	70.2

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:

$$Therm_{\text{SAVED}} = 24.24 * (11 + 14.7) * 0.218752 * 929 * 5{,}510 * 5.9\% / (100{,}000 * 80\%)$$

or

$$Therm_{\text{SAVED}} = (11 + 14.7) * 4.4 = 113.1$$

Summer Coincident Peak Savings Algorithm

There are no peak coincident savings for this measure, which does not generate electric savings.

Lifecycle Energy-Savings Algorithm

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

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	$130.24	Average unit cost of 11 projects and 742 steam traps from January 2018 to March 2020 is $130.24.
1/4”	4009	$348.37	Average unit cost of 6 projects and 22 steam traps from January 2019 to June 2020 is $348.37.
5/16”	4010	$128.60	Average unit cost of 4 projects and 52 steam traps from June 2018 to June 2019 is $128.60.
3/8” or Larger	4011	$71.27	Average unit cost of 6 projects and 336 steam traps from January 2021 to July 2022 is $71.27.
Steam Trap Repair, 50-124 psig, General Heating			
7/32” or Smaller	4012	$256.39	Average unit cost of 18 projects and 62 steam traps from January 2018 to March 2020 is $256.39.
1/4”	4013		
5/16”	4014		
3/8” or Larger	4015		
Steam Trap Repair, >125 psig, General Heating			
7/32” or Smaller	4944	$196.87	Average unit cost of 2 projects and 15 steam traps from June 2020 to June 2020 is $196.87.
1/4”	4945		
5/16”	4946		
3/8” or Larger	4947		

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial release for system pressure <50 psig
02	01/2015	Initial release for 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 derating factor to 5.9%
06	01/2020	Deleted MMIDs 4020 to 4023 and renamed MMIDs 4016 to 4019 and 4944 to 4947 to include >225 psig
07	02/2021	Updated cost
08	08/2022	Updated cost

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[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] PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0." Appendix B. Outside Air Temperature Bin Analysis table. 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, which is 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.

[4] 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.

[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 Pressure, Latent Heat, and Savings Multipliers 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.

Steam Trap Repair, < 10 psig, Radiator

	Measure Details
Measure Name	Steam Trap Repair, < 10 psig, Radiator, 2772
Workpaper ID	W0065
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)	$42.17[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]

$$Therm_{SAVED} = 1.9 * K * 60 * (\pi * D^2/4) * \sqrt{([P_{ABS} - \{P_1 - P_2\}] * [P_1 - P_2])} * h_{FG} * HOU * DF / (100{,}000 * eff)$$

Where:

Variable	Description	Units	Value
1.9	Constant based on units and fluid flow equation[3]		1.9
K	Discharge coefficient		0.55[4]
60	Unit conversion for minutes per hour	Minutes/hr	60
D	Steam trap orifice diameter	Inches	1/4 inches
P_{ABS}	System absolute pressure in pounds per square inch	Lbs/sq in	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	psig	6 psig[5]
P_2	Steam pressure at trap outlet, condensate tank pressure	psig	0 psig
h_{FG}	Latent heat of steam at P_{ABSv}	Btu/lb	959 Btu/lb[6]
HOU	Annual hours of operation the boiler is on and the system is at design pressure	Hrs	5,510[7]
DF	Derating factor to account for average percentage of time a trap fails in open position and to account for actual versus theoretical energy loss		5.9%[5]
100,000	Conversion factor	Btu/therm	100,000
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

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

Where:

EUL = Effective useful life (= 6 years)[1]

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%
05	12/2020	Updated cost

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[1] PA Consulting Group. *Focus on Energy, 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 unit cost of 9 projects and 643 steam traps from March 2018 to October 2019 is $42.17.

[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] 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. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. 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.

Chiller Plant Setpoint Adjustment

	Measure Details
Measure Master ID	EBTU Chiller Plant: Chilled Water Setpoint Adjustment, 3659 Condenser Water Setpoint Adjustment, 3660
Workpaper ID	W0066
Measure Unit	Per ton
Measure Type	Hybrid
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 reprogramming 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]

$$kWh_{\text{SAVED}} = kWh_{\text{BASE}} - kWh_{\text{PROPOSED}}$$

$$kWh_{\text{BASE}} = \Sigma\ [(\Delta T_{\text{EXISTING CHILLED H2O}} * 500 * Chiller\ GPM * bin\ hrs * Chiller\_Eff * Area\ Load\ /\ 12{,}000) - (\Delta T_{\text{BASELINE LMTD}} * 500 * Condenser\ GPM * bin\ hrs * Chiller\_Eff * Area\ Load\ /\ 12{,}000)]$$

$$kWh_{\text{PROPOSED}} = \Sigma\ [(\Delta T_{\text{PROPOSED CHILLED H2O}} * 500 * Chiller\ GPM * bin\ hrs * Chiller\_Eff * Area\ Load\ /\ 12{,}000) - (\Delta T_{\text{PROPOSED LMTD}} * 500 * Condenser\ GPM * bin\ hrs * Chiller\_Eff * Area\ Load\ /\ 12{,}000)]$$

Where:

Variable	Description	Units	Value
$\Delta T_{\text{EXISTING CHILLED H2O}}$	Estimated chilled water return temperature – existing chilled water supply temperature		
$\Delta T_{\text{PROPOSED CHILLED H2O}}$	Estimated chilled water return temperature – proposed chilled water supply temperature		
500	Water sensible heat equation constant		500
Chiller GPM		GPM/ton	2 GPM/ton[5]
bin hours	Bin hours used in workbook for each city[4]	Hrs	
Chiller_Eff	kW/ton partial load rating	kW/ton	Based on chiller type; see table below
Area Load	Percentage based on linear interpolation of 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	Conversion factor	Btu/ton	12,000
$\Delta T_{\text{BASLINE LMTD}}$	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	°F	

Variable	Description	Units	Value
Condenser GPM	GPM/ton for electric chillers	GPM/ton	3[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	°F	

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

$$kW_{\text{SAVED}} = kWh_{\text{SAVED}} / Hours_{\text{COOL}} * CF$$

Where:

$\text{Hours}_{\text{COOL}}$ = 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)
Green Bay	2,748
La Crosse	2,971
Madison	2,876
Milwaukee	2,830

CF = Coincidence factor (1)

Lifecycle Energy-Savings Algorithm

$$kh_{\text{LIFECYCLE}} = kWh_{\text{SAVED}} * EUL$$

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.

Revision History

Version Number	Date	Description of Change
01	09/2013	Initial TRM entry

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[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. Facilities Construction Cost Data. 29th Edition. 2013. Assumed $54.00 per hour labor rate and estimated two hours for completion.

[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.

Chiller System Tune-Up

	Measure Details
Measure Master ID	Chiller System Tune Up: Air Cooled, 5462 Water Cooled, 5463
Workpaper ID	W0067
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[2]

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:

$$kWh_{\text{SAVED}} = (12 \, / \, (IPLV_{\text{BASE}} * 3.412) * ton * HOU * \% \, savings$$

Where:

Variable	Description	Units	Value
12	Conversion factor	kBtu/ton	12
$IPLV_{BASE}$	Integrated part load value of baseline chiller	kBtu/kWh	3.05 for air cooled; 5.85 for water cooled[3]
3.412	Conversion factor	kBtu/kWh	3.412
ton	Chiller capacity	Tons	
HOU	Determined from weather bin hours and building design cooling load	Hrs	1,440
% savings	Percentage savings associated with a chiller tune-up	%	5%[4]

Summer Coincident Peak Savings Algorithm

Existing Equipment as a Baseline:

$$kW_{\text{SAVED}} = (12 * (FL\ COP_{\text{BASE}} * 3.412) * \%\ savings * CF * ton$$

Where:

FL COP_{BASE} = Full load coefficient of performance of baseline chiller[3]

CF = Coincidence factor (0.80)

Lifecycle Energy-Savings Algorithm

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

Where:

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

Deemed Savings

Deemed Savings by Measure Type

	MMID	kW/ton	kWh/year/ton	LC kWh /ton
Chiller System Tune-Up, Air Cooled	5462	0.0502	83	415
Chiller System Tune-Up, Water Cooled	5463	0.0255	44	218

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	10/2022	Consolidate MMIDs, correcting algorithm in WP

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[1] PA Consulting Group. *Focus on Energy, 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. 154. 2013. Incremental Cost source listed as: Act on Energy Commercial Technical Reference Manual No. 2010-4. https://www.ilsag.info/il_trm_version_3/

[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] 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%.

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
Workpaper ID	W0068
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

$$kWh_{\text{SAVED}} = kWh_{\text{SAVED,COOL}} + kWh_{\text{SAVED,HEAT}}$$

$$kWh_{\text{SAVED,COOL}} = EFLH_{\text{COOL}} * Cap_{\text{COOL}} * \%\,Savings\ /\ (1{,}000 * EER)$$

$$kWhS_{\text{AVED,HEAT}} = \{[EFLH_{\text{HEAT,EL}} * (Cap_{\text{HEAT,EL}} + CapB_{\text{OILER,EL}})] + [EFLH_{\text{HEAT,HP}} * Cap_{\text{HEAT,HP}}\ /\ (3{,}412 * COP)]\} * \%\,Savings$$

Where:

Variable	Description	Units	Value
$EFLH_{COOL}$	Equivalent full-load hours during cooling mode	Hrs	663 for hotel/motel[4]
Cap_{COOL}	Nominal cooling capacity	Btu/h	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	Conversion factor	W/kW	
EER	Energy efficiency ratio in Btu/h per watt	Btu/h/watt	Varies for MMIDs 2373 and 4748, user input for MMID 2374; see Assumptions
$EFLH_{HEAT,EL}$	Equivalent full-load hours during heating mode	Hrs	1,890 for MMIDs 2373 and 2374, 729 for MMID 4748; see Assumptions
$Cap_{HEAT,EL}$	Heating capacity of electric heater	kW	2.36 kW for MMIDs 2373 and 4748, user input for MMID 2374; see Assumptions
$Cap_{BOILER,EL}$	Heating capacity of electric boiler	kW	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	Hrs	0 for MMIDs 2373 and 2374, 1,161 for 4748; see Assumptions
$Cap_{HEAT,HP}$	Nominal heating capacity of heat pump	Btu/h	0 Btu/h for MMIDs 2373 and 2374; 0.893 * Cap_{COOL} for MMID 4748; see Assumptions
3,412	Conversion factor	Btu/kWh	3,412
COP	Coefficient of performance		1.0 for MMID 2373, varies for MMID 4748, user input for MMID 2374; see Assumptions

$$Therm_{\text{SAVED}} = EFLH_{\text{HEAT}} * Cap_{\text{HEAT}} * \%\,Savings \,/\, (100{,}000 * Eff)$$

Where:

Variable	Description	Units	Value
$EFLH_{\text{COOL}}$	Equivalent full-load hours during heating mode	Hrs	1,890; see Assumptions
Cap_{HEAT}	Heating capacity of natural gas equipment	Btu/h	0 Btu/h for MMIDs 2373 and 4748, user input for MMID 2374
% Savings	Percentage of savings	%	18.4%[5]
100,000	Conversion factor	Btu/therm	100,000
EER	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

$$kW_{\text{SAVED}} = Cap_{\text{COOL}} * \%\,Savings * CF \,/\, (1{,}000 * EER)$$

Where:

CF = Coincidence factor (= 0.8)[6]

Lifecycle Energy-Savings Algorithm

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

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%
La Crosse	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**

Revision History

Version Number	Date	Description of Change
01	10/2018	Initial TRM entry

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[1] PA Consulting Group. *Focus on Energy, 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

[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. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Section 4.5.7 Rooftop A/C. 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

Economizer Optimization

	Measure Details
Measure Master ID	Economizer, RTU Optimization, 3066 Economizer Repair / Upgrade, Building Tune-up, 5290
Workpaper ID	W0069
Measure Unit	MMID 3066: Per rooftop unit MMID 5290: Per rooftop unit (see Assumptions)
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	MMID 3066: Economizer MMID 5290: 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)	RTU Optimization = 10 (MMID 3066),[1] Economizer Optimization = 4 (MMID 5290)[2]
Incremental Cost ($/unit)	RTU Optimization = $1,301.58 (MMID 3066),[3] Economizer Optimization = $250.00 per roof-top unit (MMID 5290)[4]

Measure Description

A majority of commercial spaces are heated and cooled by packaged roof-top units or packaged air handling units. MMID 3066 is installing an air-side economizer on cooling equipment that does not already have one, which will offset or reduce the need for mechanical cooling.

The intent of MMID 5290 is to ensure proper economizer functionality and capture savings associated with correcting improper operation or damage of outside air economizer units. Additionally, this measure allows an existing dry-bulb economizer to be upgraded to an enthalpy economizer. This measure can be applied only once per building address during the EUL lifecycle. It is meant to be a part of the Whole Building Tune-up offering to help optimize building HVAC systems to operate more efficiently.

Neither measure applies to newly constructed facilities.

Description of Baseline Condition

For MMID 3066, the baseline is a packaged roof-top unit or air handler with a fixed ventilation rate (fixed damper; no economizer). For MMID 5290, the baseline is a roof-top unit or air handling unit with an economizer that is either not in operation at all or a dry-bulb economizer that is in operation but has a limited outdoor air temperature range of operation and has the potential to expand. Additionally, fixed dry-bulb changeover economizers (enable economizer at fixed outside air temperature) may be upgraded to enthalpy changeover economizers (enable economizer at fixed outside air enthalpy).

Description of Efficient Condition

For MMID 3066, the efficient equipment is a packaged roof-top unit or air handler that includes an economizer controller, actuator, and sensor that provide air-side economizing. For MMID 5290, the efficient condition is a functioning dry-bulb economizer (if not previously functional), increasing the economizer outside air temperature operating range above baseline range, or upgrading a dry-bulb changeover economizer (enable economizer at a fixed outside air temperature) to an enthalpy changeover economizer (enable at fixed outside air enthalpy). The efficient condition OAT economizer range should not exceed 55°F to 75°F.

Annual Energy-Savings Algorithm

The following algorithms calculate the hourly cooling load using TMY3 hourly weather data[5] and customer reported existing and efficient economizer operating parameters. MMID 3066 uses a baseline of no economizer and an efficient condition of a dry-bulb changeover economizer, and limits weather data to April 1 to October 31. MMID 5290 uses full year weather data and has multiple possibilities for baseline and efficient conditions.

$$kWh_{\text{SAVED}} = kWh/year_{\text{BASELINE}} - kWh/year_{\text{PROPOSED}}$$

$$kWh/year_{\text{BASELINE}} = \Sigma_{8760}\,(kW_{\text{HOUR-INTERVAL-BASELINE}} * 1\ hour)$$

$$kW_{\text{HOUR-INTERVAL-BASELINE}} = (CAP_{\text{COOL}} * R_{\text{CAP}} - CAP_{\text{ECON}}) * (12\ /\ EER) * Econ_{\text{BASE}}$$

$$kWh/year_{\text{PROPOSED}} = \Sigma_{8760}\,(kW_{\text{HOUR—INTERVAL-PROPOSED}} * 1\ hour)$$

$$kW_{\text{HOUR-INTERVAL-PROPOSED}} = (CAP_{\text{COOL}} * R_{\text{CAP}} - CAP_{\text{ECON}}) * (12\ /\ EER) * con_{\text{PROP}}$$

$$CAPE_{\text{CON}} = 4.5 * CFM * (h_{RA} - h_{\text{OA}})\ /\ 12{,}000\ for\ enthalpy\ economizers$$

$$CAPEC_{\text{ON}} = 1.08 * CFM * (T_{\text{RA}} - T_{\text{OA}})\ /\ 12{,}000\ for\ dry - bulb\ economizers$$

Where:

Variable	Description	Units	Value
CAP_{COOL}	Cooling capacity of equipment in tons		Varies by equipment, actual equipment values should be used
R_{CAP}	Cooling load at which air conditioning compressor is operating as percentage of full load cooling capacity, interpolated for every hourly temperature between (55°F, 0%) and (95°F, 90%)	°F, 0%	Hourly temperature between 55°F, 0% and 95°F, 90%
12	Conversion factor from EER to kW/ton	kW/ton	12
EER	Energy efficiency ratio of the roof-top unit or air handling unit	Btu/W*hr	User input; if not known see Energy Efficiency Ratio by System Type table below

Variable	Description	Units	Value
$Econ_{BASE}$	Binary variable (0 = off or 1 = on) that indicates whether baseline economizer is in operation		For MMID 3066, $ECON_{BASE}$ = 0 for all hours since measure assumes no economizer. For MMID 5290, $ECON_{BASE}$ varies depending on existing economizer setup (none, dry-bulb with too low of changeover temperature, or enthalpy with too low of changeover enthalpy setting).
$Econ_{PROP}$	Binary variable (0 = off or 1 = on) that indicates whether efficient economizer is in operation		For MMID 3066, $ECON_{PROP}$ = 1 when outside air temperature is less than user reported changeover temperature (minimum of 60°F). For MMID 5290, $ECON_{PROP}$ varies depending on the improvement made to economizer setup (add dry-bulb, add enthalpy, improve dry-bulb changeover temperature, or improve enthalpy changeover setting).
4.5	Total heat constant	lb_{AIR}/CFM-hr	4.5
1.08	Sensible heat constant	Btu/hr-CFM-°F	1.08
CFM	Total supply airflow through rooftop unit	cfm	User input if known, otherwise see Assumptions
h_{RA}	Enthalpy of return air	Btu/lb	Calculated using Psych[6] Excel plug-in based on user input return air temperature and relative humidity
h_{OA}	Enthalpy of outside air	Btu/lb	Calculated using Psych[6] Excel plug-in based on temperature and relative humidity from TMY3 weather data for the hour
T_{RA}	Temperature of return air	°F	User input
T_{OA}	Temperature of outside air	°F	From TMY3 weather data for the hour

Energy Efficiency Ratio by System Type

Cooling System Type	Cooling System Efficiency (EER)[7, 8]
Rooftop Unit ≥ 5.42 and < 11.25 tons	11.00
Rooftop Unit ≥ 11.25 and < 20.00 tons	10.80
Rooftop Unit ≥ 20.00 and < 63.33 tons	9.80
Rooftop Unit ≥ 63.33 tons	9.50
Air Cooled Chiller < 150 tons	9.88
Air Cooled Chiller ≥ 150 tons	9.88
Water Cooled Positive Displacement Chiller < 75 tons	15.69
Water Cooled Positive Disp Chiller ≥ 75 tons and < 150 tons	16.33
Water Cooled Positive Disp Chiller ≥ 150 tons and < 300 tons	17.91
Water Cooled Positive Disp Chiller ≥ 300 tons and < 600 tons	19.43
Water Cooled Positive Displacement Chiller ≥ 600 tons	20.96
Water Cooled Centrifugal Chiller < 150 tons	18.39
Water Cooled Centrifugal Chiller ≥ 150 tons and < 300 tons	19.28
Water Cooled Centrifugal Chiller ≥ 300 tons and < 400 tons	20.78
Water Cooled Centrifugal Chiller ≥ 400 tons and < 600 tons	20.96
Water Cooled Centrifugal Chiller ≥ 600 tons	20.96

The customer or trade ally applying for this measure must supply certain information:

- Cooling type (DX or chiller) and capacity (tons)
- Cooling efficiency (EER) when known, otherwise a default value based on cooling system type will be used
- Supply airflow of the rooftop unit or air handler if known (CFM) i.e., the total outside airflow possible when economizer is operating at 100% outside air.
- Existing economizer OAT enable temperature (°F); 'none' is also a possibility
- Type of proposed economizer (dry-bulb or enthalpy)
    - If dry-bulb, proposed economizer OAT enable temperature (°F)
    - If enthalpy, proposed economizer enthalpy enable setting (Btu/lb)

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

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

Where:

EUL = Effective useful life (10 years for MMID 3066,[1] 4 years for MMID 5290[2])

Assumptions

Measure unit is listed as 'Per Rooftop Unit' to reflect the savings calculated using the algorithms, however, this measure is part of the Whole Building Tune-Up Offering where a flat incentive is paid per building, no matter how many rooftop unit economizers are repaired.

The fraction of full capacity of direct expansion air conditioning equipment is assumed to be a linear function of outside air dry-bulb temperature (0% at 55°F and 90% at 95°F). For chillers, it is also assumed to be linear but from 34% at 53°F to 85% at 95°F, which matches the assumptions in workpaper W0059 for efficient chillers. This assumes some minor oversizing of the cooling equipment, allowing some extra capacity for cooling beyond 95°F.

In the event the CFM of the existing air handling unit or rooftop unit is not known, it can be estimated using 400 CFM per ton of cooling.[9]

Revision History

Version Number	Date	Description of Change
01	01/2016	Initial TRM entry
02	10/2020	Added MMID 3066
03	01/2022	Update MMID 3661 for requirements of new Whole Building Tune-up offer, update cost and EUL

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[1] California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." Updated 2014 EUL Table, EUL_ID = HVAC-addEcono and HVAC-RepEcono. 2014. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx

[2] Navigant. "Effective Useful Life for Retro-commissioning and Behavior Programs" memo. September 17, 2019. https://ilsag.s3.amazonaws.com/ComEd-EUL-Comm-RCx-and-Behavior-Memo-2019-09-17.pdf. Four years is the EUL for the Operational Efficiency Offering.

[3] 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*. Table 13. Cost for 15 ton capacity single enthalpy economizer, p. 31. January 2013.
www.neep.org/incremental-cost-study-phase-2
Historical project data obtained from SPECTRUM found that seven units over four projects from January 2019 to September 2020 had an average size of 15.7 tons. Interpolating this with the NEEP reference table produces $1,301.58 per ton.

[4] Focus on Energy. Engineering Judgment. While RSMeans 2016 shows $59.00 per hour under *23 09 33.10 – Electronic Control System for HVAC*, engineer stakeholders for Focus on Energy believe that $140 per hour is a more realistic rate. This measure has three possible outcomes: repair broken economizer (bad actuator, damper linkage adjustment, etc.), expand temperature range of operation (programing change), or upgrade to an enthalpy economizer (humidity sensor likely needed). An incremental cost of $250 per rooftop unit was assumed as the average cost for these possible outcomes.

[5] Natural Renewable Energy Laboratory. Bin temperature data 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] Western Cooling Efficiency Center at UC Davis. "Psych" Excel Plug-in. Accessed August 2021. https://wcec.ucdavis.edu/resources/software-resource-applications
Enthalpy for a given dry bulb temperature and relative humidity was converted assuming 14.7 PSI atmospheric pressure.

[7] 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
Direct expansion cooling efficiency values determined from minimum efficiencies for system capacities of ≥ 5.5 tons with "All Other" for heating section type.

[8] International Code Council. *2015 International Energy Conservation Code*. Table C403.2.3(7). 2015.
https://codes.iccsafe.org/public/document/IECC2015/chapter-4-ce-commercial-energy-efficiency
Chiller efficiency values determined from simple average of Path A and Path B minimum efficiencies and then converted from kW/ton to EER.

[9] Trane. "Rule of Thumb Calculations (400 cfm/ton)." Published June 24, 2021.
https://tranecds.custhelp.com/app/answers/detail/a_id/918/~/rule-of-thumb-calculations-%28400-cfm%2Fton%29

Data Center Airside Economizer

	Measure Details
Measure Master ID	Air-Side Economizer, Data Center/Telecom, 4776
Workpaper ID	W0070
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.

$$kWh_{\text{SAVED}} = \Sigma\,[(LF\ *\ CAP\ *\ Eff_{\text{COOL}} + 0.746\ *\ HP_{\text{CT\_FAN}} *\ ML_{\text{CT\_FAN}} / Eff_{\text{CT\_FAN}} + 0.746\ *\ HP_{\text{CT\_PUMP}} *\ ML_{\text{CT\_PUMP}} / Eff_{\text{CT\_PUMP}})\ *\ Econ_{\text{OPERATING}}]\ for\ each\ hour$$

Where:

Variable	Description	Units	Value
LF	Average load factor on cooling system		0.65[3]
CAP	Installed (non-backup/redundant) cooling capacity in tons	Tons	User input
Eff_{COOL}	Cooling system efficiency	kW/ton	User input
0.746	Conversion factor	kW/hp	0.746
$\text{HP}_{\text{CT\_FAN}}$	Horsepower of cooling tower fan motor, if any	hp	0 if no cooling tower, user input otherwise
$\text{ML}_{\text{CT\_FAN}}$	Motor loading of cooling tower fan motor, if any		0 if no cooling tower, user input otherwise; if not known assume 0.8
$\text{Eff}_{\text{CT\_FAN}}$	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
$\text{HP}_{\text{CT\_PUMP}}$	Horsepower of cooling tower water pump motor, if any	hp	0 if no cooling tower, user input otherwise
$\text{ML}_{\text{CT\_PUMP}}$	Motor loading of cooling tower water pump motor, if any		0 if no cooling tower, user input otherwise; if not known assume 0.8
$\text{Eff}_{\text{CT\_PUMP}}$	Motor efficiency of cooling tower water pump motor, if any	hp	0 if no cooling tower, user input otherwise; if not known assume code minimum based on horsepower
$\text{Econ}_{\text{OPERATING}}$	Fraction that indicates the degree of economizer operation		1 when the outside air (dry bulb) temperature is below design mixed air temperature, 0 when outside air temperature is above economizer high limit temperature setpoint, linear interpolation in between these values

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = average\ of\ [(LF\ *\ CAP\ *\ Eff_{\text{COOL}} + 0.746\ *\ HP_{\text{CT\_FAN}} *\ ML_{\text{CT\_FAN}} / Eff_{\text{CT\_FAN}} + 0.746\ *\ HP_{\text{CT\_PUMP}} *\ ML_{\text{CT\_PUMP}} / Eff_{\text{CT\_PUMP}})\ *\ Econ_{\text{OPERATING}}]\ across\ all\ hours\ during\ the\ peak\ period\ of\ 2{:}00\ p.m.\ to\ 6{:}00\ p.m.,\ Monday\ to\ Friday\ from\ June\ through\ September.$$

Lifecycle Energy-Savings Algorithm

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

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%

Revision History

Version Number	Date	Description of Change
01	10/2018	Initial TRM entry

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[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] RSMeans. Facilities Construction Cost Data. 29th Edition. 2013. Assumed $54.00 per hour labor rate and estimated two hours for completion.

[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

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[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

Hot Water Supply Reset

	Measure Details
Measure Master ID	Hot Water Supply Reset, Building Tune-up, 5291 Unoccupied Mode Hot Water Supply Reset, Building Tune-up, 5266
Workpaper ID	W0071
Measure Unit	Per # of HW reset controls implemented (see Assumptions)
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 measure
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	4[1]
Incremental Cost ($/unit)	$140.00[2]

Measure Description

These measures are part of the Whole Building Tune-up set of control system repairs and improvements for existing buildings. Measure 5291 (formerly 3662) was originally developed for the Express Building Tune-up offer that ran through 2019.

The intent of these measures is to capture savings by lowering the boiler hot water supply setpoint temperature for the primary heating loop based on actual building load and/or outdoor air temperature. This measure is meant to help optimize HVAC systems to operate more efficiently at existing building load conditions.

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 supply reset strategy.

Description of Efficient Condition

The efficient measure is a trained HVAC service professional adding a hot water supply reset strategy to the control system that will still safely meeting buildings heating load requirements. The reset temperatures should be appropriate for the efficiency level of the boiler, i.e., 80% boilers can use 180°F maximum supply temperatures if needed to meet peak heating loads but 90%+ condensing boilers should have a much lower maximum supply temperature that maintains the condensing ability of the boiler.

For standard hot water reset controls, 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.

For unoccupied mode hot water reset, the control strategy will reset the hot water supply temperature to a fixed lower value while the building is in unoccupied mode, and return to normal supply temperature for morning warm-up and occupied mode.

Annual Energy-Savings Algorithm

$$Therm_{\text{SAVED}} = Therm_{\text{BASELINE}} - Therm_{\text{PROPOSED}}$$

$$Therm_{\text{BASELINE}} = \Sigma\,[500 * GPM * (HWST_{\text{BASE}} - HWRT) * LF\,/\,100{,}000\,/\,Boiler\ Eff * Bin\ Hours * HRS_{\text{ADJ}}]$$

$$Therm_{\text{PROPOSED}} = \Sigma\,[500 * GPM * (HWST_{\text{PROP}} - HW\text{RT}) * LF\,/\,100{,}000\,/\,Boiler\ Eff * Bin\ Hours * HRS_{\text{ADJ}}]$$

$$GPM = BC * OF * Boiler\ Eff\,/\,(500 * \Delta T_{\text{DESIGN}})$$

Where:

Variable	Description	Units	Value
500	Water sensible heat formula constant	Btu/gpm-°F-hr	500
BC	Boiler rated input capacity	Btu/hour	
OF	Boiler oversizing factor	%	77%[3]
ΔT_{DESIGN}	Design temperature difference for the hot water system	°F	30°F, see assumptions
$HWST_{\text{BASE}}$	Existing hot water maximum supply temperature	°F	User defined
$HWST_{\text{PROP}}$	Proposed hot water reset curve temperature	°F	User defined
HWRT	Hot water return temperature	°F	Estimated based on OAT and hottest water supply temperature in system; return temperature schedule is a constant between baseline and proposed used to model heat loss reduction
LF	Load fraction, percentage of design heating load based on linear interpolation of a 60°F dry bulb OAT balance point, bin data dry bulb OAT, and average of 99% ASHRAE heating design temperatures for 22 Wisconsin cities.[4]	%	
100,000	Conversion factor	Btu/therm	100,000
Boiler Eff	Efficiency of natural gas to heat conversion for heating purposes		User defined, AFUE for < 300 MBh, Thermal Efficiency for ≥ 300 MBh
Bin Hours	Dry-bulb temperature and time of day (also known as temperature bin data)		Based on statewide BIN weather data[5]
HRS_{ADJ}	Adjustment for hours per week building is unoccupied for measure 5266	Hrs/wk	1.0 for MMID 5291, 1 – [unoccupied hours]/168 for occupied mode of MMID 5266, [unoccupied hours]/168 for unoccupied mode of MMID 5266, where [unoccupied hours] = user input

Summer Coincident Peak Savings Algorithm

There is no peak demand reduction for this measure.

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (4 years)[1]

Assumptions

- Measure unit is listed as 'Per HW reset controls implemented' to reflect the savings calculated using the algorithms, however, this measure is part of the Whole Building Tune-Up Offering where a flat incentive is paid per building, no matter how many hot water systems receive these controls.
- Return water temperature schedule is assumed to be at ΔT=30°F for the coldest OAT (design heating load) and at ΔT=10°F for the warmest OAT compared to the existing hot water heating setpoint.[6]
- 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.

Revision History

Version Number	Date	Description of Change
01	08/2015	Initial TRM entry
02	01/2022	Edit for revised structure of whole building tune-up offer, updated cost and EUL

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[1] Navigant. "Effective Useful Life for Retro-commissioning and Behavior Programs" memo. September 17, 2019. https://ilsag.s3.amazonaws.com/ComEd-EUL-Comm-RCx-and-Behavior-Memo-2019-09-17.pdf. Four years is the EUL for the Operational Efficiency Offering.

[2] Assumed $140.00 per hour labor rate for controls technician and estimated one hour for completion, assuming the digital control system is already in place.

[3] PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Page 4-28. March 22, 2010. https://focusonenergy.com/ sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

[4] American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc. ASHRAE Handbook: Fundamentals. Chapter 14 – Climatic Design Information and CD ROM handbook supplement. 2017.

[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] Edison Electric Institute. *Technical Information Handbook*. p. 24. 2000. This value converts the output to Btus (8.33 lb/gal * 60 min/hr * 1 Btu/°F-lb-hr = 500 Btu-min/gal-°F).

Chilled Water Reset Controls

	Measure Details
Measure Master ID	Chilled Water Reset Controls, Building Tune-up, 5362
Workpaper ID	W0296
Measure Unit	Per # of Chilled Water reset controls implemented (see Assumptions)
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up/Repair/Commissioning
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Electricity Savings (kWh)	Varies by temperature reset range
Peak Demand Reduction (kW)	0
Annual Natural Gas Savings (therms)	0
Lifecycle Electricity Savings (kWh)	Varies by temperature reset range
Lifecycle Natural Gas Savings (therms)	0
Annual Water Savings (gallons)	0
Effective Useful Life (years)	4[1]
Incremental Cost ($/unit)	$280.00[2]

Measure Description

This measure is about implementing a control strategy to reset the chilled water supply temperature based on the outside air temperature.

During times when the building load is at less than design conditions, reset strategy can be implemented to raise the chilled water set-point temperature. With chilled water at a warmer temperature, this will lessen the burden on compressor, leading to energy savings.

Description of Baseline Condition

The baseline condition is a chiller with no reset of chilled water temperature based on the outside air temperature or some degree of temperature reset (no more than 3 °F) based on the outside air temperature.

Description of Efficient Condition

The efficient condition is a chiller with reset of water temperature based on outside air temperature.

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = kWh_{\text{BASE}} - kWh_{\text{EE}}$$

$$kWh_{\text{BASE}} = \Sigma_{8760}[CoolLoad * Eff_{\text{CH}} * (1 - m_{\text{CH}} * (T_{\text{CWST,BASE}} - T_{\text{CWST,R}}))]$$

$$kWh_{EE} = \Sigma_{8760}[CoolLoad * Eff_{CH} * (1 - m_{CH} * (T_{CWST,EE} - T_{CWST,R}))]$$

Where:

Variable	Description	Units	Value
CoolLoad	Cooling load in tons at that hour of the year	Tons	Scales linearly from 0 at user-set balance point temperature to user-specified cooling load at 95°F, or 90% of user-specified chiller capacity
Eff_{CH}	Chiller efficiency, kW/ton	kW/ton	User input
m_{CH}	Chiller power change per °F	%/°F	1%[3]
$T_{CWST,BASE}$	Chilled water supply temperature at that hour of year before chilled water reset controls are applied	°F	Scales linearly with outdoor air temperature at that hour of year, from user-specified chilled water supply temperature at low outdoor air temperature to user-specified chilled water supply temperature at high outdoor air temperature
$T_{CWST,R}$	Chilled water supply temperature at chiller rated condition	°F	User input
$T_{CWST,EE}$	Chilled water supply temperature at that hour of the year after chilled water reset controls are applied	°F	Scales linearly with outdoor air temperature at that hour of the year, from user-specified chilled water supply temperature at low outdoor air temperature to user-specified chilled water supply temperature at high outdoor air temperature

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 (4 years[1])

Assumptions

- As a rule-of-thumb, each 1°F increase in the chilled-water temperature reduces the energy consumption of the chiller by an amount from 1% to 1.5%.[3] 1% is used in this workpaper.
- Measure unit is listed as ‘Per # of CW reset controls implemented’ to reflect the savings calculated using the algorithms, however, this measure is part of the Whole Building Tune-Up Offering where a flat incentive is paid per building, no matter how many chillers implement a reset strategy. This is similar to W0071 - Hot Water Supply Reset.

Revision History

Version Number	Date	Description of Change
01	10/2022	Initial TRM entry

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[1] Citing EUL for “Operational Efficiency.” Navigant. *Effective Useful Life of Retro-commissioning and Behavior programs*. September 17, 2019. Table 1. https://ilsag.s3.amazonaws.com/ComEd-EUL-Comm-RCx-and-Behavior-Memo-2019-09-17.pdf

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[2] Trane TRACE 700 *Building Energy and Economic Analysis. Version 6.2.* Pps. 5-24. https://software.trane.com/CDS/TRACE%20700%20-%20Users%20Manual.pdf

[3] Cadmus estimate. Based on a straightforward programming change, assuming digital controls are already in place. Estimate is 2 hours of labor at $140/hr.

Gas Furnaces, Business

	Measure Details
Measure Master ID	Furnace with ECM, ≥95%+ AFUE, NG, 3491 Furnace with ECM, ≥90%+ AFUE, NG, 3492 Furnace with ECM, ≥95%+ AFUE, Propane, 4869 Furnace with ECM, ≥90%+ AFUE, Propane, 4870
Workpaper ID	W0073
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 by sector
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Annual Propane Savings (Gallons)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	Varies by measure
Annual Propane Savings (Gallons)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	21[1]
Incremental Cost ($/unit)	≥95%+ AFUE = $664.85 (MMID 3491);[2,3] ≥90%+ AFUE = $232.31 (MMID 3492)[2,4]

Measure Description

Residential-style natural gas and propane furnaces are available with higher thermal efficiencies than the baseline code-minimum efficiency, which saves energy by consuming less natural gas. These measures are specific to business and common area multifamily applications.

In addition to natural gas savings, furnaces can save electricity through more efficient blower motors. These are commonly ECMs and can generally be constant-torque or constant airflow (true variable speed). Additional electric savings can be achieved by employing these motor types with a burner staging strategy that allows for the furnace blower to run at a lower speed when the full heating capacity of the furnace is required. While the blower may run longer on these furnaces, the reduced electrical use at these lower speeds creates significant savings.

Description of Baseline Condition

The current federal standard for residential-sized furnaces is an 80%[5] AFUE single-stage furnace with a blower motor that meets a fan energy rating (FER) performance requirement,[6,7] generally necessitating an ECM.

Description of Efficient Condition

The efficient condition is a multi-stage furnace with a minimum AFUE of 95% for MMID 3491 or 90% for MMID 3492 as listed by the Air-Conditioning, Heating and Refrigeration Institute. These efficient furnaces also generally have more efficient ECMs than baseline furnaces.

Annual Energy-Savings Algorithm

$$Therm_{\text{SAVED}} = Cap * (AFUE_{\text{EE}} / AFUE_{\text{BASE}} - 1) * EFLH_{\text{HEAT}} / ConvF$$

$$kWh_{\text{SAVED}} = kWh_{\text{MOTOR}} / AvgSize$$

Where:

Variable	Description	Units	Value
Cap	Input capacity of the efficient furnace	MBh	User input
$AFUE_{EE}$	Thermal efficiency of efficient equipment		0.95 for MMID 3491; 0.90 for MMID 3492
$AFUE_{BASE}$	Thermal efficiency of baseline equipment		0.80[3]
$EFLH_{HEAT}$	Equivalent full load heating hours	Hrs	1,890; see Assumptions[8]
ConvF	Fuel conversion factor	MBtu/therm	100 MBtu per therm, 91.3 MBtu per gallon propane[9]
kWh_{MOTOR}	Electric energy saved as a result of furnace motor upgrade	kWh	70 kWh; see Assumptions
AvgSize	Average furnace size in MBh to convert ECM per furnace savings to per MBh savings	MBh	58 MBh for multifamily,[10] 84.3 MBh for business[11]

Summer Coincident Peak Savings Algorithm

No demand savings are claimed for this measure.

Lifecycle Energy-Savings Algorithm

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

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

Where:

EUL = Effective useful life (21 years)[1]

Deemed Savings

Savings are presented in the table below.

Therm and Electric Savings by Measure, per MBh Input

MMID	Sector	Eff_{EE}	kW	Annual		Lifecycle	
				kWh	Therms	kWh	Therms
3491	Residential- multifamily	95%	0	1.21	3.54	25.4	73.5
	Commercial, Industrial, Agriculture, Schools & Government		0	0.83	3.54	17.4	73.5
3492	Residential- multifamily	90%	0	1.21	2.36	25.4	50.4
	Commercial, Industrial, Agriculture, Schools & Government		0	0.83	2.36	17.4	50.4

Propane and Electric Savings by Measure, per MBh Input

MMID	Sector	Eff_{EE}	kW	Annual		Lifecycle	
				kWh	Gallons Propane	kWh	Gallons Propane
4869	Residential- multifamily	95%	0	1.21	3.88	25.4	81.9
	Commercial, Industrial, Agriculture, Schools & Government		0	0.83	3.89	17.4	81.9
4870	Residential- multifamily	90%	0	1.21	2.59	25.4	54.6
	Commercial, Industrial, Agriculture, Schools & Government		0	0.83	2.59	17.4	54.6

Assumptions

Previously, multifamily applications for these measures reflected a mix of in-unit and common area furnaces, and the residential $EFLH_{HEAT}$ value of 1,158 was used.[8] Now, however, multifamily applications for these measures are for common areas only, and the commercial value for $EFLH_{HEAT}$ is used. Data for determining the equivalent full-load heating hours for business are presented in the table below.

Supporting Inputs for Equivalent Full-Load Heating Hours by City for Business [10]

Location	$EFLH_{HEAT}$	Weighting by Participant
Green Bay	1,852	22%
La Crosse	1,966	3%
Madison	1,934	18%
Milwaukee	1,883	48%
Wisconsin Average	1,909	9%
Weighted Average	**1,890**	**100%**

Previously, savings from furnace ECM upgrades (416 kWh) were derived from a 2014 Cadmus study that calculated savings over an assumed PSC motor baseline. However as of July 3, 2019, the U.S. Department of Energy required residential-sized furnace blower motors to meet a fan energy ratio performance standard[6,7] that can generally only be met by ECMs, rendering the 2014 study obsolete. However, there are multiple efficiency levels of ECM blower motors,[12] and a majority of Focus on Energy furnaces perform at the higher end. Because fan energy ratio values are not published, average annual auxiliary electrical energy consumption (E_{AE})[13] is used to estimate the potential savings from staging during heating and from more efficient motors.

More details on this are outlined in the residential furnaces workpaper (workpaper ID W0207).

The efficient E_{AE} is estimated to be the average from the AHRI database for Focus on Energy–qualified (AFUE ≥95%) multi-stage burner models. The average E_{AE} for 981 such models is 398.8 kWh.

The baseline E_{AE} value is estimated to be the average for noncondensing furnace models that do not otherwise meet Focus on Energy requirements. The average E_{AE} for 1,961 such models is 468.5 kWh.

Therefore, the deemed electric savings for furnaces are 468.5 – 398.8 = 70 kWh.

Incremental Costs

A 2015 U.S Department of Energy Technical Support Document[2] estimates the average cost for 80 MBh, 80% AFUE furnaces to be $2,410. Adjusting this up 12% for inflation to 2020 dollars produces $2,699.20. Data from the Focus on Energy database SPECTRUM shows the average furnace size for MMID 3491 to be 71 MBh, and the average size for MMID 3492 to be 101 MBh. SPECTRUM data also shows average costs per furnace of $3,229.09 for 3491[3] and $3,201.43 for 3492.[4] For MMIDs 3491 and 4869, adjusting the baseline cost down 5% to approximately account for the 80 MBh vs. 71 MBh sizes produces a $3,229.09 - $2,699.20 * 0.95 = $664.85 incremental cost. For MMID 3492 and 4870, adjusting the baseline cost up 10% to approximately account for the 80 MBh vs. 101 MBh sizes produces $3,201.43 - $2,699.20 * 1.1 = $232.31.

Revision History

Version Number	Date	Description of Change
01	10/2018	Initial release
02	03/2020	Updated electric savings per new motor efficiency requirements
03	02/2021	Updated incremental cost, added propane measure
04	01/2022	Updated EUL

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[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. *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
Used the difference between the north region's 80% and 95% furnaces (for MMID 3491) and between 80% and 90% furnaces (for MMID 3492).

[3] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. For MMID 3491, average cost of 654 projects, 1,277 furnaces, and 186,584 MBh from January 2018 to July 2020 is $22.15 per MBh and $3,229.09 per furnace.

[4] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. For MMID 3491, average cost of 3 projects, 7 furnaces, and 706 MBh from January 2018 to April 2020 is $41.41 per MBh and $3,201.43 per furnace.

[5] Electronic Code of Federal Regulations. https://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8

[6] Electronic Code of Federal Regulations. Title 10, Chapter II, Subchapter D, Part 430, Subpart C, §430.32. Table 1—Energy Conservation Standards for Covered Residential Furnace Fans. https://www.ecfr.gov/cgi-bin/text-idx?SID=0423028877ce42bb0c3e0e2529ac80ba&mc=true&node=se10.3.430_132&rgn=div8

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[7] Regulations.gov. *2014-07-03 Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Furnace Fans; Final Rule*. Table I.1. https://www.regulations.gov/document?D=EERE-2010-BT-STD-0011-0117

[8] 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/files/asset/document/ASHP_Sav_Calc.xls
Several Cadmus metering studies have revealed that the ENERGY STAR EFLH calculator is overestimated by 25%. $EFLH_{HEAT}$ for this workpaper was adjusted by population-weighted heating degree days and TMY3 values.

[9] U.S. Energy Information Administration. "Energy Units and Calculators Explained." https://www.eia.gov/energyexplained/?page=about_energy_units

[10] Wisconsin Focus on Energy. Historical project data.
Average size of 58 multifamily applications of MMID 3491 paid in 2019. These applications likely reflect in-unit furnaces. This value should be altered to reflect common area furnaces in the future.

[11] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. September 2014 through November 2018. Average furnace size of 719 furnaces in 517 business projects for MMID 3491.

[12] U.S. Department of Energy. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnace Fans*. June 2014. https://www.regulations.gov/document?D=EERE-2010-BT-STD-0011-0111

[13] Electronic Code of Federal Regulations. Title 10, Chapter II, Subchapter D, Part 430 Subpart B, Appendix N. https://www.govinfo.gov/app/details/CFR-2013-title10-vol3/CFR-2013-title10-vol3-part430-subpartB-appN

Outside Air Intake Control Optimization

	Measure Details
Measure Master ID	Outside Air Intake Control Optimization, Building Tune-up, 5292
Workpaper ID	W0074
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)	4[1]
Incremental Cost ($/unit)	$200.00[2]

Measure Description

The intent of this measure is to capture savings associated with reducing outside air (OA) supply cubic feet per minute (CFM) on an air handling unit to a minimum or, in the case of broken or out of adjustment OA-dampers, repairing the dampers back to original condition. The outside air intake levels should always conform to local codes and ASHRAE 62.1 standards. Measure can be applied only once per building during the EUL. This measure is meant to be a part of the Whole Building Optimization 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 or repairing broken dampers. 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/repair 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 Outside Air Intake Control Optimization workbook.[3,4] Savings assume a single fixed outside air CFM across all outdoor air temperatures. The user inputs the initial value as the baseline, and the final value as the efficient case.

$$kWh_{\text{SAVED}} = (Btu_{\text{BASELINE}} - Btu_{\text{PROPOSED}}) \mathbin{/} 12{,}000 * Chiller\_Eff$$

$$Therm_{\text{SAVED}} = (Btu_{\text{BASELINE}} - Btu_{\text{PROPOSED}}) \mathbin{/} 100{,}000 \mathbin{/} Gas\ Eff$$

$$Btu_{\text{BASELINE}} = \Sigma\ (1.08 * OA\ existing\ supply\ CFM * |SAT - OAT| * Bin\ Hours)$$

$$Btu_{\text{PROPOSED}} = \Sigma\ (1.08 * OA\ proposed\ supply\ CFM * |SAT - OAT| * Bin\ Hours)$$

Where:

Variable	Description	Units	Value
1.08	Constant for air sensible heat equation[5]	Btu/cfm-°F-hr	1.08
OA existing supply CFM	Actual outside air supply airflow		Based on user input
SAT	Supply aIr temperature	°F	60°F for SAT_C, OAT > 60°F = 75°F for SAT_H, OAT < 60°F
OAT	Outside air temperature	°F	Determined by Wisconsin BIN data in EBTU workbook[4]
Bin Hours	Dry-bulb temperature and time of day (also known as temperature bin data)	°F	
OA proposed supply CFM	Proposed air supply airflow	cfm	Based on user input
12,000	Conversion factor	Btu/tons	12,000
Chiller_Eff	Kilowatts per ton	kW/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]

Annual hours of fan operation = Hours in use (based on user input)

100,000 = Conversion factor, Btu/therm

Gas Eff = Efficiency of gas unit (variable input from customer)

The workbook calculator requires the following measure-specific inputs to be provided from the trained professional performing the repair/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)
- Number of hours outside air supply fan runs annually
- Type of cooling system (DX, air cooled, water cooled)

- Efficiency of gas fired heating system

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = kWh_{\text{SAVED}} / Hours_{\text{COOL}} * CF$$

Where:

$\text{Hours}_{\text{COOL}}$ = 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

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

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

Where:

EUL = Effective useful life (4 years)[1]

Assumptions

- Measure unit is listed as ‘Per CFM Reduced’ to reflect the savings calculated using the algorithms, however, this measure is part of the Whole Building Tune-Up Offering where a flat incentive is paid per building, no matter how much CFM is reduced.
- 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

Revision History

Version Number	Date	Description of Change
01	11/2014	Initial TRM entry
02	12/2021	Removed fan savings, added OA damper repair scenario to description, updated cost and EUL.

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[1] Navigant. "Effective Useful Life for Retro-commissioning and Behavior Programs" memo. September 17, 2019. https://ilsag.s3.amazonaws.com/ComEd-EUL-Comm-RCx-and-Behavior-Memo-2019-09-17.pdf. Four years is the EUL for the Operational Efficiency Offering.

[2] Focus on Energy. Engineering Judgment. 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 $140 per hour is a more realistic rate. This measure will either involve adjusting linkages or re-calibrating damper signals, which would be approximately 1 hour of labor, or repairing/replacing broken or damaged dampers, which would be considerably more expensive. An average cost of $200 is deemed.

[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] Appendix B: Common Variables, 'Outside Air Temperature Bin Analysis.'

Schedule Optimization

	Measure Details
Measure Master ID	Schedule Optimization, Building Tune-up, 5295
Workpaper ID	W0075
Measure Unit	Per rooftop unit
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)	4[1]
Incremental Cost ($/unit)	$420.00[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 measurewas originally part of the Express Building Tune-Up offer that ran through 2019, but has been adapted for the Whole Building Tune-up offering.

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 building's 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 building's 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 difference between the sums 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 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.

$$kWh_{\text{SAVED}} = kWh_{\text{BAS}}e - kWh_{\text{PROPOSED}}$$

$$Therm_{\text{SAVED}} = Therm_{\text{BASE}} - Therm_{\text{PROPOSED}}$$

$$kWh_{\text{BASE}} = \Sigma_{\text{EXISTING}} (1.08 * Hourly\ CFM * |SAT - MAT| * \#\ of\ days\ per\ month\ /\ 12{,}000 * chiller\_eff)$$

$$Therm_{\text{BASE}} = \Sigma_{\text{EXISTING}} (1.08 * Hourly\ CFM * |SAT - MAT| * \#\ of\ days\ per\ month\ /\ 100{,}000\ /\ boiler\_eff)$$

Baseline data is based on the user-defined existing building schedule.

$$kWh_{Proposed} = \Sigma_{\text{PROPOSED}} (1.08 * Hourly\ CFM * |SAT - MAT| * \#\ of\ days\ per\ month\ /\ 12{,}000 * chiller\_eff)$$

$$Therm_{\text{PROPOSED}} = \Sigma_{\text{PROPOSED}} (1.08 * Hourly\ CFM * |SAT - MAT| * \#\ of\ days\ per\ month\ /\ 100{,}000\ /\ boiler\_eff)$$

$$MAT = (RAT * CFM_{\text{RA}} + OAT_{\text{AVE}} * CFM_{\text{OA}})\ /\ CFM_{\text{TOT}}$$

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:

Variable	Description	Units	Value
1.08	Constant for air sensible heat equation	Btu/cfm-hr[5]	
Hourly CFM	Total building airflow in CFM multiplied by hourly area load	cfm	Where area load is percentage based on linear interpolation of 60°F dry bulb OAT balance point, bin data dry bulb OAT, and 2% dry bulb design summer (see Assumptions), 99% dry bulb design winter conditions for different Wisconsin cities[6]
SAT	Supply air temperature for occupied hours	°F	60°F for OAT > 60°F; 75°F for OAT ≤ 60°F; for scheduled unoccupied temperature setback hours, SAT is standard occupied hour temperature setting, plus or minus user-defined setback temperature for cooling and heating periods, respectively
MAT	Mixed air temperature	°F	
RAT	Return air temperature	°F	75°F for OAT > 60°F; 68°F for OAT ≤ 60°F

Variable	Description	Units	Value
CFM_{RET}	Return air CFM	cfm	Total airflow CFM - outside air CFM
OAT_{AVE}	Weighted average hourly temperature	°F	Calculated based on maximum and minimum temperatures over every given hour of day and number of occurrences per month based on bin data[3]
CFM_{OA}	Outside air CFM,	cfm	Amount of outside air expected based on facility type and square footage as determined through CBECS statistical data inserted in EBTU workbook[7,3]
CFM_{TOT}	Total airflow CFM	cfm	1 cfm/sq ft of facility space
# of days per month	Varies by month	Days/mo	31 in January, 28 in February, etc.
12,000	Conversion factor	Btu/ton	12,000
chiller_eff	Cooling efficiency of chiller		User input, if unknown use Cooling Efficiency by System Type table below
100,000	Conversion factor	Btu/therm	100,000
boiler_eff	Efficiency of natural gas to heat conversion for heating purposes		User input, if unknown use 80%

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

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

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

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

Where:

EUL = Effective useful life (4 years)[1]

Assumptions

- Measure unit is listed as 'Per Rooftop Unit' to reflect the savings calculated using the algorithms, however, this measure is part of the Whole Building Tune-Up Offering where a flat incentive is paid per building, no matter how many rooftop units have their scheduling adjusted.
- 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.

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
03	01/2022	Revisions to convert from old EBTU offer to new whole building tune-up offering, updated cost and EUL

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[1] Navigant. "Effective Useful Life for Retro-commissioning and Behavior Programs" memo. September 17, 2019. https://ilsag.s3.amazonaws.com/ComEd-EUL-Comm-RCx-and-Behavior-Memo-2019-09-17.pdf. Four years is the EUL for the Operational Efficiency Offering.

[2] Focus on Energy. Engineering Judgment. 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 $140 per hour is a more realistic rate, and that three hours is a realistic average time to complete, assuming three rooftop units at one hour each per building.

[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. This value reflects 60 min/hr * 0.24 Btu/lb_{air} * 0.075 lb_{air}/ft^3 = 1.08 Btu/CFM-hr

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[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." 2021.

[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.

Supply Air Temperature Reset

	Measure Details
Measure Master ID	Supply Air Temperature Reset, Heating, 3672 Supply Air Temperature Reset, Cooling, 3673
Workpaper ID	W0076
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)	6[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]

$$kWh_{\text{SAVED}} = \Sigma\ (SAT\ Btu\ Baseline - SAT\ Btu\ Proposed)\ /\ 12{,}000\ *\ chiller\_eff\ *\ \%\ building\ affected$$

$$Therm_{\text{SAVED}} = \Sigma\ (SAT\ Btu\ Baseline - SAT\ Btu\ Proposed)\ /\ 100{,}000\ /\ boiler\_eff\ *\ \%\ building\ affected$$

$$SAT\ Btu\ Baseline\ = [(1.08\ *\ Area\_Load\ *\ |SAT_{\text{BASE}} - OAT|\ *\ Outside\ Air\ CFM\ +\ 1.08\ *\ Area\_Load\ *\ |SAT_{\text{BASE}} - RAT|\ *\ Return\ Air\ CFM]\ *\ bin\ hours$$

$$SAT\ Btu\ Proposed\ = [(1.08\ *\ Area\_Load\ *\ |SAT_{\text{RESET}} - OAT|\ *\ Outside\ Air\ CFM\ +\ 1.08\ *\ Area\_Load\ *\ |SAT_{\text{RESET}} - RAT|\ *\ Return\ Air\ CFM]\ *\ bin\ hours$$

Where:

Variable	Description	Units	Value
1.08	Constant for air sensible heat equation[5]	Btu/cfm-°F-hr	1.08
Area Load	Percentage based on linear interpolation of 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 2.5% dry bulb design conditions
SAT_{BASE}	Supply air temperature baseline	˚F	User defined input; constant
OAT	Outside air temperature	˚F	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]	cfm	
RAT	Return air temperature	°F	75°F for OAT > 60°F; = 68°F for OAT < 60°F
Return Air CFM	Total building airflow – outside air CFM	cfm	
bin hours	Heating and cooling hours for each city based on OAT[4]	Hrs	
SAT_{RESET}	OAT reset range		User input
12,000	Conversion factor	Btu/ton	12,000
chiller_eff	Cooling efficiency of chiller		Varies by chiller type; see Cooling Efficiency by System Type table below
% building affected	Amount of total building conditioned square footage affected by implementing SAT reset control	%	User defined input
100,000	Conversion factor	Btu/therm	100,000
boiler_eff	Efficiency of natural gas to heat conversion for heating purposes		80%

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]

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

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

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

Where:

EUL = Effective useful life (6 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.

Revision History

Version Number	Date	Description of Change
01	11/2014	Initial TRM entry

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[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.

Temperature Sensor Calibration

	Measure Details
Measure Master ID	Temperature Sensor Calibration, 3674
Workpaper ID	W0077
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)	6[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]

$$kWh_{\text{SAVED}} = \Sigma\ (Temp\ Sensor\ cooling\ Btu\ Baseline - Temp\ Sensor\ cooling\ Btu\ Proposed)\ /\ 12{,}000\ *\ chiller\_eff\ *\ \%\ building\ affected\ *\ bin\ hours$$

$$Therm_{\text{SAVED}} = \Sigma\ (Temp\ Sensor\ heating\ Btu\ Baseline - Temp\ Sensor\ heating\ Btu\ Proposed)\ /\ 80\%\ /\ 100{,}000\ *\ \%\ building\ affected\ *\ bin\ hours$$

$$Temp\ Sensor\ cooling/heating\ Btu\ Baseline\ = 1.08\ *\ Area\_Load_{\text{BASE}} * |SAT\ -\ OAT|\ *\ Outside\ Air\ CFM\ +\ 1.08\ *\ Area\_Load_{\text{BASE}} *\ \Delta\ (SAT\ -\ RAT)\ *\ Return\ Air\ CFM$$

$$Temp\ Sensor\ cooling/heating\ Btu\ Proposed\ = 1.08\ *\ Area\_Load_{\text{PROP}} * |SAT\ -\ OAT|\ *\ Outside\ Air\ CFM\ +\ 1.08\ *\ Area\_Load_{\text{PROP}} *\ \Delta\ (SAT\ -\ RAT)\ *\ Return\ Air\ CFM$$

Where:

Variable	Description	Units	Value
1.08	Constant for air sensible heat equation[5]	Btu/cfm-°F-hr	1.08
$Area\_Load_{\text{BASE}}$	Percentage based on linear interpolation of 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 2.5% dry bulb design conditions
SAT	Supply air temperature	°F	60°F for OAT > 60°F; = 75°F for OAT < 60°F
OAT	Outside air temperature	°F	
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]	cfm	
RAT	Return air temperature	°F	75°F for OAT > 60°F; = 68°F for OAT < 60°F
Return Air CFM	Total building airflow – outside air CFM	cfm	Per zone
$Area\_Load_{\text{PROP}}$	Percentage value based on linear interpolation of 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	Conversion factor	Btu/ton	12,000
chiller_eff	kW/ton based on 80% of full load rating of chiller units	kW/ton	based on type of chiller; see Cooling Efficiency by System Type table below
% 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]	Hrs	
80%	Efficiency of natural gas to heat conversion for heating purposes	%	80%
100,000	Conversion factor	Btu/therm	100,000

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]

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

$$kW_{\text{SAVED}} = kWh_{\text{SAVED}} / HoursCOOL * CF$$

Where:

$\text{Hours}_{\text{COOL}}$ = 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

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

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

Where:

EUL = Effective useful life (= 6 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.

Revision History

Version Number	Date	Description of Change
01	11/2014	Initial TRM entry

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[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. Facilities Construction Cost Data. 29th Edition. 2013. Assumed $54.00 per hour labor rate and estimated two hours for completion.

[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] Appendix B: Common Variables, 'Outside Air Temperature Bin Analysis.'

Valve Repair

	Measure Details
Measure Master ID	Valve Repair, Chilled Water, Building Tune-up, 5293 Valve Repair, Hot Water, Building Tune-up, 5294
Workpaper ID	W0078
Measure Unit	Per valve (see Assumptions)
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)	4[1]
Incremental Cost ($/unit)	$140.00[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 failed at least 70% open .

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 Whole Building Tune-Up Offering 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 WBTU-Valve Repair workbook.[3,4]

$$kWh_{\text{SAVED}} = \Sigma_{\text{TEMP}} \left[BTU_{\text{COOL,BASE}} - BTU_{\text{COOL,EE}}\right] * IPLV \ / \ 12{,}000$$

$$Therm_{\text{SAVED}} = \Sigma_{\text{TEMP}} \left[BTU_{\text{HEAT,BASE}} - BTU_{\text{HEAT,EE}}\right] / (80\% * 100{,}000)$$

$$BTU_{\text{COOL,BASE}} = Tons * 12{,}000 * \%V_{\text{STUCK}} * HOU_{\text{ADJ}} * Area\ Load$$

$$BTU_{\text{COOL,EE}} = Tons * 12{,}000 * \%V_{\text{WORK}} * HOU_{\text{ADJ}} * Area\ Load$$

$$BTU_{\text{HEAT,BASE}} = MBh * 1{,}000 * \%V_{\text{STUCK}} * HOU_{\text{ADJ}} * Area\ Load$$

$$BTU_{\text{HEAT,EE}} = MBh * 1{,}000 * \%V_{\text{WORK}} * HOU_{\text{ADJ}} * Area\ Load$$

$$HOU_{\text{ADJ}} = HOU_{\text{BIN}} * EFLH / 8{,}760$$

$$\%V_{\text{WORK}} = (1 - 25\%) * (OAT - T_{\text{DES,HEAT}}) / (T_{\text{DES,HEAT}} - T_{\text{BAL}})\ for\ heating$$

$$(1 - 25\%) * (OAT - T_{\text{HIGH}}) / (T_{\text{HIGH}} - T_{\text{BAL}})\ for\ cooling$$

Where:

Variable	Description	Units	Value
Σ_{TEMP}	Summary of consumption across outdoor air temperature bins	BTU	
$\text{BTU}_{\text{COOL,BASE}}$	Efficient BTU heating consumption in a given OAT temperature bin	BTU	
$\text{BTU}_{\text{COOL,EE}}$	Efficient BTU heating consumption in a given OAT temperature bin	BTU	
$\text{BTU}_{\text{HEAT,BASE}}$	Efficient BTU heating consumption in a given OAT temperature bin	BTU	
$\text{BTU}_{\text{HEAT,EE}}$	Efficient BTU heating consumption in a given OAT temperature bin	BTU	
IPLV	Efficiency of cooling system	kW/ton	Based on user defined type of chiller; see Cooling Efficiency (IPLV) by System Type table below
12,000	Conversion factor	Btu/ton	12,000
80%	Efficiency of natural gas to heat conversion for heating purposes	%	80%
100,000	Conversion factor	Btu/therm	100,000
Tons	Capacity of cooling coil being served	Tons	User defined
$\%\text{V}_{\text{STUCK}}$	Percentage valve is stuck open in baseline condition	%	User defined
HOU_{BIN}	Average hours of occurrence during month or year of a particular range of weather condition[4]	Hrs	
EFLH	Equivalent full load hours	Hrs	See Equivalent Full Load Heating and Cooling Hours by City table below
8,760	Total hours in a year	Hrs	8,760
Area Load	Percentage based on linear interpolation of 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 balance point temperature and 2.5% dry bulb design conditions
MBh	Capacity of heat coil being served	MBh	User defined
1,000	Conversion factor	W/kW	1,000
$\%\text{V}_{\text{WORK}}$	Percent valve is open at a given outdoor temperature bin	%	See Assumptions

Variable	Description	Units	Value
OAT	Outdoor air temperature for a given outdoor temperature bin		
$T_{DES,HEAT}$	99% design temperature for heating	°F	-2.8°F for Green Bay, -4.2°F for La Crosse, -1.2°F for Madison, 3.6°F for Milwaukee
T_{BAL}	Balance point temperature	°F	60°F, assumed
T_{HIGH}	Temperature for highest temperature bin	°F	94°F, assumed

Cooling Efficiency (IPLV) by System Type

Chiller Type	Cooling System Efficiency Factor at Part Load (kW/ton)
Air-Cooled	0.95[6]
Water-Cooled	0.64[6]

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

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 (4 years)[1]

Assumptions

- Measure unit is listed as 'Per Valve' to reflect the savings calculated using the algorithms, however, this measure is part of the Whole Building Tune-Up Offering where a flat incentive is paid per building, no matter how many valves are repaired.
- 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.

- For the percent working valve position calculation, a (1 - 0.25) component is used to make a conservative adjustment, assuming the valve is still 25% open at the balancing point.

Revision History

Version Number	Date	Description of Change
01	11/2014	Initial TRM entry
02	12/2021	Added WBTU measure, updated cost and EUL

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[1] Navigant. "Effective Useful Life for Retro-commissioning and Behavior Programs" memo. September 17, 2019. https://ilsag.s3.amazonaws.com/ComEd-EUL-Comm-RCx-and-Behavior-Memo-2019-09-17.pdf. Four years is the EUL for the Operational Efficiency Offering.

[2] Focus on Energy. Engineering Judgment. 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 $140 per hour is a more realistic rate, and that one hour is a realistic average time to complete. This includes verifying valve status and re-connecting if disconnected, or changing programming parameters. This also assumes the valve actuator or valve body has not failed, in which case the cost would be much higher.

[3] Wisconsin Focus on Energy. WBTU-Valve Repair 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.

VFD Fan Motor Control Restoration

	Measure Details
Measure Master ID	VFD Fan Motor Control Restoration, 3677
Workpaper ID	W0079
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)	6[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]

$$kWh_{\text{SAVED}} = VFD\ Motor\ Baseline\ -\ VFD\ Motor\ Proposed$$

$$VFD\ Motor\ Baseline\ =\ \Sigma\,[Motor\ hp\ *\ 0.7465\ /\ Motor\ eff\ *\ (Motor\ loading\ \%_{\text{BASE}})\text{^}2.5\ *\ Adjusted\ Run\ Hours]$$

$$VFD\ Motor\ Proposed\ =\ \Sigma\ [Motor\ hp\ *\ 0.7465\ /\ Motor\ eff\ *\ (Motor\ loading\ \%_{\text{PROP}})\hat{}2.5\ *\ Adjusted\ Run\ Hours]$$

Where:

Variable	Description	Units	Value
Motor hp	VFD controlled motor nameplate horsepower rating	hp	
0.7465	Conversion factor	kW/hp	0.7465
Motor eff	VFD controlled motor nameplate efficiency	%	Specific VFD controlled motor nameplate efficiency; otherwise use default of 90%
Motor Loading $\%_{\text{BASE}}$	Percent capacity (Load Factor) of motor at baseline	%	User defined
Adjusted Run Hours	Bin hours * (annual VFD operational hours / 8,760 annual hours)	Hrs	
Motor Loading $\%_{\text{PROP}}$	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

$$kW_{\text{SAVED}} =\ kWh_{\text{SAVED}}\ /\ Hours_{\text{FAN}} *\ CF$$

Where:

$\text{Hours}_{\text{FAN}}$ = 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

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

Where:

EUL = Effective useful life (6 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.

Revision History

Version Number	Date	Description of Change
01	10/2014	Initial TRM entry

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[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.

VFD Pump Control Restoration

	Measure Details
Measure Master ID	VFD Pump Control Restoration, 3678
Workpaper ID	W0080
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)	6[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]

$$kWh_{\text{SAVED}} = VFD\ Pump\ Baseline\ -\ VFD\ Pump\ Proposed$$

$$VFD\ Pump\ Baseline\ =\ \Sigma\,[Motor\ hp\ *\ 0.7465\ /\ Motor\ eff\ *\ (Motor\ loading\ \%_{\text{BASE}})\text{^}2.5\ *\ Adjusted\ Run\ Hours]$$

$$VFD\ Pump\ Proposed\ =\ \Sigma\ [Motor\ hp\ *\ 0.7465\ /\ Motor\ eff\ *\ (Motor\ loading\ \%_{PROP})\text{^}2.5\ *\ Adjusted\ Run\ Hours]$$

Where:

Variable	Description	Units	Value
Motor hp	VFD controlled motor nameplate horsepower rating	hp	Nameplate rating
0.7465	Conversion factor	kW/hp	0.7465
Motor eff	Specific VFD controlled pump motor nameplate efficiency; otherwise use default of 90%	%	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)	Hrs	8,760
Motor Loading $\%_{PROP}$	Percent capacity (load factor) of motor proposed; assumes VFD is set back to "automatic" control based on user-defined loading minimum and maximum percentages and on area load	%	Area load is percentage based on linear interpolation of 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 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

$$kW_{SAVED} = kWh_{SAVED}\ /\ HoursPUMP\ *\ CF$$

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 (6 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.

Revision History

Version Number	Date	Description of Change
01	10/2014	Initial TRM entry

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[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.

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 Domestic Hot Water Recirculation, < 100 Watts Max Input, 3494 Domestic Hot Water Recirculation, 100-500 Watts Max Input, 3495 Domestic Hot Water Recirculation, 500-1,000 Watts Max Input, 5011 Domestic Hot Water Recirculation, 1,000-1,500 Watts Max Input, 5012 Domestic Hot Water Recirculation, >1,500 Watts Max Input, 5010 Heating Water Circulation, < 100 Watts Max Input, 3497 Heating Water Circulation, 100-500 Watts Max Input, 3498 Heating Water Circulation, 500-1,000 Watts Max Input, 5013 Heating Water Circulation, 1,000-1,500 Watts Max Input, 5014 Heating Water Circulation, >1,500 Watts Max Input, 5015 Cooling Water Circulation, < 100 Watts Max Input, 3500 Cooling Water Circulation, 100-500 Watts Max Input, 3501 Cooling Water Circulation, 500-1,000 Watts Max Input, 5016 Cooling Water Circulation, 1,000-1,500 Watts Max Input, 5017 Cooling Water Circulation, >1,500 Watts Max Input, 5018 Water Loop Heat Pump Circulation, < 100 Watts Max Input, 3503 Water Loop Heat Pump Circulation, 100-500 Watts Max Input, 3504 Water Loop Heat Pump Circulation, 500-1,000 Watts Max Input, 5019 Water Loop Heat Pump Circulation, 1,000-1,500 Watts Max Input, 5020 Water Loop Heat Pump Circulation, >1,500 Watts Max Input, 5021 Wholesale, < 100 Watts Max Input: 5166
Workpaper ID	W0081
Measure Unit	Per pump
Measure Type	Prescriptive
Measure Group	Domestic Hot Water Recirculation – Domestic Hot Water Heating Water Circulation – HVAC Cooling Water Circulation – HVAC Water Loop Heat Pump Circulation – HVAC
Measure Category	Variable Speed Drive
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential-multifamily, Residential- single family
Annual Electricity Savings (kWh)	Varies by wattage
Peak Demand Reduction (kW)	Varies by wattage
Annual Natural Gas Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by wattage
Lifecycle Natural Gas Savings (Therms)	0
Annual Water Savings (gallons)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Varies by measure and wattage, see Incremental Costs table

Measure Description

ECMs are high-efficiency brushless DC motors. These typically fractional horsepower motors have several benefits over the more common permanent split capacitor (PSC) fractional horsepower motor, including 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.

Domestic hot water (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 who have long piping runs. These recirculation pumps can be operated continuously or be controlled by a timer or an aquastat. An aquastat turns the pump on 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 of forced air systems in multifamily and commercial buildings. Single family residential homes also use heating and cooling water circulation pumps in hydronic heating systems. 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 own pump 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 pump motor size, the variable speed capability of the pump, and the increased efficiency of the ECMs versus the fraction horsepower from PSC motors.

Annual Energy-Savings Algorithm

Heating and Cooling Circulation Pumps

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

Water Loop Heat Pump Circulation Pumps

$$kWh_{\text{SAVED}} = (Watts_{\text{BASE}} - Watts_{\text{EE}}) \; / \; 1{,}000 \; * \; (HOU_{\text{HEATING}} + HOU_{\text{COOLING}})$$

$$HOU_{\text{HEATING}} = HDD \; * \; 24 \; / \; \Delta T_{\text{HEAT}}$$

$$HOU_{\text{COOLING}} = CDD \; * \; 24 \; / \; \Delta T_{\text{COOL}}$$

DHW Recirculation Pumps

$$kWh_{\mathbf{SAVED}} = (Watts_{\mathbf{BASE}} \,/\, 1{,}000 \;*\; HOU_{\mathbf{DHW}}{-}BASE) - (Watts_{\mathbf{EE}} \,/\, 1{,}000 \;*\; HOU_{\mathbf{DHW}}{-}EE)$$

$$HOU_{\mathbf{DHW}}{-}BASE \;=\; HOU_{\mathbf{UNCONTROLLED}} * \;44.5\% \;+\; HOU_{\mathbf{CONTROLLED}} * \;55.5\%$$

$$HOU_{\mathbf{DHW}}{-}EE \;=\; HOU_{\mathbf{CONTROLLED}}$$

Where:

Variable	Description	Units	Value
$Watts_{BASE}$	Power consumption of constant speed PSC pump		$Watts_{EE}$ / R
$Watts_{EE}$	Power consumption of variable speed ECM pump		See Assumed Powers for Ranges of ECM Pumps table below
1,000	Conversion factor	W/kW	1,000
HOU	Average annual pump run hours	Hrs	7,616; see Heating and Cooling Degree Days by Location table below[2]
R	Ratio of ECM watts to baseline watts	%	40%; see Assumptions[3]
HDD	Heating degree days	Days	7,616; see Heating and Cooling Degree Days by Location table below[3]
24	Conversion factor, hours per day	Hrs/day	24
ΔT_{HEAT}	Design temperature difference for heating	°F	80°F, using -15°F outdoor and 65°F indoor
CDD	Cooling degree days	Days	565; see Heating and Cooling Degree Days by Location table below[5]
ΔT_{COOL}	Design temperature difference for cooling	°F	20°F, using 95°F outdoor and 75°F indoor
$HOU_{DHW\text{-}BASE}$	Average annual baseline DHW recirculating pump run hours	Hrs	5,114[4]
$HOU_{DHW\text{-}EE}$	Average annual efficient DHW recirculating pump run hours	Hrs	2,190[3]
$HOU_{UNCONTROLLED}$	Average annual pump run hours for DHW recirculating continuously running	Hrs	8,760
44.5%	Fraction of baseline systems with no controls[5]	%	44.5%
$HOU_{CONTROLLED}$	Average annual pump run hours for DHW recirculating controlled by timer or aquastat	Hrs	2,190[4]
55.5%	Fraction of baseline systems with timer or aquastat controls[5]	%	55.5%

Assumed Powers for Ranges of ECM Pumps

Size Range, Watts	Assumed Power, Watts
<100	50
>100, ≤500	250
>500, ≤1,000	700
>1,000, ≤1,500	1,200
>1,500	1,800

Heading and Cooling Degree Days by Location

Location	HDD[3]	CDD[3]
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**

Summer Coincident Peak Savings Algorithm

The summer coincident peak savings algorithm only applies to cooling circulation pumps and DHW recirculation pumps.

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

Where:

CF = Coincidence factor (0.299 for chilled water pumps,[3] 1.0 for DHW pumps)

Lifecycle Energy-Savings Algorithm

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

Where:

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

Deemed Savings

Energy Savings for VSD ECM Pumps

Wattage	MMID	Energy Savings (kWh)	Lifecycle Savings (kWh)	Demand Reduction (kW)
DHW Recirculation Pumps				
<100	3494	530	7,946	0.0750
>100, ≤500	3495	2,649	39,731	0.3750
>500, ≤1,000	5011	7,417	111,248	1.0500
>1,000, ≤1,500	5012	12,714	190,710	1.8000
>1,500	5010	19,071	286,065	2.7000
Heating Water Circulation Pumps				
<100	3497	171	2,571	0.0000
>100, ≤500	3498	857	12,853	0.0000
>500, ≤1,000	5013	2,399	35,989	0.0000
>1,000, ≤1,500	5014	4,113	61,695	0.0000
>1,500	5015	6,170	92,543	0.0000

Wattage	MMID	Energy Savings (kWh)	Lifecycle Savings (kWh)	Demand Reduction (kW)
Cooling Water Circulation Pumps				
<100	3500	51	763	0.0224
>100, ≤500	3501	254	3,814	0.1121
>500, ≤1,000	5016	712	10,679	0.3140
>1,000, ≤1,500	5017	1,220	18,306	0.5382
>1,500	5018	1,831	27,459	0.8073
Water Loop HP Circulation Pumps				
<100	3503	222	3,333	0.0224
>100, ≤500	3504	1,111	16,667	0.1121
>500, ≤1,000	5019	3,111	46,667	0.3140
>1,000, ≤1,500	5020	5,333	80,001	0.5382
>1,500	5021	8,000	120,002	0.8073
Wholesale Circulation Pumps				
< 100 (80/20 split of MMIDs 3497 and 3494)	5166	243	3,645	0.0150

Assumptions

The Cadmus 2012 *ECM Circulator Pump* study[2] examined 18 ECM pump installations for boiler heating circulation applications. It found base pump sizes ranging from 83 watts to 774 watts and ECM pump sizes ranging from 14 watts to 88 watts, with size ratios ranging from 4% to 60% and an average ratio of 18%. This study is not viewed as statistically significant or representative of all measures in this workpaper, which can have other applications and be much larger.

Another study conducted for the U.S. DOE[6] mentioned that ECM circulator pumps can generally save 50% or more. A third study[7] showed savings ranging from 26% to 60%.

From all this information, a power ratio of 40% was chosen for these measures.

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 to 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 to 1,000 Watts Max Input

- Wattage inputs for qualifying pumps between 500 watts and 1,000 watts. 700 watts was used as a conservative midpoint.

Variable Speed ECM Pump, 1,000 to 1,500 Watts Max Input

- Wattage inputs for qualifying pumps between 1,000 watts and 1,500 watts. 1,200 watts was used as a conservative midpoint.

Variable Speed ECM Pump, >1,500 Watts Max Input

- Wattage inputs for qualifying pumps greater than 1,500 watts range from 1,501 watts to 2,500 watts. 1,800 watts was used as a conservative midpoint.

In order to provide wholesale incentives to contractors for the purchase of qualifying variable speed ECM pumps with less than 100 watts of maximum input, a blended distribution of existing measures was assumed. Estimates from participating midstream distributors indicate that 75% of pumps that receive wholesale incentives will be installed for heating water circulation and 25% will be installed for DHW recirculation. This estimate will be updated following a future survey of contractors. Recent Focus on Energy program data covering 71 units shows an 86%/14% split. An 80%/20% split is used for this workpaper.

Costs were derived by producing linear fits of cost versus wattage for 24 PSC and 23 ECM pumps, based on 2014 research.[8] Cost fits of PSC Cost = Wattage * 1.829 + 434.57 and ECM Cost = Wattage * 2.365 + 1,470.89 were derived. These fits were used with the assumed bin wattages above to produce the incremental costs in the table below.

Incremental Costs

Wattage Range	MMIDs	Assumed Wattage	PSC Cost	ECM Cost	Incremental Cost
<100	3494, 3497, 3500, 3503, 5166	50	$526.02	$1,589.14	$1,063.11
>100, ≤500	3495, 3498, 3501, 3504	250	$891.83	$2,062.15	$1,170.32
>500, ≤1,000	5011, 5013, 5016, 5019	700	$1,714.90	$3,126.43	$1,411.53
>1,000, ≤1,500	5012, 5014, 5017, 5020	1,200	$2,629.42	$4,308.97	$1,679.54
>1,500	5010, 5015, 5018, 5021	1,800	$3,726.85	$5,728.01	$2,001.16

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	01/2019	Removed MMIDs 3496, 3500, 3501, and 3503
03	02/2020	Improved algorithm, split larger motors into multiple bins, re-added previously removed MMIDs 3496, 3500, 3501, and 3503
04	01/2021	Added wholesale MMID

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[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] ASHRAE Estimation ofDegree-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.

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[3] Cadmus. *Impact Evaluation of the 2011–2012 ECM Circulator Pump Pilot Program.* Table 2: Pump Spot Measurements. October 18, 2012.

[4] 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.

[5] 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.

[6] National Renewable Energy Laboratory. *High-Performance Circulator Pump Demonstration*. September 2018. https://www.nrel.gov/docs/fy18osti/71705.pdf

[7] General Services Administration. *Small Circulator Pumps with Automated Control*. September 2018. https://www.gsa.gov/cdnstatic/GPG_Findings-035-Small_Circulator_Pumps_with_Automated_Control.pdf

[8] Pricing research, November 2014. PSC and ECM pump motors from Viridian, Stratos, Star, Top, and other brands were examined across https://www.tacocomfort.com/, https://wilo.com/us/en_us/, and https://www.grundfos.com/nz

Morning Warmup Optimization

	Measure Details
Measure Master ID	Morning Warmup Optimization, Building Tune-up, 5364
Workpaper ID	W0274
Measure Unit	Per BAS
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Commercial, Industrial, Schools & Government
Annual Electricity Savings (kWh)	Varies, see Algorithm
Peak Demand Reduction (kW)	0
Annual Natural Gas Savings (therms)	Varies, see Algorithm
Lifecycle Electricity Savings (kWh)	Varies, see Algorithm
Lifecycle Natural Gas Savings (therms)	Varies, see Algorithm
Annual Water Savings (gallons)	0
Effective Useful Life (years)	4[1]
Incremental Cost ($/unit)	$140[2]

Measure Description

Buildings with nighttime temperature setbacks will typically start heating back up to daytime temperature setpoints well before the building is occupied. This can take 2 to 3 hours or longer. When occupied, there are outdoor air (OA) requirements for ventilation. But OA intake is not needed during the warmup period, and if OA intake is present then heating it up requires extra energy. Morning Warmup Optimization (MWO) involves programming the building automation system (BAS) so that air handling units (AHUs, which also include rooftop units and unit ventilators) that deliver OA into the building during the heating season keep the OA dampers closed during the warmup period, before the building is considered occupied. Exhaust fans should also be programmed to remain off while the OA dampers are closed, to maintain neutral building pressure. If the OA dampers are kept closed and exhaust fans off during the warmup period, heating energy is reduced resulting in therm savings and the warmup period could possibly be reduced, resulting in kWh savings. This measure is part of the Whole Building Tune-Up Offering.

Description of Baseline Condition

The baseline condition is an AHU that does not have a MWO period programmed into the BAS. Baseline conditions include the AHUs going from an unoccupied mode straight to an occupied mode in the morning. This scenario has the AHUs running with OA dampers opening to their minimum position and exhaust fans running while the AHUs are heating the spaces up to reach occupied setpoint.

Description of Efficient Condition

The efficient condition is an AHU coming off unoccupied mode and going into a MWO mode where the OA dampers are closed, and exhaust fans are off while the spaces are heated up to the occupied setpoints. The MWO is programmed in the BAS for all AHUs that bring in OA for ventilation.

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = kWh_{\text{BASE}} - kWh_{\text{EE}}$$

$$kWh_{\text{BASE}} = hp_{\text{FAN}} * 0.746 * LF / Eff_{\text{FAN}} * Hrs/wk_{\text{Base}} * Wks/yr$$

$$kWh_{\text{EE}} = hp_{\text{FAN}} * 0.746 * LF / Eff_{\text{FAN}} * Hrs/wk_{\text{EE}} * Wks/yr$$

$$Therm_{\text{SAVED}} = Therm_{\text{BASE}} - Therm_{\text{EE}}$$

$$Therm_{\text{BASE}} = 1.08 * CFM_{\text{OA,BASE}} * (HDH / 8{,}760) * Hrs/wk_{\text{Base}} * Wks/yr / (Eff_{\text{HEAT}} * 100{,}000)$$

$$Therm_{\text{EE}} = 1.08 * CFM_{\text{OA,EE}} * (HDH / 8{,}760) * Hrs/wk_{\text{EE}} * Wks/yr / (Eff_{\text{HEAT}} * 100{,}000)$$

Where:

Variable	Description	Units	Value
hp_{FAN}	Total horsepower of OA supply and return fans	hp	User input
0.746	Conversion factor	kW/hp	0.746
LF	Fan motor load factor	%	User input, 45% for typical motor, 65% for motor with VFD
Eff_{FAN}	Average efficiency of OA supply and return fan		User input
Hrs/wk_{BASE}	Weekly hours that OA is supplied before building is occupied, before MWO	Hrs/wk Wks/yr	User input based on hrs/wk and wks/yr
Hrs/wk_{EE}	Weekly hours that OA is supplied before building is occupied, after MWO	Hrs/wk	User input based on hrs/wk and wks/yr
Wks/yr	Weeks per year of heating season	Wks/yr	28 weeks, if unknown
1.08	Constant for sensible heat equation; 60 min/hr * 0.075 lb_{air}/ft^3 * 0.24 Btu/lb_{air} = 1.08 Btu/CFM-°F-hr $CFM_{\text{OA,BASE}}$ = CFM of outdoor air before MWO	Btu/(CFM-°F-hr)	1.08
HDH	Heating degree hours based on balance point and location	Hrs	User input
100,000	Conversion factor	Btu/therm	100,000
Eff_{HEAT}	Efficiency of building heating system		User input
$CFM_{\text{OA,EE}}$	CFM of outdoor air after MWO	cfm	User input

Lifecycle Energy-Savings Algorithm

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

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

Where:

EUL = Effective useful life (4 years)

Assumptions

Morning warmup optimization savings is limited to heating season, October to April**.** Exhaust fan savings will occur when the exhaust fans are programmed off during MWO period. These savings are ignored in the calc to simplify the calc and to minimize inputs asked of customers applying for this measure.

The savings assume that heating load occurs equally across all times of heating. This is a very rough assumption. If this measure sees moderate use, this approach should be altered to use a temperature bin analysis or some other more complex and accurate algorithm.

Revision History

Version Number	Date	Description of Change
01	12/2021	Initial TRM entry

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[1] Based on Operational Efficiency Offering EUL of four years. Effective Useful Life for Retro-commissioning and Behavior Programs. September 17, 2019. Navigant.

[2] Billing rate is an average for commercial BAS programmer. Based on an estimated $140/hr labor rate and a duration of one hour.

Adaptive Optimal Start

	Measure Details
Measure Master ID	Adaptive Optimal Start, Building Tune-up, 5365
Workpaper ID	W0276
Measure Unit	Per BAS
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Commercial, Industrial, Schools & Government
Annual Electricity Savings (kWh)	4% of annual energy use by AHUs that implement AOS
Peak Demand Reduction (kW)	0
Annual Natural Gas Savings (therms)	4% of annual energy use by AHUs that implement AOS
Lifecycle Electricity Savings (kWh)	Annual kWh savings * EUL
Lifecycle Natural Gas Savings (therms)	Annual Therm savings * EUL
Annual Water Savings (gallons)	0
Effective Useful Life (years)	4[1]
Incremental Cost ($/unit)	$140[2]

Measure Description

Adaptive Optimal Start (AOS)[3] is a program that is part of most modern Building Automation System (BAS) controls. When implemented correctly in building with nighttime temperature setbacks, AOS will automatically start an air handling unit (AHU) in the morning with just enough time to reach the occupied setpoint of the spaces served, just before the buiding becomes occupied. Adaptive means that the program learns from previous data collected to minimize the amount of run time needed to warm up the space before the space is considered occupied. This measure assumes a 28 week heating season, October to April. This measure is part of the Whole Building Tune-Up Offering.

Description of Baseline Condition

The baseline condition is an AHU that has a morning warmup optimization (MWO) period programmed into the BAS—MWO keeps OA dampers closed and exhaust fans off during the period when the building is starting to warm up after the schedule comes off the unoccupied period, see W0274. Baseline conditions include the AHUs scheduled to go from an unoccupied mode to a MWO mode before going to occupied mode. Baseline conditions assume a set scheduled time period for MWO, usually 2 to 3 hours or more, depending on the building envelope and the HVAC equipment serving the space.

Description of Efficient Condition

The efficient condition is an AHU coming off unoccupied mode and going into an AOS/MWO mode where the OA dampers are closed and exhaust fans are off while the spaces are heated up to the occupied setpoints. The AOS will calculate how long the AHU needs to run to meet the occupied space setpoints by the scheduled occupied time. The AHUs will run longer to warm up the spaces in the morning during very cold weather compared to milder weather. The AOS will automatically shorten the morning warmup run time during milder weather, saving fan energy and heating energy.

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = hp_{\text{FAN}} * 0.746 * LF / Eff_{\text{FAN}} * Hrs/wk * Wks/yr * SF$$

$$Therm_{\text{SAVED}} = 1.08 * CFM_{OA} * HDH / 8{,}760) * Hrs/wk * Wks/yr / (Eff_{\text{HEAT}} * 100{,}000) * SF$$

Where:

Variable	Description	Units	Value
hp_{FAN}	Total horsepower of OA supply and return fans	hp	User input
0.746	Conversion factor	kW/hp	0.746
LF	Fan motor load factor	%	User input, 45% for typical motor, 65% for motor with VFD
Eff_{FAN}	Average efficiency of OA supply and return fan		User inupt
Hrs/wk	Weekly hours that OA of AHU runtime	Hrs/wk	Based on user input
Wks/yr	Weeks per year of heating season;	Wks/yr	28 weeks 1.08 = Constant for sensible heat equation; 60 min/hr * 0.075 lb_{air}/ft^3 * 0.24 Btu/lb_{air} = 1.08 Btu/CFM-°F-hr
CFM_{OA}	Flow rate of outside air	ft^3/min	
100,000	Conversion factor	Btu/therm	100,000
Eff_{HEAT}	Efficiency of gas fired unit		
HDH	Heating degree hours based on balance point and location	Hrs	
SF	Savings factor for AOS		4%[4]

Lifecycle Energy-Savings Algorithm

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

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

Where:

EUL = 4 years

Assumptions

Morning warmup with AOS savings is limited to heating season, October to April.

The savings factor for AOS is a very rough approximation, mentioned in a slideshow from March 2019.[4] If this measure sees moderate use, the savings factor should be reappraised or the measure should require building modeling or another more detailed approach.

Revision History

Version Number	Date	Description of Change
01	12/2021	Initial TRM entry

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[1] Based on Operational Efficiency Offering EUL of four years. Effective Useful Life for Retro-commissioning and Behavior Programs. September 17, 2019. Navigant.

[2] Billing rate is an average for commercial BAS programmer. Based on an estimated $140/hr labor rate and a duration of one hour.

[3] Pacific Northwest National Laboratory for the U.S. Department of Energy. *Implementation of Energy Code Controls Requirements in New Commercial Buildings*. March 2017. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-26348.pdf

[4] Pacific Northwest National Laboratory. *Basic HVAC Controls and Energy Codes?* Presented March 28, 2019. Slide 9, 5%estimate of AOS savings is provided. This estimate was lowered to 4% to be conservative, given the uncertainty of the estimate. https://www.energycodes.gov/sites/default/files/2019-09/HVAC_Controls_Webinar_Presentation_Slides.pdf

HVAC Static Fan Pressure Reset

	Measure Details
Measure Master ID	HVAC Fan Static Pressure Reset, Building Tune-up, 5366
Workpaper ID	W0278
Measure Unit	Per Air Handling Unit
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Schools & Government
Annual Electricity Savings (kWh)	Varies
Peak Demand Reduction (kW)	0
Annual Natural Gas Savings (therms)	0
Lifecycle Electricity Savings (kWh)	Varies
Lifecycle Natural Gas Savings (therms)	0
Annual Water Savings (gallons)	0
Effective Useful Life (years)	4[1]
Incremental Cost ($/unit)	$840[2]

Measure Description

Typical HVAC supply fans are controlled to a constant static pressure (SP) setpoint. This SP setpoint is chosen based on the duct SP required to adequately ventilate the space when airflow requirements are highest, and all terminal boxes are opened. As a result, the SP setpoint is usually higher than what is necessary during other times of lower demand. Supply fans must consume more power to meet the higher SP setpoint.

This measure is for controlling air handler unit (AHU) fans with an automatically adjustable SP setpoint. Duct SP will be allowed to range between a set minimum and maximum pressure, depending on the observed air demand. By reducing the duct SP most of the year, some work is saved on the supply fans, reducing electric use.

Description of Baseline Condition

The baseline condition is an AHU supply and/or return fan which operates at a constant SP setpoint. This setpoint is typically set for the worst-case, highest volume air demand, with all terminal boxes fully open, in order to supply adequate air. Fan energy use increases with higher duct SP, so a constant high SP setpoint causes increased electric use on the fan motor.

Description of Efficient Condition

The efficient condition is a rooftop unit (RTU) or AHU fan which operates at a variable SP setpoint. The controller will adjust the duct SP setpoint between a set minimum and maximum depending on zone air demands.

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = kWh_{\text{BASE}} - kWh_{\text{EE}}$$

$$kWh_{\text{BASE}} = \Sigma[OpHrs_{\text{BIN}} * kW_{\text{BASE}}]$$

$$kW_{\text{BASE}} = (HP_{\text{SF}} / \eta_{SF} * Speed_{\text{SF,BASE}}{}^{2.5} + HP_{\text{RF}} / \eta_{\text{RF}} * Speed_{\text{RF,BASE}}{}^{2.5}) * 0.746$$

$$OpHrs_{\text{BIN}} = Hrs_{\text{BIN}} * (OpHrs_{\text{ANNUAL}} / 8{,}760)$$

$$kWh_{\text{EE}} = \Sigma[OpHrs_{\text{BIN}} * kW_{\text{BASE}} * (DSP_{\text{EE}} / DSP_{\text{BASE}})]$$

Where:

Variable	Description	Units	Value
kWh_{BASE}	Electricity usage before fan pressure reset, summed across bins	kWh	
kWh_{EE}	Electricity usage after fan pressure reset, summed across bins	kWh	
kW_{BASE}	Total fan power at specified bin conditions	kW	
HP_{SF}	Supply fan motor HP	hp	User input
HP_{RF}	Return fan motor HP	hp	User input
η_{SF}	Supply fan motor efficiency		Based on NEMA premium motor efficiencies
η_{RF}	Return fan motor efficiency		Based on NEMA premium motor efficiencies
$Speed_{\text{SF,BASE}}$	Average supply fan speed at baseline		User input
$Speed_{\text{RF,BASE}}$	Average return fan speed at baseline		User input
0.746	Conversion factor	kW/hp	0.746
Hrs_{BIN}	Hours for each bin	Hrs	From TRM data, see Assumptions
$OpHrs_{\text{ANNUAL}}$	Annual hours over which SP reset occurs	Hrs/yr	User input
8,760	Conversion of years to hours	Hrs/yr	8,760
DSP_{BASE}	Baseline SP setpoint; inches of water column	In. WC	User input
DSP_{EE}	For temperature bins	°F	≥ 70°F, equals baseline SP setpoint (in. WC); < 50°F, proposed minimum SP setpoint (in. WC); ≥ 50°F and < 70°F; equals average of baseline and proposed minimum SP setpoints (in. WC)

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for this measure.

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = 4 years[1]

Assumptions

Savings calculator includes outdoor air temperature (OAT) bin data at several locations from the TRM. The closest city to the customer site should be used as an approximation of customer site weather.

Exponents for fan laws are chosen to be more conservative than ideal. The fan Affinity Law for power uses an exponent to the cubed power. Assumption is that fan speed is related to power with an exponent of 2.5, and that fan power is directly proportional to duct SP.

Motor efficiency for fan HP is based on NEMA Premium efficiencies for three phase electric 4-pole enclosed motors (1800 RPM) between 1 HP and 500 HP.[3]

Calculation assumes a default temperature profile to adjust the SP based on OAT. When the OAT is greater than 70°F, it is assumed that full ventilation is needed and that the SP setpoint will remain the same. When the OAT is between 50°F and 70°F, the ventilation demand on the AHU is less so the SP setpoint can be reduced to the average between the baseline set point and the minimum SP setpoint. When the OAT is less than 50°F, only the minimum SP setpoint is needed due to the lower demand for ventilation.

Revision History

Version Number	Date	Description of Change
01	05/2022	Initial TRM entry

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[1] Based on Operational Efficiency Offering EUL of four years. Effective Useful Life for Retro-commissioning and Behavior Programs. September 17, 2019. Navigant. https://ilsag.s3.amazonaws.com/ComEd-EUL-Comm-RCx-and-Behavior-Memo-2019-09-17.pdf

[2] Billing rate is an average for commercial BAS programmer. Based on an estimated $140/hr labor rate and a duration of six hours.

[3] National Electrical Manufacturers Association. NEMA MG 1-2018. Table 12-12. https://www.nema.org/docs/default-source/standards-document-library/mg-1-2018-parts-12-59-and-12-60-scope.pdf

Zonal Shutoff

	Measure Details
Measure Master ID	Zone-Based Scheduling, Building Tune-up, 5367
Workpaper ID	W0277
Measure Unit	Per Air Handling Unit
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Electricity Savings (kWh)	Varies
Peak Demand Reduction (kW)	Varies
Annual Natural Gas Savings (therms)	0
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Natural Gas Savings (therms)	0
Annual Water Savings (gallons)	0
Effective Useful Life (years)	4[1]
Incremental Cost ($/unit)	$70[2]

Measure Description

Typical air handling units or rooftop units (AHU/RTU) are set up to supply airflow to the space for comfort heating and cooling for all zones within the specific system. The supply airflow of the system is typically set based on the needed flow for all zones within the system to provide the ventilation whether the space is occupied or not. As a result, the airflow of the AHU/RTU may be set higher than what is needed based on occupancy which would cause the unit fans and re-heat boxes to consume more energy.

This measure is for programming an AHU/RTU to reduce the airflow to zones that may not be occupied. Zone-based scheduling can reduce the average air delivery requirements for the AHU/RTU which would result in fan, cooling and heating energy savings during the scheduled periods on the unit.

Description of Baseline Condition

The baseline condition is the average supply airflow for the AHU/RTU unit. An AHU/RTU system can consist of numerous zones that each contain variable air volume (VAV) boxes to provide ventilation to the space. The AHU/RTU would provide the average supply airflow to all the zones whether they are occupied or not. Fan use, heating and cooling remains relatively constant due to the VAV boxes for each zone still maintaining space set point settings.

Description of Efficient Condition

The efficient condition is scheduling the zones within an AHU/RTU to the minimum flow setting on the VAV box or even shut off the flow to a zone when unoccupied. This is a programming change to the schedule that would reduce the average supply airflow of the AHU/RTU and reduce the fan energy, cooling and heating usage of the unit.

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = kWh_{\text{SAVED,FAN}} + kWh_{\text{SAVED,COOL}} + kWh_{\text{SAVED,REHEAT}}$$

$$kWh_{\text{SAVED,FAN}} = \Sigma_{\text{TEMP}}[(kW_{\text{FAN,BASE}} - kW_{\text{FAN,EE}}) * Hrs_{\text{RED}}]$$

$$kW_{\text{FAN,BASE}} = (hp_{\text{SF}} * \%Sp_{\text{SF}}^{2.5} / Eff_{\text{SF}} + hp_{\text{RF}} * \%Sp_{\text{RF}}^{2.5} / Eff_{\text{RF}}) * 0.746$$

$$kW_{\text{FAN,EE}} = kW_{\text{FAN,BASE}} * (CFM_{\text{EE}} / CFM_{\text{BASE}})^{2.5}$$

$$Hrs_{\text{RED}} = Hrs_{\text{OAT}} * 52.14 * (Wkdys * Hrs_{\text{RED,WKDY}} + Wknd * Hrs_{\text{RED,WKND}}) / 8{,}760$$

$$kWh_{\text{SAVED,COOL}} = \Sigma_{\text{TEMP}}[kW_{\text{SAVED,COOL}} * Hrs_{\text{RED}}]$$

$$kW_{\text{SAVED,COOL}} = (CFM_{\text{BASE}} - CFM_{\text{EE}}) * [1.08 * (MAT - SAT) + 0.68 * \%OA_{\text{MIN}} * (h_{\text{OA}} - h_{\text{D}})] * Eff_{\text{CLG}} / 12{,}000$$

$$MAT = OAT * \%OA + RAT * (1 - \%OA)$$

If electric reheat:

$$kWh_{\text{SAVED,REHEAT}} = \Sigma_{\text{TEMP}}[\%Reheat * 1.08 * (CFM_{\text{BASE}} - CFM_{\text{EE}}) * (RHT - SAT) / (3{,}412 * Eff_{\text{RH,ELEC}}) * Hrs_{\text{RED}}]$$

$$Therms_{\text{SAVED}} = Therms_{\text{SAVED,HEAT}} + Therms_{\text{SAVED,REHEAT}}$$

$$Therms_{\text{SAVED,HEAT}} = \Sigma_{\text{TEMP}}[(CFM_{\text{BASE}} - CFM_{\text{EE}}) * (1.08 * (MAT - SAT)) / (100{,}000 * Eff_{\text{HEAT}}) * Hrs_{\text{RED,HEAT}}]$$

If gas reheat:

$$Therms_{\text{SAVED,REHEAT}} = \Sigma_{\text{TEMP}}[\%Reheat * 1.08 * (CFM_{\text{BASE}} - CFM_{\text{EE}}) * (RHT - SAT) / (100{,}000 * Eff_{\text{HEAT}}) * Hrs_{\text{RED}}]$$

Where:

Variable	Description	Units	Value
$kWh_{\text{SAVED,FAN}}$	Electricity saved due to reduced fan usage	kWh	
$kWh_{\text{SAVED,COOL}}$	Electricity saved due to cooling reduction	kWh	
$kWh_{\text{SAVED,REHEAT}}$	Electricity saved due to reduced electric reheat usage	kWh	
Σ_{TEMP}	Summary of hours reduced across outdoor air temperature bins	Hrs	
$kW_{\text{FAN,BASE}}$	Baseline combined kW of supply and return air fans	kW	
$kW_{\text{FAN,EE}}$	Efficient combined kW of supply and return air fans	kW	
Hrs_{RED}	Hours reduced within an individual outdoor air temperature bin	Hrs	

Variable	Description	Units	Value
Hrs_{OAT}	Hours within individual outdoor air temperature bin	Hrs	Varies by location
52.14	Weeks per year	Wks/yr	52.14
Wkdys	Weekdays per week that scheduling will occur	Weekdays/wk	
$Hrs_{RED,WKDY}$	Hours per weekday that scheduling will occur	Hrs/weekday	
Wknd	Weekend days per week that scheduling will occur	Weekend days	
$Hrs_{RED,WKND}$	Hours per weekend day that scheduling will occur	Hrs/weekend day	
8,760	Hours per year	Hrs/yr	8,760
hp_{SF}	Horsepower of supply fan	hp	User input
$\%Sp_{SF}^{2.5}$	Percent speed of supply fan, with 2.5 fan affinity exponent	%	User input
hp_{RF}	Horsepower of return fan	hp	User input
$\%Sp_{RF}^{2.5}$	Percent speed of return fan, with 2.5 fan affinity exponent	%	User input
0.746	Conversion factor	kW/hp	0.746
Eff_{SF}	Efficiency of supply air fans		NEMA Premium Efficiency based on motor HP
Eff_{RF}	Efficiency of return air fans		NEMA Premium Efficiency based on motor HP
CFM_{BASE}	AHU average supply CFM before scheduling	cfm	User input
CFM_{EE}	AHU average supply CFM after scheduling	cfm	User input
1.08	Sensible heat constant	Btu/hr-CFM-°F	1.08
MAT	Mixed air temperature	°F	
OAT	Outside air temperature	°F	Varies by outdoor air temperature bin
0.68	Latent heat constant	Btu- lb/hr-CFM-gr	60 min/hr * 0.075 lb_{air}/ft^3 * 1,060 Btu/lb / 7,000 grains/lb = 0.68 Where 1,060 Btu/lb equals the heat of vaporization of water and 7,000 grains/lb is a mass conversion
$\%OA_{MIN}$	Minimum percent outside air intake	%	User input
h_{OA}	Outside air humidity, grains/lb	Grains/lb	Varies by location and outdoor air temperature bin
h_D	Discharge humidity	Grains/lb	64
Eff_{CLG}	AHU cooling efficiency	kW/ton	User input
12,000	Conversion factor	Btu/ton	12,000
3,412	Conversion factor	Btu/kWh	3,412
%OA	Percent outdoor air	%	Minimum user-specified if OAT > user-specified economizer-enable temperature, 100% if OAT > SAT, (SAT - RAT)/(OAT – RAT) otherwise
RAT	Return air temperature	°F	
SAT	Supply air temperature	°F	
RHT	Reheat air temperature	°F	

Variable	Description	Units	Value
$Eff_{RH,ELEC}$	Electric reheat efficiency	%	100%
$Therms_{SAVED,HEAT}$	Therms saved due to heating reduction	Therms	
$Therms_{SAVED,REHEAT}$	Therms saved due to reduced reheat	Therms	
$Hrs_{RED,HEAT}$	Hours within an individual outdoor air temperature bin, with SAT > MAT	Hrs	
%Reheat	Percent of boxes reheating	%	User input
$Eff_{HEAT,GAS}$	Heating system efficiency	%	86%
100,000	Conversion factor	Btus/therms	100,000

Summer Coincident Peak Savings Algorithm

$$kW_{SAVED} = (kW_{BASE,FAN,PEAK} + kW_{BASE,CLG,PEAK}) - (kW_{EE,FAN,PEAK} + kW_{EE,CLG,PEAK})$$

Where:

Variable	Description	Units	Value
$kW_{BASE,FAN,PEAK}$	Average fan demand when OAT ≥ 75°F in baseline scenario, weighted by hours	°F	
$kW_{BASE,CLG,PEAK}$	Average cooling system demand when OAT ≥ 75°F in baseline scenario, weighted by hours	°F	
$kW_{EE,FAN,PEAK}$	Average fan demand when OAT ≥ 75°F in proposed scenario, weighted by hours	°F	
$kW_{EE,CLG,PEAK}$	Average cooling system demand when OAT ≥ 75°F in proposed scenario, weighted by hours	°F	

Lifecycle Energy-Savings Algorithm

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

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

Where:

EUL = 4 years[1]

Assumptions

Savings calculator includes OAT bin data at several locations from the TRM. The closest city to the customer site should be used as an approximation of customer site weather.

Exponents for fan laws are chosen to be more conservative than ideal. The fan Affinity Law for power uses an exponent to the cubed power. Assumption is that fan speed is related to power with an exponent of 2.5, and that fan power is directly proportional fan speed.

Motor efficiency for fan HP is based on NEMA Premium efficiencies for three phase electric 4-pole enclosed motors (1800 RPM) between 1 HP and 500 HP.[3]

The Supply Air Temperature (SAT), Return Air Temperature (RAT), and Reheat Temperature (RHT) can be user inputs if the values are known. If values aren't easily known, the defaults for these are as follows: SAT = 57°F, RAT =72°F, and RHT = 80°F based on typical HVAC settings for commercial type spaces.

Discharge humidity defaults to 64 grains/lb. This is based on meeting an average space set point of 70°F with 60% RH. A psychrometric chart can be used to determine the exact grains/lb if specific site information is known.

Cooling system efficiency in kW/ton would be site specific to units onsite. The default value used for the calculation 1.15 for air cooled RTUs based on information in the Focus on Energy TRM and potential study.

The economizer enable set point is based on the SAT of the unit. If the default SAT is 57°F, then the economizer set point is set very close so that the unit can utilize outside air in the economizer mode to limit the amount of mechanical cooling.

Revision History

Version Number	Date	Description of Change
01	05/2022	Initial TRM entry

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[1] Based on Operational Efficiency Offering EUL of four years. Effective Useful Life for Retro-commissioning and Behavior Programs. September 17, 2019. Navigant. https://ilsag.s3.amazonaws.com/ComEd-EUL-Comm-RCx-and-Behavior-Memo-2019-09-17.pdf

[2] RSMeans constructions cost estimating software and Cadmus judgment. Based on an estimated $140/hr labor rate and a duration of one half hour.

[3] National Electrical Manufacturers Association. NEMA MG 1-2018. Table 12-12. https://www.nema.org/docs/default-source/standards-document-library/mg-1-2018-parts-12-59-and-12-60-scope.pdf

Parking Garage Ventilation Controls

	Measure Details
Measure Master ID	Parking Garage Ventilation Controls, 4837 Parking Garage Ventilation Controls with Heating, 3493
Workpaper ID	W0047
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)	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)	10[1]
Incremental Cost ($/unit)	$827.88[2]

Measure Description

The proposed measure requires controlling ventilation airflow in enclosed parking garages based on carbon monoxide (CO) concentrations, while maintaining code required run hours. 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 CO sensor(s) with a minimum five hours of daily operation.[3]

Annual Energy-Savings Algorithm

$$kWh_{SAVED} = kWh_{BASE} - kWh_{EE}$$

$$kWh_{BASE} = hp_{FAN} * 0.746 * HOU_{BASE} * 365$$

$$kWh_{EE} = hp_{FAN} * 0.746 * HOU_{EE} * 365$$

$$Therm_{SAVED} = Therm_{BASE} - Therm_{EE}$$

$$Therm_{BASE} = CFM * 1.08 * (T_{IN} - T_{OUT}) * HOU_{BASE} * \frac{D_{HEAT}}{(100{,}000 * Eff)}$$

$$Therm_{EE} = CFM * 1.08 * (T_{IN} - T_{OUT}) * HOU_{EE} * \frac{D_{HEAT}}{(100{,}000 * Eff)}$$

Where:

Variable	Description	Units	Value
hp_{FAN}	Total horsepower of garage ventilation fan motor(s)	hp	User input
0.746	Conversion factor	kW/hp	0.746
365	Conversion factor	day/year	365
HOU_{BASE}	Daily run hours for base case	hours	24
HOU_{EE}	Average daily exhaust fan run hours with carbon monoxide control system	hours	7
CFM	Airflow of air handling unit in cubic feet per minute	ft^3/min	User input
1.08	Sensible heat constant	Btu/hr-CFM-°F	1.08
T_{IN}	Makeup air setpoint temperature	°F	50°F
T_{OUT}	Average outdoor heating temperature	°F	25.3°F; see Assumptions
D_{HEAT}	Average days per year requiring heat	day/year	145.9; see Assumptions
100,000	Conversion factor	Btu/therm	100,000
Eff	Heating efficiency	%	80%
8,760	Conversion factor	hours/year	8,760
CF	Coincidence factor	none	0.68 for Residential-multifamily 0.23 for all other sectors[4]

Summer Coincident Peak Savings Algorithm

$$kW_{SAVED} = kWh_{SAVED} / 8{,}760 * CF$$

Lifecycle Energy-Savings Algorithm

$$kWh_{LIFECYCLE} = (kWh_{BASE} - kWh_{EE}) * EUL$$

$$Therm_{LIFECYCLE} = (Therm_{BASE} - Therm_{EE}) * EUL$$

Where:

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

Assumptions

General space heating needs for a heated garage are assumed to be met by dedicated 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 for the nearest city.[5] Similarly, D_{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 CO control system was set to seven hours to account for the five-hour minimum plus additional CO sensing run time based on engineering judgment.

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	D_{HEAT} (days/yr)	T_{OUT}	Weighting by Participant[6]
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 °F**	

The coincidence factors estimated for this measure are based on parking garage car movement profiles by ASHRAE. Multifamily garages were assumed to be represented best by Profile 3, which was dominated by morning and afternoon traffic (i.e., residents leaving for and returning from work). Profile 2 was assumed for commercial garages, which are likely to have more traffic throughout the day (e.g., shopping districts, hospitals, universities).[4]

Revision History

Version Number	Date	Description of Change
01	12/2012	Initial TRM Entry
02	10/2018	Added MMID 3493 for heated garages, updated algorithm
03	9/2023	Added back to the TRM, updated EUL and CFs

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[1] "During conversations with vendors and Building Automation System (BAS) contractors, it was determined that sensors must be functional for up to 10 years. It is recommended that they are part of a normal preventive maintenance program in which calibration is an important part of extending useful life. Although they are not subject to mechanical failure, they do fall out of tolerance over time " *4.4.19 Demand Controlled Ventilation.* 2023 Illinois Statewide Technical Reference Manual for Energy Efficiency Version 11.0, Volume 2: Commercial and Industrial Measures. https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010123_v11.0_Vol_2_C_and_I_092222_FINAL.pdf.
Also, consistent with WI TRM's EUL for other DCV measures.

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 16 units over 3 projects, from 2013 to 2014.

[3] "The system shall be arranged to operate intermittently for a total of at least 5 hours in each 24-hour period…" Wisconsin Legislature SPS 364.0404(1)(b).
https://docs.legis.wisconsin.gov/code/admin_code/sps/safety_and_buildings_and_environment/361_366/364/ii/0404/1/b

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[4] These coincidence factors are derived in the hybrid calculation for this measure. They are based on an analysis of the peak period hours from ASHRAE's parking garage car movement profiles. Profile 3 is assumed for Multifamily applications and Profile 2 is used for all other non-residential applications. *Figure 16 Three Car Movement Profiles*, page 16.21. 2019 ASHRAE Handbook – HVAC Applications.

[5] National Renewable Energy Laboratory. "National Solar Radiation Data Base, 1991-2005 Update: Typical Meteorological Year 3." https://sam.nrel.gov/weather-data

[6] Cadmus. Focus on Evaluated Energy Deemed Savings Changes. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

INFORMATION TECHNOLOGY

Efficient UPS and Efficient Rectifier

	Measure Details
Measure Master ID	Efficient UPS, 4777 Efficient Rectifier, 4778
Workpaper ID	W0082
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[2]

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

$$KWh_{\text{SAVED}} = kWh_{\text{BASE}} - kWh_{\text{EE}}$$

$$kWh_{\text{BASE}} = Load * HOU_{\text{EQUIP}} / Eff_{\text{BASE}} + Load * (1 - Eff_{\text{BASE}}) * HOU_{\text{COOL}} * kW/ton_{\text{COOL}} * 3.413 / 12$$

$$kWh_{\text{EE}} = Load * HOU_{\text{EQUIP}} / Eff_{\text{EE}} + Load * (1 - Eff_{\text{EE}}) * HOU_{\text{COOL}} * kW/ton_{\text{COOL}} * 3.413 / 12$$

Where:

Variable	Description	Units	Value
Load	Average IT load in kilowatts	kW	User input; see Assumptions
HOU_{EQUIP}	Hours of operation per year for UPS or rectifier	Hrs/yr	8,760
Eff_{BASE}	Efficiency of existing UPS, fraction		User input
HOU_{COOL}	Hours of operation per year for cooling system	Hrs/yr	Varies; see Assumptions
kW/ton_{COOL}	Efficiency of cooling system	kW/ton	User input; see Assumptions
3.413 / 12	Factor to convert kilowatts of heat to tons of cooling	kW heat/tons cooling	3.413 / 12
Eff_{EE}	Efficiency of new UPS or rectifier, fraction		User input

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = kW_{\text{BASE}} - kW_{\text{EE}}$$

$$kW_{\text{BASE}} = Load * CF_{\text{EQ}} / Eff_{\text{BASE}} + Load * CF_{\text{COOL}} * (1 - Eff_{\text{BASE}}) * kW/ton_{\text{COOL}} * 3{,}413 / 12{,}000$$

$$kW_{\text{EE}} = Load * CF_{\text{EQ}} / Eff_{\text{EE}} + Load * CF_{\text{COOL}} * (1 - Eff_{\text{EE}}) * kW/ton_{\text{COOL}} * 3{,}413 / 12{,}000$$

Where:

CF_{EQ} = Coincidence factor for UPS or rectifier (1.0)

CF_{COOL} = Coincidence factor for cooling system (0.82)

Lifecycle Energy-Savings Algorithm

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

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.

Revision History

Version Number	Date	Description of Change
01	12/2018	Initial TRM entry

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[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

LAUNDRY

Modulating Commercial Dryer Controls

	Measure Details
Measure Master ID	Modulating Commercial Dryer Controls: Small Capacity Low Use, 4902 Small Capacity High Use, 4903 Large Capacity Low Use, 4904 Large Capacity High Use, 4905
Workpaper ID	W0251
Measure Unit	Per dryer
Measure Type	Hybrid
Measure Group	Laundry
Measure Category	Dryer
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
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	10;[1] see Assumptions
Incremental Cost ($/unit)	$900.00[2]

Measure Description

This measure is a retrofit electronic control unit that adds intelligence to non-modulating commercial natural gas clothes dryers to improve their energy efficiency. It employs a regulated natural gas stepping technology based on sensor readings and a proprietary algorithm to reduce natural gas consumption through several processes:

- Replaces standard natural gas valves with a two-stage valve, allowing the natural gas to be modulated
- When the dryer turns on, modulates the natural gas between high (100%) and low (50%) based on dryer exhaust temperatures
- Once the sensor detects the optimal flue gas temperature, the natural gas valve locks into low or savings mode
- If the sensor detects a sudden decrease of flue temperature, it automatically re-engages high fire

Installing the technology is straightforward and does not make modifications to the dryer workings other than the natural gas supply. The Focus on Energy Emerging Technology program evaluated this technology in 2014.

Description of Baseline Condition

The baseline condition is an existing natural gas commercial clothes dryer without a modulating natural gas valve. The dryer must be rated between a 30 pound to 250 pound capacity with a minimum of 500 drying cycles per year.

Description of Efficient Condition

The efficient condition is an existing natural gas commercial clothes dryer with a retrofit kit to provide a modulating natural gas valve with at least two firing rates.

Annual Energy-Savings Algorithm

$$Gas_{\text{SAVED}} = CAP * BurnerOn\% * (DryingTime / 60 * LoadsPerDay * DaysPerYear) * SF / 100{,}000$$

Where:

Variable	Description	Units	Value
CAP	Burner capacity	Btu/hr	User input
BurnerOn%	Percentage of drying cycle when burner is on	%	70.6%; see Assumptions[3]
DryingTime	Drying time per load in minutes	Minutes/load	User input; if unknown, use 30 minutes
60	Conversion factor	Min/hr	60
LoadsPerDay	Average loads per day of clothes dried	Loads/day	User input; if unknown, see Assumptions
DaysPerYear	Days per year the dryer is used	Days/yr	user input; assume 365 if not specified
SF	Savings fraction	%	10%[2]
100,000	Conversion factor	Btu/therm	100,000

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

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

Where:

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

Assumptions

- The incremental cost for this measure is listed as \$800.00 to \$1,000.00[2] (for material and installation), so the midpoint of this range was used (\$900.00).
- The effective useful life for the natural gas valve retrofit kit is assumed to reflect the remaining useful life of a commercial natural gas dryer, which is 14 years. The remaining useful life at time of install of a modulating dryer control is assumed to be 10 years.

- The Emerging Technologies transition report[2] lists 10.3% savings for a specific project evaluated and recommended using 10% savings going forward. The more conservative 10% savings value was used.
- The Emerging Technologies M&V report[3] indicates in the “Energy Savings and Economics” section that the tested dryer has a burner capacity of 395 MBh, typically runs for 40 minutes, and has a baseline energy use of 1.86 therms per load. Therefore, the BurnerOn% value was calculated as follows:

  BurnerOn% = 1.86 therms / [(395 MBh / 100 MBtu per therm) * (40 min / 60 min per hour)] = 70.6%
- The calculation process is the same for all four measures. The separate measures were established so a separate incentive could be set for each measure and maintain a more uniform incentive per lifecycle MMBtu across the range of dryer sizes and loads of clothes dried per year. From the dryer capacity versus burner size research,[4] typical dryer capacities are 30, 35, 50, 75, 120, 170, and 200 pounds. A 250 pound dryer (maximum size allowed under the offer) was also included. A capacity of 100 pounds was used to divide small and large capacity, putting four typical sizes in each category.
- The Emerging Technologies M&V report[3] listed the usage of the studied hotel laundry at around 9,500 loads per year (and noted this was higher than typical usage), so the incentive per MMBtu was tested for a range of 500 to 10,000 loads per year. A dividing line of 2,500 loads per year or less was set as low usage, with high usage being set as more than 2,500 loads per yearyear.
- In the event that a customer is not able to supply dryer cycles per year data, the values from the Illinois TRM[5] will be used, as shown in the following table.

Dryer Cycles Per Year Based on Facility Type

Facility Type	Cycles per Year	Cycles per Day
Coin-Operated Laundromats	1,483	4.063
Multifamily Dryers	1,074	2.942
On-Premise Laundromats	3,607	9.882

- Cycles per day assume 365 days per year of operation.
- In the event that only the pound capacity of the dryer or only the burner Btu per hour is available, the other value will be determined by using 2,340 Btu per pound capacity, which was calculated as a weighted average of specifications from three commercial dryer manufacturers, excluding the highest and lowest Btu per hour from each manufacturer (shown in the following table).

Typical Dryer Performance Data[5]

Manufacturer	Pound Capacity	Burner Btu/hr	Burner Btu/Lb Capacity	Exclude?
UniMac	25	64,000	2,560	No
	30	73,000	2,433	No
	35	90,000	2,571	No
	50	130,000	2,600	No

Manufacturer	Pound Capacity	Burner Btu/hr	Burner Btu/Lb Capacity	Exclude?
	55	112,000	2,036	Yes
	75	165,000	2,200	No
	75	225,000	3,000	Yes
	120	270,000	2,250	No
	170	395,000	2,324	No
	200	425,000	2,125	No
Maytag	35	64,000	1,829	No
	50	110,000	2,200	No
	75	130,000	1,733	Yes
	50	150,000	3,000	No
	75	175,000	2,333	No
	75	175,000	2,333	No
	120	375,000	3,125	No
	170	550,000	3,235	Yes
Speed Queen	25	64,000	2,560	No
	30	73,000	2,433	No
	35	90,000	2,571	No
	50	130,000	2,600	Yes
	55	112,000	2,036	Yes
	75	165,000	2,200	No
	120	270,000	2,250	No
	170	395,000	2,324	No
	200	425,000	2,125	No
	30	73,000	2,433	No
	45	95,000	2,111	No
Weighted Average (with exclusions)			**2,340**	--

Revision History

Version Number	Date	Description of Change
01	08/2019	Initial TRM entry

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[1] Zhang, Yanda, and Julianna Wei. *Commercial Clothes Dryers, Codes and Standards Enhancement (CASE) Initiative for PY13: Title 20 Standards Development.* California Public Utilities Commission. July 2013. https://efiling.energy.ca.gov/GetDocument.aspx?tn=71757 https://efiling.energy.ca.gov/GetDocument.aspx?tn=74287&DocumentContentId=8161

[2] Clean Tech Partners on behalf of Focus on Energy. *Emerging Technologies Program, Transition of Emerging Technology to Best Practice – Commercial Dryer Modulation Retrofit*. June 2019.

[3] Clean Tech Partners on behalf of Focus on Energy. *Emerging Technologies Program, BiO-Therm Measurement and Verification Study.* 2014.

[4] Typical dryer performance data compiled from manufacturer websites accessed on July 1 and July 2, 2019:
http://unimac.com/Products/heavy-duty-tumble-dryers
https://www.maytagcommerciallaundry.com/mclstorefront/Dryers/Multi-Load-Dryers/c/DryersMulti-LoadDryers
https://speedqueencommercial.com/en-us/products/single-pocket-tumble-dryers

[5] Illinois Stakeholder Advisory Group. 2019 *Illinois Statewide Technical Reference Manual for Energy Efficiency Version 7.0*. Volume 2: Commercial and Industrial Measures. Page 566. https://s3.amazonaws.com/ilsag/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf

LIGHTING

Daylighting Control

	Measure Details
Measure Master ID	Daylighting Control, 3406
Workpaper ID	W0084
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)	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)	$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

$$kWh_{\text{SAVED}} = Watts \;/\; 1{,}000 \, * \, HOU \, * \, SF$$

Where:

Variable	Description	Units	Value
Watts	Controlled lighting wattage	Watts	User input
SF	Savings factor for daylighting controls		28%[3]
1,000	Conversion factor	W/kW	1,000
HOU	Average annual run hours	Hrs/yr	Varies by sector; see table below

Average Annual Run Hours by Sector

Sector	HOU[4,5]
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239
Multifamily	5,950

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = Watts\ /\ 1{,}000\ *\ CF\ *\ SF$$

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

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

Where:

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

Deemed Savings

Savings

Sector	Annual kWh	kW	Lifecycle kWh
Commercial	1.04	0.0002	8.32
Industrial	1.33	0.0002	10.64
Agriculture	1.32	0.0002	10.56
Schools & Government	0.91	0.0002	7.28
Multifamily	1.67	0.0002	13.36

Revision History

Version Number	Date	Description of Change
01	04/2014	Initial TRM entry
02	12/2020	Updated savings factor

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[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 for MMID 3406, 21 applications.

[3] PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3-2 Lighting Hours of Use in Commercial Applications. 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] Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

[6] Lawrence Berkeley National Laboratory. *A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings*. September 2011. https://eta.lbl.gov/sites/default/files/publications/a_meta-analysis_of_energy_savings_from_lighting_controls_in_commercial_buildings_lbnl-5095e.pdf

Bi-Level Controls, High Bay Fixtures

	Measure Details
Measure Master ID	Bi-Level Controls, High Bay Fixtures, General, 5062
Workpaper ID	W0085
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; 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)	$0.43[2]

Measure Description

This measure is bi-level controls for high bay fixtures. Numerous new and existing installations use LED, 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, fluorescent, ceramic metal halide, 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 high-low 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

The energy savings shown below were initially determined for each space type and sector. Using several years of historical data,[5] the weighted average, based on program implementation across space and sector types, was used to calculate a single savings value for each sector.

$$kWh_{\text{SAVED}} = Watts * HOU / 1{,}000 * SF_{\text{OCC}} * SF_{\text{DIM}}$$

Where:

Variable	Description	Units	Value
Watts	Lighting wattage controlled, deemed	Watts	User input
HOU	Baseline hours per year	Hrs/yr	Varies by sector; see table below
1,000	Conversion factor	W/kW	1,000
SF_{OCC}	Occupancy savings factor, percentage of hours in unoccupied mode	% hrs	Varies by building type; see Assumptions
SF_{DIM}	Dimming savings factor, percentage of hours dimmed in unoccupied mode	% hrs	50%, see Assumptions

Hours of Use by Sector

Sector	HOU[3]
Commercial	3,730
Schools & Government	3,239
Industrial	4,745
Agriculture	4,698
Multifamily	5,950

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = Watts\ /\ 1{,}000\ *\ CF$$

Where:

CF = Coincidence factor (varies by space type; see table below)

Coincidence Factors by Space Type

Space Type	CF[3]
Gymnasiums	15%
Industrial	18%
Retail	6%
Warehouses	18%
Public Assembly	12%
Other	14%

Lifecycle Energy-Savings Algorithm

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

Where:

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

Deemed Savings

The two tables below show deemed savings by sector.

Deemed Savings for Agriculture, Commercial, and Industrial Sectors

Space Type	kW	Agriculture		Commercial		Industrial	
		Weight[4]	Ann kWh	Weight[4]	Ann kWh	Weight[4]	Ann kWh
Gymnasium	0.0002	0.167	0.92	0.155	0.73	0.000	0.93
Industrial	0.0002	0.167	1.06	0.062	0.84	0.551	1.07
Retail	0.0001	0.167	0.23	0.541	0.19	0.000	0.24
Warehouse	0.0002	0.167	0.73	0.046	0.58	0.449	0.74
Public Assembly	0.0001	0.167	0.97	0.000	0.77	0.000	0.98
Other	0.0001	0.167	0.94	0.196	0.75	0.000	0.95
Annual Savings (kWh)		**0.81**		**0.44**		**0.92**	
Annual Savings (kW)		**0.0001**		**0.0001**		**0.0002**	
Lifecycle Savings (kWh)		**6.48**		**3.52**		**7.36**	

Deemed Savings for Schools and Government and Multifamily Sectors

Space Type	kW	Schools & Government		Multifamily	
		Weight[4]	Ann kWh	Weight[4]	Ann kWh
Gymnasium	0.0002	0.839	0.63	0.333	1.16
Industrial	0.0002	0.020	0.73	0.000	1.34
Retail	0.0001	0.000	0.16	0.000	0.30
Warehouse	0.0002	0.000	0.50	0.000	0.92
Public Assembly	0.0001	0.000	0.70	0.333	1.29
Other	0.0001	0.141	0.65	0.333	1.19
Annual Savings (kWh)		**0.64**		**1.21**	
Annual Savings (kW)		**0.0001**		**0.0001**	
Lifecycle Savings (kWh)		**5.12**		**9.68**	

Assumptions

Two references show the occupancy savings factor by space type,[3,5] shown in the table below.

Occupancy Savings Factor by Space Type

Space Type	SF_{OCC}	Occupancy Savings Factor Source and Note
Gymnasiums	39%	Source 3
Industrial	45%	Source 3
Retail	10%	Average of source 3 (15%) and Table 3 in source 4 (5%)
Warehouses	31%	Table 4 in source 4 (source 3 not used because one if its three sources for warehouses is already in source 4 and the other two were not available for review)
Public Assembly	42%	Average of source 3 (47%) and Table 7 in source 4 (36%)
Other	40%	Source 3

These values were combined with usage of historical measures associated with these space types to produce savings for each sector. This data is from 28 projects from May 2014 through October 2016.[4] The weighting values are provided in the Deemed Savings tables above.

Bi-level controls are able to and must achieve at least a 50% reduction in power requirements. This value was used for the dimming savings factor.

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
05	10/2020	Change from per fixture to per watt controlled, updated savings fractions

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[1] PA Consulting Group. *Focus on Energy, 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. Data for MMID 3979, the previous per-fixture version of this measure. From January to November 2020 there were 18 applicatons and 22 measures, with an average watts controlled per fixture of 135.9 and cost per fixture of $57.90, for an average of $0.43 per watt controlled.

[3] PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. Table 4-205 for occupancy savings factor nd Table 4-206 for coincidence factor. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

[4] Lawrence Berkeley National Laboratory. *A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings*. September 2011. https://eta.lbl.gov/sites/default/files/publications/a_meta-analysis_of_energy_savings_from_lighting_controls_in_commercial_buildings_lbnl-5095e.pdf

[5] Bi Level Controls for High Bay Supplemental Data.”
Adjustment Calcs Tab showing historical data from 28 projects from May 2014 through October 2016 used to weight savings for the sensor measures.

Occupancy Sensors for High Bay Fixtures

	Measure Details
Measure Master ID	Occupancy Sensor, On/Off, High Bay, General, 5061
Workpaper ID	W0086
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)	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)	$0.36[2]

Measure Description

This measure is occupancy sensors for high bay fixtures. Numerous new and existing installations use LED, 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, 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

The kWh savings shown below were initially determined for each space type and sector. Using several years of historical data,[5] 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.

$$kWh_{\text{SAVED}} = Watts \ast HOU \;/\; 1{,}000 \ast SFOCC$$

Where:

Variable	Description	Units	Value
Watts	Lighting wattage controlled, deemed	Watts	User input
HOU	Baseline hours per year	Hrs/yr	Varies by sector; see table below
1,000	Conversion factor	W/kW	1,000
SF_{OCC}	Occupancy savings factor, percentage of hours in unoccupied mode	% hrs	Varies by building type; see Assumptions

Hours of Use by Sector

Sector	HOU[3]
Commercial	3,730
Schools & Government	3,239
Industrial	4,745
Agriculture	4,698
Multifamily	5,950

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = Watts \ / \ 1{,}000 * CF$$

Where:

CF = Coincidence factor (varies by space type; see table below)

Coincidence Factors by Space Type

Space Type	CF[3]
Gymnasiums	15%
Industrial	18%
Retail	6%
Warehouses	18%
Public Assembly	12%
Other	14%

Lifecycle Energy-Savings Algorithm

$$kWh_{\text{LIFECYCLE}} = kWh = * \ EUL$$

Where:

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

Deemed Savings

Deemed Savings for Agriculture, Commercial, and Industrial Sectors

Space Type	kW	Agriculture		Commercial		Industrial	
		Weight[4]	Ann kWh	Weight[4]	Ann kWh	Weight[4]	Ann kWh
Gymnasium	0.0002	0.000	1.83	0.006	1.45	0.000	1.85
Industrial	0.0002	0.438	2.11	0.191	1.68	0.780	2.14
Retail	0.0001	0.000	0.47	0.064	0.37	0.000	0.47
Warehouse	0.0002	0.076	1.46	0.589	1.16	0.209	1.47
Public Assembly	0.0001	0.000	1.95	0.000	1.55	0.000	1.97
Other	0.0001	0.486	1.88	0.150	1.49	0.011	1.90
Annual Savings (kWh)		**1.95**		**1.26**		**1.99**	
Annual Savings (kW)		**0.0002**		**0.0002**		**0.0002**	
Lifecycle Savings (kWh)		**15.60**		**10.08**		**15.92**	

Deemed Savings for Schools and Government and Multifamily Sectors

Space Type	kW	Schools & Government		Multifamily	
		Weight[4]	Ann kWh	Weight[4]	Ann kWh
Gymnasium	0.0002	0.420	1.26	0.333	2.32
Industrial	0.0002	0.036	1.46	0.000	2.68
Retail	0.0001	0.000	0.32	0.000	0.60
Warehouse	0.0002	0.163	1.00	0.000	1.84
Public Assembly	0.0001	0.031	1.34	0.333	2.47
Other	0.0001	0.351	1.30	0.333	2.38
Annual Savings (kWh)		**1.24**		**2.39**	
Annual Savings (kW)		**0.0002**		**0.0001**	
Lifecycle Savings (kWh)		**9.92**		**19.12**	

Assumptions

Two references show SF_{OCC} by space type, as seen in the table below.

SF_{OCC} Values by Space Type

Space Type	SF_{OCC}	SF_{OCC} Source and Note
Gymnasiums	39%	Source 3
Industrial	45%	Source 3
Retail	10%	Average of source 3 (15%) and Table 3[5] (5%)
Warehouses	31%	Table 4 in source 4. Source 3 not used because one if its three sources for warehouses is already, and the other two were not available for review in source 5
Public Assembly	42%	Average of source 3 (47%) and Table 7 in source 5 (36%)
Other	40%	Source 3

These values are combined with usage of historical measures associated with these space types to produce savings for each sector. These data are from 28 projects from May 2014 through October 2016.[4] The weighted values are provided in the tables above.

Revision History

Version Number	Date	Description of Change
01	10/2013	Updated deemed savings and all fixture options and wattages
02	11/2016	Used historical data to simplify deemed savings into one measure and updated EUL
03	10/2020	Change from per fixture to per watt controlled and update savings fractions

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[1] PA Consulting Group. *Focus on Energy, 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] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Data for MMID 3978, the previous per-fixture version of this measure. From January to November 2020 there were 72 applications and 5,895 units, with an average watts controlled per fixture of 143.7 and cost per fixure of $51.98, for an average of $0.36 per watt controlled.

[3] PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Section 4.9.17, p. 4-234. 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] Lawrence Berkeley National Laboratory. A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings. September 2011. https://eta.lbl.gov/sites/default/files/publications/a_meta-analysis_of_energy_savings_from_lighting_controls_in_commercial_buildings_lbnl-5095e.pdf

Non-High Bay Occupancy/Vacancy Sensor

	Measure Details
Measure Master ID	Non-High Bay Occupancy/Vacancy Sensor, 4812
Workpaper ID	W0087
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)	$0.55[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

$$kWh_{\text{SAVED}} = Watts\ /\ 1{,}000 * SF * HOU$$

Where:

Variable	Description	Units	Value
Watts	Controlled lighting wattage	Watts	
1,000	Conversion factor	W/kW	1,000
SF	Savings factor, deemed	%	24%[3]
HOU	Average annual run hours	Hrs/yr	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.

$$kW_{\text{SAVED}} = Watts * CF\ /\ 1{,}000$$

Where:

CF = Coincidence factor (0)

Lifecycle Energy-Savings Algorithm

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

Where:

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

Deemed Savings

Savings

Sector	Annual kWh	Lifecycle kWh
Commercial	0.90	7.20
Industrial	1.14	9.12
Agriculture	1.13	9.04
Schools & Government	0.78	6.24
Multifamily	1.43	11.44

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.

Revision History

Version Number	Date	Description of Change
01	01/2019	Initial TRM entry
02	12/2020	Updated savings factor

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[1] PA Consulting Group. *Focus on Energy, 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 unit cost of 223 projects and 2,139 units from February 2019 to July 2020 is $0.55.

[3] Lawrence Berkeley National Laboratory. *A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings*. September 2011. https://eta.lbl.gov/sites/default/files/publications/a_meta-analysis_of_energy_savings_from_lighting_controls_in_commercial_buildings_lbnl-5095e.pdf

[4] PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3-2. 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.

Occupancy Sensor, LED Refrigerated Case Lights

	Measure Details
Measure Master ID	Occupancy Sensor, LED Refrigerated Case Lights, 2482
Workpaper ID	W0088
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)	65
Peak Demand Reduction (kW)	0.0075
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	520
Lifecycle 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

$$kWh_{\text{SAVED}} = [(Watts_{\text{BASE}}) + (Watts_{\text{BASE}}) / COP] * SF / 1{,}000 * HOU$$

Where:

Variable	Description	Units	Value
$Watts_{\text{BASE}}$	Wattage of the LED case lighting	Watts	17.73[3]
COP	Coefficient of performance		2.3 for non-self-contained coolers,[4] 1.4 for non-self-contained freezers,[4] 0.5 for self-contained coolers,[5] 0.6 for self-contained freezers; weighted average savings applied, see Assumptions[5]
SF	Savings factor	%	24%[5]

Variable	Description	Units	Value
1,000	Conversion factor	W/kW	1,000
HOU	Average annual run hours	Hrs/yr	8,760

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = [(Watts_{\text{BASE}}) + (Watts_{\text{BASE}}) / COP] * SF / 1{,}000$$

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (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. Therefore the weights are 22.5% non self-contained coolers, 67.5% non self-contained freezers, 2.5% self-contained coolers, and 7.5% self-contained freezers.
- Because no studies of refrigeration occupancy sensors could be found, a savings value of 24% for occupancy sensors in general is used.
- 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.

Revision History

Version Number	Date	Description of Change
01	03/2016	Updated based on Focus on Energy Deemed Savings Manual
02	10/2017	Updated EUL
03	12/2018	Updated incremental cost
04	12/2020	Updated savings factor

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[1] PA Consulting Group. *Focus on Energy, 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

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[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] Lawrence Berkeley National Laboratory. *A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings*. September 2011. https://eta.lbl.gov/sites/default/files/publications/a_meta-analysis_of_energy_savings_from_lighting_controls_in_commercial_buildings_lbnl-5095e.pdf

Networked Lighting Controls for New Construction

	Measure Details
Measure Master ID	Networked Lighting Controls, better than code, new construction, 5233
Workpaper ID	W0288
Measure Unit	Per project (see Assumptions)
Measure Type	Hybrid
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
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)	15[1]
Incremental Cost ($/unit)	$0.57 per square foot[2]

Measure Description

The Design Lights Consortium defines NLC systems as the combination of sensors, network interfaces, and controllers that affect lighting changes in luminaires, retrofit kits, or lamps.[3] These NLCs save energy by more efficiently controlling the spaces through simplified commissioning, potential real-time usage information and analytics for end users, interoperability with other building systems, and flexible reconfiguration for when space or task uses change.

This measure is the installation of networked lighting controls in the interior of a newly constructed building.

Description of Baseline Condition

The baseline condition is a lighting system with controls designed to meet ASHRAE 90.1-2013 new construction code minimums. Due to the various space types and complexity of code requirements for different spaces, the baseline is generalized for the savings calculations. Since daylighting and high bay occupancy sensors are commonly required in the Industrial and Schools & Government sectors, and the savings factor for those control strategies exceeds the NLC savings factor, non-high bay occupancy sensors are used as the baseline and spaces with daylighting and high bay occupancy sensors will be ineligible for incentives. The Commercial sector uses on/off high bay occupancy sensors as the baseline control strategy because it has the most conservative savings factor of all the baseline control strategy options.

Description of Efficient Condition

The efficient condition is a properly designed lighting system that includes the integration of a DLC NLC QPL listed (NLC4 or higher) controls system that includes operational occupancy sensing, zoning, and individual addressability strategies for individual fixtures controlled by a central bridge or gateway.[3]

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = Watts * HOU * (SF_{\text{EFF}} - SF_{\text{BASE}}) / 1{,}000$$

Where:

Variable	Description	Units	Value
Watts	Lighting wattage controlled	Watts	User input; see Assumptions
HOU	Hours of use	Hrs	Customer input if known, otherwise varies by sector; see Hours of Use and Savings Factors by Sector table below
SF_{EFF}	Networked lighting controls savings factor		Varies by sector, see Hours of Use and Savings Factors by Sector table below
SF_{BASE}	Baseline controls savings factor		Varies by sector, see Hours of Use and Savings Factors by Sector table below
1,000	Conversion factor	W/kW	1,000

Hours of Use and Savings Factors by Sector

Sector	HOU[4]	SF_{EE}	SF_{EE} Note	SF_{BASE}*
Commercial	3,730	56%	Arithmetic average of retail (44%), restaurant (59%), and office (64%) building types from DLC study[5]	34%
Industrial	4,745	47%	Weighted average[6] of sectors from DLC study[5] (see Assumptions)	24%
Schools & Government	3,239	41%	Value for school building type from DLC study[5]	24%

* See Assumptions

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = Watts * (SF_{\text{EFF}} - SF_{\text{Base}}) * CF / 1{,}000$$

Where:

CF = Coincidence factor (varies by sector for retrofit kit only and connected controls interior; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Schools & Government[4]	0.64

Lifecycle Energy-Savings Algorithm

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

Where:

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

Assumptions

- Savings for this measure are calculated at a project level using the methodology above, though incentive rates are based on kilowatt-hour savings calculated by comparing baseline strategy (code) to a NLC system.
- New buildings will have some level of lighting controls as a code requirement for most, if not all, of the spaces. This measure is intended to capture the additional savings for installing NLC which is considered above and beyond the code requirements per ASHRAE 90.1-2013. There are a few instances where the savings are low enough that an incentive is not justified, therefore Industrial and Schools & Government customers installing NLC in high bay spaces and or spaces requiring daylighting controls are not eligible for NLC. NLC installed in other spaces are still eligible.
- The user will complete the Lighting Power Density (LPD) Workbook and the total controlled lighting wattage will be calculated as part of the LPD measure requirements (W0093).
- The Commercial sector SF_{BASE} is from workpaper W0086. The Industrial and Schools & Government sectors SF_{BASE} are from workpaper W0087.
- The Industrial sector SF_{EFF} comes from the DLC study and Focus on Energy historical data, weighted as shown in the following table.

Assumptions for Industrial Savings Factor

Building Type	Observed Savings Factor in DLC Study[5]	Fraction of MMIDs 3965 and 3966 Focus on Energy Savings for Industrial Sector Usage[6]	Weighted Average
Manufacturing	40%	36%	47%
Office	64%	11%	
Other	49% (overall average used)	53%	

Revision History

Version Number	Date	Description of Change
01	12/2021	Initial release
02	07/2022	Updated EUL, SF, and demand algorithm

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[1] Efficiency Vermont. *Technical Reference User Manual*. Lighting Power Density Measure. p. 89. March 16, 2015.

[2] Northwest Energy Efficiency Alliance. *2020 Luminaire Level Lighting Controls Incremental Cost Study*. January 7, 2021. https://neea.org/img/documents/2020-LLLC-Incremental-Cost-Study.pdf Table 4 shows the 40,000 sq ft office building has 471 fixtures. Table 6 shows $48 incremental cost per fixture. A per square foot incremental cost is calculated to be 471 * $48 / 40,000 = $0.57 per sq ft..

[3] DesignLights Consortium. “Networked Lighting Control System Technical Requirements V4.0, SSL QPL and NLC QPL.” June 4, 2020. https://www.designlights.org

[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. March 22, 2010. focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

[5] DesignLights Consortium. *Report: Energy Savings from Networked Lighting Control (NLC) Systems*. September 24, 2020. Table 1. Energy-Savings-From-Networked-Lighting-Controls-with-and-without-LLLC_FINAL_09242020.pdf (designlights.org) The multifamily controls savings factor was derived by using the “Overall” building type value

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[6] Wisconsin Focus on Energy. Historical project data for MMIDs 3965 and 3966, obtained from SPECTRUM. January 2017 through December 2019. A weighted average of manufacturing, office, and overall/other building types (36%, 11%, and 53%, respectively) was used to determine the controls savings factor for the industrial sector

Comprehensive Lighting Solutions

	Measure Details
Measure Master ID	CLS – Fixture or Retrofit Kit Only, 5029 CLS – Fixture or Retrofit Kit/Lamp with Connected Controls, Interior, 5031 CLS – Fixture or Retrofit Kit/Lamp with Connected Controls, Exterior, 5030
Workpaper ID	W0255
Measure Unit	Per watt reduced
Measure Type	Hybrid
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, 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)	Actual cost in current year

Measure Description

Comprehensive lighting solutions consist of two types of measures. First, a fixture or retrofit kit only is for lighting upgrades where fixture layouts have been redesigned, typically not one-for-one, and is installed when current conditions no longer meet the facility needs, resulting in reduced foot-candles and reduced energy usage. Second, a fixture or retrofit kit with connected controls is for lighting upgrades where either interior or exterior fixtures are upgraded in conjunction with DesignLights Consortium™ (DLC)-listed advanced/networked lighting control (NLC) systems. The DLC defines NLC systems as the combination of sensors, network interfaces, and controllers that affect lighting changes in luminaires, retrofit kits, or lamps.[2] These systems save energy by more efficiently controlling the spaces through simplified commissioning, potential real-time usage information and analytics for end users, interoperability with other building systems, and flexible reconfiguration for when space or task uses change.

Description of Baseline Condition

The baseline condition is either an overlit facility or an interior or exterior lighting system that does not include connected controls strategies.

Description of Efficient Condition

The efficient condition is a properly designed lighting layout that includes DLC Solid State Lighting *Qualified Product List* (QPL) listed (Technical Requirement Table v4.4 or higher) or ENERGY STAR® certified fixtures or retrofit kits and provides adequate light levels for the facility needs. In instances where connected controls strategies were not incorporated previously, the efficient condition also includes the integration of a DLC NLC QPL listed (Technical Requirement Table v4.0 or higher) controls system, either interior or exterior.[2]

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = [(Watts_{\text{BASE}} * HOU * (1 - SF_{\text{BASE}})) - (Watts_{\text{EE}} * HOU * (1 - SF_{\text{EE}}))] / 1{,}000$$

Where:

Variable	Description	Units	Value
$Watts_{BASE}$	Power consumption of baseline measure	Watts	Customer input
HOU	Hours of use	Hrs	Customer input or varies by sector; see table below
SF_{BASE}	Baseline controls savings factor	%	0% for retrofit kit only and connected controls exterior; 10% for connected controls interior, see Assumptions
$Watts_{EE}$	Power consumption of proposed, DLC or ENERGY STAR listed lighting equipment	Watts	Customer input
SF_{EE}	Connected controls savings factor	%	0% for retrofit kit only; varies by sector for connected controls interior and exterior; see table below and Assumptions
1,000	Conversion factor	W/kW	1,000

Hours of Use and Savings Factors by Sector

Sector	HOU[3,4]	SF_{EE}	SF_{EE} Note
Commercial	3,730	56%	Arithmetic average of retail (44%), restaurant (59%), and office (64%) building types from DLC study[5]
Industrial	4,745	47%	Weighted average[6] of sectors from DLC study[5] (see Assumptions)
Schools & Government	3,239	41%	Value for school building type from DLC study[5]
Residential- multifamily	5,950	49%	Overall average from DLC study[5]
Exterior	4,380	50%	Inferred from a paper on external bi-level controls[7]

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = (Watts_{\text{BASE}} * (1 - SF_{\text{Base}}) - Watts_{\text{EE}} * (1 - SF_{\text{EFF}})) * CF / 1{,}000$$

Where:

CF = Coincidence factor (0% for connected controls exterior; = varies by sector for retrofit kit only and connected controls interior; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[3]	0.77
Industrial[3]	0.77
Schools & Government[3]	0.64
Residential- multifamily[8]	0.77

Lifecycle Energy-Savings Algorithm

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

Where:

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

Assumptions

The full measure cost is used because of the hybrid nature of these measures: It is difficult to determine incremental costs for projects with such a variety of scopes.

The baseline controls savings factor accounts for buildings that previously had either occupancy sensors or daylighting controls. A recent study of lighting controls[9] shows the fractions of various building types that were found to have controls installed. In addition, buildings with existing controls are less likely to install connected controls and not all the spaces within the buildings included in the study had controls. Based on this information, it is assumed that buildings receiving connected controls have a baseline HOU that was already reduced by 10% on average from existing baseline controls.

The industrial sector savings factor comes from the DLC study and Focus on Energy historical data, weighted as shown in the following table.

Assumptions for Industrial Savings Factor

Building Type	Observed Savings Factor in DLC Study[5]	Fraction of MMIDs 3965 and 3966 Focus on Energy Savings for Industrial Sector Usage[6]	Weighted Average
Manufacturing	40%	36%	47%
Office	64%	11%	
Other	49% (overall average used)	53%	

For multifamily building types, only common spaces are eligible for the connected controls interior measure (in-unit spaces are not eligible).

No studies could be found that examine NLC or occupancy sensing savings for exterior fixtures. A 2013 paper[7] summarizes savings from over ten studies of exterior bi-level controls. Approximately four of these studies showed savings up to 70%, although that value for most includes savings from the LED upgrade as well. The paper’s summaries generally indicate that 30% - 40% is a conservative guess for savings from external bi-level controls. Exterior on/off occupancy controls and NLC should save more than this. An estimate of SF = 50% is used for exterior NLC.

Revision History

Version Number	Date	Description of Change
01	05/2020	Initial release
02	07/2022	Updated EUL and SF

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[1] Efficiency Vermont. *Technical Reference User Manual*. Lighting Power Density Measure. p. 89. March 16, 2015.

[2] DesignLights Consortium. "Networked Lighting Control System Technical Requirements V4.0, SSL QPL and NLC QPL." June 4, 2020. https://www.designlights.org

[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. March 22, 2010. focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

[4] U.S. Department of Commerce, National Oceanic and Atmospheric Administration. "NOAA Solar Calculator." 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] DesignLights Consortium. *Report: Energy Savings from Networked Lighting Control (NLC) Systems*. September 24, 2020. Table 1. Energy-Savings-From-Networked-Lighting-Controls-with-and-without-LLLC_FINAL_09242020.pdf (designlights.org)
The multifamily controls savings factor was derived by using the "Overall" building type value.

[6] Wisconsin Focus on Energy. Historical project data for MMIDs 3965 and 3966, obtained from SPECTRUM. January 2017 through December 2019.
A weighted average of manufacturing, office, and overall/other building types (36%, 11%, and 53%, respectively) was used to determine the controls savings factor for the industrial sector.

[7] U.S. Department of Energy. *Exterior Lighting Control Guidance.* August 2013. https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/exterior-lighting-control-guidance.pdf
Study summaries indicate that 30 - 40% is a conservative guess for external bi-level controls. 50% is used as an estimate for external NLC.

[8] Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf

[9] Seventhwave. *Light Level Analysis in Buildings: A Market Characterization Study*. October 31, 2018. Figure 10. focusonenergy.com/sites/default/files/2018-11/WI_Light_Level_Final_Report_0.pdf

LED Exterior Fixture with NLC, Lumen Based, New Construction Only

	Measure Details
Measure Master ID	LED, Exterior Fixture with Networked Lighting Controls, New Construction Only: Low Output w/ NLC, ≤4,999 lumens, 5065 Mid Output w/ NLC, 5,000–9,999 lumens, 5066 High Output w/ NLC, 10,000–29,999 lumens, 5067 Very High Output w/ NLC, ≥30,000 lumens, 5068
Workpaper ID	W0263
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	NC-Commercial, NC-Industrial, NC-Schools & Government, NC-Agriculture, NC-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)	15[1]
Measure Incremental Cost ($/unit)	Varies by measure, see Installed Measure Cost table

Measure Description

Exterior LED fixtures with networked lighting controls (NLC) are an energy-saving alternative to traditional standard wattage high intensity discharge (HID) light sources with no controls that can be 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 new construction applications only (as a compliment to the exterior CLS retrofit measure MMID 5030). This paper is similar to W0113, for LED exterior lumen-based fixtures, with an additional savings factor for controls.

Description of Baseline Condition

The baseline condition is an exterior-mounted HID area luminaire, excluding stairwell and passageway luminaires, up to 1,000 watts. The baseline luminaire operates 4,380 hours per year with dusk to dawn/photocell controls. Per IECC-2015 C405.2.5 code, controls must automatically turn off the lighting as a function of available daylight.

Description of Efficient Condition

The efficient condition is DLC-listed LED luminaire in the “Outdoor” General Application category, excluding stairwell and passageway luminaires, with a DLC-listed NLC system capturing additional control savings.

Annual Energy-Savings Algorithm

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

Where:

Variable	Description	Units	Value
$Watts_{\text{BASE}}$	Average power consumption of baseline measure	Watts	116 watts, 227 watts, 546 watts, and 1,079 watts[2]
HOU	Average annual run hours of baseline measure	Hrs	4,380[3]
$Watts_{\text{EE}}$	Average power consumption of efficient LED upgrade	Watts	27.09 watts, 60.03 watts, 133.66 watts, and 330.26 watts[4]
SF	Savings factor for exterior NLC		50%, see Assumptions[5]
1,000	Conversion factor	W/kW	1,000

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for these measures.

Lifecycle Energy-Savings Algorithm

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

Where:

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

Annual and Lifecycle Energy Savings

Measure Description	MMID	Annual kWh Savings	Lifecycle kWh Savings
Low Output w/ NLC, ≤4,999 lumens	5065	449	6,735
Mid Output w/ NLC, 5,000–9,999 lumens	5066	863	12,945
High Output w/ NLC, 10,000–29,999 lumens	5067	2,099	31,485
Very High Output w/ NLC, ≥30,000 lumens	5068	4,003	60,045

Assumptions

No studies could be found that examine NLC or occupancy sensing savings for exterior fixtures. A 2013 paper[7] summarizes savings from over 10 studies of exterior bi-level controls. Approximately four of these studies showed savings up to 70%, although that value for most includes savings from the LED upgrade as well. The paper summary generally indicate that 30% to 40% is a conservative guess for savings from external bi-level controls. Exterior on/off occupancy controls and NLC should save more than the paper estimates, so this workpaper uses a 50% savings factor for exterior NLC.

Installed Measure Cost

Measure Description	MMID	Incremental Cost
Low Output w/ NLC, ≤4,999 lumens	5065	$146.75[6]
Mid Output w/ NLC, 5,000–9,999 lumens	5066	$317.59[7]
High Output w/ NLC, 10,000–29,999 lumens	5067	$384.88[8]
Very High Output w/ NLC, ≥30,000 lumens	5068	$838.55[9]

Revision History

Version Number	Date	Description of Change
01	10/2020	Initial TRM entry
02	09/2022	Updated Watts$_{EE}$, Incremental Costs, and EUL.

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[1] Efficiency Vermont. *Technical Reference User Manual*. Lighting Power Density Measure. p. 89. March 16, 2015.

[2] *Focus on Energy Default Wattage Guide*. Version 1.0. 2013.

[3] 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.

[4] SPECTRUM. "Focus historical data." 7/1/20 to 6/30/22 application date ranges for B&I, B&I Rural, and S&G. Data based on MMIDs 4280, 4281, 4282, and 4283 cross-referenced with DLC SSL QPL to determine weighted average wattage.

[5] U.S. Department of Energy. *Exterior Lighting Control Guidance.* August 2013.
https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/exterior-lighting-control-guidance.pdf
Study summaries indicate that 30% to 40% is a conservative guess for external bi-level controls. 50% is used as an estimate for external NLC.

[6] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 716 projects and 6,630 units from January 2021 to July 2022 is $125.84. Base cost of $15.60 from July 2022 online lookups of base models, 50 - 150 watt metal halide bulbs. $125.94 - $15.60 = $110.34. To account for controls cost, add 33% to the incremental fixture cost. $110.34 * 1.33 = $146.75.

[7] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 1,253 projects and 11,978 units from January 2021 to July 2022 is $254.39. Base cost of $15.60 from July 2022 online lookups of base models, 150 - 250 watt metal halide bulbs. $254.39 - $15.60 = $238.79. To account for controls cost, add 33% to the incremental fixture cost. $238.79 * 1.33 = $317.59.

[8] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 935 projects and 12,549 units from January 2021 to July 2022 is $311.34. Base cost of $21.95 from September 2022 online lookups of base models, 250 - 1000 watt metal halide bulbs. $311.34 - $21.95 = $289.38. To account for controls cost, add 33% to the incremental fixture cost. $289.38 * 1.33 = $384.88.

[9] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 269 projects and 3,025 units from January 2021 to July 2022 is $655.59. Base cost of $25.10 from July 2022 online lookups of base models, 1000 watt metal halide bulbs. $655.59 - $25.10 = $630.49. To account for controls cost, add 33% to the incremental fixture cost. $630.49 * 1.33 = $838.55.

Interior New Construction Lighting, Lighting Power Density (LPD)

	Measure Details
Measure Master ID	Interior New Construction Lighting, Lighting Power Density, Interior, 4948
Workpaper ID	W0093
Measure Unit	Per project (see Assumptions)
Measure Type	Hybrid
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
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)	$0.90[2] per square foot

Measure Description

Newly constructed or repurposed buildings must follow lighting power density (LPD) limits defined by IECC 2015[3] 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.

Although multifamily buildings are not required to follow IECC 2015 LPD limits like other Wisconsin commercial buildings, common areas are eligible for this measure as an alternative to the Energy Design Assistance or Energy Design Review offerings. Multifamily In Unit areas are not eligible.

Description of Baseline Condition

The baseline condition is any newly constructed or repurposed multifamily building or a building subject to IECC 2015 with Wisconsin Amendments for the watts-per-square-foot building type definitions.

Description of Efficient Condition

The efficient condition is a lighting fixture design that is lower than code-defined LPD values without controls.

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = (LPD_{\text{CODE}} - LPD_{\text{DESIGN}}) * sq\,ft * HOU / 1{,}000$$

Where:

Variable	Description	Units	Value
LPD_{CODE}	Code-allowed watts per square foot	Watts/ft^2	Defined by building type; see Code Lighting Power Density by Building Type table)
LPD_{DESIGN}	Proposed watts per square foot in lighting design	Watts/ft^2	
sq ft	Building square footage	Ft^2	Defined by user
HOU	Average annual run hours	Hrs/yr	Defined by user or program-defined based on sector; see Hours of Use by Sector table[4,5]
1,000	Conversion factor	W/kW	

Code Lighting Power Density by Building Type

Building Area Type	LPD (watts/sq ft)[3]
Automotive Facility	0.80
Convention Center	1.01
Courthouse	1.01
Dining: Bar Lounge/Leisure	1.01
Dining: Cafeteria/Fast Food	0.90
Dining: Family	0.95
Dormitory	0.57
Exercise Center	0.84
Fire Station	0.67
Gymnasium	0.94
Health Care Clinic	0.90
Hospital	1.05
Hotel/Motel	0.87
Library	1.19
Manufacturing Facility	1.17
Motion Picture Theater	0.76
Multifamily – Common Area	0.51
Museum	1.02
Office	0.82
Parking Garage	0.21
Penitentiary	0.81
Performing Arts Theater	1.39
Police Station	0.87
Post Office	0.87
Religious Building	1.00
Retail	1.26
School/University	0.87

Building Area Type	LPD (watts/sq ft)[3]
Sports Arena	0.91
Town Hall	0.89
Transportation	0.70
Warehouse	0.66
Workshop	1.19

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

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = (LPD_{\text{CODE}} - LPD_{\text{DESIGN}}) * sq\,ft \,/\, 1{,}000 * CF$$

Where:

CF = Coincidence factor (varies by sector; see table below)[4,6]

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[6]	0.77

Lifecycle Energy-Savings Algorithm

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

Where:

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

Assumptions

Savings for this measure are calculated at a project level using the methodology above, though incentive rates are based on kilowatt-hour savings below code.

This measure is a consolidation of MMIDs 4336, 4337, and 4338. Their historical project costs were used to produce the cost for this measure. Details can be seen in the Incremental Costs table.

Incremental Costs

MMID	Measure Name	Projects	Square Feet	Average Cost
4336	Interior New Construction Lighting LPD ≥20% below code	10	253,508	$1.31
4337	Interior New Construction Lighting LPD ≥30% below code	24	927,990	$1.42
4338	Interior New Construction Lighting LPD ≥40% below code	153	6,256,881	$1.28
Average / Total (used for MMID 4948)		**187**	**7,438,379**	**$1.30**

Revision History

Version Number	Date	Description of Change
01	11/2017	Initial TRM entry
02	12/2019	Added new MMID based on kilowatt-hours below code instead of percentage below code, updated baseline to 2015 IECC, and updated incremental cost
03	07/2020	Added multifamily common area sector

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[1] Efficiency Vermont. *Technical Reference User Manual*. Lighting Power Density Measure. p. 89. March 16, 2015.

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM, for MMID 4948. Average cost of 10 projects and 159,321 square feet from March 2020 to May 2021 is $0.90 per square foot. This sample does not include the 3 projects with 115,796 square feet that used the previous default of $1.30 per square foot.

[3] International Energy Conservation Code. Table C405.4.2(1). https://codes.iccsafe.org/content/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*. Table 3-2. 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

[6] Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

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 Replacing 8FT 1L T8 or T12, Exterior, 4315 Replacing 8FT 1L T8 or T12, Exterior 24/7, 4316 Replacing 8FT 1L T8HO or T12HO, 4317 Replacing 8FT 1L T8HO or T12HO, Exterior, 4318 Replacing 8FT 1L T8HO or T12HO, Exterior 24/7, 4319 4FT Linear LED 4L: Replacing 8FT 2L T8 or T12, 4320 Replacing 8FT 2L T8 or T12, Exterior, 4321 Replacing 8FT 2L T8 or T12, Exterior 24/7, 4322 Replacing 8FT 2L T8HO or T12HO, 4323 Replacing 8FT 2L T8HO or T12HO, Exterior, 4324 Replacing 8FT 2L T8HO or T12HO, Exterior 24/7, 4325 4FT Linear LED 2L: Replacing 8FT 2L T8 or T12, 4326 Replacing 8FT 2L T8 or T12, Exterior, 4327 Replacing 8FT 2L T8 or T12, Exterior 24/7, 4328 Replacing 8FT 2L T8HO or T12HO, 4329 Replacing 8FT 2L T8HO or T12HO, Exterior, 4330 Replacing 8FT 2L T8HO or T12HO, Exterior 24/7, 4331
Workpaper ID	W0094
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)	Varies by sector[1]
Incremental Cost	1-lamp upgrades = $58.65 (MMIDs 4314–4319)[2] 2-lamp upgrades = $103.00 (MMIDs 4320–4325)[3] 2-lamp 8-foot to 2-lamp 4-foot standard upgrades = $47.13 (MMIDs 4326 – 4328)[4] 2-lamp 8-foot to 2-lamp 4-foot HO upgrades = $44.32 (MMIDs 4329 – 4331)[5]

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 less than 24. This measure is not intended to be used in refrigerated case lighting applications.

Annual Energy-Savings Algorithm

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

Where:

Variable	Description	Units	Value
$Watts_{\text{BASE}}$	Average wattage of T8 and T12 systems	Watts	1 lamp = 65 watts, 2 lamp = 108 watts, 1 lamp HO = 103.5 watts, 2 lamp HO = 184 watts
$Watts_{\text{EE}}$	Average wattage consumption of DLC-listed 4-foot linear LED < 24 watts	Watts	16.79 watts[6]
1,000	Conversion factor	W/kW	1,000
HOU	Hours of use	Hrs	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
Exterior[9]	4,380
Exterior 24/7	8,760

Summer Coincident Peak Savings Algorithm

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

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[10]	0.77
Exterior	0.00
Exterior 24/7	1.00

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (see table below)[1]

Deemed Savings

4FT Linear LED 2L

Measure	MMID	Sectors	EUL (yrs)	Annual Savings (kWh)	Peak Demand Savings (kW)	Lifecycle Savings (kWh)
Replacing 8-Foot 1L T8 or T12	4314	Commercial	14	117	0.0242	1,638
		Industrial	11	149	0.0242	1,639
		Schools & Gov	16	102	0.0201	1,632
		Agriculture	11	148	0.0211	1,628
		Multifamily	9	187	0.0242	1,683
Replacing 8-Foot 1L T8 or T12, Exterior	4315	All Sectors	12	138	0.0000	1,656
Replacing 8-Foot 1L T8 or T12, Exterior 24/7	4316	All Sectors	6	275	0.0314	1,650
Replacing 8-Foot 1L T8HO or T12HO	4317	Commercial	14	261	0.0538	3,654
		Industrial	11	332	0.0538	3,652
		Schools & Gov	16	226	0.0447	3,616
		Agriculture	11	328	0.0468	3,608
		Multifamily	9	416	0.0538	3,744
Replacing 8-Foot 1L T8HO or T12HO, Exterior	4318	All Sectors	12	306	0.0000	3,672
Replacing 8-Foot 1L T8HO or T12HO, Exterior 24/7	4319	All Sectors	6	612	0.0699	3,672

4FT Linear LED 4L

Measure	MMID	Sectors	EUL (yrs)	Annual Savings (kWh)	Peak Demand Savings (kW)	Lifecycle Savings (kWh)
Replacing 8-Foot 2L T8 or T12	4320	Commercial	14	152	0.0314	2,128
		Industrial	11	194	0.0314	2,134
		Schools & Gov	16	132	0.0261	2,112
		Agriculture	11	192	0.0274	2,112
		Multifamily	9	243	0.0314	2,187
Replacing 8-Foot 2L T8 or T12, Exterior	4321	All Sectors	12	179	0.0000	2,148
Replacing 8-Foot 2L T8 or T12, Exterior 24/7	4322	All Sectors	6	358	0.0408	2,148
Replacing 8-Foot 2L T8HO or T12HO	4323	Commercial	14	436	0.0900	6,104
		Industrial	11	554	0.0900	6,094
		Schools & Gov	16	378	0.0748	6,048
		Agriculture	11	549	0.0783	6,039
		Multifamily	9	695	0.0900	6,255
Replacing 8-Foot 2L T8HO or T12HO, Exterior	4324	All Sectors	12	512	0.0000	6,144
Replacing 8-Foot 2L T8HO or T12HO, Exterior 24/7	4325	All Sectors	6	1,024	0.1168	6,144

4FT Linear LED 2L

Measure	MMID	Sectors	EUL (yrs)	Annual Savings (kWh)	Peak Demand Savings (kW)	Lifecycle Savings (kWh)
Replacing 8-Foot 2L T8 or T12	4326	Commercial	14	278	0.0573	3,892
		Industrial	11	353	0.0573	3,883
		Schools & Gov	16	241	0.0476	3,856
		Agriculture	11	350	0.0499	3,850
		Multifamily	9	443	0.0573	3,987
Replacing 8-Foot 2L T8 or T12, Exterior	4327	All Sectors	12	326	0.0000	3,912
Replacing 8-Foot 2L T8 or T12, Exterior 24/7	4328	All Sectors	6	652	0.0744	3,912
Replacing 8-Foot 2L T8HO or T12HO	4329	Commercial	14	561	0.1158	7,854
		Industrial	11	714	0.1158	7,854
		Schools & Gov	16	487	0.0963	7,792
		Agriculture	11	707	0.1008	7,777
		Multifamily	9	895	0.1158	8,055
Replacing 8-Foot 2L T8HO or T12HO, Exterior	4330	All Sectors	12	659	0.0000	7,908
Replacing 8-Foot 2L T8HO or T12HO, Exterior 24/7	4331	All Sectors	6	1,318	0.1504	7,908

Version Number	Date	Description of Change
01	10/2017	Initial TRM entry
02	02/2020	Updated cost for MMIDs 4326 –4328, 4457 – 4459, 4329 – 4331, and 4460 – 4462
03	02/2020	Updated costs
04	09/2022	Updated Watts$_{EE}$, EUL, and reorganized references. Removed SBP measures.
05	10/2023	Updated interior measure EULs to reflect individual sector HOU

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[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. The EUL for each sector is calculated based on their sector HOU. With an HOU of 4,380 for exterior 12-hour measure, the EUL is 13 years. With an HOU of 8,760 for exterior 24-hour measure, the EUL is 6 years.

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 467 projects and 1,277 units from February 2018 to July 2020 is $68.08. Base cost of $9.43 from November 2020 lookups of T8 and T8HO models on www.1000bulbs.com, www.homedepot.com, www.bulbs.com, and www.lightbulbs.com. $68.08 - $9.43 = $58.65.

[3] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 148 projects and 2,059 units from February 2018 to July 2020 is $85.55. Base cost of $9.43 from November 2020 lookups of T8 and T8HO models on www.1000bulbs.com, www.homedepot.com, www.bulbs.com, and www.lightbulbs.com. $85.5.5 - $9.43 * 2 = $66.69.

[4] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 74 projects and 8,625 units from February 2018 to July 2020 is $56.95. Base cost of $9.43 from November 2020 lookups of T8 and T8HO models on www.1000bulbs.com, www.homedepot.com, www.bulbs.com, and www.lightbulbs.com. $56.95 - $9.43 * 2= $38.09.

[5] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 10 projects and 418 units from February 2018 to July 2020 is $50.83. Base cost of $12.49 from November 2020 lookups of T8 and T8HO models on www.1000bulbs.com, www.homedepot.com, www.bulbs.com, and www.lightbulbs.com. $50.83 - $12.49 = $38.34.

[6] DesignLights Consortium. *Product List.* Accessed August 2022. https://www.designlights.org/search/

[7] PA Consulting Group. *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

[8] 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

[9] 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.

[10] Summit Blue Consulting. Con Edison Callable Load Study. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

LED Fixtures, High-Bay Linear Fluorescent to LED

	Measure Details
Measure Master ID	LED Fixture, High Bay, DLC Listed: ≤ 180 Watts, Replacing 4 Lamp T5HO or 6 Lamp T8, 3393 ≤ 180 Watts, Replacing 4 Lamp T5HO or 6 Lamp T8, Agriculture, 4701 ≤ 250 Watts, Replacing 6 Lamp T5HO or 8 Lamp T8, 4347 ≤ 250 Watts, Replacing 6 Lamp T5HO or 8 Lamp T8, Agriculture, 4702 ≤ 300 Watts, Replacing 8 Lamp T5HO or 10 Lamp T8, 4795 ≤ 350 Watts, Replacing 10 Lamp T5HO or 12 Lamp T8, 4796
Workpaper ID	W0259
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)	Varies by sector[1]
Incremental Cost ($/unit)	≤ 180 Watts = $191.41 (MMIDs 3393 & 4701)[2] ≤ 250 Watts, ≤ 300 Watts, and ≤ 350 Watts = $271.65 (MMIDs 4347, 4702, 4795, and 4796)[3]

Measure Description

LED high-bay fixtures save energy when replacing fluorescent lamp 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 fluorescent lamp high-bay luminaires.

Description of Baseline Condition

The baseline condition is a combination of similar lumen output 4-foot fluorescent T5HO and T8 lamp high/low bay fixtures for existing buildings and new construction buildings. An average of 4-foot T5HO lamp and T8 lamp high/low bay luminaires was used to generate the baseline wattage. See the Assumptions section for a breakdown. For new construction applications, the baseline references T8 lamp configurations only.

Description of Efficient Condition

The efficient condition is a DesignLights Consortium™ (DLC)-listed fixture listed in the High-Bay General Application, consuming less than or equal to the wattage respective to its measure name.

Annual Energy-Savings Algorithm

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

Where:

Variable	Description	Units	Value
$Watts_{\text{BASE}}$	Average power consumption of respective T5HO lamp or T8 lamp configuration, high/low bay luminaires	Watts	See Baseline and Efficient Lamp Consumption table below; new construction baseline wattage is based on T8 only.
$Watts_{\text{EE}}$	Efficient consumption of LED fixture	Watts	See Baseline and Efficient Lamp Consumption table below for both existing building and new construction
HOU	Hours of use	Hrs	Varies by sector; see Hours of Use by Sector table below
1,000	Conversion factor	W/kW	1,000

Baseline and Efficient Lamp Consumption

Measure	Existing Building $Watts_{\text{BASE}}$	New Construction $Watts_{\text{BASE}}$	$Watts_{\text{EE}}$[4]
LED Fixture, ≤ 180 Watts, Replacing 4 Lamp T5HO or 6 Lamp T8, High Bay, DLC Listed, 3393, 4701	227	224	128
LED Fixture, ≤ 250 Watts, Replacing 6 Lamp T5HO or 8 Lamp T8, High Bay, DLC Listed, 4347, 4702	323	291	171
LED Fixture, ≤ 300 Watts, Replacing 8 Lamp T5HO or 10 Lamp T8, High Bay, DLC Listed, 4795	418	368	211
LED Fixture, ≤ 350 Watts, Replacing 10 Lamp T5HO or 12 Lamp T8, High Bay, DLC Listed, 4796	514	442	264

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[6]	5,950

Summer Coincident Peak Savings Algorithm

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

Where:

CF = Coincidence factor (varies by sector, see Coincidence Factor by Sector table below)

Coincidence Factor by Sector

Sector	HOU
Commercial[5]	0.77
Industrial[5]	0.77
Agriculture[5]	0.67
Schools & Government[5]	0.64
Multifamily[7]	0.77

Lifecycle Energy-Savings Algorithm

$$kWh_{\text{LIFECYCLE}} = kWh_{Saved} * EUL$$

Where:

EUL = See tables below

Deemed Savings

Measure	MMID	Sectors	EUL (yrs)	Annual Savings (kWh)	Peak Demand Savings (kW)	Lifecycle Savings (kWh)
LED Fixture, ≤ 180 Watts, Replacing 4 Lamp T5HO or 6 Lamp T8, High Bay, DLC Listed	3393	Commercial	20	369	0.0763	7,380
		Industrial	20	470	0.0763	9,400
		Schools & Gov	20	321	0.0634	6,420
		Multifamily	19	589	0.0763	11,191
		NC - Commercial	20	358	0.0740	7,160
		NC - Industrial	20	456	0.0740	9,120
		NC - Schools & Gov	20	311	0.0615	6,220
		NC - Multifamily	19	571	0.0740	10,849
	4701	Agriculture	20	465	0.0664	9,300
		NC - Agriculture	20	451	0.0644	9,020
LED Fixture, ≤ 250 Watts, Replacing 6 Lamp T5HO or 8 Lamp T8, High Bay, DLC Listed	4347	Commercial	20	567	0.1171	11,340
		Industrial	20	722	0.1171	14,440
		Schools & Gov	20	493	0.0973	9,860
		Multifamily	19	905	0.1171	17,195
		NC - Commercial	20	448	0.0924	8,960
		NC - Industrial	20	570	0.0924	11,400
		NC - Schools & Gov	20	389	0.0768	7,780
		NC - Multifamily	19	714	0.0924	13,566
	4702	Agriculture	20	714	0.1019	14,280
		NC - Agriculture	20	564	0.0804	11,280

Measure	MMID	Sectors	EUL (yrs)	Annual Savings (kWh)	Peak Demand Savings (kW)	Lifecycle Savings (kWh)
LED Fixture, ≤ 300 Watts, Replacing 8 Lamp T5HO or 10 Lamp T8, High Bay, DLC Listed	4795	Commercial	20	771	0.1592	15,420
		Industrial	20	981	0.1592	19,620
		Schools & Gov	20	670	0.1323	13,400
		Agriculture	20	971	0.1385	19,420
		NC - Commercial	20	585	0.1207	11,700
		NC - Industrial	20	744	0.1207	14,880
		NC - Schools & Gov	20	508	0.1003	10,160
		NC - Agriculture	20	737	0.1050	14,740
LED Fixture, ≤ 350 Watts, Replacing 10 Lamp T5HO or 12 Lamp T8, High Bay, DLC Listed	4796	Commercial	20	933	0.1925	18,660
		Industrial	20	1,186	0.1925	23,720
		Schools & Gov	20	810	0.1600	16,200
		Agriculture	20	1,175	0.1675	23,500
		NC - Commercial	20	664	0.1371	13,280
		NC - Industrial	20	845	0.1371	16,900
		NC - Schools & Gov	20	577	0.1139	11,540
		NC - Agriculture	20	836	0.1193	16,720

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 (see Baseline Fixture Wattage table below).

Baseline Fixture Wattage

MMID	4-Foot Fixture Description	Fixture Wattage	Percentage Weighted	Baseline Wattage
3393, 4701	4 Lamp T5HO	234	25%	227
	6 Lamp T8	224	75%	
4347, 4702	6 Lamp T5HO	355	50%	323
	8 Lamp T8	291	50%	
4795	8 Lamp T5HO	468	50%	418
	10 Lamp T8	368	50%	
4796	10 Lamp T5HO	585	50%	514
	12 Lamp T8	442	50%	

In discussions with the DLC, it was determined that the rated lifetime hours reported in the DLC *Qualified Product List*[8] 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 do list actual L70 test data, so these data were used to obtain a weighted average rated lifetime for participating models.[1]

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
04	02/2020	Updated cost
05	09/2020	Combined MMIDs 3393, 4347, 4795, and 4796 (W0095, W0096, W0098, and W0099) into single workpaper and updated efficient consumption wattage of LED fixtures; added MMIDs 4701 & 4702 (Ag counterpart measures created to offer varying incentive amounts)
06	09/2022	Updated Watts_{EE}
07	10/2023	Added NC baseline details. Updated EULs based on sector specific HOUs.

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[1] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. January 1, 2019 to June 30, 2020. Programs included LEU, BIP, MF, S&G, SBP, B&I, and Midstream. The 39 participating models comprising 28,467 units and over 50% of total measure participation have a weighted average specification sheet rated life of 110,771 hours. The EUL for each sector is calculated based on their sector HOU. All measures are capped at a 20 year EUL except Multifamily measures 3393 & 4347, which have an EUL of 19 years.

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 1,307 projects and 73,102 units from February 2018 to July 2020 is $208.75. Base cost of $17.34 from August 2018 lookups of eight T8 and T5 models. $208.75 - $17.34 = $191.41.

[3] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 172 projects and 14,236 units from April 2018 to September 2019 is $289.62. Base cost of $17.97 from August 2018 lookups of four T8 and T5 models. $289.62 - $17.97 = $271.65. Note that the costs for MMIDs 4795 and 4796 are likely higher than those for MMID 4347/4702, but their usage is 20 times less, so the same cost is applied.

[4] SPECTRUM. “Focus historical data.” 7/1/20 to 6/30/22 application date ranges for B&I, B&I Rural, and S&G. Data cross-referenced with DLC SSL QPL to determine weighted average wattage

[5] PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0.* Table 3-2 Lighting Hours of Use and Coincidence Factors by Sector. 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. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf

[7] Summit Blue Consulting. *Con Edison Callable Load Study.* May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows a multifamily housing (in unit) coincidence factor of 65% to 89%.

[8] DesignLights Consortium. *Product List*. Accessed August 2020. https://www.designlights.org/search/

DLC Listed 2x2 LED Fixtures

	Measure Details
Measure Master ID	LED Fixture, 2x2, DLC Listed: Low Output, 3400 High Output, 3401
Workpaper ID	W0097
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)	Varies by sector[1]
Incremental Cost ($/unit)	$93.15 for MMID 3400[2] $190.48 for MMID 3401[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.

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™ (DLC)-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 39 watts.

For high output 2x2 measures, the efficient condition is DesignLights Consortium™ (DLC)-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.

Annual Energy-Savings Algorithm

Low Output 2x2

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

Where:

Variable	Description	Units	Value
$Watts_{BASE}$	Baseline wattage, 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%	Watts	56, see Assumptions section
$Watts_{EE}$	Energy efficient wattage, average power consumption of DLC-listed LED fixtures less than or equal to 39 watts	Watts	28.21[4]
1,000	Conversion factor	W/kW	1,000
HOU	Hours of use	Hrs	Varies by sector, see Hours of Use by Sector table

High Output 2x2

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

Where:

Variable	Description	Units	Value
$Watts_{BASE}$	Baseline wattage, average power consumption of 2-, 3-, or 4-lamp 2G11 base fixtures, weighted between 40-watt, 50-watt, and 55-watt lamps	Watts	146, see Assumptions section
$Watts_{EE}$	Energy efficient wattage, average power consumption of DLC-listed LED fixtures less than or equal to 85 watts	Watts	33.37[4]
1,000	Conversion factor	W/kW	1,000
HOU	Hours of use	Hrs	Varies by sector; see Hours of Use by Sector table

Hours of Use by Sector

Sector	HOU[5,6]
Commercial[5]	3,730
Industrial[5]	4,745
Agriculture[5]	4,698
Schools & Government[5]	3,239
Multifamily[6]	5,950

Summer Coincident Peak Savings Algorithm

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

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[7]	0.77

Lifecycle Energy-Savings Algorithm

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

Where:

EUL= Effective useful life (see table below)

Deemed Savings

Measure	MMID	Sectors	EUL (yrs)	Annual Savings (kWh)	Peak Demand Savings (kW)	Lifecycle Savings (kWh)
Low Output	3400	Commercial	16	104	0.0214	1,664
		Industrial	13	132	0.0214	1,716
		Schools & Gov	19	90	0.0178	1,710
		Agriculture	13	131	0.0186	1,703
		Multifamily	10	165	0.0214	1,650
High Output	3401	Commercial	16	420	0.0867	6,720
		Industrial	13	534	0.0867	6,942
		Schools & Gov	19	365	0.0721	6,935
		Agriculture	13	529	0.0755	6,877
		Multifamily	10	670	0.0867	6,700

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

2 Lamp T8 Wattage	2 Lamp T8 U Bend Wattage	3 Lamp T8 Wattage	4 Lamp T8 Wattage
36	55	52	66
2%	40%	38%	20%

2-Lamp 40W 2G11 2x2	3-Lamp 40W 2G11 2x2	4-Lamp 40W 2G11 2x2
5%	25%	5%
2-Lamp 50W 2G11 2x2	**3-Lamp 50W 2G11 2x2**	**4-Lamp 50W 2G11 2x2**
5%	25%	5%
2-Lamp 55W 2G11 2x2	**3-Lamp 55W 2G11 2x2**	**4-Lamp 55W 2G11 2x2**
5%	20%	5%

In discussions with the DesignLights Consortium™, it has been determined that the rated lifetime hours reported in the DLC *Qualified Product* List[8] 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 a weighted average rated lifetime for participating models.[1]

Revision History

Version Number	Date	Description of Change
01	04/2014	Initial TRM entry
02	10/2015	Updated savings and definitions
03	10/2017	Included 2x2 measures with LLLC
04	12/2018	Updated incremental cost
05	02/2020	Updated incremental cost
06	09/2020	Removed MMIDs 4332, 4463, 4333, 4464. Updated Watts_{EE} and EUL.
07	09/2022	Updated Watts_{EE} and EUL
08	10/2023	Updated WattsEE; updated EUL to reflect individual sector HOU

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[1] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. 24 participating models comprising 6,050 units and >50% of total measure participation, have a weighted average spec sheet rated life of 59,974 hours. The EUL for each sector is calculated based on their sector HOU.

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 1,030 projects and 31,968 units from April 2018 to September 2019 is $106.37. Base cost of $13.22 from October 2019 online lookups. $106.37 - $13.22 = $93.15.

[3] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 208 projects and 8,194 units from April 2018 to September 2019 is $214.35. Base cost of $23.88 from October 2019 online lookups. $214.35 - $23.88 = $190.48.

[4] SPECTRUM. "Focus historical data." 7/1/20 to 6/30/22 application date ranges for B&I, B&I Rural, and S&G. Data cross-referenced with DLC SSL QPL to determine weighted average wattage. DLC SSL QPL only reports highest wattage for field adjustable light output fixtures. For MMID 3400, some fixtures were set to lower outputs to meet the 39W limit for this measure. Therefore, any historical projects where the DLC data showed above 39W were excluded from the average wattage calculation. All projects for MMID 3401 were less than the stated 85W limit.

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[5] PA Consulting Group. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0. March 22, 2010. Table 3.2 for nonresidential HOU and CF. 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] Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

[8] DesignLights Consortium™. *Product List.* Accessed August 2020. https://www.designlights.org/search/

Four Pin-Base LED Lamp

	Measure Details
Measure Master ID	DLC Listed, Four Pin-Base Lamp Replacing CFL, Interior, 10039 DLC Listed, Four Pin-Base Lamp Replacing CFL, Exterior, 10040
Workpaper ID	W0100
Measure Unit	Per lamp
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)	Varies by sector (see Assumptions)[1]
Incremental Cost ($/unit)	$22.68 (see Assumptions)[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 v5.0minimum) 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

$$kWh_{\text{SAVED}} = Watts_{Reduced} * HOU / 1{,}000$$

Where:

Variable	Description	Units	Value
1,000	Conversion factor	W/kW	1,000
HOU	Hours of use	Hrs	Varies by sector, see table below
$\text{Watts}_{\text{REDUCED}}$	Watt reduction	Watts	27[3]

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
Average (non-exterior)	**4,472**

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = (Watts_{Reduced}) * CF / 1{,}000$$

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[7]	0.77
Exterior	0.00

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (see table below; see Assumptions)

Deemed Savings

Measure	MMID	Sectors	EUL (yrs)	Annual Savings (kWh)	Peak Demand Savings (kW)	Lifecycle Savings (kWh)
DLC Listed, Four Pin-Base Lamp Replacing CFL, Interior	10039	Commercial	13	102	0.0210	1,326
		Industrial	11	130	0.0210	1,430
		Schools & Gov	15	88	0.0175	1,320
		Agriculture	11	128	0.0183	1,408
		Multifamily	8	162	0.0210	1,296
DLC Listed, Four Pin-Base Lamp Replacing CFL, Exterior	10040	All Sectors	11	120	0.0000	1,320

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 sector specific HOU for the interior measure and by 4,380 hours for the exterior measure.

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] The resulting value was $0.84 per watt, and applied to the average wattage reduction of 27 watts, the incremental cost is $22.68.

Revision History

Version Number	Date	Description of Change
01	10/2018	Initial TRM entry
02	10/2023	Updated EUL based on sector specific HOU and changed savings from per watt reduced to per lamp based on historical projects. New MMIDs resulted from UOM change.

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[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] SPECTRUM. The average watts reduced was determined by analyzing historical data from January 2021 – June 2023. 18,054 lamps were installed in 160 projects with an average of 27 watts reduced.

[4] PA Consulting Group. *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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[5] Tetra Tech. *ACES Deemed Savings Desk Review*. Table 1. November 3, 2010. 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] Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

LED Downlights Replacing CFL Downlight

	Measure Details
Measure Master ID	LED Fixture, Downlights: ≤ 18 Watts, Replacing 1-Lamp Pin-Based CFL Downlight, 3394
Workpaper ID	W0110
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

$$kWh_{\text{SAVED}} = (Watts_{\text{CFL}} - Watts_{\text{LEDEE}}) / 1{,}000 * HOU$$

Where:

Variable	Description	Units	Value
$Watts_{\text{CFL}}$	Wattage of 1-lamp or 2-lamp pin-based CFL downlights with 26-watt, 32-watt, or 42-watt lamps	Watts	37 as average for low wattage system; 75 as average for high wattage systems
$Watts_{\text{LEDEE}}$	Average power consumption of ENERGY STAR-rated and/or Wisconsin Focus on Energy QPL-listed LED fixture	Watts	13 for systems ≤ 18 watts; 32 for systems > 18 watts)[3]
1,000	Conversion factor	W/kW	1,000
HOU	Hours of use	Hrs	Varies by sector; see Hours of Use 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

$$kW_{\text{SAVED}} = (Watts_{\text{CFL}} - Watts_{\text{LEDEE}}) / 1{,}000 * CF$$

Where:

CF = Coincidence factor (varies by sector; see table below)

Coincidence Factor

Sector	CF
Commercial[6]	0.77
Industrial[6]	0.77
Agriculture[6]	0.67
Schools & Government[6]	0.64
Multifamily[7]	0.77

Lifecycle Energy-Savings Algorithm

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

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.

Revision History

Number	Date	Description of Change
01	04/2014	Initial TRM entry
02	08/2015	Updated savings information
03	10/2017	Updated EUL
04	12/2018	Updated incremental cost, removed MMID 3394

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[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.

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[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. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use in Commercial Applications. 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. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Coincidence Factor for Lighting in Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

[7] Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

LED Exterior Fixture, Lumen Based

	Measure Details
Measure Master ID	LED, Exterior Fixture: Low Output, ≤4,999 lumens, 4280 Mid Output, 5,000–9,999 lumens, 4281 High Output, 10,000–29,999 lumens, 4282 Very High Output, ≥30,000 lumens, 4283
Workpaper ID	W0113
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 Energy 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 = $110.34 (MMID 4280)[2] Mid Output, 5,000–9,999 lumens = $238.79 (MMID 4281)[3] High Output, 10,000–29,999 lumens = $289.38 (MMID 4282)[4] Very High Output, ≥30,000 lumens = $630.49 (MMID 4283)[5]

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

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

Where:

Variable	Description	Units	Value
$Watts_{BASE}$	Power consumption of baseline measure	Watts	Varies by lumen output, see Wattage Used for Deemed Savings Calculations table below and Assumptions
$Watts_{EE}$	Power consumption of efficient LED luminaire	Watts	varies by lumen output, see table below
1,000	Conversion factor	W/kW	1,000
HOU	Average annual run hours	Hrs	4,380[6]

Wattages Used for Deemed Savings Calculations

Measure	MMID	$Watts_{BASE}$	$Watts_{EE}$[7]
Low Output ≤4,999 lumens	4280	116	27.09
Mid Output 5,000–9,999 lumens	4281	227	60.03
High Output 10,000–29,999 lumens	4282	546	133.66
Very High Output ≥30,000 lumens	4283	1,079	330.26

Annual Deemed Savings

Measure	MMID	Commercial, Industrial, Agriculture, Schools & Gov, Multifamily	
		kWh	kW
Low Output ≤4,999 lumens	4280	389	N/A
Mid Output 5,000–9,999 lumens	4281	731	N/A
High Output 10,000–29,999 lumens	4282	1,806	N/A
Very High Output ≥30,000 lumens	4283	3,279	N/A

Summer Coincident Peak Savings Algorithm

There are no peak savings for these measures.

Lifecycle Energy-Savings Algorithm

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

Where:

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

Deemed Savings

Deemed Lifecycle Savings

Measure	MMID	Commercial, Industrial, Agriculture, Schools & Gov, Multifamily (kWh)
Low Output ≤4,999 lumens	4280	5,057
Mid Output 5,000–9,999 lumens	4281	9,503
High Output 10,000–29,999 lumens	4282	23,478
Very High Output ≥30,000 lumens	4283	42,627

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.*[8] 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.

Revision History

Version Number	Date	Description of Change
01	09/2017	Initial TRM entry
02	02/2020	Updated incremental costs
03	09/2020	Removed MMIDs 4441, 4442, 4443, and 4444. Updated Watts$_{EE}$. Reorganized sources.
04	08/2022	Updated costs MMIDs: 4280, 4281, 4283
05	09/2022	Updated Watts$_{EE}$

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[1] DesignLights Consortium. *Qualified Product List*. Accessed August 2020. https://www.designlights.org/search
Average rated life of models in the DLC “Outdoor” category is 57,756 hours. With an exterior HOU of 4,380, the EUL is 13 years.

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 716 projects and 6,330 units from January 2021 to July 2022 is $125.94. Base cost of $15.60 from July 2022 online lookups of base models, 50 - 150 watt metal halide bulbs. $125.94 - $15.60 = $110.34.

[3] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 1,253 projects and 11,978 units from January 2021 to July 2022 is $254.39. Base cost of $15.60 from July 2022 online lookups of base models, 150 - 250 watt metal halide bulbs. $254.39 - $15.60 = $238.79

[4] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 1,287 projects and 12,549 units from January 2021 to July 2022 is $311.34. Base cost of $21.95 from September 2022 online lookups of base models, 250 - 1000 watt metal halide bulbs. $311.34 - $21.95 = $289.38.

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[5] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 269 projects and 3,025 units from January 2021 to July 2022 is $655.59. Base cost of $25.10 from July 2022 online lookups of base models, 1000 watt metal halide bulbs. $655.59 - $25.10 = $630.49.

[6] 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.

[7] SPECTRUM. "Focus historical data." 7/1/20 to 6/30/22 application date ranges for B&I, B&I Rural, and S&G. Data cross-referenced with DLC SSL QPL to determine weighted average wattage.

[8] Wisconsin Focus on Energy. Default Wattage Guide. Version 1.0. 2013.

LED Fixture Downlights

	Measure Details
Measure Master ID	LED Fixture, Downlights, Interior, 10028 LED Fixture, Downlights, Exterior, 10029
Workpaper ID	W0114
Measure Unit	Per fixture
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)	Varies by sector (see Assumptions)[1]
Incremental Cost ($/unit)	$59.22 for MMID 10028[2] $76.00 for MMID 10029[3]

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 for retrofits 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).[4]

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

$$kWh_{\text{SAVED}} = Watts_{\text{REDUCED}} * HOU \ / \ 1{,}000$$

Where:

Variable	Description	Units	Value
1,000	Conversion factor	W/kW	1,000
HOU	Hours of use	Hrs	Varies by sector; see table below
$\text{Watts}_{\text{REDUCED}}$	Watt reduction	Watts	10028 (retrofit = 42, new construction = 25.5); 10029 (retrofit = 80, new construction = 32). See assumptions

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
Exterior[7]	4,380

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = \ (Watts_{\text{REDUCEDEE}}) \ * \ CF \ / \ 1{,}000$$

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 – Common Area[8]	0.77
Exterior[8]	0.00

Lifecycle Energy-Savings Algorithm

$$kWh_{\text{LIFECYCLE}} = \ kWh = * \ EUL$$

Where:

EUL = Effective useful life (see table below)[1]

Deemed Savings

Measure	MMID	Sectors	EUL (yrs)	Annual Savings (kWh)	Peak Demand Savings (kW)	Lifecycle Savings (kWh)
LED Downlights, Interior	10028	Commercial	14	157	0.0323	2,198
		NC-Commercial		95	0.0196	1,330
		Industrial	11	199	0.0323	2,189
		NC-Industrial		121	0.0196	1,331
		Schools & Gov	16	136	0.0269	2,176
		NC-Schools & Gov		83	0.0163	1,328
		Agriculture	11	197	0.0281	2,167
		NC-Agriculture		120	0.0171	1,320
		Multifamily	9	250	0.0323	2,250
		NC-Multifamily		152	0.0196	1,368
LED Downlights, Exterior	10029	All (Existing Retrofit)	12	350	0.0000	4,200
		All (New Construction)	12	140	0.0000	1,680

Assumptions

For the retrofit measures, the average watts reduced was determined by analyzing historical data from January 2021 – June 2023. For 10028, 29,271 fixtures were installed in 554 projects, with an average of 42 watts reduced per fixture. For 10029, 1,700 fixtures were installed in 135 projects, with an average of 80 watts reduced per fixture.

For new construction 10028, 815 fixtures were installed in 23 projects, with an average of 17 watts installed per fixture. To be conservative, we removed projects with fixtures of 40 watts or higher. A baseline of 42.5 watts (2.5 X average installed wattage) results in an average of 25.5 watts reduced. For 10029, 1,049 fixtures were installed in 55 projects, with an average of 32 watts reduced per fixture.

The incremental cost on a per-watt basis was calculated using the following:

$$\text{Cost in \$/W} = [\text{Actual Measure Cost Sum}] / [\text{First Year kWh Savings} \\ * 1{,}000 / \text{Average Sector Hours } (4{,}472)]$$

For the 2024 TRM, the previous incremental cost, per-watt basis, is multiplied by the new watts reduced per fixture. To be revised the following year upon historical data.

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**

Revision History

Version Number	Date	Description of Change
01	11/2017	Initial TRM entry
02	12/2018	Updated incremental cost
03	02/2020	Updated incremental cost
04	7/2023	Updated incremental cost. Removed SBP measures. Updated EULs based on sector specific HOU. Changed from watts reduced to per fixture savings. Added NC baseline. New MMIDs resulted from UOM change.

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[1] ENERGY STAR. *Qualified Product List*. Accessed November 2017. https://www.energystar.gov/productfinder/
Average rated life of 6,210 LED downlight fixtures is 51,487 hours. EUL for interior measure calculated based on sector specific HOU. Exterior measure EUL is 12 years based on 4,380 HOU.

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 1,152,763.5 watts reduced over 536 projects from 1/1/2021 to 6/30/2023 is $1.46. 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 $1.41 per watt reduced or $59.22 per fixture.

[3] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 123,147 watts reduced over 134 projects from 1/1/2021 to 6/30/2023 is $1.00. 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 $0.95 per watt reduced or $76.00 per fixture.

[4] ENERGY STAR. *Qualified Product List*. Accessed November 2017. https://www.energystar.gov/productfinder/

[5] PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use and Coincidence Factors by Sector. 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] 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. *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%.

LED Fixtures, High Bay

	Measure Details
Measure Master ID	LED Fixture, High Bay: < 155 Watts, Replacing 250 Watt HID, 3091, 4695 < 250 Watts, Replacing 320–400 Watt HID, 3092, 4696 < 250 Watts, Replacing 400 Watt HID, 3093, 4697 < 365 Watts, Replacing 400 Watt HID, 3094, 4698 < 500 Watts, Replacing 1,000 Watt HID, 3095, 4699 < 800 Watts, Replacing 1,000 Watt HID, 3096, 4700
Workpaper ID	W0115
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)	Varies by measure and sector[1]
Incremental Cost ($/unit)	< 155 Watts = $214.89 (MMIDs 3091, 4695)[2] < 250 Watts and < 365 Watts = $254.08 (MMIDs 3092, 3093, 3094, 4696, 4697, 4698)[3] < 500 Watts and < 800 Watts = $522.59 (MMIDs 3095 3096, 4699, 4700)[4]

Measure Description

High-bay LED fixtures are an energy-saving alternative to traditional standard wattage high intensity discharge (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.[5] Agriculture measures under MMIDs 4695, 4696, and 4698 assume LDL operations for a percentage of the applications,[6] 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

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

Where:

Variable	Description	Units	Value
$Watts_{\text{BASE}}$	Baseline consumption of standard HID fixture	Watts	Varies by sector; see Baseline and Efficient Lamp Consumption table below
$Watts_{\text{EE}}$	Efficient consumption of LED fixture	Watts	Varies by sector; see Baseline and Efficient Lamp Consumption table below
1,000	Conversion factor	W/kW	1,000
HOU	Hours of use	Hrs	Varies by sector; see Hours of Use by Sector table below

Baseline and Efficient Lamp Consumption

MMID	Measure	$Watts_{\text{BASE}}$[7]	$Watts_{\text{EE}}$
3091, 4695	LED Fixture, High Bay, < 155 Watts Replacing 250-Watt HID	293	102.78[8]
3092, 4696	LED Fixture, High Bay, < 250 Watts Replacing 320-Watt to 400-Watt HID	356	154.56[8]
3093, 4697	LED Fixture, High Bay, < 250 Watts Replacing 400-Watt HID	455	161.35[8]
3094, 4698	LED Fixture, High Bay, < 365 Watts Replacing 400-Watt HID	455	252.57[8]
3095, 4699	LED Fixture, High Bay, < 500 Watts Replacing 1,000-Watt HID	1,079	261.19[8]
3096, 4700	LED Fixture, High Bay, < 800 Watts Replacing 1,000-Watt HID	1,079	290.65[9]

Hours of Use by Sector

Sector	HOU
Commercial[10]	3,730
Industrial[10]	4,745
Agriculture[6] (see Assumptions)	5,698 (MMID 4695) 6,093 (MMID 4696) 4,698 (MMIDs 4697, 4699, and 4700) 6,182 (MMID 4698)
Schools & Government[10]	3,239

Summer Coincident Peak Savings Algorithm

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

Where:

CF = Coincidence factor (varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF[9]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (see table below)[1]

Deemed Savings

Average Deemed Savings for High Bay LED Fixtures

Measure	Sectors	MMID	EUL[1]	Annual kWh	kW	Lifecycle kWh
LED Fixture, High Bay:						
< 155 Watts, Replacing 250 Watt HID	Commercial	3091	20	710	0.1465	14,200
	Industrial			903	0.1465	18,060
	Schools & Government			616	0.1217	12,320
	Agriculture	4695	17	1,084	0.1274	18,428
< 250 Watts, Replacing 320–400 Watt HID	Commercial	3092	20	751	0.1551	15,020
	Industrial			956	0.1551	19,120
	Schools & Government			652	0.1289	13,040
	Agriculture	4696	15	1,227	0.1350	18,405
< 250 Watts, Replacing 400 Watt HID	Commercial	3093	20	1,095	0.2261	21,900
	Industrial			1,393	0.2261	27,860
	Schools & Government			951	0.1879	19,020
	Agriculture	4697	20	1,380	0.1967	27,600
< 365 Watts, Replacing 400 Watt HID	Commercial	3094	20	755	0.1559	15,100
	Industrial			961	0.1559	19,220
	Schools & Government			656	0.1296	13,120
	Agriculture	4698	15	1,251	0.1356	18,765
< 500 Watts, Replacing 1,000 Watt HID	Commercial	3095	20	3,050	0.6297	61,000
	Industrial			3,881	0.6297	77,620
	Schools & Government			2,649	0.5234	52,980
	Agriculture	4699	20	3,842	0.5479	76,840
< 800 Watts, Replacing 1,000 Watt HID	Commercial	3096	20	2,941	0.6070	58,820
	Industrial			3,741	0.6070	74,820
	Schools & Government			2.553	0.5045	51,060
	Agriculture	4700	20	3,704	0.5282	74,080

Historical data for agriculture measures was examined to produce fractions of standard and long daylighting applications. Agricultural HOU is a weighted average from this analysis, per the Agriculture HOU Table.

Agriculture HOU

New MMID	Standard			Long Daylighting			New HOU
	Old MMIDs	Old % of Units	Old HOU	Old MMIDs	Old % of Units	Old HOU	
4695	3806, 3091	34%	4,698	3019	66%	6,205	5,688
4696	3810, 3092	7%		3020	93%		6,093
4698	3808, 3094	2%		3021	98%		6,182

Assumptions

In discussions with the DesignLights Consortium™, it was determined that the rated lifetime hours reported in the DLC *Qualified Product List*[11] 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 a weighted average rated lifetime for participating models.[1]

Agricultural measures 4695, 4696, and 4698 have the highest HOU out of all the sectors and result in an EUL lower than the 20-year cap applied to all other sectors and remaining Agricultural measures.

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	05/2018	Updated savings and EUL
05	02/2020	Updated Incremental Cost and Sources, clarified Agriculture MMIDs
06	09/2020	Updated Watts$_{EE}$ and EUL.
07	09/2022	Updated Watts$_{EE}$ and reorganized references.
08	10/2023	Updated EUL based on sector HOU.

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[1] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. 21 participating models comprising 7,477 units and >50% of total measure participation, have a weighted average spec sheet rated life of 94,359 hours. EULs are calculated based on the sector (and measures within a sector) HOU. All but three measures (4695, 4696, and 4698) are capped at a 20 year EUL.

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 672 projects and 18,470 units from January 2018 to July 2020 is $232.87. Base cost of $17.98 from October 2019 online lookups of base models, 250 watt metal halide bulbs. $232.87 - $17.98 = $214.89.

[3] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 2,315 projects and 56,873 units from January 2018 to July 2020 is $278.42. Base cost of $24.34 from November 2020 lookups of 320 - 400 watt metal halide bulbs. $278.42 - $24.34 = $254.08.

[4] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 143 projects and 5,407 units from January 2018 to July 2020 is $547.73. Base cost of $25.14 from November 2020 lookups of 1000 watt metal halide bulbs. $547.73 - $25.14 = $522.59.

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[5] 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

[6] 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.

[7] 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.

[8] SPECTRUM. "Focus historical data." 7/1/20 to 6/30/22 application date ranges for B&I, B&I Rural, and S&G. Data cross-referenced with DLC SSL QPL to determine weighted average wattage.

[9] SPECTRUM. "Focus historical data." 1/1/18 to 6/30/22 application date ranges for B&I, B&I Rural, and S&G. Data cross-referenced with DLC SSL QPL to determine weighted average wattage.

[10] PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. Table 3.2 for nonresidential HOU and CF. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

[11] DesignLights Consortium™. *Product List.* Accessed August 2020. https://www.designlights.org/search/

LED Linear Ambient Fixture

	Measure Details
Measure Master ID	LED Fixture, Linear Ambient, Replacing: 1 or 2 Lamp(s) in Cross Section, 5445 1 or 2 Lamp(s) in Cross Section, Exterior, 5446 1 or 2 Lamp(s) in Cross Section, Exterior 24/7, 5447 3 or 4 Lamps in Cross Section, 5448 3 or 4 Lamps in Cross Section, Exterior, 5449 3 or 4 Lamps in Cross Section, Exterior 24/7, 5450
Workpaper ID	W0118
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 = Varies by sector, Exterior = 13 (MMIDs 5446, 5449), Exterior 24/7 = 6 (MMIDs 5447, 5450)[1]
Incremental Cost ($/unit)	1 or 2 Lamp(s) = $13.85 (MMIDs 5445, 5446, 5447)[2] 3 or 4 Lamps = $34.34 (MMIDs 5448, 5449, 5450)[2]

Measure Description

LED linear ambient fixtures save energy when replacing one to four T5, T8, or 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 T5, T8, or T12 luminaires.

LED linear ambient luminaires are typically a surface mount or pendant type fixture for office, retail, school, etc. applications. Because these fixtures come in many lengths and may be bolted together, the measure unit is per linear foot and measure types are based on how many lamps wide the baseline luminaire is composed of—the cross section.

Description of Baseline Condition

The baseline condition is one to four lamp(s) in cross section surface-mount or suspended fixtures in existing and new construction buildings.

Description of Efficient Condition

The efficient condition is LED products that are DesignLights Consortium™ (DLC)-listed in the Linear Ambient General Application category.

Annual Energy-Savings Algorithm

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

Where:

Variable	Description	Units	Value
$Watts_{\text{BASE}}$	Per-foot power consumption of baseline fixture	Watts	10.5 watts for 1- and 2-lamp products, weighted 56.63% and 43.37%, respectively; 25.3 watts for 3- and 4-lamp products, weighted 33.54% and 66.46%, respectively)[3,4]
$Watts_{\text{EE}}$	Per-foot power consumption of DLC-listed LED fixtures based on weighted historical participation	Watts	7.13 watts for 1- and 2-lamp products; 18.71 watts for 3- and 4-lamp products)[5]
1,000	Conversion factor	W/kW	1,000
HOU	Hours of use	Hrs	Varies by sector; see Hours of Use for Interior Fixtures table below for interior and see Assumptions for exterior fixtures

Hours of Use for Interior Fixtures

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

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

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[8]	0.77
Exterior	0.00
Exterior 24/7	1.00

Lifecycle Energy-Savings Algorithm

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

Where:

EUL= Effective useful life (see table below)

Deemed Savings

Measure	MMID	Sectors	EUL (yrs)	Annual Savings (kWh)	Peak Demand Savings (kWh)	Lifecycle Savings (kWh)
1 or 2 Lamp(s)	5445	Commercial	15	13	0.0026	195
		Industrial	12	16	0.0026	192
		Schools & Gov	17	11	0.0022	187
		Agriculture	12	16	0.0023	192
		Multifamily	9	20	0.0026	180
1 or 2 Lamp(s), Exterior	5446	All Sectors	13	15	0.0000	195
1 or 2 Lamp(s), Exterior 24/7	5447	All Sectors	6	30	0.0034	180
3 or 4 Lamp(s)	5448	Commercial	15	25	0.0051	375
		Industrial	12	31	0.0051	372
		Schools & Gov	17	21	0.0042	357
		Agriculture	12	31	0.0044	372
		Multifamily	9	39	0.0051	351
3 or 4 Lamp(s), Exterior	5449	All Sectors	13	29	0.0000	377
3 or 4 Lamp(s), Exterior 24/7	5450	All Sectors	6	58	0.0066	348

Assumptions

In discussions with the DesignLights Consortium™, it was determined that the Rated Lifetime hours reported in the DLC Qualified Product List[9] 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 a weighted average rated lifetime for participating models.[1]

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. Baseline wattage was then weighted by participation model's equivalent lumen output.[4]

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.

Revision History

Version Number	Date	Description of Change
01	10/2015	Initial TRM entry
02	10/2018	Added exterior and in-unit measures, updated cost
03	02/2020	Updated incremental costs
04	09/2020	Removed MMIDs 4620, 4621, 4789, and 4790. Updated $\text{Watts}_{\text{BASE}}$, Watts_{EE}, and EUL.
05	10/2022	Combined W0117 and W0118. Updated $\text{Watts}_{\text{BASE}}$, Watts_{EE}, Incremental Cost, and EUL.
06	10/2023	Updated EUL based on sector HOU

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[1] SPECTRUM. "Focus historical data." 7/1/20 to 6/30/22 application date ranges for B&I, B&I Rural, and S&G. 22 participating models comprise >80% of total measure participation have a weighted average spec sheet rated life of 55,425 hours. The EUL for each sector is calculated based on their sector HOU. With an HOU of 4,380 for exterior 12-hour measure, the EUL is 13 years. With an HOU of 8,760 for exterior 24-hour measure, the EUL is 6 years.

[2] SPECTRUM. "Focus historical data." 7/1/20 to 6/30/22 application date ranges for B&I, B&I Rural, and S&G. Average unit cost of 715 projects from 7/1/20 to 6/30/22 is $15.28 for 1- or 2-lamp(s) and $37.98 for 3- or 4-lamps. Base cost of $3.97 from October 2022 online lookups for Four-Foot T8 Lamp. Base Cost was then weighted by lamp quantity in cross-section per measure participation. $15.28 - $1.42 = $13.85 for 1- or 2-lamp(s). $37.98 - $3.64 = $34.34 for 3- or 4-lamps.

[3] Consortium for Energy Efficiency. *Legacy Ballast List*. Normal ballast factor. 2015. http://library.cee1.org/content/commercial-lighting-qualifying-products-lists

[4] SPECTRUM. "Focus historical data." 7/1/20 to 6/30/22 application date ranges for B&I, B&I Rural, and S&G. 1- and 2-lamp products, it was found that 56.63% of products are equivalent to 1-lamp lumen output. For 3- and 4-lamp products, it was found that 33.54% of products are equivalent to 3-lamp lumen output.

[5] SPECTRUM. "Focus historical data." 7/1/20 to 6/30/22 application date ranges for B&I, B&I Rural, and S&G. For 1- and 2-lamp products, participating models installed were 5.41W/ft and 9.38W/ft, respectively. For 3- and 4-lamp products, participating models installed were 14.73W/ft and 20.72W/ft, respectively. Values were then weighted by equivalent lamp quantities' lumen output.

[6] PA Consulting Group. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0. Table 3-2 Lighting Hours of Use and Coincidence Factors by Sector. 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
Table 1 lists 16.3 hours per day for multifamily common areas.

[8] Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

[9] DesignLights Consortium™. *Product List.* Accessed June 2022. https://www.designlights.org/search/

Linear LED Replacement Lamps

	Measure Details
Measure Master ID	2' TLED, replacing 2’ T8 or T12 Lamp, Interior, 5453 4’ or U-Bend TLED, ≤24W, replacing 4’ or U-Bend T5, T8 or T12 Lamp, Interior, 5451 4’ or U-Bend TLED, ≤24W, replacing 4’ or U-Bend T5, T8 or T12 Lamp, Exterior, 5456 4’ or U-Bend TLED, ≤24W, replacing 4’ or U-Bend T5, T8 or T12 Lamp, Exterior 24/7, 5455 4' TLED, replacing 4’ T5HO, Interior, 5452 8' TLED, replacing 8’ T8 or T12 Lamp, Interior, 5454 8' TLED, replacing 8’ T8 or T12 Lamp, Exterior, 5458 8' TLED, replacing 8’ T8 or T12 Lamp, Exterior 24/7, 5457
Workpaper ID	W0119
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)	Varies
Incremental Cost	Varies

Measure Description

Linear or tubular LEDs (TLEDs) are an energy-efficient alternative to standard linear fluorescent lamps found commonly throughout commercial, industrial, agriculture, schools and government, and multifamily sectors. These products can directly replace fluorescent lamps one-for-one and may involve replacing or removing the existing fluorescent ballast(s).

Description of Baseline Condition

The baseline conditions consist of varying T5, T8, and/or T12 fluorescent combinations (see Assumptions section).

Description of Efficient Condition

The efficient condition is DesignLights Consortium™ (DLC)-listed equipment in the “Two-Foot Linear Replacement Lamps,” “Four-Foot Linear Replacement Lamps,” “U-Bend Replacement Lamps,” “T5HO Four-Foot Linear Replacement Lamps” or “Eight-Foot Linear Replacement Lamps” general application Category. Additionally, Four-Foot Linear and U-Bend Replacement Lamps must be ≤24W. This measure is not intended to be used in refrigerated case lighting applications.

Annual Energy-Savings Algorithm

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

Where:

Variable	Description	Units	Value
$\text{Watts}_{\text{BASE}}$	Baseline wattage	Watts	See Fixture Wattage Input Values table below and Assumptions
Watts_{EE}	Energy efficient wattage	Watts	See Fixture Wattage Input Values table below
1,000	Conversion factor	W/kW	1,000
HOU	Hours of use	Hrs.	Varies by sector; see Hours of Use by Sector table below

Fixture Wattage Input Values

LED Type	MMID	$\text{Watts}_{\text{BASE}}$	Watts_{EE}[1]	IMC ($)
2' TLED, Interior	5453	20	9.71	$7.70[2]
4' TLED or U-Bend, ≤24W, Interior	5451	27.43	15.6	$5.59[3]
4' TLED or U-Bend, ≤24W, Exterior	5456	27.43	15.6	$5.59[3]
4' TLED or U-Bend, ≤24W, Exterior 24/7	5455	27.43	15.6	$5.59[3]
4' TLED, replacing T5HO, Interior	5452	62	25.33	$12.35[4]
8' TLED, Interior	5454	61	41.17	$12.92[5]
8' TLED, Exterior	5458	61	41.17	$12.92[5]
8' TLED, Exterior 24/7	5457	61	41.17	$12.92[5]

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
Exterior[8]	4,380
Exterior 24/7	8,760

Summer Coincident Peak Savings Algorithm

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

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[9]	0.77
Exterior	0.00
Exterior 24/7	1.00

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life, see table below

Deemed Savings

Deemed Savings for Linear LED Lamps

Measure	MMID	Sectors	EUL (yrs)	Annual Savings (kWh)	kW	Lifecycle Savings (kWh)
2' TLED	5453	Commercial	16[10]	38	0.0079	608
		Industrial	13[10]	49	0.0079	637
		Schools & Gov	18[10]	33	0.0066	594
		Agriculture	13[10]	48	0.0069	624
		Multifamily	10[10]	61	0.0079	610
4' TLED or U-Bend, ≤24W	5451	Commercial	15[11]	44	0.0091	660
		Industrial	12[11]	56	0.0091	672
		Schools & Gov	17[11]	38	0.0076	646
		Agriculture	12[11]	56	0.0079	672
		Multifamily	9[11]	70	0.0091	630
4' TLED, replacing T5HO	5452	Commercial	14[12]	137	0.0282	1,918
		Industrial	11[12]	174	0.0282	1,914
		Schools & Gov	16[12]	119	0.0235	1,904
		Agriculture	11[12]	172	0.0246	1,892
		Multifamily	8[12]	218	0.0282	1,744
8' TLED	5454	Commercial	14[13]	74	0.0153	1,036
		Industrial	11[13]	94	0.0153	1,034
		Schools & Gov	16[13]	64	0.0127	1,024
		Agriculture	11[13]	93	0.0133	1,023
		Multifamily	8[13]	118	0.0153	944

Measure	MMID	Sectors	EUL (yrs)	Annual Savings (kWh)	kW	Lifecycle Savings (kWh)
4' TLED or U-Bend, ≤24W, Exterior	5456	All Sectors	13[11]	52	0.0000	676
4' TLED or U-Bend, ≤24W, Exterior 24/7	5455	All Sectors	6[11]	104	0.0118	624
8' Linear LED Lamp, Exterior	5458	All Sectors	12[13]	87	0.0000	1,044
8' Linear LED Lamp, Exterior 24/7	5457	All Sectors	6[13]	174	0.0198	1,044

Assumptions

Each baseline lamp wattage is sourced from the Focus on Energy Default Wattage Guide, where a 2-foot 17-watt T8 lamp equals 20 watts, a 4-foot 54-watt T5HO lamp equals 62 watts, and an 8-foot 59 watt T8 lamp equals 61 watts.

For 4-foot T8, 4-foot T5 and U-Bend Replacement Lamps, 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.

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.

In discussions with the DesignLights Consortium™, it was determined that the Rated Lifetime hours reported in the DLC Qualified Product List often do not reflect actual L70 test data.[14] 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 a weighted average rated lifetime for participating models.[1]

Revision History

Version Number	Date	Description of Change
01	03/2015	Initial TRM entry
02	10/2017	Added 12-hour and 24-hour measures
03	12/2018	Updated incremental cost, removed MMID 4094
04	02/2020	Updated incremental cost
05	09/2020	Removed MMID 4471 and 4472. Updated Watts$_{EE}$ and EUL.
06	08/2022	Cost update
07	09/2022	Combined workpapers W0119, W0120, W0121, W0122, W0123, W0124, W0125, W0126, W0127, W0128, W0129, W0130. Updated Watts$_{EE}$, EUL, Incremental Cost.
08	10/2023	Updated EULs based on sector specific HOU

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[1] SPECTRUM. “Focus historical data.” 7/1/20 to 6/30/22 application date ranges for B&I, B&I Rural, and S&G. Data cross-referenced with DLC SSL QPL to determine weighted average wattage.

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 134 projects and 12,177 units from 7/1/20 to 6/30/22 is $13.77. Base cost of $6.07 from October 2022 online lookups of base models. $13.77 - $6.07 = $7.70.

[3] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 2,334 projects and 895,395 units from 7/1/20 to 6/30/22 is $10.67. Base cost of $5.08 from October 2022 online lookups of base models. $10.67 - $5.08 = $5.59.

[4] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 138 projects and 28,117 units from 7/1/20 to 6/30/22 is $16.63. Base cost of $4.28 from October 2022 online lookups of base models. $16.63 - $4.28 = $12.35.

[5] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 210 projects and 11,931 units from 7/1/20 to 6/30/22 is $27.30. Base cost of $14.39 from October 2022 online lookups of base models. $27.30 - $14.39 = $12.92.

[6] PA Consulting Group. *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

[7] 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

[8] 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,

[9] Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

[10] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 7/1/20 to 6/30/22 application date ranges for B&I, B&I Rural, and S&G. 13 participating models comprise >80% of total measure participation have a weighted average spec sheet rated life of 59,725 hours. The EUL for each sector is calculated based on their sector HOU.

[11] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 7/1/20 to 6/30/22 application date ranges for B&I, B&I Rural, and S&G. 47 participating models comprise >50% of total measure participation have a weighted average spec sheet rated life of 55,796 hours. The EUL for each sector is calculated based on their sector HOU. With an HOU of 4,380 for exterior 12-hour measure, the EUL is 13 years. With an HOU of 8,760 for exterior 24-hour measure, the EUL is 6 years.

[12] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 7/1/20 to 6/30/22 application date ranges for B&I, B&I Rural, and S&G. 17 participating models comprise >80% of total measure participation have a weighted average spec sheet rated life of 50,368 hours. The EUL for each sector is calculated based on their sector HOU.

[13] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 7/1/20 to 6/30/22 application date ranges for B&I, B&I Rural, and S&G. 10 participating models comprise >50% of total measure participation have a weighted average spec

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sheet rated life of 50,376 hours. The EUL for each sector is calculated based on their sector HOU. With an HOU of 4,380 for exterior 12-hour measure, the EUL is 12 years. With an HOU of 8,760 for exterior 24-hour measure, the EUL is 6 years.

[14] DesignLights Consortium™. *Product List.* Accessed June 2022. https://www.designlights.org/search/

LED Track/Mono/Accent Fixtures

	Measure Details
Measure Master ID	LED Fixture, Track/Mono/Accent, 4813
Workpaper ID	W0131
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)	Varies by sector[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. 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 equipment is an ENERGY STAR or DLC rated fixture.

Annual Energy-Savings Algorithm

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

$$= (Watts_{\text{REDUCED}}) * HOU / 1{,}000$$

Where:

Variable	Description	Units	Value
$Watts_{\text{BASE}}$	Per-fixture power consumption of current installed lighting equipment	Watts	Actual; provided by the trade ally for each project. For new construction, use 2.5X $Watts_{\text{EE}}$ value
$Watts_{\text{EE}}$	Power consumption of qualified LED fixture	Watts	Actual; provided by the trade ally for each project
1,000	Conversion factor	W/kW	1,000
HOU	Hours of use	Hrs	Varies by sector; see Hours of Use by Sector 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 – Common Area[5]	5,950

Summer Coincident Peak Savings Algorithm

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

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 – Common Area[6]	0.77

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (see table below)[1]

Deemed Savings

Deemed Savings per Watt Reduced

Measure	MMID	Sectors	Unit	EUL (yrs)	Annual Savings (kWh)	Peak Demand Savings (kWh)	Lifecycle Savings (kWh)
LED Fixture, Track/Mono/Accent	4813	Commercial	Per Watt reduced	13	3.73	0.0008	48.5
		Industrial	Per Watt reduced	10	4.75	0.0008	47.5
		Schools & Gov	Per Watt reduced	15	3.24	0.0006	48.6
		Agriculture	Per Watt reduced	10	4.70	0.0007	47.0
		Multifamily	Per Watt reduced	8	5.95	0.0008	47.6

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 new construction scenarios, a photometric and input wattage analysis was performed comparing CFL upgrade options under retired 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. In new construction applications, where a baseline fixture does not exist, the baseline wattage is defined as 2.5x the installed LED wattage.

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**

Revision History

Version Number	Date	Description of Change
01	10/2018	Initial TRM entry, replacing MMIDs 3736 and 3737
02	10/2023	Added NC baseline, removed MMID 4814, updated EULs based on sector specific HOU.

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[1] Average rated life of ENERGY STAR and DLC listed products divided by average nonresidential sector hours = 47,. EUL calculated based on sector specific HOU 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] ENERGY STAR. *Qualified Product List*. Accessed November 2017. https://www.energystar.gov/productfinder/

[4] PA Consulting Group. *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] Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

LED Troffer, 1x4 or 2x4, Replacing 4' 1- and 2-Lamp T8 Troffer

	Measure Details
Measure Master ID	LED Troffer, 1x4 or 2x4, Replacing 4-Foot 1- or 2-Lamp T8 Troffer, 5459
Workpaper ID	W0132
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)	Varies by sector[1]
Measure Incremental Cost ($/unit)	$84.81[2]

Measure Description

LED 1x4 and 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.

Description of Baseline Condition

The baseline condition is 4-foot 1- and 2-lamp T8 troffers in existing buildings.

Description of Efficient Condition

The efficient condition is LED products that are DesignLights Consortium™ (DLC)-listed in the “1x4 Luminaires for Ambient Lighting of Interior Commercial Spaces,” “Integrated Retrofit Kits for 1x4 Luminaires,” “Linear Retrofit Kits for 1x4 Luminaires,” “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 ≤ 43 watts.

Annual Energy-Savings Algorithm

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

Where:

Variable	Description	Units	Value
$Watts_{\text{BASE}}$	Baseline wattage, or average power consumption of 1-lamp 32-watt T8 and 2-lamp 32-watt T8, weighted 50%/50%	Watts	43.56 watts[3]
$Watts_{\text{EE}}$	Energy efficient wattage	Watts	29.84 watts[4]
1,000	Conversion factor	W/kW	1,000
HOU	Hours of use	Hrs	Varies by sector; see Hours of Use by Sector table below

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[6]	5,950

Summer Coincident Peak Savings Algorithm

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

Where:

CF = Coincidence (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[7]	0.77

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (see table below)[1]

Deemed Savings

Deemed Savings

Measure	MMID	Sectors	EUL (yrs)	Annual Savings (kWh)	Peak Demand Savings (kWh)	Lifecycle Savings (kWh)
LED Troffer, 1x4 or 2x4, Replacing 4' 1- and 2-Lamp T8 Troffer	5459	Commercial	16	51	0.0106	816
		Industrial	13	65	0.0106	845
		Schools & Gov	19	44	0.0088	836
		Agriculture	13	64	0.0092	832
		Multifamily	10	82	0.0106	820

Assumptions

In discussions with the DesignLights Consortium™, it was determined that the rated lifetime hours reported in the DLC *Qualified Product List* often do not reflect actual L70 test data.[8] 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 a weighted average rated lifetime for participating models.[1]

Revision History

Version Number	Date	Description of Change
01	01/2013	Initial TRM entry
02	08/2015	Updated savings information
03	09/2017	Updated to include 1x4 LED troffer without controls (MMID 3760) and with controls (MMID 4334)
04	09/2020	Removed MMID 4334 and 4465. Updated Watts$_{EE}$ and EUL.
05	09/2022	Merged workpaper W0132 & W0134. Updated Watts$_{EE,}$ EUL, and Incremental Cost.
06	10/2023	Updated EULs based on sector specific HOU.

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[1] SPECTRUM. "Focus historical data." 7/1/20 to 6/30/22 application date ranges for B&I, B&I Rural, and S&G. 10 participating models comprising >50% of total measure participation have a weighted average spec sheet rated life of 59,937 hours. EULs calculated based on sector specific HOU.

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 291 projects and 20,374 units from 7/1/20 to 6/30/22 is $90.65. Base cost of $5.96 from online lookups of 1.5X 32W T8 lamps. Accessed October 2022. $90.65 - $5.96 = $84.69.

[3] Consortium for Energy Efficiency. "Legacy Ballast List." 2015.

[4] SPECTRUM. "Focus historical data." 7/1/20 to 6/30/22 application date ranges for B&I, B&I Rural, and S&G. Data cross-referenced with DLC SSL QPL to determine weighted average wattage.

[5] PA Consulting Group. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0. Table 3-2 Lighting Hours of Use and Coincidence Factors by Sector. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

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[6] Tetra Tech. *ACES Deemed Savings Desk Review*. Table 1. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf

[7] Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf Tetra Tech. *ACES Deemed Savings Desk Review*. Table 1. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf

[8] DesignLights Consortium™. *Product List.* Accessed June 2022. https://www.designlights.org/search/

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
Workpaper ID	W0133
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)	Varies by sector[1]
Incremental Cost	$106.02[2]

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.

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™ (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 55 watts or less.

Annual Energy-Savings Algorithm

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

Where:

Variable	Description	Units	Value
$Watts_{BASE}$	Average power consumption of three-lamp, 32-watt T8 and 4-lamp, 32-watt T8, weighted 50% each	Watts	97.3 watts[3]
$Watts_{EE}$	Energy efficient wattage	Watts	39.63 watts[4]
1,000	Conversion factor	W/kW	1,000
HOU	Hours of use	Hrs	Varies by sector; see Hours of Use by Sector table below

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[6]	5,950

Summer Coincident Peak Savings Algorithm

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

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[7]	0.77

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (see table below)[1]

Deemed Savings

Deemed savings for LED Replacement of 4-Foot T8

MMID	Sector	EUL (yrs)	Annual Savings (kWh)	Peak Demand Savings (kW)	Lifecycle Savings (kWh)
3111	Commercial	17	215	0.0444	3,655
	Industrial	13	274	0.0444	3,562
	Schools & Gov	19	187	0.0369	3,553
	Agriculture	13	271	0.0386	3,523
	Multifamily	10	343	0.0444	3,430

Assumptions

In discussions with the DesignLights Consortium™, it was determined that the rated lifetime hours reported in the DLC *Qualified Product List* often do not reflect actual L70 test data.[8] 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.

Revision History

P	Date	Description of Change
01	01/2013	Initial TRM measure
02	08/2015	Updated savings information
03	11/2016	Updated savings information and definitions
04	10/2017	Updated EUL
05	11/2017	Added 2x4 measure with LLLC
06	02/2020	Updated incremental cost
07	09/2020	Removed MMID 4335 and 4466. Updated Watts$_{EE}$ and EUL.
08	09/2022	Updated Watts$_{EE}$ and EUL
09	10/2023	Updated EULs based on sector specific HOU.

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[1] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. 37 participating models comprise >50% of total measure participation have a weighted average spec sheet rated life of 62,168 hours. EULs calculated based on sector specific HOU.

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 3,413 projects and 247,509 units from January 2018 to July 2020 is $114.00. Base cost of $7.98 from October 2019 online lookups of 32 watt T8 lamps, average of 3x and 4x. $114.00 - $7.98 = $106.02.

[3] Consortium for Energy Efficiency. *Legacy Ballast List*. 2015.

[4] SPECTRUM. "Focus historical data." 7/1/20 to 6/30/22 application date ranges for B&I, B&I Rural, and S&G. Data cross-referenced with DLC SSL QPL to determine weighted average wattage. DLC SSL QPL only reports highest wattage for field adjustable light output fixtures. Some fixtures were set to lower outputs to meet the 55W limit for this measure. Therefore, any historical projects where the DLC data showed above 55.5W were excluded from the average wattage calculation.

[5] PA Consulting Group. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0. Table 3-2 Lighting Hours of Use and Coincidence Factors by Sector. March 22, 2010.
https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

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[6] Tetra Tech. *ACES Deemed Savings Desk Review*. Table 1. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluation report.pdf

[7] Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

[8] DesignLights Consortium™. *Product List.* Accessed August 2020. https://www.designlights.org/search/

Mogul Screw-Base (E39) Light Emitting Diode Lamp

	Measure Details
Measure Master ID	LED Lamp, DLC: High/Low-Bay Mogul Screw-Base (E39), 10042 High/Low-Bay Mogul Screw-Base (E39), Agriculture, 10044 Mogul Screw-Base (E39), Exterior, 10043
Workpaper ID	W0135
Measure Unit	Per lamp
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)	Varies by sector[1]
Incremental Cost ($/unit)	$75.96 for interior (MMIDS 3962 and 4703), $86.75 for exterior (MMID 3963)[2]

Measure Description

This measure is replacing interior or exterior HID, compact fluorescent or incandescent lighting with mogul screw bases (E39).

Description of Baseline Condition

The baseline equipment is interior or exterior HID, compact fluorescent or incandescent lighting with mogul screw bases (E39).

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

$$kWh_{\text{SAVED}} = Watts_{\text{REDUCED}} * HOU / 1{,}000$$

Where:

Variable	Description	Units	Value
1,000	Conversion factor	W/kW	1,000
HOU	Hours of use	Hrs	Varies by sector; see Hours of Use by Sector table below
$Watts_{\text{REDUCED}}$	Wattage reduction per fixture	Watts	258 (MMID 3962); 391 (MMID 4703); 172 (MMID 3963); see Assumptions[1]

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

$$kW_{\text{SAVED}} = (Watts_{REDUCED}) * CF / 1{,}000$$

Where:

CF = Coincidence factor (varies by sector; see Coincidence Factor 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

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

Where:

EUL = Effective useful life (see table below)[1]

Deemed Savings

Deemed Savings

Measure	MMID	Sectors	EUL (yrs)	Annual Savings (kWh)	Peak Demand Savings (kW)	Lifecycle Savings (kWh)
High/Low-Bay Mogul Screw-Base (E39)	10042	Commercial	15	961	0.1984	14,415
		Industrial	12	1,222	0.1984	14,664
		Schools & Gov	18	834	0.1649	15,012
		Multifamily	10	1,533	0.1984	15,330
High/Low-Bay Mogul Screw-Base (E39), Agriculture	10044	Agriculture	12	1,837	0.2620	22,044
Mogul Screw-Base (E39), Exterior	10043	All Sectors	13	751	0.0000	9,763

Assumptions

The average watts reduced was determined by analyzing historical data from January 2021 – June 2023. For MMID 3962, 3,162 lamps were installed in 81 projects with an average of 258 watts reduced. For MMID 4703, 36 lamps were installed in 8 projects with an average of 391 watts reduced. For MMID 3963, 9,111 lamps were installed in 460 projects with an average of 172 watts reduced.

Revision History

Version Number	Date	Description of Change
01	11/2016	Initial release
02	10/2017	Updated EUL
03	02/2020	Updated measure description and baseline condition text and baseline technology incremental cost
04	12/2020	Added Ag sector MMID
05	08/2022	Updated Cost
06	10/2023	Updated EUL based on sector specific HOU and changed savings from per watt reduced to per lamp based on historical projects. New MMIDs resulted from UOM change.

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[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. EUL based on sector specific HOU for MMIDs 3962 and 4703; MMID 3963 EUL based on 4,380 HOU for all sectors.

[2] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM.
Average cost of new mogul base LED lamps from January 2021 to June 2022 is $90.85 for interior and $102.25 for exterior. Base cost is $14.89 for interior and $15.50 for exterior per August 2022 online lookups at 1000bulbs.com, lightingsupply.com, amazon.com, and bulbs.com. For interior, lighting is assumed to be 80% HID, 10% CFL, and 10% incandescent. For exterior, lighting is assumed to be 90% HID, 5% CFL, and 5% incandescent. The incremental cost is therefore $75.96 for interior and $86.75 for exterior.

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[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] Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Bi-Level Controls for Interior and Parking Garages

	Measure Details
Measure Master ID	LED Fixture, Bi-Level: Stairwell and Passageway, 3097 Lighting Controls, Bi-Level: Parking Garage Fixtures, Dusk to Dawn, 5063 Parking Garage Fixtures, 24 Hour, 5064
Workpaper ID	W0136
Measure Unit	MMID 3097: Per fixture MMIDs 5063 and 5064: Per watt controlled
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	MMID 3097 = Light Emitting Diode (LED) MMIDs 5063 and 5064 = Controls
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)	LED Fixture = Varies by sector[1], Lighting Controls = 8 (MMIDs 5063 and 5064)[2]
Incremental Cost ($/unit)	See Incremental Cost By Measure table

Measure Description

Numerous existing installations use LED, fluorescent, ceramic metal halide, and pulse-start metal halide fixtures to light their interior stairwells and passageways as well as parking garages. These fixtures commonly operate 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 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, fluorescent, ceramic metal halide, and pulse-start metal halide fixture input wattages with no lighting controls at building interiors and parking garages.

Description of Efficient Condition

The efficient condition is individually controlled light fixtures that may include dimming, stepped dimming, high-low ballast controls, or a combination. Control must include a passive infrared or ultrasonic occupancy sensor (or both) with a fail-safe feature (where it 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

$$kWh_{\text{SAVED}} = kWh_{BASE} - kWh_{EE}$$

$$kWh_{\text{BASE}} = Watts_{\text{BASE}} * HOU / 1{,}000$$

$$kWh_{\text{EE}} = Watts_{\text{EE}} * HOU / 1{,}000 * [(1 - SF_{\text{OCC}}) + SF_{\text{OCC}} * (1 - SF_{\text{DIM}})]$$

Where:

Variable	Description	Units	Value
kWh_{BASE}	Energy consumption of baseline equipment (standard non-controlled fixture)	kWh	
kWh_{EE}	Energy consumption of efficient equipment (bi-level controlled fixture)	kWh	
$Watts_{BASE}$	Input wattage of the baseline fixture	Watts	57.4 for MMID 3097,[1] user input for MMIDs 5063 and 5064
HOU	Hours of use	Hrs	8,760 for parking garages, 4,380 for dusk to dawn use, varies by sector for interior; see Interior Hours of Use by Sector table
1,000	Conversion factor	W/kW	1,000
$Watts_{EE}$	Input wattage of efficient fixture on full power	Watts	36.8 for MMID 3097,[2] $Watts_{BASELINE}$ for MMIDs 5063 and 5064
SF_{OCC}	Occupancy savings factor, percentage of hours in unoccupied mode	%	73% for MMID 3097,[3] 56.3% for MMIDs 5063 and 5064[4]
SF_{DIM}	Dimming savings factor, percentage dimmed in unoccupied mode	%	50% for MMID 3097,[5] 60% for MMIDs 5063 and 5064[6]

Interior Hours of Use by Sector

Sector	Hours of Use
Commercial[7]	3,730
Industrial[9]	4,745
Agriculture[9]	4,698
Schools & Government[9]	3,239
Multifamily[8]	5,950

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = kWh_{\text{SAVED}} / HOU * CF$$

Where:

CF = Coincidence factor (1 for 24/7 parking; 0 for dusk to dawn parking; varies by sector for interior; see table below)

Interior Coincidence Factor by Sector

Sector	CF
Commercial[9]	0.77
Industrial[9]	0.77
Agriculture[9]	0.67
Schools & Government[9]	0.64
Multifamily[9]	0.77

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = [1,2] See table below

Deemed Savings

Annual and lifecycle savings are shown in the following table.

Annual and Lifecycle Savings

Measure	MMID	Unit	Sector	EUL[1,2] (yrs)	Annual Savings (kWh)	Peak Demand Savings (kW)	Lifecycle Savings (kWh)
LED Fixture, Bi-Level, Stairwell and Passageway	3097	Per fixture	Commercial	15	127	0.0262	1,905
			Industrial	15	161	0.0262	2,415
			Agriculture	15	160	0.0228	2,400
			Schools & Gov	15	110	0.0218	1,650
			Multifamily	12	202	0.0262	2,424
Lighting Controls, Bi-Level, Parking Garage Fixtures, Dusk to Dawn	5063	Per watt reduced	All	8	1.48	0.0000	11.8
Lighting Controls, Bi-Level, Parking Garage Fixtures	5064		All	8	2.96	0.0003	23.7

Assumptions

It was assumed that an exterior lamp for dusk to dawn use is “on” for an average of 4,380 hours (or 8,760 hours for 24/7 parking garages). Savings for interior are based on the sector hours.

General bi-level controls are able to and must achieve at least a 50% reduction in power requirements. This value is used for the dimming savings factor for stairwell and passageway measures.

For parking garage measures, the California Energy Commission indicates high and low wattages as shown in the table below. From this data, 60% was used as conservative value for the dimming savings factor.

High and Low Wattages for Dimming Savings Factor[8]

Site	High Wattage	Low Wattage	SF_{DIM}
Site 1	165	77	53.3%
Site 2	47	16	66.0%
Site 3	70	7	90.0%
Average	**282**	**100**	**64.5%**

Incremental Costs

Incremental costs are shown in the following table.

Incremental Cost by Measure

Measure	MMID	Unit	Incremental Cost
LED Fixture, Bi-Level, Stairwell and Passageway	3097	Per fixture	\$215.15[10]
Lighting Controls, Bi-Level, Parking Garage Fixtures, Dusk to Dawn	5063	Per watt controlled	\$0.78[11]
Lighting Controls, Bi-Level, Parking Garage Fixtures	5064		\$0.78[13]

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
04	10/2020	Updated savings algorithm, removed MMID 3343, replaced MMIDs 3251 and 3252 with new MMIDs that are per watt controlled
05	10/2023	Updated EUL based on sector specific HOU

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[1] Consortium for Energy Efficiency. *Legacy Ballast List*. Normal ballast factor and two-lamp, 32-watt T8 lamps. 2015. http://library.cee1.org/content/commercial-lighting-qualifying-products-lists
Average input watts for 2-lamp, 32 watts per lamp, normal ballast factor (155 models).

[2] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. January 2019 through September 2020. Participation data for MMID 3097 and online lookups performed in October 2020 show that the average of participating products is 36.8 watts.

[3] California Energy Commission. Public Interest Energy Research Program. *Project 5.1 Bi-Level Stairwell Fixture Performance Final Report.* October 2005. ww2.energy.ca.gov/publications/displayOneReport_cms.php?pubNum=CEC-500-2005-141-A16
Average of “Time Dimmed(%)” across the four test sites during weekday operation (Table 2, pg. 22). Also cited by the New York TRM Version 7.0.

[4] California Energy Commission. Public Interest Energy Research Program. *Case Study: Bi-Level LED Parking Garage Luminaires.* https://cltc.ucdavis.edu/sites/default/files/files/publication/case-study-bi-level-led-garage-luminaires.pdf
Average occupied across the three test sites is 43.7%, therefore the occupancy savings factor is 56.3%. Also cited by the New York TRM Version 7.0.

[5] The incentive catalog requirement for this measure is that when in unoccupied mode it cannot exceed 50% of full wattage, making the dimming savings factor = 100% - 50% = 50%.

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[6] California Energy Commission. Public Interest Energy Research Program. *Case Study: Bi-Level LED Parking Garage Luminaires*. https://cltc.ucdavis.edu/sites/default/files/files/publication/case-study-bi-level-led-garage-luminaires.pdf
Average dimmed across the three test sites is 64.5%, conservatively rounded to 60%.

[7] PA Consulting Group. 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. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

[8] 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

[9] Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) coincidence factor of 65% to 89%.

[10] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. 2016 to 2018.
Average cost of 1,939 units over 101 projects.

[11] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM for MMIDs 3251 and 3252. January 2019 to March 2020.
Average cost of 1,158 fixtures controlled over 29 projects is $0.78 per watt controlled, with an average of 81 watts controlled per fixture.

LED Signage Retrofit

	Measure Details
Measure Master ID	LED, Signage Retrofit, Interior, 3903 LED, Signage Retrofit, Exterior, 3904
Workpaper ID	W0138
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)	Varies by sector[1]
Incremental Cost ($/unit)	Interior = $3.55[2] (MMID 3903) Exterior = $2.35[3] (MMID 3904)

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

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

Where:

Variable	Description	Units	Value
$Watts_{BASE}$	Power consumption of baseline installed signage system	Watts	
$Watts_{EE}$	Power consumption of LED signage product	Watts	
1,000	Conversion factor	W/kW	1,000
HOU	Hours of use	Hrs	Varies by sector; see Hours of Use by Sector table below
$Watts_{REDUCED}$	Watt reduction	Watts	

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

Summer Coincident Peak Savings Algorithm

Exterior applications have no summer coincident peak savings.

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

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[7]	0.77
Exterior	0.00

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (see table below)[1]

Deemed Savings

Annual and Lifecycle Savings (per watt reduced)

MMID	Sector	EUL (yrs)	Annual Savings (kWh)	Peak Demand Savings (kW)	Lifecycle Savings (kWh)
3903	Commercial	13	3.73	0.0008	48.5
3903	Industrial	11	4.75	0.0008	52.2
3903	Agriculture	11	4.70	0.0007	51.7
3903	Schools & Government	15	3.24	0.0006	48.6
3903	Multifamily	8	5.95	0.0008	47.6
3904	All	11	4.38	0.0000	48.2

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:

$(kWh_{\text{SAVED}}$ / Incremental Cost per foot) / HOU * 1,000$

Revision History

Version Number	Date	Description of Change
01	06/2016	Initial TRM entry.
02	10/2017	Updated EUL.
03	12/2020	Updated cost.
04	10/2023	Updated MMID 3903 EUL based on sector specific HOU and MMID 3094 lifecycle kWh (rounding).

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[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. EUL for MMID 3903 is calculated based on sector specific HOU; MMID 3904 EUL is 11 years based on 4,380 HOU for all sectors.

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 12 projects and 2,759 units from March 2018 to November 2019 is $3.65 per watt reduced. Base cost of $0.10 per watt reduced estimated from Decembver 2020 online lookups of T8 and metal halide lamps

[3] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 328 projects and 251,914 units from January 2018 to July 2020 is $2.45 per watt reduced. Base cost of $0.10 per watt reduced estimated from December 2020 online lookups of T8 and metal halide lamps.

[4] PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use in Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

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[5] Tetra Tech. *ACES Deemed Savings Desk Review*. Table 1. November 3, 2010. 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 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.

[7] Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

LED, Horizontal Case Lighting

	Measure Details
Measure Master ID	LED, Horizontal Case Lighting, 3114
Workpaper ID	W0143
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)	112
Peak Demand Reduction (kW)	0.0174
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	1,120
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$27.17[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

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

Where:

Variable	Description	Units	Value
$Watts_{BASE}$	Wattage of linear fluorescent case lighting	Watts	15 watts for 4 feet of 60-watt fixtures[3]
$Watts_{EE}$	Wattage of LED case lighting	Watts	3.01 watts per foot[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	Conversion factor	W/kW	1,000
HOU	Average annual run hours	Hrs	6,471[6]

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = ((Watts_{\text{BASE}} - Watts_{\text{EE}}) + (Watts_{\text{BASE}} - Watts_{\text{EE}}) / COP) / 1{,}000$$

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (10 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).

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
05	02/2020	Updated incremental cost
06	09/2022	Updated $Watts_{EE}$, HOU, and EUL

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[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 6,471, the EUL is 10 years.

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 141 projects and 32,626 units from April 2018 to September 2019 is $27.90. Base cost of $0.73 per foot. $27.90 - $0.73 = $27.17.

[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] SPECTRUM. “Focus historical data.” 7/1/20 to 6/30/22 application date ranges for B&I, B&I Rural, and S&G. Data cross-referenced with DLC SSL QPL to determine weighted average wattage.

[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] Pennsylvania Statewide Act 129. 2014 Commercial & Residential Light Metering Study. January 13, 2014. Table 4-13, page 55. https://www.puc.pa.gov/pcdocs/1340978.pdfThe metering study found the average hours for a grocery store were 6,471 hours/year. Assume that if grocery store is open, the refrigerated case lights are on.

LED, Vertical Case Lighting, Replacing Linear Fluorescent

	Measure Details
Measure Master ID	LED, Reach-In Refrigerated Case, Replacing T12 or T8, 2456
Workpaper ID	W0144
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)	441
Peak Demand Reduction (kW)	0.068
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	4,410
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$60.40[2]

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

$$kWh_{\text{SAVED}} = ((Watts_{\text{BASE}} - Watts =) + (Watts = - Watts_{\text{EE}}) / COP) / 1{,}000 * HOU$$

Where:

Variable	Description	Units	Value
$Watts_{BASE}$	Wattage of linear fluorescent case lighting	Watts	60[3]
$Watts_{EE}$	Wattage of LED case lighting	Watts	21.15[4]
COP	Coefficient of performance		1.52 weighted average: 2.3 for non-self-contained coolers,[5] 1.4 for non-self-contained freezers,[5] 0.5 for self-contained coolers,[6] 0.6 for self-contained freezers[6]
1,000	Conversion factor	W/kW	1,000
HOU	Average annual run hours	Hrs	6,471[7]

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 (= 10 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.

Revision History

Version Number	Date	Description of Change
01	03/2016	Initial TRM entry
02	04/2017	Added MMID 4095
03	10/2017	Updated EUL
04	12/2018	Updated incremental cost, removed MMID 4095
05	02/2020	Updated incremental cost
06	09/2022	Updated $Watts_{EE}$, HOU, and EUL

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[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 6,471, the EUL is 10 years.

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 758 projects and 20,599 units from April 2018 to September 2019 is $67.29. October 2019 online lookups of 3 models show average base cost of $6.89. $67.29 - $6.89 = $60.40.

[3] 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

[4] SPECTRUM. “Focus historical data.” 7/1/20 to 6/30/22 application date ranges for B&I, B&I Rural, and S&G. Data cross-referenced with DLC SSL QPL to determine weighted average wattage.

[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. 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.

[6] PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

[7] Pennsylvania Statewide Act 129. 2014 Commercial & Residential Light Metering Study. January 13, 2014. Table 4-13, page 55. https://www.puc.pa.gov/pcdocs/1340978.pdf The metering study found the average hours for a grocery store were 6,471 hours/year. Assume that if grocery store is open, the refrigerated case lights are on.

LED Exit Signs

	Measure Details
Measure Master ID	LED Exit Sign, Retrofit, 2768 LED Exit Sign, Retrofit, Pack-Based, 4687
Workpaper ID	W0148
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[1]
Incremental Cost ($/unit)	Prescriptive = $16.24 (MMID 2768)[2] Pack-Based = $10.49 (MMID 4687)[3]

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.[4] 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:

Variable	Description	Units	Value
$Watts_{BASE}$	Wattage of baseline measure	Watts	11 for CFL exit sign, 35 for incandescent exit sign[5]
$Watts_{EE}$	Wattage of LED exit sign	Watts	1.67 for MMID 2768,[6] 4.0 for MMID 4687[7]
1,000	Conversion factor	W/kW	1,000
HOU	Hours of use	Hrs	8,760[8]
ISR	In-service rate		1 for prescriptive measures, 0.66 for pack-based measures[9]

Summer Coincident Peak Savings Algorithm

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

Where:

CF = Coincidence factor (1.0)[8]

Lifecycle Energy-Savings Algorithm

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

Where:

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

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).

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	03/2018	Added pack-based measure

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[1] 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.

[2] 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.

[3] Quote from Resource Action Programs. March 2018.

[4] ENERGY STAR. "ENERGY STAR Savings Calculator." http://www.energystar.gov/index.cfm?c=exit_signs.pr_exit_signs

[5] 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

[6] 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.

[7] 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.

[8] 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

[9] 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.

[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

LED Fixtures, High-Bay Replacing Linear Fluorescent

	Measure Details
Measure Master ID	LED Fixture, High Bay, DLC Listed: ≤ 85 Watts, Replacing T8 or vT12 Strip Fixtures, 5460 ≤ 125 Watts, Replacing T12HO Strip Fixtures, 5461
Workpaper ID	W0304
Measure Unit	Per fixture
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)	Varies by sector[1]
Incremental Cost ($/unit)	≤85 Watts = $157.87 (MMID 5460)[2] ≤125 Watts = $137.40 (MMID 5461)[3]

Measure Description

LED high-bay fixtures save energy when replacing fluorescent lamp products by providing a similar lumen output with lower input wattage. These products can be installed on a one-for-one basis to replace fluorescent lamp strip fixtures.

Description of Baseline Condition

For 5460, the baseline condition is fluorescent strip fixtures with a similar lumen output (approximately 10,100 lumens), including four lamp 4-foot T8, four lamp 4-foot T12, two lamp 8-foot T8, and two lamp 8-foot T12. For new construction applications, the baseline references T8 lamp configurations only.

For 5461, the baseline condition is fluorescent strip fixtures with a similar lumen output (approximately 15,800 lumens), including four lamp 4-foot T12HO and two lamp 8-foot T12HO. This measure is not eligible for new construction as the baseline lamps are T12HOs.

The average of the fixture wattages for four lamp 4-foot T8, four lamp 4-foot T12, two lamp 8-foot T8 and two lamp 8-foot T12 was used to generate the baseline wattage for measures 5460. The average fixture wattages for four lamp 4-foot T12HO and two lamp 8-foot T12HO was used to generate the baseline wattage for measures 5461.

Description of Efficient Condition

The efficient condition is a DesignLights Consortium™ (DLC)-listed fixture listed in the High-Bay General Application, consuming less than or equal to the wattage respective to its measure name.

Annual Energy-Savings Algorithm

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

Where:

Variable	Description	Units	Value
$Watts_{\text{BASE}}$	Average power consumption of respective T8, T12, or T12HO lamp configuration, fluorescent strip fixture	Watts	See Baseline and Efficient Lamp Consumption table below
$Watts_{\text{EE}}$	Efficient consumption of LED fixture	Watts	See Baseline and Efficient Lamp Consumption table below
HOU	Hours of use	Hrs	Varies by sector; see Hours of Use by Sector table below
1,000	Conversion factor	W/kW	1,000

Baseline and Efficient Lamp Consumption

Measure	$Watts_{\text{BASE}}$[4]	$Watts_{\text{EE}}$[5,6]
Existing Building: LED Fixture, ≤ 85 Watts, Replacing T8 or T12 Strip Fixtures, High-Bay, DLC Listed, 5460	118	85
New Construction: LED Fixture, ≤ 85 Watts, Replacing T8 or T12 Strip Fixtures, High-Bay, DLC Listed, 5460	113.5	85
LED Fixture, ≤ 125 Watts, T12HO Strip Fixtures, High-Bay, DLC Listed, 5461	233	125

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

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

Where:

CF = Coincidence factor (varies by sector, see Coincidence Factor by Sector table below)

Coincidence Factor by Sector

Sector	HOU
Commercial[7]	0.77
Industrial[7]	0.77
Agriculture[7]	0.67
Schools & Government[7]	0.64
Multifamily[9]	0.77

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = See tables below

Deemed Savings

Annual and Lifecycle Savings by Measure

Measure	MMID	Sectors	EUL (yrs)	Annual Savings (kWh)	Peak Demand Savings (kWh)	Lifecycle Savings (kWh)
LED Fixture, ≤ 85 Watts, Replacing T8 or T12 Strip Fixtures, High Bay, DLC Listed	5460	Commercial	20	123	0.0254	2,460
		Industrial	20	157	0.0254	3,140
		Schools & Gov	20	107	0.0211	2,140
		Agriculture	20	155	0.0221	3,100
		Multifamily	19	196	0.0254	3,724
		NC - Commercial	20	106	0.0219	2,120
		NC - Industrial	20	135	0.0219	2,700
		NC - Schools & Gov	20	92	0.0182	1,840
		NC - Agriculture	20	134	0.0191	2,680
		NC - Multifamily	19	170	0.0219	3,230
LED Fixture, ≤ 125 Watts, T12HO Strip Fixtures, High Bay, DLC Listed	5461	Commercial	20	403	0.0832	8,060
		Industrial	20	512	0.0832	10,240
		Schools & Gov	20	350	0.0691	7,000
		Agriculture	20	507	0.0724	10,140
		Multifamily	19	643	0.0832	12,217

Assumptions

Fixture weightings are not known, so a straight average of fixture wattages was used for each measure.

In discussions with the DLC, it was determined that the rated lifetime hours reported in the DLC *Qualified Product* List[10] 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 do list actual L70 test data, so these data were used to obtain a weighted average rated lifetime for participating models.[1]

Revision History

Version Number	Date	Description of Change
01	09/2022	Initial TRM entry
02	10/2023	Added NC baseline detail; only applicable to MMID 5460. Updated EULs based on sector specific HOU.

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[1] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. January 1, 2019 to June 30, 2020. Programs included LEU, BIP, MF, S&G, SBP, B&I, and Midstream.
The 39 participating models comprising 28,467 units and over 50% of total measure participation have a weighted average specification sheet rated life of 110,771 hours. The EUL for each sector is calculated based on their sector HOU. All sectors are capped at a 20 year EUL except Multifamily which has a 19 year EUL.

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM.
Average unit cost of 136 projects and 6,466 units from January 2021 to July 2022 which have LED high bay wattage ≤85W is $171.86. Base cost of $13.99 is average of October 2019 online lookups for workpapers W0133 and W0094. $171.86 - $13.99 = $157.87.

[3] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM.
Average unit cost of 576 projects and 28,281 units from January 2021 to July 2022 which have LED high bay wattage ≤125W is $172.28. Base cost of $34.88 is average of October 2019 online lookups for workpaper W0094 and online lookups for four T8HO lamps from July 2022. $172.28 - $34.88 = $137.40.

[4] *Focus on Energy Default Wattage Guide*. Version 1.0. 2013. Average input watts of four lamp 4-foot T8, four lamp 4-foot T12, two lamp 8-foot T8, and two lamp 8-foot T12 = 118 watts. Average input watts of four lamp 4-foot T8 and two lamp 8-foot T8 = 113.5 watts. Average input watts of four lamp 4-foot T12HO and two lamp 8-foot T12HO = 233 watts.

[5] Online lookups on 1000bulbs.com, HomeDepot.com, Amazon.com, and store.usesi.com of spec sheet lumens for T8, T12, and T12HO lamps, July 2022. Average lumens of four lamp 4-foot T8, four lamp 4-foot T12, two lamp 8-foot T8, and two lamp 8-foot T12 = 10,100 lumens. Average lumens of four lamp 4-foot T12HO and two lamp 8-foot T12HO = 15,800 lumens.

[6] DesignLights Consortium. Qualified Product List. Accessed June 2022. Average input watts of General Application of High-Bay and Low-Bay fixtures that are 10,100 ±1,000 lumens = 84.0, which was rounded to 85W to have a multiple of 5 (like other high-bay measures with wattage limits). Average input watts of General Application of High-Bay and Low-Bay fixtures that are 15,800 ±1,000 lumens = 123.3, which was rounded to 125W.

[7] PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0.* Table 3-2 Lighting Hours of Use and Coincidence Factors by Sector. March 22, 2010.
https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

[8] Tetra Tech. ACES Deemed Savings Desk Review. Table 1. November 3, 2010.
https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf

[9] Summit Blue Consulting. *Con Edison Callable Load Study.* May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows a multifamily housing (in unit) coincidence factor of 65% to 89%.

[10] DesignLights Consortium. *Product List*. Accessed August 2020. https://www.designlights.org/search/

MOTORS AND DRIVES

Variable Frequency Drive (Variable Torque and Constant Torque)

	Measure Details
Measure Master ID	VFD, Process Fan, 2647 VFD, Process Pump, 2648, 3835, 4414 VFD, Constant Torque, 3280, 3836, 4412 VFD, Boiler Draft Fan, 2640 VFD, Cooling Tower Fan, 2641 VFD, Chilled Water Distribution Pump, 2726 VFD, HVAC Fan, 2643 VFD, HVAC Heating Pump, 2644 VFD, Pool Pump Motor, 2646 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, 4949 VFD, Ventilation/Circulation Fan, 3777 VFD, Domestic Water Pump, 4757 VSD Vacuum Pump, Variable Torque, 4361 VSD Vacuum Pump, Constant Torque, 4362
Workpaper ID	W0155
Measure Unit	Per horsepower
Measure Type	Hybrid
Measure Group	Agriculture: MMIDs 2639, 4949, 3777, 4043, 4411 Boilers & Burners: MMIDs 2640 and 2644 Compressed Air, Vacuum Pumps: MMIDs 4361, 4362 HVAC: MMIDs 2641, 2643, and 2726 Domestic Hot Water: MMID 4757 Pools: MMID 2646 Process: MMIDs 2647, 2648, 3280, 3835, 3836, 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
Water Savings (gal/yr)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Varies by measure

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, but only two (variable torque and constant torque) have the potential for energy savings when adding VFDs:[2]

- ***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% in this example).
- ***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 include lathes, drilling, and milling equipment. This equipment category does not offer energy savings for installing VFDs[3] 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 (Hertz) going to the motor, which allows 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.

Non-HVAC Fan Measures

Energy savings for non-HVAC fan measures are custom calculated using a spreadsheet tool,[4] which is based on an engineering bulletin[5] and savings calculators from two different VFD manufacturers.[6,7] Energy savings for the HVAC fan measure (MMID 2643) are described in the next section.

The spreadsheet tool uses power curves developed from data obtained by measuring the operating characteristics of various fans and pumps. The curves are representative of typical VFD operation.

The spreadsheet tool uses this equation:

$$\text{Power at Design GPM [CFM]} = \text{Controlled Horsepower} * \text{Conversion Constant [kW/hp]} * \text{Motor Load at Design GPM [CFM]} / \text{Nameplate Efficiency}$$

These two equations are used to determine energy usage for each capacity level:

$$\text{Percentage of Design Kilowatts} = A1 + (A2 * \text{Capacity}) + (A3 * (\text{Capacity})^2) + (A4 * (\text{Capacity})^3)$$

$$\text{Percentage of Design Kilowatts for VFD} = A1 + (A2 * \text{Capacity}) + (A3 * (\text{Capacity})^2) + (A4 * (\text{Capacity})^3)$$

In the equations above, the A1, A2, A3, and A4 variables are unique to each “before VFD” control type, which allows for a quadratic equation to represent the load profile. The Equation Variables: Before VFD 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, Forward Curved 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, Forward Curved 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,[4] but with a different algorithm that relies on data collected by Cadmus from 2014 through 2016.[8]

Cadmus installed 56 meters on HVAC fan VFD motors in the fall of 2014 and removed them in the fall of 2015. These meters provided hourly average power consumption for these VFD motors for one year, and their hourly average consumption per motor horsepower is used as an efficient-case input. Cadmus also installed 66 meters on constant-speed HVAC fans in March 2015 and removed them in April 2016. These meters provided monthly average motor consumption per horsepower for these motors, serving as a baseline.

These two datasets were combined with user-imputed weekly motor run schedules and motor size to calculate baseline and efficient energy consumption, as well as energy savings. The savings were calculated for every hour of the year and summed to produce annual savings.

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective 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 system controlled by VFD (customer input)

CF = Coincidence factor (varies by VFD use; see Coincidence Factor by VFD Use 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, 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, Agriculture Primary/Secondary Water Pumps	0.78	Per Michigan Energy Measures Database[9]
Process Fan	0.78	Assume same CF as for other process equipment
Constant Torque (process applications)	0.78	
Pool Pump	0.78	
Boiler Draft Fan (HVAC)	0.0	Does not run in summer
Boiler Draft Fan (process)	0.78	Assume same CF as for other process equipment

VFD Use	CF	Source
Agriculture 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
Agriculture Ventilation/Circulation Fans	1.0	Assumes 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 Illinois and Minnesota TRMs[10,11]
Domestic Water Pump	0.50	Hawaii Technical Reference Manual, PY2016[12]

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 being determined using 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[8]

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 a VFD can provide. These system aspects must be well-understood and discussed with the equipment vendor in advance of applying VFD technology.
- Incremental cost are assumed to equal the 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 and government, and residential multifamily sectors. A minimum of 1,000 hours is required for the agriculture sector, except for applications with low HOUs (MMIDs 4411–4414), where equipment operates between 500 and 1,000 hours annually. MMID 4949 must operate a minimum of 500 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.
- Several HVAC-related VFD measures are not eligible for new construction applications because they are considered part of the baseline condition:[13] MMID 2641 (cooling tower fan), MMID 2643 (HVAC fan), MMID 2644 (heating pump), and MMID 2726 (chilled water distribution pump).

Incremental Costs

The full average cost per horsepower, based on historical Focus on Energy data, is used as the incremental cost. Costs and additional information can be seen in the Incremental Costs table.

Incremental Costs[14,15]

Measure Types	MMIDs	SPECTRUM Data January 2018 - July 2020			Incremental Cost
		Project	Units	Average HP	
VFD, Boiler Draft, HVAC, or Cooling Tower Fan	2640, 2643, 2641	804	1,588	14	$196.94
VFD, Non-Process Pump	4949, 2726, 2644	309	583	20	$171.04
VFD, High Speed Vent or Circ Fan	3777	2020 - 2022 data for 32 projects			$134.03
VFD, Ag Water System	2639, 4043, 4411	61	76	11	$317.03
VFD, Pool Pump Motor	2646	7	7	12	$659.59
VFD, Process Pumps	2648, 3835, 4414	2021 - 2022 data for 290 projects			$178.35
VFD, Process Fans	2647	216	1,468	13	$222.89
VFD, Constant Torque	3280, 3836, 4412	2021 - 2022 data for 506 projects			$153.37
VSD Vacuum Pump, 30 hp, Variable Torque	4361	2016 - 2017 data for 1,069 projects			$210.52
VSD Vacuum Pump, 30 hp, Constant Torque	4362	2016 - 2017 data for 111 projects			$122.48

Revision History

Version Number	Date	Description of Change
01	11/2013	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	Added domestic water pump measure
04	12/2019	Added MMID 4949 for irrigation well pump—combining and replacing MMIDs 3776 and 4415 with 500 annual operating hours minimum requirement
05	10/2020	Added assumption regarding ineligible new construction applications, updated costs
06	08/2022	Cost update for process pumps, constant torque VFDs, and highspeed ventilation/circulation fans
07	10/2023	Removed MMID 4413, sunset measure

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[1] California Public Utilities Commission. *2008 Database for Energy-Efficiency Resources.* Version 2008.2.05. “Effective/Remaining Useful Life Values.” December 16, 2008. http://www.deeresources.com/

[2] U.S. Department of Energy, Energy Efficiency and Renewable Energy Advanced Manufacturing Office. “Motor Systems Tip Sheet #11, Adjustable Speed Drive Part Load Efficiency.” https://energy.gov/sites/prod/files/2014/04/f15/motor_tip_sheet11.pdf

[3] Smart Energy Design Assistance Center. “SEDAC Tech Note – Variable Frequency Drives.” November 2011. http://smartenergy-form.arch.illinois.edu/pdf/TechNote_VFD.pdf

[4] Focus on Energy. “2020 VFD Calc-Business and Ag Measures.” VFD calculation spreadsheet.

[5] Westinghouse. “Flow Control.” Bulletin B-851, F/86/Rev-CMS 8121.

[6] ABB Pump Save (version 4.4). ABB energy saving spreadsheet tools. Previously available. http://www.abb.com/product/seitp322/5fcd62536739a42bc12574b70043c53a.aspx
ABB Fan Save (version 4.4). Previously available. http://www.abb.com/product/seitp322/5b6810a0e20d157fc1256f2d00338395.aspx
ABB has replaced both Fan Save and Pump Save with EnergySave Calculator

[7] Toshiba Cost Savings Estimator. https://www.toshiba.com/tic/motors-drives/low-voltage-adjustable-speed-drives/hvac (Click “View Technical Downloads” button, then click “Software” tab in pop-up window, then look for “Cost Savings Estimator”),

[8] Cadmus. *HVAC fan VFD metering study*. July 2016.
Monthly power consumption data for 56 HVAC fan VFD motors over one year and hourly power consumption data for 66 HVAC fan constant speed motors over one year.

[9] Michigan Public Service Commission. *Michigan Energy Measure Database*. 2020. https://www.michigan.gov/mpsc/0,9535,7-395-93309_94801_94808_94811---,00.html
Refer to “VFD HP 1.5 Process Pumping” and “VFD for Process Fans” measures.

[10] Illinois Energy Efficiency Stakeholder Advisory Group. “Illinois Statewide Technical Reference Manual for Energy Efficiency.” Version 6.0. p. 464. 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

[11] Minnesota Department of Commerce Division of Energy Resources. “State of Minnesota Technical Reference Manual for Energy Conservation Improvement Programs.” Version 2.1. http://mn.gov/commerce-stat/pdfs/mn-trm-v2.1.pdf

[12] Hawaii Energy Efficiency Program. *Technical Reference Manual (TRM).* PY2016. https://hawaiienergy.com/files/about/information-and-reports/PY16_-_Hawaii_Energy_TRM.pdf

[13] American Society of Heating, Refrigerating and Air Conditioning Engineers. *ASHRAE Standard 90.1-2013.* Sections 6.5.3.2, 6.5.4.2, 6.5.4.5.2, 6.5.5.2.1, 6.5.11.1.c, footnote d of Table 11.5.2-1. Appendix G, section G3.1.3.5, G3.1.3.10, G3.1.3.11, G3.1.3.15.

[14] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. For process pumps, cost set at $178.35 per horsepower based on 2021 - 2022 data of 290 projects. For constant torque VFDs, cost set at $153.37 per horsepower based on 2021 - 2022 data of 506 projects. For high-speed ventilation/circulation agricultural fans, cost set at $134.03 per horsepower based on 2020 - 2022 data of 32 projects.

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[15] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. The vacuum pump VFD measures saw little use between 2018 and 2020, only 18 units total. Older data is used for costs for these measures. For variable torque vacuum pump VFDs, cost set at $210.52 per hp, based on 2016 - 2017 data of 1,069 projects. For constant torque vacuum pump VFDs, cost set at $122.48 per horsepower based on 2016 - 2017 data of 111 projects.

Smart Switched Reluctance Motor

	Measure Details
Measure Master ID	Smart Switched Reluctance Motor, Supply Fan, 5435
Workpaper ID	W0305
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 Electricity Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Natural Gas Savings (therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Natural Gas Savings (therms)	0
Annual Water Savings (gallons)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$243.00[2]

Measure Description

Smart Switched Reluctance Motor technology includes a combination of a high rotor switch reluctance motor (HRSRM), variable speed control, and a controller capable of providing real time monitoring and cloud-based connectivity. The motor uses a design that is simpler to manufacture and more reliable and efficient to operate.

Description of Baseline Condition

The baseline condition is a Rooftop Unit (RTU) or Air Handling Unit (AHU) with a standard AC induction motor and a single speed, constant flow fan ≥ 1hp and ≤ 20 hp.[3]

Description of Efficient Condition

The efficient condition is an HRSRM with intelligent motor controller enabling variable fan speeds that is equivalent size to the motor being replaced.

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = hp * 0.746 * LF * (HOU \,/\, Eff_{\text{BASE}} - FanSavings \,/\, Eff_{\text{EE}})$$

$$\begin{aligned} FanSavings = {} & P40 * \%Vent * HOU + P75 * \%Clg1st * HOU + P90 * \%Clg2nd * HOU \\ & + P90 * \%Htg1st + P90 * \%Htg2nd * HOU \end{aligned}$$

Where:

Variable	Description	Units	Value
hp	Horsepower of smart switched reluctance motor	hp	Customer provided
0.746	Conversion factor	kW/hp	0.746
LF	Fan motor load factor		75%, see Assumptions
HOU	Average annual hours of operation	Hrs/yr	Varies by sector; see Hours of Use by Sector table below
Eff_{BASE}	Motor efficiency of induction motor	%	90%[4]
Eff_{EE}	Motor efficiency of switched reluctance motor	%	93%[5]
P_{40}	Fan power while operating at 40% load		Using fan laws with 2.5 exponent[6]
%Vent	Percentage of time in ventilation only mode	%	69%[3]
P_{75}	Fan power while operating at 75% load		Using fan laws with 2.5 exponent[5]
%Clg1st	Percentage of time in cooling first stage mode	%	11%[3]
P_{90}	Fan power while operating at 90% load		Using fan laws with 2.5 exponent[6]
%Clg2nd	Percentage of time in cooling second stage mode	%	5%[3]
%Htg1st	Percentage of time in heating first stage mode	%	10%[3]
%Htg2nd	Percentage of time in heating second stage mode	%	5%[3]

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

$$kW_{\text{SAVED}} = hp * 0.746 * LF * (1 / Eff_{\text{BASE}} - P90 / Eff_{\text{EE}})$$

Lifecycle Energy-Savings Algorithm

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

Where:

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

Deemed Savings

Annual Savings per HP

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Switched Reluctance Motor	5435	1,697	0.1594	2,159	0.1594	2,137	0.1594	1,474	0.1594	2,707	0.1594

Lifecycle Savings (kWh) per HP

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
Switched Reluctance Motor	5435	25,455	32,385	32,055	22,110	40,605

Assumptions

Load Factor references RTU Supply Fan measure’s Load Factor for Advanced Rooftop Unit Controllers measure (see Wisconsin TRM 2023 workpaper W0045).

Average annual hours of operation reference common program lighting measure run hours.

Revision History

Version Number	Date	Description of Change
01	10/2022	Initial TRM entry

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[1] California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” Version July 3, 2014. Workpaper SCE13HC031.1. https://cedars.sound-data.com/deer-resources/deemed-measure-packages/measure-package-archive/file/1989/download

[2] General Services Administration. *Software-Controlled Switched Reluctance Motor*. Pg 3. November 2019. Cost of 10hp Smart Motor is $2,430.00. $2,340 / 10hp = $234/hp. https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/GPG-043%20Findings%20Smart%20Motors-11-2019.pdf

[3] Wisconsin Focus on Energy. Emerging Technologies Program. “Smart Switch Reluctance Motors – RTU Application” November 2020. Pg 9.

[4] Washington State University – Extension Energy Program. “Induction Motor Efficiency Standards.” October 2005. Average of 1-20hp NEMA TEFC Premium Motor Efficiency at 1800 RPM. https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/motor_efficiency_standards.pdf

[5] Online lookup for Smart Switched Reluctance Motor efficiency. October 2022. www.turntide.com

[6] ComEd Energy Efficiency Program. *Switched-Reluctance Motor Field Evaluation*. Table 2. March 5, 2022. https://turntide.com/wp-content/uploads/2022/05/SRM_final_report_03_25_2022-1.pdf

[7] PA Consulting Group. *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

[8] 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

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
Workpaper ID	W0156
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.

Delivering 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.

$$kWh_{\text{SAVED}} = kWh_{\text{BP}} - kWh_{\text{RP}}$$

$$Therm_{\text{SAVED}} = Therm_{\text{BP}} - Therm_{\text{RP}}$$

$$Therm_{\text{BP}} = (ThermBPACT) * (HDD_{\text{30YRAVG}} / HDD_{\text{BP}})$$

$$Therm_{\text{RP}} = Therm_{\text{NORM}} = (Therm_{\text{RPACT}}) * (HDD_{\text{30YRAVG}} / HDD_{\text{RP}})$$

Where:

Variable	Description	Units	Value
kWh_{BP}	Electrical consumption during baseline period	kWh	Varies by building
kWh_{RP}	Electrical consumption during reporting period	kWh	Varies by building
$Therm_{BP}$	Natural gas consumption during baseline period	Therms	Varies by building
$Therm_{RP}$	Natural gas consumption during reporting period	Therms	Varies by building
$Therm_{BPACT}$	Natural gas consumption during reporting period	Therms	Varies by building
$HDD_{30YRAVG}$	30-year average heating degree days	Days	
HDD_{BP}	Heating degree days during baseline period	Days	Varies by year
$Therm_{NORM}$	Natural gas consumption normalized for heating loads	Therms	Varies by building
$Therm_{RPACT}$	Actual natural gas consumption for reporting period	Therms	Directly from utility bill; varies by building
HDD_{RP}	Heating degree days during reporting period	Days	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

$$\text{Lifetime Savings} = 1^{st}\text{ Yr Savings} + \sum_{t=2}^{\infty} 1^{st}\text{ Yr Savings} * (1-\delta)^{t-1} * (1-\alpha)^{t-1}$$

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:

$$\text{EUL} = 1 / (0.20 + 0.07 - 0.20 * 0.07) \approx 4 \text{ Years}$$

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.

Revision History

Version Number	Date	Description of Change
01	09/2015	Initial TRM entry
02	09/2017	Updated EUL and added new model measure

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[1] The Cadmus Group, Inc. (Khawaja, Sami M. and J. Stewart). *Long-Run Savings and Cost-Effectiveness of Home Energy Report Programs*. Winter 2014/2015. http://www.cadmusgroup.com/wp-content/uploads/2014/11/Cadmus_Home_Energy_Reports_Winter2014.pdf

[2] Staff estimate. $2,000.00 for energy projects and $10,000.00 average staff time in average-sized building.

[3] United States Environmental Protection Agency. *Schools: An Overview of Energy Use and Energy Efficiency Opportunities.* Brochure. 2006. http://www.energystar.gov/ia/partners/publications/pubdocs/Schools.pdf

[4] National Renewable Resource Laboratory, Renewable Resource Data Center. “National Solar Radiation Database (Base of 65°F) Typical Meteorological Year 3.” http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html

[5] Salary.com. “Public School Teacher Salaries, La Crosse, WI.” 2015. http://www1.salary.com/WI/La-Crosse/Public-School-Teacher-salary.html

PROCESS

Process Exhaust Filtration

	Measure Details
Measure Master ID	Process Exhaust Filtration, 3244
Workpaper ID	W0157
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)	$2.98[4]

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

$$Btu/°F = CFM * Specific\ Heat$$

$$Btu_{SAVED} = Btu/°F * \Delta T * HOU$$

$$Therm_{SAVED} = Btu_{SAVED} / (System\ Efficiency * 100{,}000)$$

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:

Variable	Description	Units	Value
Btu/°F	Energy required to heat volume of make-up air for each additional degree Fahrenheit	Btu/°F	
CFM	Volumetric flow rate of eliminated make-up air unit	CFM	Actual
Specific Heat	1.08 Btu/hr/CFM-°F (dry air)	Btu/hr/CFM-°F	1.08
Btu_{SAVED}	Total energy required to heat eliminated make-up air	Btu	
ΔT	Difference between average indoor temperature and average outside winter temperature	°F	
HOU	Annual hours requiring exhaust	Hrs/yr	Actual
$Therm_{SAVED}$	Natural gas energy required to heat make-up air before eliminated	Therms	
System Efficiency	Heating efficiency of make-up air system		Actual
100,000	Conversion factor	Btu/therm	100,000

Summer Coincident Peak Savings Algorithm

There are no peak savings associated with this measure.

Lifecycle Energy-Savings Algorithm

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

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).

Revision History

Version Number	Date	Description of Change
01	07/2015	Initial TRM entry
02	12/2018	Updated incremental cost
03	12/2021	Updated incremental cost

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[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] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 236,800 CFM over 12 projects (average size 19,733 CFM) from January 2018 to July 2021.

[5] Focus on Energy Deemed Savings Manual.

Pressure Screen Rotor

	Measure Details
Measure Name	Pressure Screen Rotor, 2496
Workpaper ID	W0158
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[1]
Incremental Cost ($/unit)	$200.77[2]

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)

$$kWh_{\text{SAVED}} = (Amps_{\text{PRE}} - Amps_{\text{POST}}) * 1.73 * V * PF * Hrs/wk * Weeks$$

Method #2: Deemed Approach (Amps Unknown)

$$kWh_{\text{SAVED}} = hp * LF \,/\, Eff * 0.746 * S * Hrs/wk * Weeks$$

Where:

Variable	Description	Units	Value
$Amps_{PR}$	Pre-retrofit pulper amps	Amps	Actual; requested in program application or measured
$Amps_{POST}$	Post-retrofit pulper amps	Amps	Actual; requested in program application or measured
1.73	Constant to calculate kWh	kWh	1.73
V	Voltage of pulper	Volts	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	Hrs/wk	Actual; requested in program application or reported by customer
Weeks	Weeks of operation per year	Wks/yr	Actual; requested in program application or reported by customer
hp	Motor horsepower	hp	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 factor	kW/hp	0.746
S	Deemed savings factor	%	30%[3]

Summer Coincident Peak Savings Algorithm

Method #1: Custom Approach (Amps Known)

$$kW = (Amps_{\mathbf{PRE}} - Amps_{\mathbf{POST}}) * 1.73 * V * PF$$

Method #2: Deemed Approach (Amps Unknown)

$$kW = hp * LF / Eff * 0.746 * S$$

Lifecycle Energy-Savings Algorithm

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

Where:

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

Revision History

Version Number	Date	Description of Change
01	05/2015	Initial TRM entry
02	12/2018	Updated incremental cost

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[1] Engineering judgment.

[2] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 12 units from 2012 to 2014.

[3] Focus on Energy industrial sector project history. 2013.

Repulper Rotor

	Measure Details
Measure Name	Repulper Rotor Without Extraction Plate, 2538 Repulper Rotor With Extraction Plate, 5210
Workpaper ID	W0159
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[1]
Incremental Cost ($/unit)	$200.44 for no extraction plate (MMID 2538)[2] $245.01 for with extraction plate (MMID 5210)[3]

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 (new energy efficient repulping blades) replacing conventional rotors (existing conventional repulping blades, baseline). Energy efficient 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 conventional rotor.

Description of Efficient Equipment

The efficient condition is an efficient rotor.

Annual Energy-Saving Algorithm

There are two mefthods for estimating savings. The first method relies on pre-retrofit and post-retrofit current measurements as provided in the participant application or obtained; the second method uses deemed savings using an energy savings factor of 23%.[4,5]

Method #1: Custom Approach (Amps Known)

$$kWh_{\text{SAVED}} = (Amps_{\text{PRE}} - Amps_{\text{POST}}) * 1.73 * V * PF * Bwk * t * Weeks$$

Method #2: Deemed Approach (Amps Unknown)

$$kWh_{\text{SAVED}} = hp * LF / Eff * 0.746 * Bwk * t * Weeks * SF$$

Where:

Variable	Description	Units	Value
$Amps_{PR}$	Pre-retrofit pulper amps	Amps	Actual; from program application or measured
$Amps_{POST}$	Post-retrofit pulper amps	Amps	Actual; from program application or measured
1.73	Constant to calculate kWh with three-phase power	kWh	1.73
V	Voltage of pulper	Volts	Actual; from program application or reported by customer
PF	Power factor		Actual reported by customer or deemed 0.75
Bwk	Batches per week	Batches/wk	Actual; from program application or reported by customer
t	Time per pulp batch in minutes	Minutes	Actual; from program application or reported by customer
Weeks	Weeks of pulping per year	Wks/yr	Actual; from program application or reported by customer
hp	Motor horsepower	hp	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 factor	kW/hp	0.746
SF	Savings factor	%	Deemed 23%[4,5]

Summer Coincident Peak Savings Algorithm

Method #1: Custom Approach (Amps Known)

$$kW = (Amps_{\text{PRE}} - Amps_{\text{POST}}) * 1.73 * V * PF$$

Method #2: Deemed Approach (Amps Unknown)

$$kW = hp * LF / Eff * 0.746 * SF$$

Lifecycle Energy-Savings Algorithm

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

Where:

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

Revision History

Version Number	Date	Description of Change
01	05/2015	Initial TRM entry
02	12/2018	Updated incremental cost
03	11/2021	Added repulper rotor with extraction plate measure and updated incremental costs

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[1] Engineering judgment.

[2] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of ten units from 2014 through October 2021 = $200.44/hp.

[3] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of five units from 2014 to October 2021 = $44.57/hp, plus cost of repulper rotor from Reference 2 = $245.01.

[4] 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

[5] *Focus on Energy Business Programs - Industrial Sector*. December 16, 2005. Repulper rotor reduces energy costs by 23%.

High Efficiency Side Entry Agitator

	Measure Details
Measure Master ID	High Efficiency Side Entry Agitator, 4763
Workpaper ID	W0160
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

$$kWh_{\text{SAVED}} = HP * 0.746 * LF * Op\ Hours * SF$$

Where:

Variable	Description	Units	Value
HP	Agitator horsepower	hp	Actual
0.746	Conversion factor	kW/hp	0.746
LF	Load factor; percentage load on the agitator motor over operating hours	%	Actual
Op Hours	Agitator operating hours	Hrs	Actual
SF	Savings factor	%	15%; see Assumptions[3]

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = kWh_{\text{SAVED}} / Op\ Hours$$

Lifecycle Energy-Savings Algorithm

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

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%.

Revision History

Version Number	Date	Description of Change
01	12/2018	Initial TRM entry

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[1] Engineering judgment. 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.

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[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.

Spline Rotor Upgrade for Refiners

	Measure Details
Measure Master ID	Spline Rotor Upgrade for Refiners, 4764
Workpaper ID	W0161
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

$$kWh_{\text{SAVED}} = HP * 0.746 * LF * HOU * SF$$

Where:

Variable	Description	Units	Value
HP	Refiner horsepower	hp	Actual
0.746	Conversion factor	kW/hp	0.746
LF	Load factor; percentage load on refiner over operating hours	%	Actual
Op Hours	Refiner operating hours	Hrs	Actual
SF	Savings factor	%	Estimated as 10%; see Assumptions[3,4,5]

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = kWh_{\text{SAVED}} / HOU$$

Lifecycle Energy-Savings Algorithm

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

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%.

Revision History

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

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[1] Engineering judgment. 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.

Radiant Heater Band for Plastics

	Measure Details
Measure Master ID	Plastics Equipment, Radiant Heater Band Retrofit, 2490
Workpaper ID	W0162
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

$$kWh_{\text{SAVED}} = LF * kW_{\text{EXISTING}} * HOU * \%\, Savings$$

Where:

Variable	Description	Units	Value
LF	Load factor		0.5; see Assumptions
kW_{EXISTING}	Existing heater kilowatt usage	Kw	User input
HOU	Hours of use	Hrs	User input
% Savings	Percentage savings	%	15%; see Assumptions)[3]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = LF * kW_{EXISTING} * \% \text{ Savings}$

Lifecycle Energy-Savings Algorithm

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

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.

Revision History

Version Number	Date	Description of Change
01	10/2018	Initial TRM entry

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[1] PA Consulting Group. *Focus on Energy, 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. "Review of Work Paper 'Plastics Equipment – Efficient Radiant Heater and Retrofit.'" Memo prepared by Dave Korn and Charles Bicknell. May 29, 2012.

Industrial High Frequency Battery Chargers

	Measure Details
Measure Master ID	Industrial High Frequency Battery Chargers, 4765
Workpaper ID	W0163
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

$$kWh_{\text{SAVED}} = kWh_{\text{BASELINE}} - kWh_{\text{EE}}$$

$$kWh_{\text{BASELINE}} = ((CAP * DOD * CHG * CRF_{\text{BASE}} / PCE_{\text{BASE}}) + (P_{\text{NBM,BASE}} * HOU_{\text{MM}}) + (P_{\text{NBM,BASE}} * HOU_{\text{NBM}})) / 1{,}000$$

$$kWh_{\text{EE}} = ((CAP * DOD * CHG * CRF_{\text{EE}} / PCE_{\text{EE}}) + (P_{\text{MM,EE}} * HOU_{\text{MM,EE}}) + (P_{\text{NBM,EE}} * HOU_{\text{NBM,EE}})) / 1{,}000$$

Where:

Variable	Description	Units	Value
CAP	Battery charger capacity in watt-hours	Watt-hrs	User input
DOD	Degree of discharge	%	User input; if unknown use 80%[2]
CHG	Number of charging cycles per year	Charges/yr	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
$P_{\text{MM,BASE}}$	Baseline power in maintenance mode	Watts	99.1 watts; see Assumptions
HOU_{MM}	Baseline number of hours per year in maintenance mode	Hrs/yr	User input
$P_{\text{NBM,BASE}}$	Baseline power in no battery mode	Watts	55.4 watts; see Assumptions
HOU_{NBM}	Baseline number of hours per year in no battery mode	Hrs/yr	User input
1,000	Conversion factor	W/kW	1,000
CRF_{EE}	Efficient charge return factor at degree of discharge		User input
PCE_{EE}	Efficient power conversion efficiency		User input
$P_{\text{MM,EE}}$	Efficient power in maintenance mode in watts	Watts	User input
$P_{\text{NBM,EE}}$	Efficient power in no battery mode in watts	Watts	User input

Summer Coincident Peak Savings Algorithm

There are no peak demand savings for this measure.

Lifecycle Energy-Savings Algorithm

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

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,[4] 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[5]

Charger Type	Population Fraction[4]	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**

Revision History

Version Number	Date	Description of Change
01	10/01/2018	Initial TRM entry

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[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] 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

[5] 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

Steam Trap Repair, < 10 psig, Industrial Process Heating

	Measure Details
Measure Name	Steam Trap Repair, < 10 psig, Industrial, 3999
Workpaper ID	W0164
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)	4,656
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

$$Therm_{\text{SAVED}} = 1.9 * K * 60 * (\pi * D^2/4) * \sqrt{}([P_{\text{ABS}} - \{P_1 - P_2\}] * [P_1 - P_2]) * h_{\text{FG}} * HOU * DF \, / \, (100{,}000 * eff)$$

Where:

Variable	Description	Units	Value
1.9	Constant based on units and fluid flow equation[3]		1.9
K	Discharge coefficient		0.55[4]
60	Conversion factor	Mins/hrs	60
D	Steam trap orifice diameter	Inches	1/4 inch
P_{ABS}	System absolute pressure	Lbs/in^2	20.7 psia; steam gage pressure at trap inlet (6 psig) + atmospheric pressure at sea level in lbs/in^2 (14.7 psi)[5]
P_1	Steam pressure at trap inlet	psig	6 psig[5]
P_2	Steam pressure at trap outlet, condensate tank pressure	psig	0 psig
h_{FG}	Latent heat of steam at P_{ABS}	Btu/lb	959 Btu/lb[6]
HOU	Annual hours of operation boiler is on and system is at design pressure	Hrs/yr	7,000[7]
DF	Derating factor to account for average percentage of time a trap fails in open position and actual versus theoretical energy loss	%	32%[5]
100,000	Conversion factor	Btu/therm	100,000
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

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

Where:

EUL = Effective useful life (6 years)[1]

Revision History

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

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[1] PA Consulting Group. *Focus on Energy, 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: $1.9 * (\pi/4 * D^2) * K * \sqrt{}([P_1 – 0.42 * P_1] * 0.42 * P_1) * 60 = 24.24 * P_1 * D^2$. 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 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.

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
Workpaper ID	W0165
Measure Unit	Per system psi (absolute)
Measure Type	Prescriptive
Measure Group	HVAC
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
Lifecycle Electricity Savings (kWh)	0
Lifecycle 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]

$$Therm_{\text{SAVED}} = 24.24 * P_{\text{ABS}} * D2 * h_{\text{FG}} * HOU * DF / (100{,}000 * eff)$$

Where:

Variable	Description	Units	Value
24.24	Constant from Napier equation when units for absolute system pressure are in psia and units of steam trap diameter are in inches. Psia to inches	Inches	24.24
P_{ABS}	System absolute pressure in pounds per square inch	Lbs/in^2	Steam gauge pressure at trap inlet (as measured by implementers) + atmospheric pressure at sea level in lbs/in^2 of 14.7
D	Steam trap orifice diameter in inches	Inches	Varies by measure, and assumed based on system pressure range; see Diameters, Pressures, Latent Heats and Savings Multipliers table below
h_{FG}	Latent heat of vaporization for water at P_{ABS}		Varies by measure; see Diameters, Pressures, Latent Heats and Savings Multipliers table below
DF	Derating factor to account for average percentage open a trap fails and actual versus theoretical energy loss	%	32%[3]
HOU	Annual hours of operation boiler is on and system is at design pressure	Hrs/yr	7,000[4]
100,000	Conversion factor	Btu/therm	100,000
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:

$$Therm_{\text{SAVED}} = System\ Absolute\ Pressure\ *\ Annual\ Savings\ Multiplier$$

$$= [System\ Gauge\ Pressure\ +\ 14.7]\ *\ Annual\ Savings\ Multiplier$$

Diameters, Pressures, Latent Heats, and Savings Multipliers

Measure Name	MMID	Assumed Orifice Diameter[3]	Assumed P_{ABSs} 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.

$$Therm_{\text{SAVED}} = 24.24\ *\ (25\ +\ 14.7)\ *\ 0.18752\ *\ 933.4\ *\ 7{,}000\ *\ 32\%\ /\ (100{,}000\ *\ 80\%)$$

Or

$$Therm_{\text{SAVED}} = (25\ +\ 14.7)\ *\ 22.3\ =\ 885.3$$

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure, as it does not generate electric savings.

Lifecycle Energy-Savings Algorithm

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

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.

Revision History

Version Number	Date	Description of Change
01	07/2016	Initial TRM entry
02	01/2017	Revised Assumptions and algorithm

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[1] PA Consulting Group. *Focus on Energy, 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.

REFRIGERATION

Anti-Sweat Heater Controls

	Measure Details
Measure Master ID	Anti-Sweat Heater Controls: Freezer Case, 5439 Refrigerated Case, 5440
Workpaper ID	W0166
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)	$68.78[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

$$kWh_{\text{SAVED}} = Watts_{\text{BASE}} * (1 + 1 / COP) / 1{,}000 * FS * HOU$$

Where:

Variable	Description	Units	Value
$Watts_{\text{BASE}}$	Wattage of door heaters	Watts	170.3 for MMID 5439, 98.7 for MMID 5440, see $Watts_{\text{BASE}}$ from Historical Participation table below
COP	Coefficient of performance		1.4 for MMID 5439; 2.3 for MMID 5440[3]
1,000	Conversion factor	W/kW	1,000
F_S	Savings factor	%	46.5% for MMID 5439; 74.2% for MMID 5440[4]
HOU	Average annual run hours	Hrs/yr	8,760

$Watts_{\text{BASE}}$ from Historical Participation

MMID	Case Type	$Watts_{\text{BASE}}$	$Watts_{\text{BASE}}$ Source
5439	Freezer	170.3	Weighted Avg of MMIDs 2197, 2198, 2199 (See assumptions)
5440	Refrigerated	98.7	Weighted Avg of MMIDs 2200, 2201 (See assumptions)

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = Watts_{\text{BASE}} * (1 + 1 / COP) / 1{,}000 * CF$$

CF = Coincidence factor (10%)[4]

Lifecycle Energy-Savings Algorithm

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

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

Savings

Deemed Savings for Anti-Sweat Heater Controls

Measure	MMID	First Year kWh Savings	Summer Peak kW Savings	Lifecycle kWh Savings
Freezer Case	5439	1,189	0.029	14,268
Refrigerated Case	5440	920	0.014	11,040

Assumptions

Based on historical program data and discussions with customers, it is assumed that low-heat cooler doors ($Watts_{\text{BASE}}$ = 63[5]) make up 75% of the installations, and no-heat cooler doors ($Watts_{\text{BASE}}$ = 52[5]) make up 25% of the installations, for the combined measure for anti-sweat heater controls for low-heat and no-heat cooler doors.

The historical participation by MMID what went into creating the weighted average $Watts_{\text{BASE}}$ is shown in the table below:

$\text{Watts}_{\text{BASE}}$ from Historical Participation

MMID	Case Type	Door Type	$\text{Watts}_{\text{BASE}}$	Participation %[6]
2197	Freezer	Low Heat	132	33.75%
2198		No Heat	54	0.61%
2199		Standard	191	65.65%
2200	Refrigerated	Low or No Heat	60.25	21.15%
2201		Standard	109	78.85%

Revision History

Version Number	Date	Description of Change
01	03/11/2016	Update from Focus on Energy Deemed Savings Manual
02	10/7/2022	Merge measures based on historical data

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[1] PA Consulting Group. *Focus on Energy, 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 unit cost of 1,048 projects and 17,986 doors for MMIDs 2197, 2198, 2199, 2200, 2201 from January 2018 to July 2020 is $68.78.

[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. http://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf

[4] 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.

[5] 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.

[6] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Total quantities of anti-sweat heater controls installed from January 2016 to September 2022 are: 7,072 for MMID 2197, 127 for MMID 2198, 13,758 for MMID 2199, 2,612 for MMID 2200, and 9,739 for MMID 2201.

Demand Defrost Controls

	Measure Details
Measure Master ID	Demand Defrost Controls, 4758
Workpaper ID	W0167
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

$$kWh_{\text{SAVED}} = kW_{\text{DEFROST}} * HOU_{\text{BASE}} * Fs * [1 + 3.412 / (12 * COP)]$$

Where:

Variable	Description	Units	Value
$kW_{DEFROST}$	Wattage of electric defrost	kW	1 kW
HOU_{BASE}	Hours of use for baseline equipment	Hrs	487; see Assumptions[3]
F_s	Savings factor	%	30%[4]
3.412/12	Conversion factor	kW/ton	3.412 kW/MBh; 12 MBh/ton
COP	Coefficient of performance		1.4[3]

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = (kWh_{\text{SAVED}} / HOU)$$

Where:

HOU = Hours of freezer use (8,760 hours per year)

Lifecycle Energy-Savings Algorithm

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

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.[5]

Revision History

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

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[1] PA Consulting Group. *Focus on Energy, 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] 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

[4] 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.

[5] 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

Evaporator Fan Control

	Measure Details
Measure Master ID	Cooler Evaporator Fan Control, 2269 Evaporator Fan Control for Reach-in Cooler/Freezer, 4759
Workpaper ID	W0168
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[2]

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:

- The evaporator fans consume less energy.
- 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:

Variable	Description	Units	Value
$Watts_{FULL}$	Wattage of the fan motor at normal speed of 1,550 RPM	Watts	Varies by motor type; see table belowE
LS	Fraction of time fan motor is on low speed setting	%	37%, average of 32% for freezers and 42% for coolers[2]
$Watts_{LOW}$	Wattage of the fan motor at low speed of 550 RPM	Watts	Varies by motor type; see table below
COP	Coefficient of performance		1.85, average of 1.4 for freezers and 2.3 for coolers[3]
HOU	Average annual run hours	Hrs/yr	8,517, see Assumptions[4]
1,000	Conversion factor	W/kW	1,000

Energy Savings for MMID 2269

Motor Nameplate HP[5]	Input Wattage		COP[3]	LS[2]	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%
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[3]	LS[2]	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

$$kW_{\text{SAVED}} = \sum[Watts_{\text{FULL}} * (1 - LS) + Watts_{\text{LOW}} * (LS)] / 1{,}000 * (1 + 1 / COP)$$

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (16 years)[1]

Assumptions

Based on engineering judgment, 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,[7] 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, were 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[5]	Motor Type Weighting	
			Full Speed[7]	Low Speed		Historical[5]	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%
	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[7]	Low Speed		Historical[5]	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.[4] 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.[5] These output wattages were used to obtain the motor input wattages, based on motor efficiencies.[2] 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.[3] The capacity and power values were calculated to yield the EER and then converted to COP, based on COP = EER / 3.412.

Revision History

Version Number	Date	Description of Change
01	03/2016	Initial TRM entry
02	09/2018	Added measure 4759

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[1] California Energy Commission and California Public Utilities Commission. “Database for Energy Efficiency Resources.” Evaporator Fan Controller for Walk-In Coolers. 2008. www.deeresources.com/files/deer0911planning/downloads/EUL_Summary_10-1-08.xls

[2] 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/

[3] 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

[4] 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

[5] Focus on Energy historical application data for MMIDs 2308–2311, June 2012 through July 2015.

[6] Pacific Gas & Electric Company. “Display Case ECM Motor Retrofit.” Workpaper PGE3PREF124. Table 10. 2014.

[7] 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).

Refrigeration Controls, Floating Head Pressure

	Measure Details
Measure Master ID	Refrigeration Controls, Floating Head Pressure, 4360
Workpaper ID	W0169
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

$$kWh_{\text{SAVED}} = \sum [(-0.00239 * DB_{\text{AVE}} + 0.1791) * Hours_{\text{BIN TEMP}}]$$

Where:

Variable	Description	Units	Value
-0.00239	Interpolation constant, units of kW / (hp * °F)[3]	kW / (hp * °F)	-0.00239
DB_{AVE}	Average bin dry bulb temperature in °F, from TRM Appendix B: Common Variables	°F	
0.1791	Interpolation constant, units of kW / hp[3]	kW/hp	0.1791
$Hours_{\text{BIN TEMP}}$	Annual hours of Wisconsin Outside Air Temperature, from TRM Appendix B: Common Variables	Hrs	

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

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

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.

Revision History

Version Number	Date	Description of Change
01	03/2016	Initial TRM entry
02	07/2017	Updated savings

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[1] PA Consulting Group. “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

ENERGY STAR Commercial Ice Machines

	Measure Details
Measure Master ID	Ice Making Head, 3906 Remote Condensing Unit, 3907 Self-Contained Unit, 3908
Workpaper ID	W0170
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)	9[1]
Measure Incremental Cost ($/unit)	$222.00[2]

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.[3]

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.[4]

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.[3] 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

$$kWh_{\text{SAVED}} = (kWh_{\text{BASE}} - kWh_{ENERGY\ STAR}) + (Gal_{SAVED} * kWh_{WATER} / 1{,}000)$$

Where:

Variable	Description	Units	Value
kWh_{BASE}	Average annual energy consumption for specific equipment types using the DOE federal standards that took effect January 28, 2018	kWh	Varies by equipment type; see table below
$kWh_{\text{ENERGY STAR}}$	Average annual energy consumption for specific equipment types using ENERGY STAR Version 3.0 Energy Consumption Rate algorithms with average ice harvest rates by qualifying product data set as of August 14, 2017	kWh	Varies by equipment type; see table below
Gal_{SAVED}	Annual water savings	gal/year	
kWh_{WATER}	Energy saved from water and wastewater utilities	kWh/kgal	3.89[5]
1,000	Conversion factor	gal/kgal	1,000

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[3]

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	1.2811
Remote Condensing Unit	17,222	1.9660
Self-Contained Unit	4,050	0.4624

DOE Federal Standards – Effective January 28, 2018 (Air-Cooled Models)[4]

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

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)
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	1.4232
Remote Condensing Unit	20,187	2.3046
Self-Contained Unit	4,730	0.5400

Based on the harvest rate for various ENERGY STAR-qualifying models pulled from the Qualified Products List[3] 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[6] 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

$$kW_{\text{SAVED}} = (kWh_{\text{BASE}} - kWh_{\text{ENERGY STAR}}) \ / \ HOU$$

Where:

HOU = Hours of use (8,760 hours)[2]

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (9 years)[1]

Deemed Savings

Annual and Lifecycle Deemed Savings

Equipment Type	MMID	Demand Savings (kW)	Annual Electric Savings (kWh)	Lifecycle Electric Savings (kWh)	Annual Water Savings (Gallons)
Ice Making Head	3906	0.1421	1,250	11,250	4,693
Remote Condensing Unit	3907	0.3385	2,978	26,802	4,581
Self-Contained Unit	3908	0.0777	683	6,147	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.[2]

For incremental measure cost, the ENERGY STAR commercial kitchen savings calculator[2] 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.

Revision History

Version Number	Date	Description of Change
01	08/2016	New measure replacing CEE Tier 2 Ice Machines, removed MMIDs 3414–3424
02	08/2017	Updated savings to reflect ENERGY STAR Version 3.0
03	12/2018	Updated incremental cost
04	07/2022	Update EUL
05	10/2023	Water-Related Energy Savings updated

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[1] U.S. Department of Energy. Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment. p. 212; 8-27. https://downloads.regulations.gov/EERE-2010-BT-STD-0037-0136/content.pdf

[2] 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

[3] ENERGY STAR. “Commercial Ice Makers.” Website. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ice_makers

[4] 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

[5] Water-Related Energy Savings using updated CMAR (2016-2020) and WI Water Utility databases (2015-2022). A weighted average was used for the calculation of the water energy savings factor for groundwater/surface water, and for facilities with 0-1 MGD/ >1 MGD. Calculations and data provided in Huddle folder of this workpaper.

[6] “ENERGY STAR Version 3.0 Requirements for Air-Cooled Ice Makers.” https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ice__makers/partners

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
Workpaper ID	W0171
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)	8,304
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

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

Where:

Variable	Description	Units	Value
$Watts_{\text{BASE}}$	Input of SP or PSC motor	Watts	221.0 watts, weighted average; see table below[3]
$Watts_{\text{EE}}$	Input of ECM	Watts	137.7 watts, weighted average; see table below[3]
1,000	Conversion factor	W/kW	1,000
HOU	Average annual run hours	Hrs/yr	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 (248.7)*	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

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

Lifecycle Energy-Savings Algorithm

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

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 horespowers 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.

Revision History

Version Number	Date	Description of Change
01	03/2016	Initial TRM entry

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[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. "Focus on Energy Evaluation Business Programs: Deemed Savings Manual V 1.0." p. 4–91. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

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
Workpaper ID	W0172
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)	Varies by measure

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

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

Where:

Variable	Description	Units	Value
$\text{Watts}_{\text{BASE}}$	Wattage of existing SP and PSC fan motor	Watts	Weighted average based on historical data, see Deemed Savings table below)[2]
Watts_{EE}	Wattage of ECM fan motor	Watts	Weighted average based on historical data, see Deemed Savings table below)[2]
1,000	Conversion factor	W/kW	1,000
COP	Coefficient of performance		2.3 for MMID 2308 and 2309, 1.4 for MMID 2310 and 2311)[3]
HOU	Average annual run hours	Hrs/yr	8,760 for MMID 2308 and 2309, 8,273 for MMID 2310 and 2311; see Assumptions

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = (Watts_{\text{BASE}} - Watts_{\text{EE}}) / 1{,}000 * (1 + 1 / COP)$$

Lifecycle Energy-Savings Algorithm

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

Where:

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

Deemed Savings

Deemed Savings for ECM Evaporator Fan Motors

Measure Name	MMID	$\text{Watts}_{\text{BASE}}$[2]	Watts_{EE}[2]	COP[3]	Summer Peak kW Savings	First Year kWh Savings	EUL[1]	Lifecycle kWh Savings
Walk-In Cooler, < 1/20 hp	2308	78.23	26.64	2.3	0.07	613	15	9,195
Walk-In Cooler, 1/20 - 1 hp	2309	208.5	71.04	2.3	0.20	1,752	15	26,280
Walk-In Freezer, < 1/20 hp	2310	89.38	30.44	1.4	0.10	827	15	12,405
Walk-In Freezer, 1/20 - 1 hp	2311	240.6	81.97	1.4	0.27	2,234	15	33,510

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 $Watts_{BASE}$ and $Watts_{EE}$.

Efficiency Values for ECM Evaporator Fan Motors

Measure Name	MMID	% of Motors Surveyed[2]	Weighted Output Horsepower[2]	SP Eff.[4]	SP Weight[2]	PSC Eff.[4]	PSC Weight[2]	ECM Eff.[4]
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.

Incremental Cost

Efficient costs are derived from historical project data and online lookups of shaded pole motors.

Incremental Costs

Measure Name	MMID	SPECTRUM Data			Base Cost	Incremental Cost
		Projects	Units	Average Unit Cost		
Walk-In Cooler, < 1/20 hp	2308	52	323	$162.85	$114.90	$47.95
Walk-In Cooler, 1/20 - 1 hp	2309	721	4,249	$198.50	$169.04	$29.46
Walk-In Freezer, < 1/20 hp	2310	12	40	$238.69	$136.33	$102.36
Walk-In Freezer, 1/20 - 1 hp	2311	205	669	$212.76	$175.46	$37.30

Revision History

Version Number	Date	Description of Change
01	03/2016	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
05	12/2020	Updated cost

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[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] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit costs for 990 projects and 5,281 units from January 2018 to July 2020. Minus base costs for shaded pole motors derived from December 2020 online lookups, from www.grainger.com and www.regalbeloit.com

[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] 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, 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.

ECM Motor, Cooler/Freezer Case

	Measure Details
Measure Master ID	ECM Motor, Cooler/Freezer Case, 2312
Workpaper ID	W0173
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)	$20.30[2]

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

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

Where:

Variable	Description	Units	Value
$Watts_{BASE}$	Wattage of existing SP fan motor	Watts	112.6 weighted average[3,4]
$Watts_{EE}$	Wattage of ECM fan motor	Watts	37[3,4]
1,000	Conversion factor	W/kW	1,000
COP	Coefficient of performance		1.85, average of 1.4 for freezers and 2.3 for coolers[5]
HOU	Average annual run hours	Hrs/yr	8,517, see Assumptions

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = (Watts_{\text{BASE}} - Watts_{\text{EE}}) / 1{,}000 * (1 + 1 / COP)$$

Lifecycle Energy-Savings Algorithm

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

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,[3] 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.[4] The input wattages were averaged, based on the motor size ratio,[3] to obtain the overall baseline and efficient motor input wattages for the savings algorithms.

Revision History

Version Number	Date	Description of Change
01	03/2016	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
05	12/2020	Updated incremental cost

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[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] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 199 projects and 3,894 units January 2018 to May 2020 is $110.06. Minus baseline cost of $89.76, derived from December 2020 online lookups of shaded pole motors: 8 models of 1/83 hp motors averaging $58.75 and weighted at 9%, 4 models of 1/47 hp motors averaging $66.50 and weighted at 49%, and 6 models of 1/20 hp motors averaging $123.55 and weighted at 42%.

[3] Pacific Gas & Electric Company. “Display Case ECM Motor Retrofit.” Workpaper PGE3PREF124. Table 10. 2014.

[4] U.S. 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.

[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. 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.

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
Workpaper ID	W0174
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
Lifecycle Energy Savings (kWh)	15,540
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$92.40[2]

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

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

Where:

Variable	Description	Units	Value
$Watts_{\text{BASE}}$	Wattage of existing SP fan motor	Watts	112.630 watts as weighted average of three motor size categories, see Assumptions)[3,4]
$Watts_{\text{EE}}$	Wattage of PMS fan motor	Watts	33.643 watts[5,6]
1,000	Conversion factor	W/kW	1,000
COP	Coefficient of performance		1.85 averaged, 1.4 for freezers and 2.3 for coolers[7]
HOU	Average annual run hours	Hrs/yr	8,517, see Assumptions

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = (Watts_{\text{BASE}} - Watts_{\text{EE}}) / 1{,}000 * (1 + 1 / COP)$$

Lifecycle Energy-Savings Algorithm

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

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,[3] 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.[4] 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.[2]

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.[7] 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.[5] 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%.[2,5,6] 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.[6] The Oak Ridge National Laboratory completed a laboratory measurement of 73% for a 12-watt Q Sync motor.[6] 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.[2] Since the market is a mix of smaller and larger motors, a 77% efficiency average is assumed.

Revision History

Version Number	Date	Description of Change
01	05/2017	Initial TRM entry
02	09/2017	Modified inputs from Business Incentive Program, Aptim, and Cadmus
03	12/2018	Updated incremental cost

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[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] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 10 units over two projects in 2018.

[3] Pacific Gas & Electric Company. "Display Case ECM Motor Retrofit." Table 10. Workpaper PGE3PREF124. 2014.

[4] 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

[5] 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

[6] 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

[7] 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

Cooler Night Curtains, Open Coolers

	Measure Details
Measure Master ID	Cooler Night Curtains, Open Coolers, 2271
Workpaper ID	W0175
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)	249
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	1,245
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

$$kWh_{\text{SAVED}} = Load_{\text{CASE}} \,/\, (3.412 * COP) * SF * HOU \,/\, 1{,}000$$

Where:

Variable	Description	Units	Value
$\text{Load}_{\text{CASE}}$	Average refrigeration load without curtains	Btu/h	1,733.625 Btu/h perlinear foot weighted average of 1,727.5 Btu/h per linear foot for coolers[3] and 1,850 Btu/h per linear foot for freezers[4]
3.412	Conversion factor	Btuh/W	3.412
COP	Coefficient of performance		2.255, weighted average of 1.4 for freezers and 2.3 for coolers[3]
SF	Savings factor		12.6%[5]
HOU	Hours of use	Hrs	8,760[5]
1,000	Conversion factor	W/kW	1,000

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

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

Where:

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

Assumptions

The savings factor and hours of use values reflect e-mail communication with the authors of the Southern California Edison study.[5] The authors recommended a savings factor of 12.6% for this application, and stated that the study reflected savings over a 24-hour period—not only at night when the night covers were applied.

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.

Revision History

Version Number	Date	Description of Change
01	03/2016	Updated based on Focus on Energy Deemed Savings Manual
02	12/2018	Updated incremental cost
03	01/2022	Updated HOU, baseline load calculation, and savings factor

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[1] PA Consulting Group. *Focus on Energy, 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.econofrost.com/acrobat/SouthernCaliforniaEdison.pdf

Energy-Efficient Case Doors

	Measure Details
Measure Master ID	Case Door: Freezer, Low Heat, 2234 Freezer, No Heat, 2235 Cooler, No Heat, 2236
Workpaper ID	W0176
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
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle 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

$$kWh_{\text{SAVED}} = [(Watts_{\text{BASE}} - Watts_{\text{EE}}) * (1 + 1 / COP)] / 1{,}000 * HOU$$

Where:

Variable	Description	Units	Value
$Watts_{\text{BASE}}$	Wattage of standard door heaters	Watts	191 for MMIDs 2234 and 2235; 63 for MMID 2236[3]
$Watts_{\text{EE}}$	Wattage of door heaters	Watts	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	Conversion factor	W/kW	1,000
HOU	Average annual run hours	Hrs/yr	8,760

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = [(Watts_{\text{BASE}} - Watts_{\text{EE}}) * (1 + 1 / COP)] / 1{,}000$$

Lifecycle Energy-Savings Algorithm

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

EUL = Effective useful life (11 years)[1]

Deemed Savings

Deemed Savings

Measure Name	MMID	$Watts_{\text{BASE}}$	$Watts_{\text{EE}}$	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	22,627
Case Door, Cooler, No Heat	2236	63	52	2.3	138	0.016	11	1,518

Revision History

Version Number	Date	Description of Change
01	03/2016	Update based on Focus on Energy Deemed Savings Manual

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[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

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
Workpaper ID	W0177
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[1]
Incremental Cost ($/unit)	$881.92[2]

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

$$\mathrm{kWh_{SAVED}} = \{(\mathrm{P_{CE}} - \mathrm{P_{LE}} - \mathrm{P_{ME}} - \mathrm{P_{CE}}\cdot\mathrm{F_{CR}}) - [\mathrm{P_{CP}}\cdot(1 - \mathrm{F_I}) - \mathrm{P_{LP}} - \mathrm{P_{MP}} - \mathrm{P_{CP}}\cdot\mathrm{F_{CR}}\cdot(1 - F_I)]\} \cdot \left[\frac{\mathrm{LF \cdot HOU}}{3{,}412 \cdot \mathrm{COP_{REFRIG}}} - \frac{24 \cdot \mathrm{CDD}}{(\mathrm{T_S} - \mathrm{T_R}) \cdot 3{,}412 \cdot \mathrm{COP_{ROOFTOP}}}\right]$$

$$\mathrm{Therm_{SAVED}} = \{(\mathrm{P_{CE}} - \mathrm{P_{LE}} - \mathrm{P_{ME}} - \mathrm{P_{CE}}\cdot\mathrm{F_{CR}}) - [\mathrm{P_{CP}}\cdot(1 - \mathrm{F_I}) - \mathrm{P_{LP}} - \mathrm{P_{MP}} - \mathrm{P_{CP}}\cdot\mathrm{F_{CR}}\cdot(1 - \mathrm{F_I})]\} \cdot \left[\frac{24 \cdot \mathrm{HDD}}{(\mathrm{T_S} - \mathrm{T_R}) \cdot \mathrm{eff} \cdot 100{,}000}\right]$$

Where:

Variable	Description	Units	Value
P_{CE}	Total load of multideck case	Btuh	1,727.5 Btuh/linear foot for coolers;[3] 1,850 Btuh/linear foot for freezers[4]
P_{LE}	Lighting load of existing case	Btuh	6.7 Btuh/linear foot[4]
P_{ME}	Motor load of existing case	Btuh	7.3 Btuh/linear foot[4]
F_{CR}	Amount of case load associated with conduction and radiation	%	13%[5]
P_{CP}	Total load of new enclosed case	Btuh	332 Btuh/linear foot for coolers; 528 Btuh/linear foot for freezers[6]
F_I	Amount of case load associated with infiltration reduction	%	68%[7]
P_{LP}	Lighting load of new case	Btuh	8.2 Btuh/linear foot[6]
P_{MP}	Motor load of new case	Btuh	2.7 Btuh/linear foot for coolers; 3.5 Btuh/linear foot for freezers[6]
LF	Case load factor, compressor duty cycle needed to maintain case temperatures, deemed	%	62% for coolers; 80% for freezers[8]
3,412	Conversion factor	Btu/kWh	
HOU	Average annual operating hours of the case measured in hours per year, deemed	Hrs/yr	8,760[8]
COP_{REFRIG}	Coefficient of performance of refrigeration system: measure of refrigeration system efficiency equal to ratio of net heat removal to total energy input, deemed		2.3 for coolers; 1.4 for freezers[3]
24	Hours per day	Hrs/day	24
CDD	Cooling degree days, sum of number of degrees average daily temperature is greater than base temperature for given time period, deemed	Days	535[8]
T_S	Temperature of store, deemed	°F	65°F[8]
T_R	Temperature of refrigerated case that needs to be maintained	°F	36.5°F for coolers; -11°F for freezers[9]
$COP_{ROOFTOP}$	Coefficient of performance of rooftop system: measure of efficiency of rooftop system equal to ratio of net heat removal to total energy input		3.2[9]
HDD	Heating degree days, sum of number of degrees average daily temperature is less than base temperature for given time period, deemed	Days	7,699[8]
eff	Heating system efficiency, average combustion efficiency of boiler	%	78%[9]
100,000	Conversion factor	Btu/therm	100,000

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = \{(P_{CE} - P_{LE} - P_{ME} - P_{CE} \cdot F_{CR}) - [P_{CP} \cdot (1 - F_I) - P_{LP} - P_{MP} - P_{CP} \cdot F_{CR} \cdot (1 - F_I)]\} \cdot \left[\frac{1}{3{,}412 \cdot COP_{REFRIG}} - \frac{24 \cdot CDD}{(T_S - T_R) \cdot 3{,}412 \cdot COP_{ROOFTOP} \cdot HOU}\right] \cdot CF$$

Where:

CF = Coincidence factor (1)

Lifecycle Energy-Savings Algorithm

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

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

Where:

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

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.[9]

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.[3] 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[1] 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.

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
03	12/2020	Updated cost
04	08/2022	Updated cost

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[1] 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

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 15 projects and 552 units for MMID 2509 from January 2021 to July 2022 is $881.92.

[3] 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

[4] Manufacturer's specification sheet for open multideck style freezer case. Hussmann Excel F6L. November 2010.

[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] Manufacturer's specification sheet for enclosed reach-in cases. Zero Zone RVCC30 and RVZC30. 2012.

[7] 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.

[8] PA Consulting Group. "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

[9] 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

Retrofit Open Multi-Deck Cases with Doors

	Measure Details
Measure Master ID	Retrofit Open Refrigerated Cases with Doors, 3409
Workpaper ID	W0178
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[1]
Incremental Cost ($/unit)	$313.29[2]

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:

Variable	Description	Units	Value
P_C	Total case load, average energy consumption of refrigerated case	Btuh	1,727.5 Btuh for coolers;[3] 1,850 Btuh for freezers[4]
F_I	Amount of infiltration reduction, fraction of case energy associated with infiltration	%	68%[5]
F_{CR}	Amount of case load energy associated with conduction and radiation	%	13%[6]

Variable	Description	Units	Value
LF	Case load factor, compressor duty cycle needed to maintain case temperatures, deemed	%	62% for coolers; 80% for freezers[7]
HOU	Average annual operating hours of cases, deemed	Hrs/yr	8,760[7]
3,412	Conversion factor	Btu/kWh	3,412
COP_{REFRIG}	Coefficient of performance of refrigeration system, measure of refrigeration system efficiency equal to ratio of net heat removal to total energy input, deemed		2.3 for coolers; 1.4 for freezers[3]
24	Hours per day	Hrs/day	24
CDD	Cooling degree days, sum of number of degrees that average daily temperature is greater than base temperature for given time period (State of Wisconsin uses base temperature of 65°F, a standard value used in HVAC industry), deemed	Days	535[7]
T_S	Temperature of store, deemed	°F	65°F[7]
T_R	Temperature that the refrigerated case needs to be maintained	°F	36.5°F for coolers; -11°F for freezers[8]
$COP_{ROOFTOP}$	Coefficient of performance of rooftop system, measure of rooftop system efficiency equal to ratio of net heat removal to total energy input		3.2[8]
HDD	Heating degree days, sum of number of degrees that average daily temperature is less than base temperature for given time period (State of Wisconsin uses a base temperature of 65°F, a standard value used in HVAC industry), deemed	Days	7,699[7]
eff	Heating system efficiency, average combustion efficiency of boiler	%	78%[8]
100,000	Conversion factor	Btu/therm	100,000

Summer 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

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

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

Where:

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

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.[8]

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.[3] 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[1] 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.

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
03	12/2021	Updated incremental cost

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[1] 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

[2] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 1,434 units over 26 projects from January 2018 to July 2021.

[3] 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

[4] Manufacturer's specification sheet for open multideck style freezer case. Hussmann Excel F6L. November 2010.

[5] 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.

[6] 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.

[7] PA Consulting Group. "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

[8] 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

Strip Curtains for Walk-In Freezers and Coolers

	Measure Details
Measure Master ID	Strip Curtains for Walk-In Freezers and Coolers, 3183
Workpaper ID	W0179
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[2]

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

$$kWh_{\text{SAVED}} = \Delta kWh/LF \ * \ LF$$

Where:

Variable	Description	Units	Value
LF	Linear feet of door width of installation	Ft	

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = \Delta kW/LF \ * \ LF$$

Lifecycle Energy-Savings Algorithm

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

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.[3] 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
	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: $kWh = 365 * t_{OPEN} * (\eta_{NEW} - \eta_{OLD}) * 20 * CD * A * \{[(T_i - T_r)/T_i] * g * H\}^{\wedge}0.5 * 60 * (\rho_i * h_i - \rho_r * h_r) / (3{,}413 * COP_{ADJ})$

*** $kW_{SAVED} = kWh_{SAVED} / 8{,}760$

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.
>
> $$\Delta kW_{PEAK} = \Delta kWh / 8760\text{”}$$

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	Number with Walk-In Refrigeration	Percentage with Walk-In Refrigeration	Percentage of Total Facilities
Restaurant	424	139.92	33%	59%
Convenience Store	96	67.2	70%	28%
Supermarket	39	31.2	80%	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.

Revision History

Version Number	Date	Description of Change
01	04/2013	Initial submittal
02	01/2019	Removed MMID 3284

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[1] GDS Associates, Inc. The Measure Life Report for Residential and Commercial/Industrial Lighting and HVAC Measures. June 2007.

[2] WESCO Distribution Pricing ($45.00) + Labor ($5.00) = $50.00.

[3] *Pennsylvania Technical Reference Manual*. 2013. http://www.puc.state.pa.us/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx

Refrigeration Savings for Lighting Upgrades

	Measure Details
Measure Master ID	Refrigeration Savings for Lighting Upgrades in Cooler, 5236 Refrigeration Savings for Lighting Upgrades in Freezer, 5235
Workpaper ID	W0286
Measure Unit	Per watt reduced
Measure Type	Prescriptive
Measure Group	Refrigeration
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)	Varies by sector[1]
Incremental Cost ($/unit)	$0 (see Assumptions)

Measure Description

Light emitting diode (LED) fixtures use less electricity than fluorescent or HID 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. This measure provides a prescriptive method to claim refrigeration savings only for LEDs replacing traditional lighting sources in refrigerated warehouses. These refrigeration savings are registered as measures separately from the lighting savings—they represent the additional savings coming only from the reduction in refrigeration load stemming from a refrigerated lighting upgrade. These measures will typically be paired with workpapers W0115 and W0118, though others are possible.

Description of Baseline Condition

The baseline condition is fluorescent or HID lighting fixtures. For new construction applications, the baseline wattage will be determined by multiplying the proposed LED wattage by 2.0 (see the Assumptions section).

Description of Efficient Condition

The efficient condition is ENERGY STAR or DLC-qualified LED lighting in a refrigerated warehouse. Walk-in coolers and freezers are not eligible. Cooler space is defined as having evaporator temperatures from 10 to 35°F. Freezer space is defined as having evaporator temperatures from -25 to -15°F.

Annual Energy-Savings Algorithm

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

$$= Watts_{\text{REDUCED}} * HOU / (COP * 1{,}000)$$

Where:

Variable	Description	Units	Value
$Watts_{\text{BASE}}$	Total system wattage of fluorescent or HID lighting	Watts	For new construction, use 2.0X $Watts_{\text{EE}}$ value
$Watts_{\text{EE}}$	Total system wattage of ENERGY STAR and/or DLC-listed LED product	Watts	
COP	Coefficient of performance		2.3 for coolers, 1.4 for freezers[2]
1,000	Conversion factor	W/kW	
HOU	Average annual run hours	Hrs/yr	Varies by sector; see Hours of Use by Sector table below[3]

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

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

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life, see table below

Deemed Savings

Here, deemed savings are calculated on a per-watts reduced basis. The values in the table below indicate the savings from defining $Watts_{\text{REDUCED}}$ = 1 in the algorithm above for each sector.

Annual and Lifecycle Energy Savings per Watt Reduced

Measures	MMID	Sector	EUL[1]	Annual kWh	Lifecycle kWh	kW
Refrigeration Savings, Cooler	5236	Commercial	20	1.62	32.4	0.0004
		Industrial	19	2.06	39.1	0.0004
		Agriculture	19	2.04	38.8	0.0004
		Schools & Gov	20	1.41	28.2	0.0004
Refrigeration Savings, Freezer	5235	Commercial	20	2.66	53.2	0.0007
		Industrial	19	3.39	64.4	0.0007
		Agriculture	19	3.36	63.8	0.0007
		Schools & Gov	20	2.31	46.2	0.0007

Assumptions

No additional costs for claiming refrigeration savings associated with LED fixtures. Costs are associated with LED fixtures only.

For new construction projects, a 2.0 factor of the proposed LED wattage was assumed to obtain the baseline wattage. Based on workpaper W0259's T8 lamp configuration wattage relative to energy efficient LED wattage.

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).

Revision History

Version Number	Date	Description of Change
01	10/2021	Initial TRM entry
02	10/2023	Added NC Baseline. Updated EULs based on sector specific HOUs.

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[1] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Rated lifetime data for fixtures used in custom lighting projects (MMID 2455, LED Not Otherwise Specified) in refrigerated warehouses. 51 projects and 493 fixtures from January 2019 to November 2021. 91.4% high bay (W0115, EUL = 20 for all sectors) and 8.6% linear ambient fixture (W0118, EUL = 12-17 depending on sector) installations. EUL is 19 years for Industrial and Agricultural sectors; 20 years for Commercial and Schools & Government sectors.

[2] 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

[3] PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. Table 3.2 for nonresidential HOU. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

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
Workpaper ID	W0180
Measure Unit	Per MBh (heating capacity)
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Geothermal
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	114
Peak Demand Reduction (kW)	0.0271
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	2,842
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	25[1]
Incremental Cost ($/unit)	Based on actual program data in current year

Measure Description

This measure is installing geothermal (ground-source) heat pump systems in nonresidential 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.[2]

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

$$kWh_{\text{SAVED}} = (EFLH_{\text{COOL}} * CAP_{\text{COOL}} * (1 / SEER_{\text{BASE}} - 1 / (EER_{\text{EE}} * 1.02))) / 1{,}000 + (EFLH_{\text{HEAT}} * CAP_{\text{HEAT}} * (1 / HSPF_{\text{BASE}} - 1 / (COP_{\text{EE}} * 3.412))) / 1{,}000$$

Where:

Variable	Description	Units	Value
$EFLH_{COOL}$	Full-load cooling hours	Hrs	599[3]
CAP_{COOL}	Cooling capacity of equipment	$Btu/hr/MBh_{HEAT}$	1,311 (see Assumptions)
$SEER_{BASE}$	Seasonal energy efficiency ratio of baseline equipment	kBtu/kWh	13.0[2]
EER_{EE}	Energy efficiency ratio of efficient equipment	kBtu/kWh	22.43[4]
1.02	Factor to determine SEER based on its EER		1.02
1,000	Conversion factor	W/kW	1,000
$EFLH_{HEAT}$	Full-load heating hours	Hrs	1,466[4]
CAP_{HEAT}	Heating seasonal performance factor of baseline equipment	$Btu/hr/MBh_{HEAT}$	1,000 (see Assumptions)
$HSPF_{BASE}$	Heating seasonal performance factor of baseline equipment	kBtu/kWh	7.7[2]
COP_{EE}	Coefficient of performance of efficient equipment		4.18[4]
3.412	Conversion factor	kBtu/kW	3,412

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = (Btu/h_{\text{COOL}} * (1 / EER_{\text{BASE}} - 1 / EER_{\text{EE}})) / 1{,}000 * CF$$

Where:

EER_{BASE} = Energy efficiency ratio of baseline equipment (12.75)[2]

CF = Coincidence factor (0.61)

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (25 years)[1]

Assumptions

This workpaper estimates savings based on a per-MBh-heating basis. The previous version of this workpaper used deemed heating capacity (30,579 Btu/h) and cooling capacity (40,089 Btu/h) values based on past projects.[5] The ratio of cooling-to-heating capacities is used to estimate a cooling capacity that corresponds to an MBh of heating capacity (calculation follows).

$$1{,}000 \frac{Btu_{HTG}}{h} * \left(\frac{40{,}089\ Btu_{CLG}}{30{,}579\ Btu_{HTG}}\right) = 1{,}311\ Btu_{CLG}/h$$

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[3] 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)[5]	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)	WI TRM (hours)[6]
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	$EFLH_{HEAT}$[5]	$EFLH_{COOL}$[3]
Average Commercial	**1,466**	**599**

The installation of a ground-source heat pump is more likely to occur in the northern part of the state due to the lack of available natural gas service. Consequently, it is assumed that the cooling hours of operation for ground-source heat pumps in Wisconsin are fewer compared to air conditioners. A lower coincidence factor than residential (0.68)[3] and nonresidential (0.80)[5] air conditioning is used to account for the reduced cooling hours of operation for ground-source heat pumps.

Coincidence Factors by Sector

Sector	Air Conditioner	GSHP
Residential	0.68[3]	0.50[6]
Nonresidential	0.80[7]	0.61[7]

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	10/2017	Updated EUL
03	05/2018	Deemed savings update applied
04	10/2023	EUL Update, updated to a per-ton basis

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[1] Office of Energy and Efficiency & Renewable Energy. Geothermal Heat Pumps. 2017. https://www.energy.gov/eere/articles/5-things-you-should-know-about-geothermal-heat-pumps. Indoor equipment EUL is 25 years, but ground equipment will have a much longer life. An EUL of 25 years is deemed.

[2] International Energy Conservation Code. Table 503.2.3(1). 2009.

[3] See similar measures A/C Split System, ≤ 65 MBh: SEER 14, 2194; SEER 15, 2192; and SEER 16+, 2193.

[4] *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.

[5] *Tracking data model look-ups of AHRI certifications.* Via the 2015 WI TRM.
https://assets.focusonenergy.com/production/Focus%20on%20Energy_TRM_January2015_0.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 were weather normalized for statewide use by population density.

[7] PA Consulting Group. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0. Page 4-153. March 22, 2010. www.focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

VENDING & PLUG LOADS

Engine Block Heater Timer

	Measure Details
Measure Master ID	Timer, Engine Block Heater, 2810
Workpaper ID	W0181
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

$$kWh_{\text{SAVED}} = (P * hours * days * UF)$$

Where:

Variable	Description	Units	Value
P	Average power consumption of engine block heater	kW	1.3 kW[3]
hours	Reduction in number of hours block heater is used per night	Hrs/night	9[3]
days	Number of operating days per year	Days/yr	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

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

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.

Revision History

Version Number	Date	Description of Change
01	10/2015	Initial release
02	06/2016	Updated Assumptions values and source

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[2] Implementer research, 2013. Average online cost of Engine Block Heat Timer.
[3] 2015 Survey Data (27 customers; 65 timers). See Assumptions.

7 Outlet Advanced Power Strip, Business, Pack Based

	Measure Details
Measure Master ID	7 Outlet Advanced Power Strip, Business, Pack Based, 4684
Workpaper ID	W0028
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

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

Where:

Variable	Description	Units	Value
kW_{WkDay}	Standby power consumption of connected electronic on weekday off-hours	kW	0.0315 kW[3]
$Hours_{\text{WkDay}}$	Total hours during the work week, from Monday at 7:30 a.m. to Friday at 5:30 p.m.	Hrs	106 hours
HOU_{WkDay}	Number of hours business is open during work week	Hrs	Varies by sector; see Hours of Use by Sector table below and Assumptions
kW_{WkEnd}	Standby power consumption of connected electronics on weekend off-hours	kW	0.00617 kW[3]
$Hours_{\text{WkEnd}}$	Total hours during weekend, from Friday at 5:30 p.m. to Monday at 7:30 a.m.	Hrs	62
HOU_{WkEnd}	Number of hours business is open during weekend	Hrs	Varies by sector; see Hours of Use by Sector table below and Assumptions
Weeks	Number of weeks per year	Wks/yr	52.14
ISR	In-service rate		0.77 for pack-based measures[4]

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

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for this measure.

Lifecycle Energy-Savings Algorithm

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

Where:

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

Deemed Savings

Annual and Lifecycle Deemed Savings by Sector

Sector	kWh_{SAVED}	$kWh_{\text{LIFECYCLE}}$
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.[3]

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.

Revision History

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

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[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] 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

[4] 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

[5] PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. Table 3.2 Lighting Hours of Use in Commercial Applications.

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, NG, 3559 Boiler, Tier 2, 95%+ AFUE, With DHW, NG, 3778 Boiler, 95%+ Efficient, With DHW, Multifamily, NG, 5234
Workpaper ID	W0183
Measure Unit	Per combination boiler for MMIDs 3559 and 3778 Per MBh for MMID 5234
Measure Type	Prescriptive for MMIDs 3559 and 3778) Hybrid for MMID 5234
Measure Group	Boilers & Burners
Measure Category	Boiler
Sector(s)	Residential- single family, Residential- multifamily
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)	26[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 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 84% annual fuel utilization efficiency (AFUE)[3] (< 300 MBh) or 84%[3] thermal efficiency (TE) (≥ 300 MBh) and a residential, natural gas-fueled, 0.6 EF storage water heater.[4] While water heater baselines vary by type and size, 0.6 is used as a representation of average uniform energy factor (UEF) for medium to high draw for a 50-gallon tank, as discussed in workpaper W0267. This UEF is used to set baseline recovery efficiency.

Description of Efficient Condition

The efficient condition is a combination boiler unit with boiler AFUE or TE 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

$$Therm_{SAVED} = Therm_{SAVED,BOILER} + Therm_{SAVED,WH}$$

$$Therm_{SAVED,BOILER} = BC * EFLH * (EFF_{EE} / EFF_{BASE} - 1) / 100$$

$$Therm_{SAVED,WH} = (GPD * N_{UNITS} * 365 * 8.33 * 1 * \Delta Tw / 100{,}000) * (1 / RE_{BASE} - 1 / E_{C,EE}) + (UA_{BASE} / RE_{BASE} - UA_{EE} / E_{C,EE}) * \Delta Ts * 8{,}760 / 100{,}000$$

Where:

Variable	Description	Units	Value
BC	Boiler capacity	Mbtu/hr	132 MBtu/hour for non-multifamily;[5] user input for multifamily
EFLH	Equivalent full-load hours	Hrs	1,158[6]
EFF_{EE}	Efficient condition	%	95% for non-multifamily; = user input for multifamily
EFF_{BASE}	Baseline condition	%	84% AFUE for boilers < 300 MBh and 84% TE for boilers ≥ 300 MBh)[4,3]
100	Conversion factor	Mbtu/therm	100
GPD	Gallons of hot water used per day		42.75 for non-multifamily;[7,8] 34.14 for multifamily[7,9]
N_{UNITS}	Number of apartments or condos served by boiler system		1 for non-multifamily; user input for multifamily
365	Days per year	Days/yr	365
8.33	Density of water	Lbs/gallon	8.33
1	Specific heat of water	Btu/lb °F	1.0
ΔT_W	Average difference between cold water inlet temperature (52.3°F) and hot water delivery temperature (125°F)	°F	72.7°F[10]
100,000	Conversion factor	Btu/therm	100,000
RE_{BASE}	Recovery efficiency of the baseline tank type water heater	%	76%[11]
$E_{C,EE}$	Combustion efficiency of combination boiler used to provide DHW	%	95% for non-multifamily;[12] user input for multifamily
UA_{BASE}	Overall heat loss coefficient of baseline tank-type water heater	Btu/hr-°F	14.0 Btu/hr-°F[13]
UA_{EE}	Overall heat loss coefficient of combination boiler	Btu/hr-°F	0 Btu/hr-°F
ΔT_S	Temperature difference between stored hot water (125°F) and ambient indoor temperature (65°F)	°F	60°F
8,760	Hours per year	Hrs	8,760

Summer Coincident Peak Savings Algorithm

There is no peak demand reduction for this measure.

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (26 years)[1]

Deemed Savings

Prescriptive Savings for Non-Multifamily Combination Boiler

MMID	Annual Therms	Lifecycle Therms
3559, 3778	322	8,372

Assumptions

Because the efficiency of a residential water heater is measured in UEF, 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.[7] An average value of 2.43 occupants per single family home and 1.93 per multifamily home was used for Wisconsin, based on U.S. Census data.[8] The fitted equation is GPD = -0.0089 * x2 + 16.277 * x + 3.25, where x is the average number of occupants per home.

Revision History

Version Number	Date	Description of Change
01	11/2014	Original
02	12/2014	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
04	10/2021	Included Residential- Multifamily MMID. Reorganized sources.
05	07/2022	Updated boiler capacity for non-multifamily measures
06	09/2022	Update MMID 5234 baseline to 84% TE for boilers ≥300 MBh.

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[1] U.S. Department of Energy. *Technical Support Document: Energy Efficiency Standards for Consumer Products and Industrial Equipment: Residential Boilers.* December 22, 2015.

[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] U.S. Code of Federal Regulations. 10 CFR 431, Table I.1. *https://www.regulations.gov/document/EERE-2013-BT-STD-0030-0099*

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[4] Code of Federal Regulations. Title 10, Chapter II, Subchapter D, Part 430, Subpart C, § 430.32. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32

[5] Average input capacity of boilers under 300 MBh in the 2021 SPECTRUM Database

[6] 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

[7] 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

[8] U.S. Census Bureau. "Demographic Profile for Wisconsin." May 12, 2011. https://www.census.gov/newsroom/releases/archives/2010_census/cb11-cn137.html

[9] U.S. Energy Information Administration. Residential Energy Consumption Survey. 2009. https://www.eia.gov/consumption/residential/index.php

[10] Public Service Commission of Wisconsin. Request for Proposals. Issued for Mass Markets Portfolio Residential Energy Efficiency Program Implementation. July 26, 2011.

[11] Air-Conditioning, Heating, and Refrigeration Institute. https://www.ahridirectory.org/NewSearch?programId=24&searchTypeId=3. Average RE for 476 gas storage water heaters with UEF between 0.58 and 0.62.

[12] ENERGY STAR. "ENERGY STAR Most Efficient 2015 — Boilers." https://www.energystar.gov/index.cfm?c=most_efficient.me_boilers

[13] U.S. Department of Energy. *Technical Support Document: Energy Efficiency Standards for Consumer Products, Residential Water Heaters, Including Regulatory Impact Analysis*. 2000.

Residential Hot Water Boiler

	Measure Details
Measure Master ID	Hot Water Boiler, 95%+ AFUE, 1983 Hot Water Boiler, 95%+ AFUE, 3780 (Tier 2) Hot Water Boiler, 90% AFUE, 5263 Hot Water Boiler, 90% AFUE, 5264 (Tier 2)
Workpaper ID	W0184
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)	Varies by measure
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure
Effective Useful Life (years)	26[1]
Incremental Cost ($/unit)	Varies by measure, see Assumptions[2]

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
90% Efficient Boiler	≤ 300 MBh	AFUE ≥ 90%
95% Efficient Boiler	≤ 300 MBh	AFUE ≥ 95%

Description of Baseline Condition

The baseline equipment is a hot water boiler with 82% AFUE.[3]

Description of Efficient Condition

Energy-efficient space heating boilers often feature high-efficiency and/or low-NO_X 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

$$Therm_{SAVED} = CAP * EFLH * (EFF_{EE} / EFF_{BASELINE} - 1) / 100$$

Where:

Variable	Description	Units	Value
CAP	Boiler input capacity	MBtu/hr[4]	117 MBtu/hr[4]
EFLH	Equivalent full-load hours	Hrs	1,158[5]
$EFF_{BASELINE}$	AFUE of baseline measure	%	82%
EFF_{EE}	AFUE of efficient measure	%	95% or 90%
100	Conversion factor	Mbtu/therm	100

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 (26 years)[1]

Deemed Savings

Deemed Savings by Measure

Boiler Efficiency	Tier	MMID	Annual Therms	Lifecycle Therms	Incremental Cost
95% Boiler	Standard	1983	214	5,564	$1,854
	Tier 2	3780			
90% Boiler	Standard	5263	132	3,432	$1,400
	Tier 2	5264			

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
04	12/2021	Added 90% measure, updated CAP, EUL, and cost

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[1] U.S. Department of Energy. *Technical Support Document: Energy Efficiency Program For Consumer Products and Commercial and Industrial Equipment: Residential Boilers.* December 22, 2015. Page 8F-10. https://www.regulations.gov/document/EERE-2012-BT-STD-0047-0070https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

[2] CLEAResult. Survey of trade allies. Summer 2021. $5,960.63 average cost for an 82% boiler and install, $7,815.00 cost for a 95% boiler and install. $7,815.00 - $5,960.63 = $1,854.38 cost for 95% boiler. Incremental cost for a 90% boiler estimated to be $1,400.

[3] 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

[4] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average input capacity of 1,012 boilers delivered between January 2020 and June 2021.

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[5] 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.

Boiler Tune-Up, Single-Family

	Measure Details
Measure Master ID	Boiler Tune-Up, Single Family, 4659
Workpaper ID	W0186
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

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

Where:

Variable	Description	Units	Value
BOF	Boiler oversize factor	%	77%, deemed
CAP	Size of the boiler being tuned	MBh	108 MBh[3]
SF	Savings factor	%	1.6%, deemed[4]
HDD	Heating degree days	Days	7,699[4]
T_{INDOOR}	Indoor design temperature	°F	65°F[4]
T_{OUTDOOR}	Outdoor design temperature	°F	-15°F[4]
$AFUE_{\text{PRE}}$	AFUE of boiler prior to tune-up	%	82%[5]
100	Conversion factor	MBtu/therm	100

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

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

Where:

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

Revision History

Version Number	Date	Description of Change
01	05/2018	Initial TRM entry

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[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. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Program: Deemed Savings Manual V1.0." March 22, 2010. p. 4-11 (saving factor). https://focusonenergycom/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

[5] PA Consulting Group. "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

BUILDING SHELL

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
Workpaper ID	W0188
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.

$$kWh_{\text{SAVED}} = kWh_{\text{SAVED\_COOL}} + kWh_{\text{SAVED\_HEAT}}$$

$$kWh_{\text{SAVED\_COOL}} = [60 * 0.075 * V * (H_{\text{OUT}} - H_{\text{IN}}) / (1{,}000 * EER)] * HOU_{\text{COOL}} * SF$$

(This should be summed for each temperature bin above the outside temperature when the cooling system is "on.")

$$kWh_{\text{SAVED\_HEAT}} = [1.08 * V * (T_{\text{HEAT}} - T_{\text{OUT}}) / (COP * 3{,}412)] * HOU_{\text{HEAT}} * SF$$

(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:

Variable	Description	Units	Value
60	Conversion factor	Min/hr	60
0.075	Air density	Lbs/ft^3	0.075
V	Volume rate of infiltration air in CFM ACH * A_{FLOOR} * HT_{CEILING} / 60	cfm	
ACH	Baseline air infiltration rate in air changes per hour	Chgs/hr	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	Ft^2	User input
HT_{CEILING}	Average ceiling height	Ft	User input
H_{OUT}	Enthalpy of outside air during the cooling season	Btu/lb	Varies, from weather data
H_{IN}	Enthalpy of inside air during the cooling season	Btu/lb	28.3, see Assumptions
1,000	Conversion factor	Btu/Mbtu	1,000
EER	Efficiency of cooling equipment in Btu/watt	Btu/watt	User input
HOU_{COOL}	Number of hours per year the outside temperature is above T_{COOL} + ΔT_{COOL}	Hrs/yr	Varies, from weather data
T_{COOL}	Thermostat setpoint during cooling season	°F	75°F, see Assumptions
ΔT_{COOL}	Degrees above cooling thermostat setpoint (T_{COOL}) that cooling equipment is off	°F	5°F, see Assumptions
SF	Savings fraction		0.10, see Assumptions
1.08	Sensible heat constant	Btu/hr-CFM-°F	
T_{HEAT}	Thermostat setpoint during heating season	°F	65°F, see Assumptions
T_{OUT}	Temperature of outside air during the heating season	°F	From weather data
COP	Coefficient of performance in watts of heat transferred per watt of electrical input	Watts	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 factor	Btu/kWh	3,412
HOU_{HEAT}	Number of hours per year the outside temperature is below T_{HEAT} + ΔT_{HEAT}	Hrs/yr	Varies, from weather data
ΔT_{HEAT}	Degrees below the heating thermostat setpoint (T_{HEAT}) that the heating equipment is off	°F	10°F, see Assumptions

Variable	Description	Units	Value
$Therms_{SAVED}$	[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.)	°F	
Eff_{HEAT}	Thermal efficiency of heating equipment, fraction		User input
100,000	Conversion factor	Btu/therm	100,000

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = CF * kWh_{\text{SAVED\_COOL}} / HOU_{\text{COOL}}$$

Where:

CF = Coincidence factor (0.68)[4]

Lifecycle Energy-Savings Algorithm

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

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)[5]
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
-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[5]

Temperature Range	Green Bay	La Crosse	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%
La Crosse	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[6] 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[7] 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[8] 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 was the most conservative (highest) and local to Wisconsin.[2]

Revision History

Version Number	Date	Description of Change
01	04/2019	Initial TRM entry

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[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] 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

[6] 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

[7] 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

[8] 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

[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.

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 Existing Insulation R-20 to R-38, 5167 New Construction to R-49, 4824 Natural Gas Heat without Cooling: Existing Insulation R-12 to R-19, 3710 Existing Insulation ≤ R-11, 3708 Existing Insulation R-20 to R-38, 5168 New Construction to R-49, 4379 Electric Heat with Cooling: Existing Insulation ≤ R-11, 3711 Existing Insulation R-12 to R-19, 3713 Existing Insulation R-20 to R-38, 5169 New Construction to R-49, 4380 Electric Heat without Cooling: Existing Insulation ≤ R-11, 3712 Existing Insulation R-12 to R-19, 3714 Existing Insulation R-20 to R-38, 5170 New Construction to R-49, 4381
Workpaper ID	W0189
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)	32[1]
Incremental Cost ($/unit)	Existing Insulation ≤ R-11 = $1.87 (MMIDs 3707, 3708, 3711, and 3712); Existing Insulation R-12 to R-19 = $1.62 (MMIDs 3709, 3710, 3713, and 3714); Existing Insulation R20 to R-38 = $1.01 (MMIDs 5167, 5168, 5169, 5170) New Construction to R-49 = $1.01 (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.[4]

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.

$$Therms_{\text{SAVED}} = [(1 / R_{\text{BASE}} - 1 / R_{\text{EE}}) * HDD * 24 * Area] / (100{,}000 * AFUE)$$

$$kWh_{\text{SAVED}} = kWh_{\text{SAVED\_HEAT}} + kWh_{\text{SAVED\_COOL}}$$

$$kWh_{\text{SAVED\_HEAT}} = [(1 / R_{\text{BASE}} - 1 / R_{\text{EE}}) * HDD * 24 * Area] / (1{,}000 * HSPF)$$

$$kWh_{\text{SAVED\_COOL}} = [(1 / R_{\text{BASE}} - 1 / R_{\text{EE}}) * CDD * 24 * Area] / (1{,}000 * SEER)$$

Where:

Variable	Description	Units	Value
R_{BASE}	Existing R-value of attic	$(ft^2 \cdot °F \cdot h)/Btu$	R-11, R-19, or R-38 for existing buildings, R-38 for new construction
R_{EE}	Proposed R-value of attic after retrofit	$(ft^2 \cdot °F \cdot h)/Btu$	R-49[5]
HDD	Heating degree days	Days	7,616; see Cooling and heating Degree Days by City table below
24	Hours per day	Hrs/day	24
Area	Attic area to be insulated	Ft^2	
100,000	Conversion factor	Btu/therm	100,000
AFUE	Natural gas heating system efficiency	%	84%[6]
1,000	Conversion factor	W/kW	1,000
HSPF	Electric heating system efficiency	Btu/watt-hr	3.412 for electric resistance heat
CDD	Cooling degree days	Days	565; see Cooling and heating Degree Days by City table below
SEER	Cooling system efficiency	Btu/watt-hr	13[7,8]

Cooling and Heating Degree Days by City

Location	HDD[9]	CDD[7]
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**

Summer Coincident Peak Savings Algorithm[10]

$$kW_{SAVED} = (kWh_{SAVED\_COOL} \,/\, EFLH_{COOL}) * CF$$

Where:

$EFLH_{COOL}$ = Equivalent full-load cooling hours (410)[11]

CF = Coincidence factor (0.68)[11]

Lifecycle Energy-Savings Algorithm

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

$$Therms_{LIFECYCLE} = ThermsS_{AVED} * EUL$$

Where:

EUL = Effective useful life (32 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	0.07	0.15	0.0001	2.21	4.6
Existing Insulation R-12 to R-19	3709	0.03	0.07	0.0001	1.01	2.1
Existing Insulation R-20 to R-38	5167	0.01	0.01	0.0000	0.18	0.4
New Construction to R-49	4824					
Natural Gas Heat without Cooling						
Existing Insulation ≤ R-11	3708	--	0.15	--	--	4.6
Existing Insulation R-12 to R-19	3710	--	0.07	--	--	2.1
Existing Insulation R-20 to R-38	5168	--	0.01	--	--	0.4
New Construction to R-49	4379					
Electric Heat with Cooling						
Existing Insulation ≤ R-11	3711	3.85	--	0.0001	115.5	--
Existing Insulation R-12 to R-19	3713	1.76	--	0.0001	52.8	--
Existing Insulation R-20 to R-38	5169	0.32	--	0.0000	9.7	--
New Construction to R-49	4380					
Electric Heat without Cooling						
Existing Insulation ≤ R-11	3712	3.78	--	--	113.3	--
Existing Insulation R-12 to R-19	3714	1.73	--	--	51.8	--
Existing Insulation R-20 to R-38	5170	0.32	--	--	9.5	--
New Construction to R-49	4381					

Assumptions

The summer coincident peak savings algorithm is derived from the Illinois TRM.[10]

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. Costs from 2008 are increased 19% for inflation from 2008 to 2021.

Measure Details from Database for Energy Efficient Resources

Insulation Improvement	MMIDs	DEER 2008 Measure	Inflation-Adjusted DEER Cost ($/Sq Ft)		
			Material	Labor	Total
Retrofit R-11 to R-49 (R-38 improvement)	3707, 3708, 3711, 3712	Extrapolation of next two rows	$1.06	$0.81	$1.87
Retrofit R-19 to R-49 (R-30 improvement)	3709, 3710, 3713, 3714	Ceiling - Add R-30 batts	$0.89	$0.73	$1.62
Retrofit R-38 to R-49 (R-11 improvement)	4824, 4379, 4380, 4381	Ceiling - Add R-11 batts	$0.48	$0.54	$1.01
New Construction R-38 to R-49 (R-11 improvement)	5167, 5168, 5169, 5170				

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
04	01/2021	Updated efficient insulation level to R-49 for existing
05	07/2022	Updated EUL to 32

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[1] Guidehouse. EMV Group A, Deliverable 16 EUL Research – Residential Insulation. June 29, 2021. https://pda.energydataweb.com/api/view/2518/CPUC%20Insulation%20EUL%20Draft%20Report%2006292021.pdf. Median insulation age value across all material types is 32 years.

[2] California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” Revised Measure Cost Summary. June 2, 2008. Costs from 2008 are increased 19% for inflation from 2008 to 2021. 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] ENERGY STAR website. Accessed November 1, 2018. www.energystar.gov/index.cfm?c=home_sealing.hm_improvement_insulation_table

[5] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average installed insulation level for existing insulation measures is R-49. Based on 32 projects from June through November 2020.

[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] 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

[8] International Energy Conservation Code. Table 503.2.3(1). 2009.

[9] 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.

[10] Illinois Energy Efficiency Statewide Advisory Group. *Illinois Statewide Technical Reference Manual.* Section 5.6.1 Air Sealing. June 1, 2015. http://ilsagfiles.org/SAxG_files/Technical_Reference_Manual/Version_4/2-13-15_Final/Updated/Illinois_Statewide_TRM_Effective_060115_Final_02-24-15_Clean.pdf

[11] Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

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
Workpaper ID	W0190
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)	32[1]
Incremental Cost ($/year)	$1.22 for retrofit measures; $1.25 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

$$Therms_{\text{SAVED}} = [(1 \,/\, R_{\text{BASE}} - 1 \,/\, R_{\text{EE}}) * Area * (1 - FramingF)] * 24 * HDD \,/\, (100{,}000 * AFUE)$$

$$kWh_{\text{SAVED}} = kWh_{\text{SAVED\_HEAT}} + kWh_{\text{SAVED\_COOL}}$$

$$kWh_{\text{SAVED\_HEAT}} = [(1 \,/\, R_{\text{BASE}} - 1 \,/\, R_{\text{EE}}) * Area * (1 - FramingF)] * 24 * HDD \,/\, (1{,}000 * HSP)$$

$$kWh_{\text{SAVED\_COOL}} = [(1 \,/\, R_{\text{BASE}} - 1 \,/\, R_{\text{EE}}) * Area * (1 - FramingF)] * 24 * CDD \,/\, (1{,}000 * SEER)$$

Where:

Variable	Description	Units	Value
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	Ft^2	
FramingF	Adjustment to account for area of framing	%	25%[4]
HDD	Heating degree days	Days	7,616; see Heating and Cooling Degree Days by Location 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	Days	565; see Heating and Cooling Degree Days by Location 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]

$$kW_{\text{SAVED}} = (kWh_{\text{SAVED\_COOL}} / EFLH_{\text{COOL}}) * CF$$

Where:

$EFLH_{\text{COOL}}$ = Equivalent full-load cooling hours (410)[9]

CF = Coincidence factor (0.68)[9]

Lifecycle Energy-Savings Algorithm

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

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

Where:

EUL = Effective useful life (32 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	3.52	7.83
NG Heat without Cooling	3704	-	0.245	-	-	7.83
Electric Heat with Cooling	3705	6.144	-	0.0002	196.61	-
Electric Heat without Cooling	3706	6.027	-	-	192.96	-
NC-Residential - Multifamily						
NG Heat with Cooling	3703	0.008	0.016	0.0000	0.25	0.52
NG Heat without Cooling	**3704**	**-**	**0.016**	**-**	**-**	**0.52**
Electric Heat with Cooling	3705	0.410	-	0.0000	13.11	-
Electric Heat without Cooling	3706	0.402	-	-	12.86	-

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	$0.41	$0.81	$1.22
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)	$0.44	$0.81	$1.25

Revision History

Version Number	Date	Description of Change
01	01/2016	Initial TRM entry
02	11/2017	Added measures for new construction
03	07/2022	Updated EUL
04	07/2023	Updated IMC

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[1] Guidehouse. EMV Group A, Deliverable 16 EUL Research – Residential Insulation. June 29, 2021. https://pda.energydataweb.com/api/view/2518/CPUC%20Insulation%20EUL%20Draft%20Report%2006292021.pdf. Median insulation age value across all material types is 32 years.

[2] California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." https://www.caetrm.com/media/reference-documents/2010-2012_WO017_Ex_Ante_Measure_Cost_Study_-_Final_Report.pdf (Appendix F.1. page 20)

[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

Whole Home Completion

	Measure Details
Measure Master ID	Project Completion, Electric Heat, 4883 Project Completion, Natural Gas Heat, 4884 Project Completion, Natural Gas Only, 4887 Project Completion, Tier 2, Electric Heat, 4885 Project Completion, Tier 2, Natural Gas Heat, 4886 Project Completion, Tier 2, Natural Gas Only, 4888
Workpaper ID	W0239
Measure Unit	Per residence
Measure Type	Prescriptive
Measure Group	Building Shell
Measure Category	Insulation
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)	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)	25[1,2] (see Assumptions)
Incremental Cost ($/unit)	Varies by measure,[3] see Annual Savings and Cost table below

Measure Description

This measure is insulation and air sealing work completed by a contractor in a home or in one, two, or three units of an owner-occupied condo or apartment in a multifamily (3+ unit building). For any rental, or if improving more than 4 units in a building, use Workpaper(s) W0188, W0189 and/or W0190. 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,[4] 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: basic air sealing installed to *Materials and Installation* standards,[4] 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 PY 2020 evaluation to produce evaluated savings.[5,6] As part of this analysis, billing data from participant and nonparticipant sites was analyzed and incorporated into final results. Results are used here to produce prescriptive savings for each site instead of continuing to use modeling for individual projects.

Billing Analysis Participant Count

Measure Set	Participants	Nonparticipants (Control Group)
Tier 1 gas	1,295	138
Tier 1 electric	1,124	130
Tier 2 gas	168	47
Tier 2 electric	134	48

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: no air sealing work performed, 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: air sealing work performed, closed cavity filled with insulation, framed floor cavity filled with insulation
- Duct sealing: ductwork sealed and insulated to R-8

Annual Energy-Savings Algorithm

$kWh_{\text{SAVED}} = kWh_{\text{BA}}$

$Therm_{\text{SAVED}} = Therm_{\text{BA}}$

Where:

Variable	Description	Units	Value
kWh_{BA}	Average kilowatt-hours saved per site, as determined by PY 2020 billing analysis data	kWh	See Annual Savings and Cost tables below, see Assumptions
$Therm_{\text{BA}}$	Average therms saved per site, as determined by PY 2020 billing analysis	Therms	See Annual Savings and Cost tables below, see Assumptions

Summer Coincident Peak Savings Algorithm

$kW_{\text{SAVED}} = kW_{\text{NET}}$

Where:

kW_{NET} = Net kilowatts saved per site (see Annual Savings and Cost table below, see Assumptions)

Lifecycle Energy-Savings Algorithm

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

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

Where:

EUL = Effective useful life (25 years,[1,2] see Assumptions)

Assumptions

EUL

An EUL of 32 is assumed for insulation savings[2] and an EUL of 15 is assumed for air sealing savings.[1] Approximately 58% of annual Whole Home savings come from insulation, and 42% from air sealing. This produces a weighted Whole Home measure EUL of 25 years.

Billing Analysis

The 2020 Focus on Energy Evaluation Report[5] and its appendices[6] present results for the PY 2020 billing analysis. This analysis represents an update of the one performed for the PY 2017 evaluation, which previously informed deemed TRM savings for these measures.

For gas savings, as seen in the report's Table 54 and Table 58, Tier 1 sites have 135 therm savings with ±9% precision at 90% confidence, and Tier 2 sites save 186 therms with ±22% 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.

For electric savings, as seen the report's Table 54 and Table 55, Tier 1 gas heat sites save 854 kWh with ±20% precision at 90% confidence, Tier 1 electric heat sites save 2,395 kWh with ±21% precision at 90% confidence, Tier 2 gas heat sites save 945 kWh with ±12% precision at 90% confidence.

As was the case for the 2017 billing analysis and the previous version of this workpaper, the precision for Tier 2 electric heat sites was too poor to use. In the previous version of this workpaper,[7] Tier 2 electric heat site savings was estimated as [Tier 2 all sites electric savings] * [Tier 1 gas heat site electric savings] / [Tier 1 all sites electric savings] to produce 749 kWh. For this current version of the workpaper, the Tier 2 electric heat site savings are estimated by multiplying the previous savings by the PY 2020 net to gross ratio (in this case essentially the realization rate) of 97%. This 97% value can be seen in Table 55 of the PY 2020 report.[5] Therefore PY 2021 Tier 2 electric heat sites savings are 2,880 * 97% = 2,793 kWh.

Demand reduction cannot be derived from billing analysis results. In the previous version of this workpaper, an initial demand reduction per unit was calculated by first dividing the total net demand reduction from 2017 (from Snugg pro modeling) by the total site count from 2017 (1,244 Tier 1 and 282 Tier 2 sites). Then the deemed 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.

There is no updated set of Snugg Pro models with which to repeat this derivation. Therefore in this current version of the workpaper, the PY 2020 net to gross ratios (in this case essentially the realization rates) are multiplied by the previous demand savings. They are 0.3151 * 133% = 0.4191 kW for Tier 1 gas heat, 0.3151 * 97% = 0.3056 kW for Tier 1 electric heat, 0.3688 * 126% = 0.4647 kW for Tier 2 gas heat, and 0.3688 * 97% = 0.3577 for Tier 2 electric heat.

Multifamily Adjustment

Whole Home measures are also offered for specific multifamily sites. Savings for these sites follow those for single family sites, but are decremented a further 20% based on differences in delivered furnace sizes for single family and multifamily sectors. Their costs are also decremented 20%.

Deemed Savings

Project Completion Measure	Sector	MMID	kW[5,6]	Annual		Lifecycle	
				kWh[5,6]	Therms[5,6]	kWh	Therms
Project Completion, Electric Heat	SF	4883	0.3056	2,395	0	59,875	0
Project Completion, Natural Gas Heat		4884	0.4191	854	135	21,350	3,375
Project Completion, Natural Gas Only		4887	0.0000	0	135	0	3,375
Project Completion, Tier 2, Electric Heat		4885	0.3577	2,793	0	69,825	0
Project Completion, Tier 2, Natural Gas Heat		4886	0.4647	945	186	23,625	4,650
Project Completion, Tier 2, Natural Gas Only		4888	0.0000	0	186	0	4,650
Project Completion, Tier 1 Electric Heat	MF	4883	0.2445	1,916	0	47,900	0
Project Completion, Tier 1 Natural Gas Heat		4884	0.3353	683	108	17,075	2,700

Project Completion Measure	Sector	MMID	kW[5,6]	Annual		Lifecycle	
				kWh[5,6]	Therms[5,6]	kWh	Therms
Project Completion, Tier 1 Natural Gas Only		4887	0.0000	0	108	0	2,700
Project Completion, Tier 2 Electric Heat		4885	0.2862	2,235	0	55,875	0
Project Completion, Tier 2 Natural Gas Heat		4886	0.3717	756	149	18,900	3,725
Project Completion, Tier 2 Natural Gas Only		4888	0.0000	0	149	0	3,725

Costs

Measure	Sector	MMID	Cost	Note
Project Completion, Electric Heat	SF	4883	$5,015.95	Average of 1,576 sites
Project Completion, Natural Gas Heat		4884		
Project Completion, Natural Gas Only		4887		
Project Completion, Tier 2, Electric Heat		4885	$5,688.17	Average of 229 sites
Project Completion, Tier 2, Natural Gas Heat		4886		
Project Completion, Tier 2, Natural Gas Only		4888		
Project Completion, Tier 1 Electric Heat	MF	4883	$4,012.76	20% reduction of SF
Project Completion, Tier 1 Natural Gas Heat		4884		
Project Completion, Tier 1 Natural Gas Only		4887		
Project Completion, Tier 2 Electric Heat		4885	$4,550.54	20% reduction of SF
Project Completion, Tier 2 Natural Gas Heat		4886		
Project Completion, Tier 2 Natural Gas Only		4888		

Revision History

Version Number	Date	Description of Change
01	01/2019	Initial TRM entry
02	12/2021	Updated with new billing analysis results, new EUL
03	10/2023	Updated with multifamily

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[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
15-year value for air sealing is used

[2] Guidehouse. *EMV Group A, Deliverable 16 EUL Research – Residential Insulation*. June 29, 2021. https://pda.energydataweb.com/api/view/2518/CPUC%20Insulation%20EUL%20Draft%20Report%2006292021.pdf
Page 29 shows median age of 32 years for household insulation.

[3] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. January 2021 to November 2021. Average actual measure cost based on 1,805 projects

[4] 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

[5] Cadmus. *Focus on Energy Calendar Year 2020 Evaluation Report, Volume II*. May 21, 2021. https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_II.pdf

[6] Cadmus. *Focus on Energy Calendar Year 2020 Evaluation Report, Volume III*. May 21, 2021. https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_III.pdf

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[7] Cadmus. *Wisconsin Focus on Energy 2020 Technical Reference Manual*. 2020. Page 1,028. https://www.focusonenergy.com/sites/default/files/Focus_on_Energy_2020_TRM.pdf

DIY Building Shell Project Completion

	Measure Details
Measure Master ID	DIY Building Shell, Electric Heat, 5103 DIY Building Shell, Natural Gas Heat, 5104 DIY Building Shell, Natural Gas Heat, Non-Participating Electric Utility, 5105 Multifamily DIY Building Shell, Electric Heat, 5260 Multifamily DIY Building Shell, Natural Gas Heat, 5261 Multifamily DIY Building Shell, Natural Gas Heat, NPE Utility, 5262
Workpaper ID	W0256
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)	25[1,2]
Incremental Cost ($/unit)	Varies by measure[3]

Measure Description

This measure is very similar to the whole-home project completion measures (W0239), typically contractor installed, consisting of insulation and air sealing work completed by a homeowner after completing a do-it-yourself (DIY) weatherization training, and adjusted for homeowner installation. These measures consist largely of work completed primarily in the attic. Additional work can be done to the foundation, though attic insulation and air sealing are required.

Eligible weatherization measures:

- Air sealing and attic insulation (existing effective R-19 or less)
- Foundation insulation

This measure covers all insulation and air sealing improvements completed as a single entity with combined savings:

- Attic insulation: basic air sealing installed to *Material and Installation Standards*,[4] at least 600 square feet of attic area must be improved
- Sill box foundation insulation: at least 50% of the sill area must be improved

These measures must be installed according to the homeowner-adapted version of the program's *Material and Installation Standards* used in the contractor offering. Health and safety education is included in this training related to insulation and air sealing measures, combustion safety, and hazardous materials. Pre-existing conditions and the installation of measures must be verified by photographic or video records with program quality assurance staff. These records are submitted along with the incentive application.

Note that NPE (non-participating electric utility) is for sites that do not receive electric savings.

Description of Baseline Condition

The baseline condition is the air sealing and insulation levels of an existing home with the following maximum existing conditions:

- Attic insulation: no air sealing work performed, open cavity with an effective insulation of R-19 or less, closed cavity with no effective insulation
- Sill box foundation insulation: no effective existing insulation

Description of Efficient Condition

The efficient condition is the air sealing and insulation levels of an existing home after the homeowner completes a weatherization training class and installs materials according to industry guidelines. Work is completed by the homeowner with the following minimum conditions:

- Attic insulation: air sealing work performed, open cavity with insulation of R-38 or greater; closed cavity filled with insulation
- Sill box foundation insulation: sill insulation of R-5 or greater

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = kWh_{\text{BA,DIY}} * F_{\text{DIY}}$$

$$Therm_{\text{SAVED}} = Therm_{\text{BA,DIY}} * F =$$

Where:

Variable	Description	Units	Value
$kWh_{\text{BA,DIY}}$	Average kilowatt-hours saved per site, as determined by analysis of 2020 billing analysis data	kWh	See Annual Savings and Cost tables below, see Assumptions
F_{DIY}	Adjustment factor to account for expected quality of the work performed by a homeowner	%	75%[5]
$Therm_{\text{BA,DIY}}$	Average therms saved per site, as determined by analysis of 2020 billing analysis data	Therms	See Annual Savings and Cost tables below, see Assumptions

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = kW$$

Where:

kW_{NET} = Kilowatts saved per site (see Annual Savings and Cost table below, see Assumptions)

Lifecycle Energy-Savings Algorithm

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

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

Where:

EUL = Effective useful life (25 years,[1,2] see Assumptions)

Assumptions

EUL

An EUL of 30 is assumed for insulation savings,[2] and an EUL of 15 is assumed for air sealing savings.[1] Approximately 58% of annual Whole Home savings come from insulation, and 42% from air sealing. This produces a weighted Whole Home measure EUL of 25 years.

Billing Analysis

These measures are derived in part from DIY offerings cited in the Vermont TRM,[5] which decrements savings for a DIY installation by 25% relative to a professional contractor installation.

The billing analysis results presented in the *Focus on Energy Calendar Year 2020 Evaluation Report*[6] reflect savings for the billing analysis sample. These sites all had professional installs of the full suite of whole-home measures, including attic insulation and sealing, sill box insulation, foundation insulation, wall insulation, and duct sealing.

However, the DIY whole-home measures only include attic insulation, attic sealing, and sill box insulation. Therefore, the 2020 data were re-analyzed to examine only sites that received these two measures—617 Tier 1 sites with natural gas heat, 22 Tier 1 sites with electric heat, and 58 Tier 2 sites with gas heat. The resulting kilowatt-hour savings were 3%% to 34% lower than those for the full suite of whole-home measures. Precision was poor in many cases, and assumptions were sometimes made to adjust results.

These results were then decremented by an additional 25% to account for DIY installation. They were also adjusted to reflect the fact that the DIY measures are not divided into Tier 1 and Tier 2 measures like the standard whole-home measures. In PY2020, 8.6% of sites with just attic insulation and air sealing were Tier 2 sites, and the results were weighted to reflect this difference.

To estimate demand reduction, the demand reduction for the current standard whole-home measures are altered. The current standard whole-home demand savings are 0.3056 for Tier 1 electric heat, 0.4191 for Tier 1 natural gas heat, 0.3577 for Tier 2 electric heat, and 0.4647 for Tier 2 natural gas heat. These were decreased by 38% to reflect the DIY measure mix, decreased by 25% to reflect DIY versus professional installation, and weighted to reflect 8.6% of sites being Tier 2.

Multifamily Adjustment

Whole Home DIY measures are also offered for multifamily sites. Savings for these sites follow those for single family sites, but are decremented a further 20% based on differences in delivered furnace sizes for single family and multifamily sectors.[7] Their costs are also decremented 20%.

Deemed Savings and Cost

Measure	MMID	Cost[3]	kW	Annual Savings		Lifecycle Savings	
				kWh	Therms	kWh	Therms
DIY Building Shell, Electric Heat	5103	$1,115.29	0.1684	1,200	0	30,000	0
DIY Building Shell, Natural Gas Heat	5104		0.2298	543	101	13,575	2,525
DIY Building Shell, Natural Gas Heat, NPE	5105		0.0000	0	101	0	2,525
Multifamily DIY Building Shell, Electric Heat	5260	$892.23	0.1347	960	0	24,000	0
Multifamily DIY Building Shell, NG Heat	5261		0.1838	434	81	10,860	2,020
Multifamily DIY Building Shell, NG Heat, NPE	5262		0.0000	0	81	0	2,020

Revision History

Version Number	Date	Description of Change
01	01/2021	Initial TRM entry
02	12/2021	Update to reflect PY2020 billing analysis, multifamily measures

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[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
A 20-year value for weatherization was used.

[2] Guidehouse. *EMV Group A, Deliverable 16 EUL Research – Residential Insulation*. June 29, 2021. https://pda.energydataweb.com/api/view/2518/CPUC%20Insulation%20EUL%20Draft%20Report%2006292021.pdf
Page 29 shows median age of 32 years for household insulation. An EUL of 30 was used due to concern over extending EULs in Focus on Energy over 30 years.

[3] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 40 projects from January 2021 to November 2021 is $1,115.29. Multifamily costs are assumed to be 80% of this, or $892.23.

[4] 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

[5] Efficiency Vermont. *Technical Reference Manual Measure Savings Algorithms and Cost Assumptions*. pp. 262–267. December 31, 2018. https://puc.vermont.gov/sites/psbnew/files/doc_library/Vermont%20TRM%20Savings%20Verification%202018%20Version_FINAL.pdf

[6] Cadmus. *Focus on Energy Calendar Year 2020 Evaluation Report*. May 21, 2021. https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_III.pdf

[7] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average delivered furnace size of 14,362 single family units in 2020 was 70.0 MBh, and for 264 multifamily units was 56.1 MBh. (70.0 - 56.1) / 70.0 = a 20% reduction. This ratio is assumed to apply to disparities in DIY Whole Home savings as well.

DOMESTIC HOT WATER

Kitchen/Bathroom Aerators and Showerheads

	Measure Details
Measure Master ID	Faucet Aerator, Kitchen: 1.5 GPM, Online Store, 4910 1.5 GPM, Pop-Up Retail , 5311 1.5 GPM, Pack-based, 5312 Faucet Aerator, Bath: 1.0 GPM, Pack-based, 3863 1.0 GPM, Online Store, 4909 1.0 GPM, Online Store LTO, 5047 1.0 GPM, Pop-Up Retail , 5313 Showerhead: Upgraded, 1.5 GPM, Pack-based 4273 Handheld, 1.5 GPM, Pack-based 4274 Upgraded, 1.5 GPM, Online Store, 4911 Handheld, 1.5 GPM, Online Store, 5043 Upgraded, 1.5 GPM, Online Store LTO, 5048 Handheld, 1.5 GPM, Pop-Up Retail, 5314 Upgraded, 1.5 GPM, Pop-Up Retail, 5315
Workpaper ID	W0191
Measure Unit	Per aerator
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Aeration
Sector(s)	Residential- single family, Residential- multifamily, Upstream
Annual Energy Savings (kWh)	Varies by measure and sector
Peak Demand Reduction (kW)	Varies by measure and sector
Annual Therm Savings (Therms)	Varies by measure and sector
Lifecycle Electricity Savings (kWh)	Varies by measure and sector
Lifecycle Therm Savings (Therms)	Varies by measure and sector
Water Savings (gal/year)	Varies by measure and sector
Effective Useful Life (years)	10[1]
Measure Incremental Cost ($/unit)	Varies by measure[2]

Measure Description

This measure is installing low-flow kitchen or bathroom aerators or low-flow showerheads in existing buildings or new construction. Pack-based, upstream retail, and online store measures reduce both natural gas and electric consumption, based on building stock splits derived from the *2016 Focus on Energy Potential Study*.[3] 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 1.5 GPM, a bathroom aerator at 1.0 GPM, or a showerhead at 1.5 GPM.

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = Gallons_{\text{SAVED}} * ((8.33 * C * (T_{\text{POU}} - T_{\text{ENTERING}}) / (EF_{\text{ELECTRIC}} * 3{,}412) * \%Elec) + (kWh_{\text{WATER}} / 1{,}000))$$

$$Therm_{\text{SAVED}} = Gallons_{Saved} * 8.33 * C * (T_{\text{POU}} - T_{\text{ENTERING}}) / (EF_{\text{GAS}} * 100{,}000) * \%Gas$$

Aerators

$$Gallon_{\textbf{SAVED}} = (GPM_{\textbf{EXIST}} - GPM_{\textbf{NEW}}) * (PH / FH) * FLU * 365 * IR * DF$$

Showerheads

$$Gallon_{\textbf{SAVED}} = (GPM_{\textbf{EXIST}} - GPM_{\textbf{NEW}}) * (PH * SPD / FH) * SLU * 365 * IR * DF$$

Where:

Variable	Description	Units	Value
$\text{Gallons}_{\text{SAVED}}$	First-year water savings in gallons	Gallons	
8.33	Density of water	Lbs/gallon	8.33
C	Specific heat of water	Btu/lb °F	1 Btu/lb °F
T_{POU}	Temperature of water at point of use	°F	93°F for kitchen aerators; 86°F for bathroom aerators; 101°F for showerheads[4]
$\text{T}_{\text{ENTERING}}$	Temperature of water entering water heater	°F	52.3°F[5]
$\text{EF}_{\text{ELECTRIC}}$	Energy factor of electric water heater	%	94% for single-family; 92% for multifamily,[3] see Assumptions
3,412	Conversion factor	Btu/kWh	3,412
%Elec	Fraction of sites with electric water heaters	%	20% for single-family; 14% for multifamily, see Assumptions[3]
$\text{kWh}_{\text{WATER}}$	Energy saved from water and wastewater utilities	kWh/kgal	3.89 kWh/kgal[6]
1,000	Conversion factor	Gal/kgal	1,000
EF_{GAS}	Fraction of sites with natural gas water heaters	%	61% for single-family; 75% for multifamily,[3] see Assumptions
%Gas	Fraction of sites with electric water heaters	%	73% for single-family; 86% for multifamily, see Assumptions[3]
100,000	Conversion factor	Btu/therm	100,000
$\text{GPM}_{\text{EXIST}}$	Baseline flow rate	gpm	2.2 GPM for kitchen and bathroom aerators; 2.5 GPM for showerheads[7]
GPM_{NEW}	Efficient flow rate	gpm	1.0 or 1.5 GPM for kitchen and bathroom aerators; 1.5 GPM for showerheads
PH	Persons per house		2.52 for single-family homes, 1.93 for multifamily units[8]

Variable	Description	Units	Value
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[4]
FLU	Fixture length of use in minutes per person per day	Min/ person	4.5 for kitchen aerators; 1.6 for bathroom aerators[4]
365	Conversion factor	Days/yr	365
IR	Installation rate		See Installation Rates table[8,9,10]
DF	Drain factor		0.75 for kitchen aerators, 0.90 for bathroom aerators, 1.0 for showerheads; see Assumptions
SPD	Showers per person per day	Showers/ person	0.6[4]
SLU	Shower length of use	Mins/ shower	7.8 minutes per shower[4]

Installation Rates

Measure Name	MMID	Sector	IR	Source
Faucet Aerator, Kitchen, 1.5 GPM, Online Store	4910	SF/MF	82%	10
Faucet Aerator, Kitchen, 1.5 GPM, Pop-Up Retail	5311	Pop-Up	42%	12
Faucet Aerator, Kitchen, 1.5 GPM, Pack-based	5312	SF/MF	55%	11
Faucet Aerator, Bath, 1.0 GPM, Pack-based	3863	SF/MF	55%	11
Faucet Aerator, Bath, 1.0 GPM, Online Store	4909	SF/MF	82%	10
Faucet Aerator, Bath, 1.0 GPM, Online Store LTO	5047	SF/MF	82%	10
Faucet Aerator, Bath, 1.0 GPM, Pop-Up Retail	5313	Pop-Up	40%	12
Showerhead, Upgraded, 1.5 GPM, Pack-based	4273	SF	72%	11
	4273	MF	66%	11
Showerhead, Handheld, 1.5 GPM, Pack-based	4274	SF	73%	11
	4274	MF	58%	11
Showerhead, Upgraded, 1.5 GPM, Online Store	4911	SF/MF	77%	10
Showerhead, Handheld, 1.5 GPM, Online Store	5043	SF/MF	77%	10
Showerhead, Upgraded, 1.5 GPM, Online Store LTO	5048	SF/MF	77%	10
Showerhead, Handheld, 1.5 GPM, Pop-Up Retail	5314	Pop-Up	55%	12
Showerhead, Upgraded, 1.5 GPM, Pop-Up Retail	5315	Pop-Up	55%	12

Summer Coincident Peak Savings Algorithm

Aerators

$$kW_{\text{SAVED}} = kWh_{\text{SAVED}} * CF \ / \ (PH * LU * 365 \ / \ 60 \ / \ FH)$$

$$CF = \%Peak_{\text{AERATOR}} * FLU \ / \ 240$$

Showerheads

$$kW_{\text{SAVED}} = kWh_{\text{SAVED}} * CF / (PH * SPD * SLU * 365 / 60 / FH)$$

$$CF = \%Peak_{\text{SHOWER}} * SLU * SPD / 240$$

Where:

Variable	Description	Units	Value
kWh_{SAVED}	Calculated savings per faucet	kWh	
CF	Coincidence factor		0.0035 for kitchen aerators, 0.0013 for bathroom aerators, 0.0025 for showerheads
60	Conversion factor	Min/hr	60
$\%Peak_{\text{AERATOR}}$	Amount of time faucet aerator is used during peak period	%	18.77%[10]
240	Number of minutes during peak period	Minutes	240
$\%Peak_{\text{SHOWER}}$	Amount of time shower is used during peak period	%	12.86%[9,10]

Lifecycle Energy-Savings Algorithm

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

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

Where:

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

Deemed Savings and Costs

Deemed Savings

Description	MMIDs	Sector	Water Savings	Annual		kW	Lifecycle	
				kWh	Therms		kWh	Therms
Kitchen Aerators, 1.5 GPM								
Online Store	4910	SF	1,782	45	7.23	0.0023	450	72.3
		MF	1,365	26	5.31	0.0017	260	53.1
Pop-Up Retail	5311	Pop-Up	898	22	3.63	0.0011	220	36.3
Pack-based	5312	SF	1,195	30	4.85	0.0015	300	48.5
		MF	915	17	3.56	0.0012	170	35.6
Bathroom Aerators, 1.0 GPM								
Pack-based	3863	SF	429	9.17	1.44	0.0010	92	14.4
		MF	468	7.68	1.51	0.0007	77	15.1
Online Store, Online Store LTO	4909, 5047	SF	639	14	2.15	0.0014	140	21.5
		MF	698	11.46	2.25	0.0011	110	22.5
Pop-Up Retail	5313	MF	314	6.59	1.05	0.0007	66	10.5

Description	MMIDs	Sector	Water Savings	Annual		kW	Lifecycle	
				kWh	Therms		kWh	Therms
Showerheads, 1.5 GPM								
Upgraded, Pack-based	4273	SF	2,066	60	10	0.0032	600	100
		MF	2,176	48	10	0.0022	480	100
Handheld, Pack-based	4274	SF	2,095	61	10	0.0032	610	100
		MF	1,912	42	8.89	0.0019	420	88.9
Upgraded, Online Store Handheld, Online Store Upgraded, Online Store LTO	4911, 5043, 5048	SF	2,210	65	11	0.0034	650	110
		MF	2,539	56	12	0.0025	560	120
Handheld, Pop-Up Retail Upgraded, Pop-Up Retail	5314, 5315	Pop-Up	2,210	65	11	0.0034	650	110

Incremental Costs

Costs for Aerator and Showerhead Measures[2]

Description	MMIDs	Cost
Kitchen Aerators, 1.5 GPM		
Online Store	4910	$5.00
Retail	5311	$3.50
Pack-based	5312	$1.96
Bathroom Aerators, 1.0 GPM		
Pack-based	3863	$0.86
Online Store	4909	$1.25
Online Store LTO	5047	
Retail	5313	$1.25
Showerheads, 1.5 GPM		
Upgraded, Pack-based	4273	$5.91
Handheld, Pack-based	4274	$17.96
Upgraded, Online Store	4911	$7.00
Handheld, Online Store	5043	$19.00
Handheld, Pop-Up Retail	5314	$15.00
Upgraded, Online Store LTO	5048	$7.00
Upgraded, Pop-Up Retail	5315	$6.00

Assumptions

The peak percentage values of 12.68% and 18.77% for showerheads and aerators, respectively, were determined from Figure 2 of a study conducted by Aquacraft, Inc.[10] The peak values are from the 2 p.m. to 6 p.m. time period.

Two programs have independently applied drain factors. First, the Illinois TRM uses values of 75% for kitchen usage and 90% for bathroom usage.[11] These values were agreed to by the Illinois Technical Advisory Group, as no studies of drain factor are known. Second, the Ontario Energy Board uses values of 50% for bathrooms and 70% for kitchens, citing a study from 2008.[12] 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,*[3] 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.* 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%.

Fuel Splits

All 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% of single-family homes had propane water heaters).[3]

Ninety-two multifamily sites were visited as part of the *2016 Potential Study,* 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.

Pop-Up Retail Sector Split

For Pop-Up Retail measures, savings are weighted by approximate single family / multifamily participant counts, from 2020 program year Pop-Up Retail Survey results. Nine out of 120 respondents (7.5%) receiving an Energy and Water Savings Kit (containing showerheads, aerators, bulbs, pipe wrap, and a DHW turndown card) were multifamily participants. Nine out of 147 respondents receiving an LED Starter Kit, containing omnidirectional bulbs and a desk lamp, were multifamily participants. A rounded value of 7% is applied for these types of Pop-Up Retail measures, including TSVs.

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
07	01/2021	Added retail and online store measures
08	08/2021	Updated installation rates and costs, and added retail pop-up MMIDs
09	09/2022	Updated cost for MMID 4274, added secondary water savings to algorithm
10	06/2023	Updated showerheads OLM ISRs, and energy saved from water and wastewater utilities

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[1] GDS Associates, Inc. and Summit Blue Consulting. "Natural Gas Energy Efficiency Potential in Massachusetts." Table B-2a, measure C-WH-15. April 22, 2009.

[2] Aerators and showerheads are treated as modification measures, with no baseline cost. Costs reflect the full cost to the Focus on Energy program for the measures, including discount and customer price.

[3] Cadmus. *2016 Potential Study for Focus on Energy.* Data maintained by Cadmus and Wisconsin PSC.

[4] Cadmus. *Showerhead and Faucet Aerator Meter Study*. Memo to Michigan Evaluation Working Group. June 2013.

[5] National Renewable Energy Laboratory. "Tool for Generating Realistic Residential Hot Water Event Schedules." https://www.nrel.gov/docs/fy10osti/47685.pdf
Average water main temperature of all locations measured in Wisconsin by scheduler, weighted by city populations.

[6] Water-Related Energy Savings using updated CMAR (2016-2020) and WI Water Utility databases (2015-2022). A weighted average was used for the calculation of the water energy savings factor for groundwater/surface water, and for facilities with 0-1 MGD/ >1 MGD. Calculations and data provided in Huddle folder of this workpaper.

[7] Alliance Water Efficiency. *National Efficiency Standards and Specifications for Residential and Commercial Water-Using Fixtures and Appliances.* August 2011. https://www.nwf.org/~/media/PDFs/Eco-schools/matrix508.ashx

[8] U.S. Energy Information Administration. Residential Energy Consumption Survey. 2009. https://www.eia.gov/consumption/residential/index.php

[9] Cadmus. *Focus on Energy Calendar Year 2020 Evaluation Report Volume II.* p. 22. May 21, 2021. *https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_II.pdf*

[10] DeOreo, William B. and Peter Mayer. *Residential End Uses of Water.* Figure 5.22, p. 125. https://irp.cdn-website.com/bd62ee4a/files/uploaded/WRF%20%281999%29%20Residential%20End%20Uses%20of%20Water.pdf

[11] Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 6.0*. Volume 3: Residential Measures. February 8, 2017.

[12] Navigant Consulting. *Measures and Assumptions for Demand Side Management (DSM) Planning. Appendix C: Substantiation Sheets.* April 16, 2009. https://www.oeb.ca/oeb/_Documents/EB-2008-0346/Navigant_Appendix_C_substantiation_sheet_20090429.pdf

Showerhead Thermostatic Shut-off Valves

	Measure Details
Measure Master ID	Thermostatic Shut-Off Valve, Online Store, 5184 Thermostatic Shut-Off Valve, Pop-Up Retail, 5309 Thermostatic Shut-Off Valve with 1.5 GPM Showerhead, Online Store, 5186 Thermostatic Shut-Off Valve with 1.5 GPM Showerhead, Pop-Up Retail, 5310
Workpaper ID	W0268
Measure Unit	Per valve
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Aeration
Sector(s)	Residential- single-family, Residential- multifamily, Residential- upstream
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)	10[1]
Measure Incremental Cost ($/unit)	Thermostatic Shut-Off Valve = $29.99 (MMIDs 5184 and 5309)[2] Thermostatic Shut-Off Valve with 1.5 GPM Showerhead = $39.99 (MMIDs 5186 and 5310)[2]

Measure Description

This measure is installing a thermostatic shut-off valve (TSV) to the existing showerhead or shower arm. The valve reduces the water flow to a trickle once the temperature reaches 95°F, prior to user entering the shower, thereby conserving water and saving energy required for water heating. The measure can also be installed in combination with a low-flow showerhead.

Description of Baseline Condition

The baseline condition is an existing showerhead without a TSV installed.

Description of Efficient Condition

The efficient condition is a TSV on a residential showerhead or shower arm.

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = Gallons_{\text{SAVED}} * ((8.33 * C * (T_{\text{POINT OF USE}} - T_{\text{ENTERING}}) * \%Elec / (EF_{\text{ELECTRIC}} * 3{,}412)) + (kWh_{\text{WATER}} / 1{,}000))$$

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

TSV alone

$$Gallon_{SAVED} = GPM_{STOCK} * (PH * SPD / FH) * BW * 365 * IR_{TSV}$$

TSV with low-flow showerhead

$$Gallon_{SAVED} = (GPM_{BASE} - GPM_{NEW}) * (PH * SPD / FH) * SLU * 365 * IR_{SH} + GPM_{NEW} * (PH * SPD / FH) * BW * 365 * IR_{TSV}$$

Where:

Variable	Description	Units	Value
$Gallons_{SAVED}$	First-year water savings in gallons	Gallons	
8.33	Density of water	Lbs/gal	8.33
C	Specific heat of water	Btu/lb °F	1
$T_{POINT\ OF\ USE}$	Temperature of water at point of use	°F	101°F for showerheads[3]
$T_{ENTERING}$	Temperature of water entering water heater	°F	52.3°F[4]
%Elec	Fraction of sites with electric water heaters	%	20% for single-family; 14% for multifamily, see Assumptions[5]
$EF_{ELECTRIC}$	Energy factor of electric water heater	%	94% for single family,[5] 92% for multifamily,[5] see Assumptions
3,412	Conversion factor	Btu/kWh	3,412
kWh_{WATER}	Energy saved from water and wastewater utilities	kWh/kgal	3.89[6]
1,000	Gallons per kilogallon	Gal/kgal	1,000
EF_{GAS}	Energy factor of natural gas water heater	%	61% for single family;[5] 75% for multifamily,[5] see Assumptions
%Gas	Fraction of sites with natural gas water heaters	%	73% for single family; 86% for multifamily, see Assumptions[5]
100,000	Conversion factor	Btu/therm	100,000
GPM_{STOCK}	Flow rate of average showerhead installed	gpm	2.35 GPM[7]
GPM_{BASE}	Baseline flow rate	gpm	2.5 GPM for showerheads[8]
GPM_{NEW}	Efficient flow rate	gpm	1.5 GPM
PH	Persons per house		2.52 for single-family homes, 1.93 for multifamily units[9]
SPD	Showers per person per day		0.6[3]
SLU	Shower length of use	Minutes	7.8 minutes per shower[3]
FH	Fixtures per house		1.5 for for single-family homes, 1.0 for multifamily units[3]
BW	Behavioral waste time in minutes per shower	Minutes	0.89[10]
365	Conversion factor	Days/yr	365
IR_{TSV}	Installation rate for TSVs		0.78 for online store and 0.55 for retail pop-up,[11] see Assumptions
IR_{SH}	Installation rate for showerheads		0.78 for online store and 0.55 for retail pop-up[11]

Summer Coincident Peak Savings Algorithm

$$kW_{SAVED} = kWh_{SAVED} * CF / (PH * SPD * SLU * 365 / 60 / FH)$$

$$CF = \%Peak_{SHOWER} * SLU * SPD / 180$$

Where:

kWh$_{SAVED}$ = Calculated savings per faucet

CF = Coincidence factor (0.0023)

60 = Conversion factor, min/hr

180 = Number of minutes during peak period

%Peak$_{SHOWER}$ = Amount of time shower is used during peak period (9%)[12]

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 by Measure and Sector

Description	MMID	Sector	Water Savings (Gallons)	kW Saved	kWh Saved		Therms Saved	
					Annual	Lifecycle	Annual	Lifecycle
Thermostatic Shut-Off Valve								
Online Store	5184	SF	600	0.0009	18	180	2.91	29.1
		MF	690	0.0006	15	150	3.21	32.1
Retail Pop-Up	5309	Pop-Up	428	0.0006	12	120	2.07	20.7
Thermostatic Shut-Off Valve with 1.5 GPM Showerhead								
Online Store	5186	SF	2,622	0.0037	77	770	13	130
		MF	3,012	0.0028	66	660	14	140
Retail Pop-Up	5310	Pop-Up	1,868	0.0026	53	530	9.04	90.4

Assumptions

The installation rate for retail pop-up combination measure of showerhead and thermostatic shut-off valve together is based off of the 2020 retail participant survey results for the showerhead measure.

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.[12] The peak values are from 2:00 p.m. to 6:00 p.m., Monday to Friday from June through September.

Energy Factors

Based on six units observed as part of the *2016 Potential Study,*[5] 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.* 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%.

Fuel Splits

Retail/Online 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% of single-family homes had propane water heaters).[4]

Ninety-two multifamily sites were visited as part of the *2016 Potential Study* 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.

Pop-Up Retail Sector Split

For Pop-Up Retail measures, savings are weighted by approximate single-family/multifamily participant counts, from 2020 program year Pop-Up Retail Survey results. Nine out of 120 respondents (7.5%) receiving an Energy and Water Savings Kit (containing showerheads, aerators, bulbs, pipe wrap, and a DHW turndown card) were multifamily participants. Nine out of 147 respondents receiving an LED Starter Kit, containing omnidirectional bulbs and a desk lamp, were multifamily participants. A rounded value of 7% is applied for these types of Pop-Up Retail measures, including TSVs.

Revision History

Version Number	Date	Description of Change
01	01/2021	Initial TRM entry
02	08/2021	Updated installation rates and added retail pop-up MMID placeholders
03	06/2022	Added annual energy savings from water and WWTP utilities
04	06/2023	Updated OLM Thermostatic Shut-Off Valve ISRs, and energy saved from water and wastewater utilities

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[1] Navigant. "ComEd Effective Useful Life Research Report."May 2018. https://www.icc.illinois.gov/docket/P2017-0312/documents/287811/files/501915.pdf

[2] Showerheads and TSVs are treated as modification measures, with no baseline cost. Costs reflect the total cost to Focus on Energy for program year 2021.

[3] Cadmus. *Showerhead and Faucet Aerator Meter Study*. Memo to Michigan Evaluation Working Group. June 2013.

[4] National Renewable Energy Laboratory. "Tool for Generating Realistic Residential Hot Water Event Schedules." https://www.nrel.gov/docs/fy10osti/47685.pdf

Average water main temperature of all locations measured in Wisconsin by scheduler, weighted by city populations.

[5] Cadmus. *2016 Potential Study for Focus on Energy.* Data maintained by Cadmus and Wisconsin PSC.

[6] Water-Related Energy Savings using updated CMAR (2016-2020) and WI Water Utility databases (2015-2022). A weighted average was used for the calculation of the water energy savings factor for groundwater/surface water, and for facilities with 0-1 MGD/ >1 MGD. Calculations and data provided in Huddle folder of this workpaper.

[7] Alliance Water Efficiency. *National Efficiency Standards and Specifications for Residential and Commercial Water-Using Fixtures and Appliances.* August 2011. https://www.nwf.org/~/media/PDFs/Eco-schools/matrix508.ashx

[8] U.S. Energy Information Administration. Residential Energy Consumption Survey. 2009. https://www.eia.gov/consumption/residential/index.php

[9] Cadmus. *Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2014*. May 15, 2015. https://www.efis.psc.mo.gov/mpsc/commoncomponents/viewdocument.asp?DocId=935933383

[10] Illinois Energy Efficiency Statewide Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency Version 8.0.* Volume 3. October 17, 2019. Page 219. IL-TRM_Effective_01-01-20_v8.0_Vol_3_Res_10-17-19_Final.pdf (ilsag.info)

[11] *Cadmus. Focus on Energy Calendar Year 2020 Evaluation Report Volume II.* Pages 14 and 22. May 21, 2021. *https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_II.pdf*

[12] DeOreo, William B and Peter W. Mayer. *Residential End Uses of Water.* Figure 5.22, page 125. RESIDENTIAL END USES OF WATER (cdn-website.com). Accessed 25 October 2022.

Tub Spout Thermostatic Shut-off Valves

	Measure Details
Measure Master ID	Tub Spout Thermostatic Shut-Off Valve – OLM, 10056 Tub Spout Thermostatic Shut-Off Valve – Contractor, 10055
Workpaper ID	W0317
Measure Unit	Per valve
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Aeration
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)	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)	Valve = $191.99[2]

Measure Description

This measure is installing a thermostatic shut-off valve (TSV) to the existing tub spout and a normally closed, low-flow shower head (or a shower head equipped with a thermostatic valve) to replace a typical tub spout diverter valve and standard-flow showerhead. The valve diverts water flow to the shower head once the temperature reaches 95°F, then the showerhead also closes, thereby conserving water and saving energy required for water heating.

Description of Baseline Condition

The baseline condition is an existing tub spout and standard-flow showerhead without a TSV installed.

Description of Efficient Condition

The efficient condition is a TSV on a tub spout and a TSV installed on a new residential low-flow showerhead or shower arm.

Annual Energy-Savings Algorithm

$$kWh_{SAVED} = Gallons_{SAVED} * ((8.33 * C * (T_{POU} - T_{ENTER}) * \%Elec / (EF_{ELECTRIC} * 3{,}412)) + (kWh_{WATER} / 1{,}000))$$

$$Therm_{SAVED} = Gallons_{SAVED} * 8.33 * C * (T_{POU} - T_{ENTER}) / (EF_{GAS} * 100{,}000) * \%Gas$$

$$Gallon_{SAVED} = (GPM_{SH,BASE} - GPM_{SH,NEW}) * (PH * SPD / FH) * SLU * 365 * IR_{SPOUT} + GPM_{SPOUT} * (PH * SPD / FH) * BW * 365 * IR_{SPOUT} + DL * TSL * TSF * (PH * SPD / FH) * SLU * 365 * IR_{SPOUT}$$

Where:

Variable	Description	Units	Value
8.33	Density of water	lbs/gal	8.33
C	Specific heat of water	Btu/lb-hr-°F	1.0
T_{POU}	Temperature at point-of-use	°F	101 (showerheads)[3]
T_{ENTER}	Temperature of water entering water heater	°F	52.3[4]
%Elec	Fraction of sites with electric water heaters	%	20% (single family)[5] 14% (multifamily)[5]
$EF_{ELECTRIC}$	Energy factor of electric water heater	none	0.94 (single family)[5] 0.92 (multifamily)[5]
3,412	Conversion factor	Btu/kWh	3,412
kWh_{WATER}	Energy saved from water and wastewater utilities	kWh/kgal	3.89[6]
1,000	Conversion factor	gal/kgal	1,000
EF_{GAS}	Energy factor of gas water heater	none	0.61 (single family)[5] 0.75 (multifamily)[5]
100,000	Conversion factor	Btu/therm	100,000
%Gas	Fraction of sites with natural gas water heaters	%	73% (single family)[5] 86% (multifamily)[5]
GPM_{SPOUT}	Flow rate of average tub spout installed	gal/min	5.0[7]
$GPM_{SH,BASE}$	Baseline showerhead flow rate	gal/min	2.5[8]
$GPM_{SH,NEW}$	Efficient showerhead flow rate	gal/min	1.5
PH	Persons per house	Person/house	2.52 (single family)[9] 1.93 (multifamily)[9]
SPD	Showers per day per person	shower/day/person	0.6[3]
FH	Fixtures per house	fixture/house	1.5 (single family)[3] 1.0 (multifamily) [3]
SLU	Shower length of use	min/shower	7.8[3]
365	Conversion factor	day/yr	365
IR_{SPOUT}	Installation rate for tub spout TSV	none	0.78 (online store; see Assmuptions) 0.55 (retail pop-up; see Assmuptions)
BW	Behavioral waste time	minutes	0.89[10]
IR_{SH}	Installation rate for showerhead	none	0.78 (online store)[11] 0.55 (retail pop-up)[11]
TSL	Tub spout leakage; portion of tub spouts that leak	%	34%[12]
TSF	Tub spout leakage – savings factor	%	70%[12]
DL	Average diverter leakage	gal/min	0.80[12]

Summer Coincident Peak Savings Algorithm

$$kW_{SAVED} = kWh_{SAVED} * CF / (PH * SPD * SLU * 365 / 60 / FH)$$

$$CF = \%Peak_{SHOWER} * SLU * SPD / 240$$

Where:

Variable	Description	Units	Value
CF	Coincidence factor	none	0.0023
60	Conversion factor	min/hr	60
240	Minutes during peak period	min	240
$\%Peak_{SHOWER}$	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

Average Annual Deemed Savings

Measure	MMID	Sectors	Peak Demand Savings (kW)	Annual Electric Savings (kWh)	Annual Gas Savings (therms)	Annual Water Savings (gal)
Tub Spout Thermostatic Shut-Off Valve – OLM	10056	SF	0.0042	115	19	3,942
		MF	0.0032	100	21	4,528
Tub Spout Thermostatic Shut-Off Valve – Contractor	10055	SF	0.0054	147	25	5,053
		MF	0.0041	128	27	5,805

Average Lifecycle Deemed Savings

Measure	MMID	Sectors	Lifecycle Electric Savings (kWh)	Lifecycle Gas Savings (therms)	Lifecycle Water Savings (gal)
Tub Spout Thermostatic Shut-Off Valve – OLM	10055	SF	1,150	190	39,420
		MF	1,000	210	45,280
Tub Spout Thermostatic Shut-Off Valve – Contractor	10056	SF	1,470	250	50,530
		MF	1,280	270	58,050

Assumptions

The installation rate for retail pop-up combination measure of showerhead and thermostatic shut-off valve together is based off of the 2020 retail participant survey results for the showerhead measure.

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 2 p.m. to 6 p.m. time period.

The EUL for the tub spout is expected to be the same as a showerhead thermostatic shut off valve. The flow rate of a tub spout is assumed to be 5 gallons per minute.

Effective Usefull Life (EUL) is assumed to be the same as Showerhead Thermostatic Shut-off Valve.

Energy Factors

Based on six units observed as part of the *2016 Potential Study,*[5] 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.*[5] 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%.

Fuel Splits

Retail/Online 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*[4] (7% of single family homes had propane water heaters).

Ninety-two multifamily sites were visited as part of the *2016 Potential Study*[5] 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.

Pop-Up Retail Sector Split

For Pop-Up Retail measures, savings are weighted by approximate single family / multifamily participant counts, from 2020 program year Pop-Up Retail Survey results. Nine out of 120 respondents (7.5%) receiving an Energy and Water Savings Kit (containing showerheads, aerators, bulbs, pipe wrap, and a DHW turndown card) were multifamily participants. Nine out of 147 respondents receiving an LED Starter Kit, containing omnidirectional bulbs and a desk lamp, were multifamily participants. A rounded value of 7% is applied for these types of Pop-Up Retail measures, including TSVs.

Revision History

Version Number	Date	Description of Change
01	10/2023	Initial TRM Entry

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[1] Navigant. "ComEd Effective Useful Life Research Report." May 2018. https://www.icc.illinois.gov/docket/P2017-0312/documents/287811/files/501915.pdf

[2] Southern California Gas Company. "Auto-Diverting Tub Spout with Thermostatic Shut-off Valve." April 25, 2016 $119.99 material cost plus $72.00 labor cost.

[3] Cadmus. Showerhead and Faucet Aerator Meter Study. Memo to Michigan Evaluation Working Group. June 2013.

[4] National Renewable Energy Laboratory. "Tool for Generating Realistic Residential Hot Water Event Schedules ." https://www.nrel.gov/docs/fy10osti/47685.pdf.

Average water main temperature of all locations measured in Wisconsin by scheduler, weighted by city populations.

[5] Cadmus. 2016 Potential Study for Focus on Energy. Data maintained by Cadmus and Wisconsin PSC.

[6] Water-Related Energy Savings using updated CMAR (2016-2020) and WI Water Utility databases (2015-2022). A weighted average was used for the calculation of the water energy savings factor for groundwater/surface water, and for facilities with 0-1 MGD/ >1 MGD. Calculations and data provided in Huddle folder of this workpaper.

[7] *Flow Rates for Faucets, Showers, and Tub/Shower Values.* Presented by Gary Klein (Gary Klein and Associates) at 2019 ACEEE Hot Water Forum. https://www.aceee.org/sites/default/files/pdf/conferences/hwf/2019/1b-klein.pdf

[8] U.S. Energy Information Administration. Residential Energy Consumption Survey. 2009. https://www.eia.gov/consumption/residential/index.php

[9] Cadmus. Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2014. May 15, 2015. https://www.efis.psc.mo.gov/mpsc/commoncomponents/viewdocument.asp?DocId=935933383

[10.] Illinois Energy Efficiency Statewide Advisory Group. Illinois Statewide Technical Reference Manual for Energy Efficiency Version 8.0. Volume 3. October 17, 2019. Page 219. IL-TRM_Effective_01-01-20_v8.0_Vol_3_Res_10-17-19_Final.pdf (ilsag.info)

[11] Cadmus. Focus on Energy Calendar Year 2020 Evaluation Report Volume II. p. 14 and p. 22. May 21, 2021. https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_II.pdf OLM TSV and SH. Cadmus 2021 participant survey.

[12] Taitem Tech Tip. https://www.taitem.com/wp-content/uploads/Diverter-Valve-Tech-Tip-2011.7.20.pdf

[13] DeOreo, William B and Peter W. Mayer. Residential End Uses of Water. Figure 5.22, p. 125

DHW Temperature Turndown, Pack-Based

	Measure Details
Measure Master ID	DHW Temperature Turn Down: Pack-based, Blended Natural Gas and Electric, 4271 Pop-Up Retail, 5308
Workpaper ID	W0192
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Controls
Sector(s)	Residential- single-family, Residential- multifamily, Residential-upstream
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	Varies by sector
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	Varies by sector
Water Savings (gal/year)	Varies by sector
Effective Useful Life (years)	2[1]
Incremental Cost ($/unit)	Pack-based = $0.95 (MMID 4271);[2] Pop-Up Retail = $3.00 (MMID 5308)[3]

Measure Description

This measures is one part of a homeowner kit—a card that measures the domestic hot water temperature, where the homeowner is responsible for turning the water heater temperature down to 120°F. The card comes included in packs containing other measures, through the Simple Energy Efficiency and Pop-Up Retail programs.

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:

- 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, and 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.
- 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 a 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

$$kWh_{\mathbf{SAVED}} = [(HW_{\mathbf{BASE}} + SB_{\mathbf{BASE}}) - (HW_{\mathbf{EFF}} + SB_{\mathbf{EFF}})] * 365 * (1 / 3{,}412) * BR_{\mathbf{ELEC}} * IR$$

$$\mathrm{HW} = \frac{\mathrm{GPD} * \mathrm{C_P} * (\mathrm{T_{WH}}\text{-}\mathrm{T_{ENTERING}})}{\mathrm{RE_{ELEC}}} * \left[1 - \frac{\mathrm{UA_{ELEC}} * (\mathrm{T_{WH}}\text{-}\mathrm{T_{ROOM}})}{\mathrm{Input_{ELEC}}}\right]$$

$$SB = UA_{\mathrm{ELEC}} * 24 * (T_{\mathrm{WH}} - T_{\mathrm{ROOM}})$$

$$\mathrm{UA_{ELEC}} = \left(\frac{1}{\mathrm{EF_{ELEC}}} - \frac{1}{\mathrm{RE_{ELEC}}}\right) \Big/ \left[67.5 * \left(\frac{24}{\mathrm{Q_{OUT}}} - \frac{1}{\mathrm{RE_{ELEC}} * \mathrm{Input_{ELEC}}}\right)\right]$$

Where:

Variable	Description	Units	Value
HW_{BASE}	Baseline hot water energy use		
SB_{BASE}	Baseline standby energy use		
HW_{EFF}	Efficient hot water energy use		
SB_{EFF}	Efficient standby energy use		
365	Number of days per year	Days/yr	365
3,412	Conversion factor	Btu/kWh	3,412
BR_{ELEC}	Electric blended rate	%	20%[4]
IR	Installation rate	%	16% for single family and upstream, 5% for multifamily; see Assumptions[5]
GPD	Gallons of hot water use per day	Gal/day	32.8 for baseline measure, 34.8 for efficient measure; see Assumptions
C_P	Heat capacity of water	Btu/gal/°F	8.33
T_{WH}	Temperature in tank	°F	125°F for baseline, 120°F for efficient
$T_{ENTERING}$	Cold water mains temperature	°F	52.3°F[6]
RE_{ELEC}	Water heater recovery efficiency		0.98[7]
UA_{ELEC}	Electric water heater equivalent heat loss factor	Btu/hr-°F	1.24
T_{ROOM}	Ambient temperature surrounding tank	°F	65°F; see Assumptions
$Input_{ELEC}$	Firing rate	Btu/hr	15,354; see Assumptions[8]
24	Number of hours per day	Hrs/day	24
EF_{ELEC}	Energy factor		0.94[4]
67.5	Temperature difference during 24-hour test		See Assumptions[8]

Variable	Description	Units	Value
Q_{OUT}	Energy content of water drawn from water heater during 24-hour test	Btu/day	41,094; see Assumptions[8]

Therm Measures

$$Therm_{SAVED} = [(HW_{BASE} + SB_{BASE}) - (HW_{EFF} + SB_{EFF})] * 365 * (1 / 100{,}000) * BR_{GAS} * IR$$

$$HW = GPD * CP * (T_{WH} - T_{ENTERING}) * 1 / RE_{GAS} * [1 - UA_{GAS} * (T_{WH} - T_{ROOM}/Input_{GAS})]$$

$$SB = UA_{GAS} * 24 * (T_{WH} - T_{ROOM})$$

$$UA_{GAS} = \left(\frac{1}{EF_{GAS}} - \frac{1}{RE_{GAS}}\right) \Big/ \left[67.5 * \left(\frac{24}{Q_{OUT}} - \frac{1}{RE_{GAS} * Input_{GAS}}\right)\right]$$

Where:

BR_{GAS} = Natural gas blended rate (73%)

RE_{GAS} = Water heater recovery efficiency (0.76)[7]

UA_{GAS} = Water heater equivalent heat loss factor (8.72 Btu/hr-°F)

$Input_{GAS}$ = Firing rate (= 38,000 Btu/hr; see Assumptions)[8]

EF_{GAS} = Energy factor (0.61)[4]

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)[9]

Lifecycle Energy-Savings Algorithm

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

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

Where:

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

Deemed Savings

Annual and Lifecycle Deemed Savings

Measure	MMID	Sector	Annual Savings		Demand Reduction (kW)	Lifecycle Savings	
			kWh	Therms		kWh	Therms
Pack Based	4271	Single family	1.51	0.62	0.0002	3.0	1.2
		Multifamily	0.47	0.19	0.0001	1.0	0.4
Retail Pop-Up	5308	Pop-Up	1.44	0.59	0.0002	2.9	1.1

Assumptions

Both the pack-based measure and pop-up retail event measure is applied to a mix of electric and natural gas water heaters. This mix was derived from the *2016 Potential Study for Focus on Energy* and is 73% natural gas, 20% electric, and 7% propane water heaters.[4]

Participant survey results from the Focus on Energy 2020 Packs program evaluation revealed an installation rate of 16% for this measure.[5] Of the 312 single family respondents, 151 (48%) said they had used the card to check their water temperature, and 49 (16%) said they had actually reduced their water temperature as a result of using the card.

These results are assumed to reflect the single family sector. Multifamily participants who receive turndown cards have sufficiently similar installation rates and so also use the 16% single family installation rate. However, potential study data indicates that only 30% of multifamily participants will have access to their water heater. Therefore, the multifamily installation rate is deemed to be 30% * 16% = 5%. This assumption may be revisited in future.

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.[10] 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 * 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[2] 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.

The derivation of heat loss factor (UA) comes from the U.S. Department of Energy test procedures for consumer and commercial water heaters.[12]

Some algorithm inputs were derived from the Home Energy Saver engineering documentation from the Lawrence Berkeley National Laboratory website:[8]

- $Input_{ELEC}$ 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.

Pop-Up Retail Sector Split

For Pop-Up Retail measures, savings are weighted by approximate single family / multifamily participant counts, from 2020 program year Pop-Up Retail Survey results. Nine out of 120 respondents (7.5%) receiving an Energy and Water Savings Kit (containing showerheads, aerators, bulbs, pipe wrap, and a DHW turndown card) were multifamily participants. Nine out of 147 respondents receiving an LED Starter Kit, containing omnidirectional bulbs and a desk lamp, were multifamily participants. A rounded value of 7% is applied for these types of Pop-Up Retail measures, including DHWs.

Revision History

Version Number	Date	Description of Change
01	01/2012	Initial TRM entry
02	03/2013	Updated to new template and added lifecycle savings
03	04/2013	Revised and added comments
04	12/2013	Added multifamily sector and larger domestic hot water heater savings
05	10/2016	Removed MMIDs 2125 and 2131
06	03/2018	Added pack-based MMID
07	01/2021	Added pop-up retail MMID
08	08/2021	Updated installation rates and EUL, cost
09	07/2022	Updated EUL

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[1] Illinois Technical Reference User Manual (TRM) V 10. This value is also supported by the Minnesota, Pennsylvania, Vermont, and Mid-Atlantic latests TRM User Manuals.

[2] The pack-based domestic hot water turndown card is included in a free pack with other measures. The incremental cost is therefore the full bulk pricing cost of the card to Focus on Energy, or $0.95.

[3] The Pop-Up Retail domestic hot water turndown card is included in a kit with other retail measures. The incremental cost is therefore the full bulk pricing cost of the card to Focus on Energy, or $3.00.

[4] Cadmus. *2016 Potential Study for Focus on Energy*.
Data maintained by Cadmus and Wisconsin PSC. 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. Weighted fractions of 99 water heaters were 73% natural gas, 20% electric, and 7% propane.

[5] Cadmus*. Focus on Energy Calendar Year 2020 Evaluation Report Volume II. p. 17. May 21, 2021.* https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_II.pdf

[6] U.S. Department of Energy. *DHW Scheduler*.
Used average water main temperature of all Wisconsin locations, weighted by city population.

[7] National Renewable Energy Laboratory. *Building America Research Benchmark Definition*. p. 12. 2009. http://www.nrel.gov/docs/fy10osti/47246.pdf

[8] Lawrence Berkley National Laboratory. *Home Energy Saver and Score: Engineering Documentation*. http://hes-documentation.lbl.gov/calculation-methodology/calculation-of-energy-consumption/water-heater-energy-consumption

[9] Illinois Energy Efficiency Stakeholder Advisory Group. *2021 Illinois Statewide Technical Reference Manual for Energy Efficiency Version 9.0*. September 25, 2020. https://ilsag.s3.amazonaws.com/IL-TRM_Effective_010121_v9.0_Vol_3_Res_09252020_Final.pdf

[10] 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

[11] U.S. Census. “Demographic Profile for Wisconsin.” 2010. https://www.census.gov/newsroom/releases/archives/2010_census/cb11-cn137.html

[12] U.S. Department of Energy. *Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters*. p. 45. 2016. https://www.energy.gov/sites/prod/files/2016/08/f33/Water%20Heaters%20Test%20Procedure%20SNOPR.pdf

Pipe Insulation

	Measure Details
Measure Master ID	Insulation, DHW Pipe, Pack-based, 4272 Insulation, DHW Pipe, Pop-Up Retail, 5319
Workpaper ID	W0193
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)	Pack-based = $3.67 (MMID 4272)[2] Pop-Up Retail = $6.00 (MMID 5319)[3]

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.

The “Pack-based” measure comes in packs as part of the Simple Energy Efficiency Solution, and the “Pop-Up Retail” measure comes in packs as part of the Pop-Up Retail program.

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 and upstream kits include a 15-foot long, 2-inch wide roll of R-2 foam insulation[4] for use with domestic hot water systems only. Each roll can insulate approximately nine linear feet of pipe. Pack-based insulation is delivered as part of a free pack. Upstream insulation is delivered as part of a discounted pack.

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:

Variable	Description	Units	Value
kWh_{UNCOND}	Kilowatt-hours saved for insulation installed in unconditioned space, averaged across HVAC system splits	kWh	72.8 for single-family, 52.1 for multifamily; calculated values
%Uncond	Fraction of insulation installed in unconditioned space	%	19% for single-family,[5] 0% for multifamily; see Assumptions
kWh_{COND}	Kilowatt-hours saved for insulation installed in conditioned space, averaged across HVAC system splits	kWh	88.6 for single-family, 21.3 for multifamily; calculated values
%Cond	Fraction of insulation installed in conditioned space	%	81% for single-family, 100% for multifamily; see Assumptions[5]
ISR	Installation rate for insulation	%	35% for single-family Pack-based, 27% for multifamily Pack-based, 25% for Pop-Up Retail[6]
Insul	Hot water heat loss prevented by installing pipe insulation	Btuh/ft	14.81; see Assumptions[7]
Length	Length of pipe covered by wrap	Ft	9
HOU	Hours of use	Hrs	8,760
EF_{ELEC}	Energy factor of electric water heater	%	94% for single-family, 92% for multifamily[5]
3,412	Conversion factor	kWh/Btu	3,412
f_{ELEC}	Fraction of sites receiving insulation packs with electric hot water heating	%	20% for single-family, 14% for multifamily[5]
kWh_{HEAT}	Heating kilowatt-hours reduced by pipe heat losses in conditioned space for average pack	kWh	4.10 for single-family, 35.96 for multifamily; see Assumptions
kWh_{COOL}	Cooling kilowatt-hours increased by pipe heat losses in conditioned space for average pack	kWh	19.85 for single-family, 5.21 for multifamily; see Assumptions

Natural Gas Savings

$$Therms_{SAVED} = (Therms_{UNCOND} * \%Uncond + Therms_{COND} * \%Cond) * ISR$$

$$Therms_{UNCOND} = Insul * Length * HOU / (EF_{GAS} * 100{,}000) * f_{GAS}$$

$$Therms_{COND} = Therms_{UNCOND} - Therms_{HEAT}$$

Where:

Variable	Description	Units	Value
$Therms_{UNCOND}$	Therms saved for insulation installed in unconditioned space, averaged across HVAC system splits	Therms	14.0 for single family, 13.4 for multifamily; calculated values
$Therms_{COND}$	Therms saved for insulation installed in conditioned space, averaged across HVAC system splits	Therms	8.6 for single family, 8.1 for multifamily; calculated values
EF_{GAS}	Energy factor of natural gas water heater	%	61% for single family, 75% for multifamily[6]
100,000	Conversion factor for Btu per therm	Btu/ therm	100,000
f_{GAS}	Fraction of sites receiving insulation packs with natural gas hot water heating	%	73% for single family, 86% for multifamily[6]
$Therms_{HEAT}$	Heating therms reduced by pipe heat losses in conditioned space for an average pack	Therms	5.41 for single family, 5.313 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 (100%)[8]

%Cool = Portion of constant pipe heat loss that goes to increasing cooling needed (27%; see Assumptions)

Lifecycle Energy-Savings Algorithm

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

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

Where:

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

Deemed Savings

Deemed Savings for Natural Gas and Electricity

Measure	MMID	Sector	kW	Annual		Lifecycle		Incre-mental Cost
				kWh	therms	kWh	therms	
Insulation, DHW Pipe, Pack-Based	4272	Single Family	0.0064	36	4.04	540	60.6	$2.43
		Multifamily	0.0026	6.94	2.63	104.1	39.5	$2.43
		Pop-Up	0.0044	24	2.86	369	42.9	$6.00

Assumptions

The heat loss per foot of pipe insulation installed was calculated using CheCalc[7] 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 = 65°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 31.68 Btuh/ft, and the resulting loss factor for insulated pipe was 13.84 Btuh/ft, for a difference of 17.84 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.[9] 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[5] 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 $Therms_{HEAT}$, 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[5]	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.[5]

** 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[5]	26.050
Room air conditioner	19%	10.2 SEER	Potential Study[5]	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.[5]

** 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[5]	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.[5]

** 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[5]	26.050
Room air conditioner	19%	10.2 SEER	Potential Study[5]	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.[5]

** 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.

Pop-Up Retail Sector Split

For Pop-Up Retail measures, savings are weighted by approximate single family / multifamily participant counts, from 2020 program year Pop-Up Retail Survey results. Nine out of 120 respondents (7.5%) receiving an Energy and Water Savings Kit (containing showerheads, aerators, bulbs, pipe wrap, and a DHW turndown card) were multifamily participants. Nine out of 147 respondents receiving an LED Starter Kit, containing omnidirectional bulbs and a desk lamp, were multifamily participants. A rounded

Revision History

Version Number	Date	Description of Change
01	08/2018	Initial TRM entry
02	08/2021	Updated installation rates and costs, changed to pop-up retail MMID

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[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] Pack-based pipe insulation is included in a free pack with other measures. The incremental cost is the full bulk pricing cost of the insulation to Focus on Energy, $3.67.

[3] Pop-Up Retail pipe insulation is included in a kit with other Pop-Up Retail measures. The incremental cost is the full bulk pricing cost of the insulation to Focus on Energy, $6.00.

[4] 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

[5] 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.

[6] Cadmus. *Focus on Energy Calendar Year 2020 Evaluation Report Volume II.* Table 13 and Table 20. *May 21, 2021. https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_II.pdf*

[7] CheCalc. "Insulation Heat Loss Calculation." Accessed March 2018. https://checalc.com/calc/inshoriz.html

[8] This measure assumes a flat loadshape since savings relate to reducing standby losses and as such the coincidence factor is 1.

[9] 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-

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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

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
Workpaper ID	W0194
Measure Unit	Per linear foot of piping
Measure Type	Prescriptive
Measure Group	Boilers & Burners
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

$$kWh_{\text{SAVED}} = Insul_{\text{SAVINGS}} * Length * HOU / (TE * 3{,}412)$$

$$Therms_{\text{SAVED}} = Insul_{\text{SAVINGS}} * Length * HOU / (TE * 100{,}000)$$

Where:

Variable	Description	Units	Value
$Insul_{\text{SAVINGS}}$	Energy savings through insulating nominal pipe sizes		See Insulation Savings Space Heating tables
Length	Length of insulated pipe	Ft	1
HOU	Annual hours of operation	Hrs/yr	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 factor	Btu/kWh	3,412
100,000	Conversion factor	Btu/therm	100,000

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	$Insul_{\text{SAVINGS}}$
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	$\text{Insul}_{\text{SAVINGS}}$
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	$\text{Insul}_{\text{SAVINGS}}$
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

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

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

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.

Revision History

Version Number	Date	Description of Change
01	01/2016	Initial TRM entry
02	09/2018	Updated efficiencies

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[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

Heat Pump Water Heater

	Measure Details
Measure Master ID	Heat Pump Water Heater: 3.3 UEF, 5008
Workpaper ID	W0200
Measure Unit	Per water heater
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Water Heater
Program(s)	Home Performance
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	781
Peak Demand Reduction (kW)	0.0370
Annual Therm Savings (Therms)	70
Lifecycle Energy Savings (kWh)	9,372
Lifecycle Therm Savings (Therms)	840
Water Savings (gal/yr)	0
Effective Useful Life (years)	12[1]
Measure Incremental Cost ($/unit)	$1,763.00 (see Assumptions)

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 the assumption of a natural gas–heated home with electric water heating.

Description of Baseline Condition

The baseline equipment is a residential water heater, summarized by the following table. See Assumptions for explanation of baseline derivation from current federal standards.[2]

Baseline Fuel	Weighting Factor	Uniform Energy Factor (UEF)
Electric	47%	0.926
Natural Gas	46%	0.603
Propane	7%	N/A

Description of Efficient Condition

The efficient condition is a heat pump water heater that meets ENERGY STAR Version 4.0 specifications, effective March 29, 2022.[3]

Annual Energy-Savings Algorithm

$$kWh_{SAVED} = \Delta kWh_{ELEC} * Frac_{ELEC} + \Delta kWh_{GAS} * Frac_{GAS} + \Delta kWh_{PROP} * Frac_{PROP}$$

$$Therms_{SAVED} = \Delta Therms_{ELEC} * Frac_{ELEC} + \Delta Therms_{GAS} * Frac_{GAS} + \Delta Therms_{PROP} * Frac_{PROP}$$

Where:

Variable	Description	Units	Value
ΔkWh_{ELEC}	Electric impact from replacing electric water heater	kWh	
$Frac_{ELEC}$	Fraction of installations replacing electric water heaters	%	47%; see Assumptions[4]
ΔkWh_{GAS}	Electric impact from replacing natural gas water heater	kWh	
$Frac_{GAS}$	Fraction of installations replacing natural gas water heaters	%	46%; see Assumptions[4]
ΔkWh_{PROP}	Electric impact from replacing propane water heater	kWh	
$Frac_{PROP}$	Fraction of installations replacing propane water heaters	%	7%; see Assumptions[4]
$\Delta Therms_{ELEC}$	Natural gas impact from replacing electric water heater	Therms	
$\Delta Therms_{GAS}$	Natural gas impact from replacing natural gas water heater	Therms	
$\Delta Therms_{PROP}$	Natural gas impact from replacing propane water heater	Therms	

Electric Water Heater Replacement

$$\Delta kWh_{ELEC} = \frac{GPD * 365 * 8.33 * \Delta T * C_P}{3{,}412} * \left(\frac{1}{UEF_{BASE,ELEC}} - \frac{1}{UEF_{EFF}}\right) + \Delta kWh_{COOL} + \Delta kWh_{ElectricHeat} + \Delta kWh_{Deh}$$

$$\Delta kWh_{COOL} = \frac{GPD * 365 * 8.33 * \Delta T * C_P}{3{,}412} * \frac{LF * 27\%}{COP_{COOL}} * LM * \%AC$$

$$\Delta kWh_{ElectricHeat} = -\frac{GPD * 365 * 8.33 * \Delta T * C_p}{3{,}412} * (1 - \frac{1}{UEF_{EFF}}) * \frac{LF * 5\%}{COP_{HEAT}} * (1 - Frac_{NGHEAT})$$

Gas Water Heater Replacement

$\Delta Therms_{ELEC} = \Delta Therms_{HEAT}$

$$\Delta Therms_{HEAT} = -\frac{GPD * 365 * 8.33 * \Delta T * C_P}{100{,}000} * (1 - \frac{1}{UEF_{EFF}}) * \frac{LF * 5\%}{EFF_{HEAT}} * Frac_{NGHEAT}$$

Where:

Variable	Description	Units	Value
GPD	Gallons per day	Gallons/day	42.75[5,6]
365	Number of days per year	Days/yr	365
8.33	Specific weight of water	Lbs/gallon	8.33
ΔT	Average difference between cold water inlet tmperature and hot water delivery temperature	°F	Average difference between cold water inlet temperatures (52.3°F[7]) and hot water delivery temperature (125°F[8])
C_P	Specific heat of water	Btu/(lb * °F)	1.0
3,412	Conversion factor	Btu/kWh	3,412
$UEF_{BASE,ELEC}$	Baseline uniform energy factor for electric water heater		0.926; see Assumptions[2]
UEF_{EFF}	Efficient uniform energy factor		3.3[2]

Variable	Description	Units	Value
ΔkWh_{COOL}	Cooling savings from conversion of heat in home to water heat that reflects a reduction in cooling load	kWh	
$\Delta kWh_{ElectricHeat}$	Electric heating cost from conversion of heat in home to water heat	kWh	Dependent on heating fuel
ΔkWh_{DEH}	Savings resulting from reduced dehumidification	kWh	72[9]
LF	Location factor		0.81[4]
27%	Reduction of waste heat resulting in cooling savings[9]	%	27%
COP_{COOL}	Coefficient of performance of cooling system		3.3 [9]
LM	Latent multiplier		1.33[10]
%AC	Percentage of homes with AC	%	92.5%[4]
COP_{HEAT}	Space heating savings, reflects increase in heating load		1.0[9]
$\Delta Therms_{HEAT}$	Space heating savings, reflects increase in heating load	Therms	
100,000	Conversion factor	Btu/therm	100,000
5%	Reduction of waste heat resulting in heating increase[9]	%	5%
EFF_{HEAT}	Efficiency of natural gas heating system	%	91.5%[11]
$Frac_{NGHEAT}$	Fraction of single-family homes with natural gas heating	%	86%[4]

Summer Coincident Peak Savings Algorithm

$$kW_{SAVED} = kWh_{SAVED} / Hours * CF$$

Where:

Hours = Hours of use (2,533)[9]

CF = Coincidence factor (0.12)[9]

Lifecycle Energy-Savings Algorithm

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

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

Where:

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

Assumptions

The incremental measure cost of the heat pump water heater equipment was determined to be $1,763 for ≥ 3.3 UEF units, based on the Illinois TRM.[9] This is relatively high since it is still considered to be an emerging technology, but given the appropriate market uptake and awareness is expected to decrease over time.

Deemed measure algorithms and associated savings for the heat pump water heater were derived from the *Illinois Statewide Technical Reference Manual*, Section 5.4.3 Heat Pump Water Heaters (except where noted).[9]

The baseline efficiency was derived from federal standard for electric storage water heaters[12] and generally follows the form UEF = 0.9307 – (0.0002 * V), where V is the tank size volume. Several sets of coefficients exist across water heater types, tank size ranges, and draw patterns, as shown in the Baseline UEF Values for Tank Sizes of ≥20 Gallons and ≤55 Gallons table below. Reviewing water heater models with tank size ≤55 gallons in the AHRI database shows 12 low-use models, 435 medium-use models, and 583 high-use models. It also shows that a majority of units are between 40 and 50 gallons.

Therefore, for the baseline UEFs, values of 0.926 and 0.603 were chosen for electric and natural gas, respectively. These reflect averages of 40 gallon to 50 gallon, medium and high draw pattern values.

Baseline UEF Values for Tank Sizes of ≥20 Gallons and ≤55 Gallons

Fuel	Draw Pattern	UEF Formula	UEF Value for Tank Size Of (Gallons)			
			30	40	50	55
Natural gas	Very Small	0.3456 – (0.0020 * V)	0.2856	0.2656	0.2456	0.2356
	Low	0.5982 – (0.0019 * V)	0.5412	0.5222	0.5032	0.4937
	Medium	0.6483 – (0.0017 * V)	0.5973	0.5803	0.5633	0.5548
	High	0.6920 – (0.0013 * V)	0.6530	0.6400	0.6270	0.6205
Electric	Very Small	0.8808 – (0.0008 * V)	0.8568	0.8488	0.8408	0.8368
	Low	0.9254 – (0.0003 * V)	0.9164	0.9134	0.9104	0.9089
	Medium	0.9307 – (0.0002 * V)	0.9247	0.9227	0.9207	0.9197
	High	0.9349 – (0.0001 * V)	0.9319	0.9309	0.9299	0.9294

Gallons per day were calculated by fitting a polynomial equation to data from Table 3 of the Florida Solar Energy Center study.[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 91.5% was assumed.[11]

For midstream and downstream delivery, the average splits of water heater fuel types being replaced is unknown. Data from the 2016 Focus on Energy Potential Study[9] shows that the stock residential hot water fuel splits are 73% natural gas, 20% electric, and 7% propane. However, it is expected that these midstream heat pump water heaters will replace a higher fraction of electric water heaters, so the electric fraction was increased to 47% at the expense of the natural gas fraction, for overall fractions of 47% electric, 46% natural gas, and 7% propane. There is some chance that the propane fraction may actually be higher as well; these fractions will be investigated in future via installations, survey data, or both.

Revision History

Version Number	Date	Description of Change
01	11/2012	Initial release
02	12/2016	Updated to new formatting
03	01/2017	Made edits to align with latest formatting, corrected some values and references
04	12/2019	Updated for midstream delivery, including propane baseline
05	10/2022	Updated for new ENERGY STAR spec and more recent IL TRM sources.

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[1] U.S. Department of Energy. Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment. p. 299; 8-22. https://downloads.regulations.gov/EERE-2014-BT-STD-0042-0016/attachment_1.pdf

[2] Federal standards for residential water heaters. Title 10/Chapter II/Subchapter D/Part 430/ Subpart C/§ 430.32/(d) https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8

[3] ENERGY STAR. "Program Requirements for Residential Water Heaters." Accessed October 27, 2022. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.0%20Water%20Heaters%20Final%20Specification%20and%20Partner%20Commitments-March2022_5.pdf

[4] Cadmus. *Potential Study for Focus on Energy.* 2016. 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. Data for 104 single-family homes

[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] 2010 U.S. Census Demographic Profile for Wisconsin. https://www.census.gov/newsroom/releases/archives/2010_census/cb11-cn137.html

[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] 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

[9] Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 11.0.* Volume 3: Residential Measures. Measure 5.4.3 https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010123_v11.0_Vol_3_Res_09222022_FINAL.pdf, accessed October 25, 2022.
Waste heat cooling savings factor: REMRate determined a percentage of lighting savings (27%) that results in reduced cooling loads (lighting is used as a proxy for hot water heating since load shapes suggest that their seasonal usage patterns are similar).
Hours: Full load hours assumption is based on Efficiency Vermont analysis of Itron eShapes.
COP_{COOL}: To reduce complexity of the measure and since this relates to a small waste heat impact, instead of assuming actual existing unit HVAC efficiency and a mid-life adjustment to account for future replacement efficiency, the code minimum baseline should be applied. Starting from federal baseline of SEER 13 central AC unit, converted to 11.1 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 3.3 COP. Same calculation starting with federal baseline of SEER 14 heat pump results in COP of 3.4.
COP_{HEAT}: Assume 1.0, consistent with electric heating system efficiency assumption within WI TRM residential insulation measures
5%: The operation of a HPWH causes both sensible and latent heat transfer with the surrounding air (and water vapor). The amount of sensible heat transfer is governed by the specific heat capacity of water: 4,186 J/kg·°C (which is 4x larger than that of dry air) and the temperature change. The latent heat transfer is governed by the latent heat of vaporization for water: 22.6x105 J/kg. Only the sensible heat transfer increases the heating load, and because of the relative sizes of these parameters, the latent heat transfer is several orders of magnitude greater than the sensible heat transfer.
Hours: Full load hours assumption based on Efficiency Vermont analysis of Itron eShapes.

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[10] Andrade, M. A., and C. W. Bullard. *Controlling Indoor Humidity Using Variable-Speed Compressors and Blowers*. July 1999. https://www.ideals.illinois.edu/bitstream/handle/2142/11894/TR151.pdf
Sensible heat ratio of 0.75 for typical split system from page 10.

[11] Air-Conditioning, Heating, & Refrigeration Institute. *AHRI Directory of Certified Product Performance*. Accessed December 2019. https://www.ahridirectory.org/Search/SearchHome

[12] Federal standards for residential water heaters. Title 10/Chapter II/Subchapter D/Part 430/ Subpart C/§ 430.32/(d) https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8

Water Heater, Indirect

	Measure Details
Measure Master ID	Water Heater, Indirect, 90% to 94%, 5267, Water Heater, Indirect, 90% to 94%, Tier 2, 5268 Water Heater, Indirect, 1988 (95%+) Water Heater, Indirect, Tier 2, 3784 (95%+)
Workpaper ID	W0201
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)	Varies by measure
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$988.50[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 0.6.[4] While water heater baselines vary by type and size, 0.6 is used as a representation of average UEF for medium to high draw for a 50-gallon tank, as discussed in workpaper W0267. This UEF is used to set baseline recovery efficiency.

Description of Efficient Condition

Indirect water heaters must be connected to a boiler with an AFUE of 90% or greater.

Annual Energy-Savings Algorithm

$$Therm_{\text{SAVED}} = (GPD * 365 * 8.33 * 1 * \Delta Tw / 100{,}000) * (1 / RE_{\text{BASE}} - 1 / E_{\text{C,EE}}) \\ + (UA_{\text{BASE}} / RE_{\text{BASE}} - UA_{\text{EE}} / E_{\text{C,EE}}) * \Delta Ts * 8{,}760 / 100{,}000$$

Where:

Variable	Description	Units	Value
GPD	Average daily hot water consumption	Gal/day	42.75 gal/day, see Assumptions[5,6]
365	Days per year	Days/yr	365
8.33	Specific heat of water	Lbs/gal	8.33
1	Specific heat of water	Btu/lb °F	1
ΔT_w	Average difference between the cold water inlet temperatures (52.3°F) and the hot water delivery temperature (125°F)	°F	72.7°F[7]
100,000	Conversion factor	Btu/therm	100,000
RE_{BASE}	Recovery efficiency of the baseline tank type water heater	%	76%[7]
$E_{C,EE}$	Combustion efficiency of energy-efficient boiler used to heat indirect water heater	%	90% or 95%[8]
UA_{BASE}	Overall heat loss coefficient of base tank type water heater	Btu/hr-°F	14.0[9]
UA_{EE}	Overall heat loss coefficient of indirect water heater storage tank	Btu/hr-°F	6.1; see Typical Values for UA_{EE} table below[10]
ΔT_S	Temperature difference between stored hot water temperature (125°F) and ambient indoor temperature (65°F)	°F	60°F
8,760	Conversion factor	Hrs/yr	8,760

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

Summer Coincident Peak Savings Algorithm

Indirect 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 (15 years)[1]

Deemed Savings

Deemed Savings by Measure

Measure	MMID	Annual Therms	Lifecycle Therms
Water Heater, Indirect, 90% to 94%	5267	81	1,215
Water Heater, Indirect, 90% to 94%, Tier 2	5268		
Water Heater, Indirect (95%+)	1988	88	1,320
Water Heater, Indirect, Tier 2, 3784 (95%+)	3784		

Assumptions

Because the efficiency of residential water heater is measured in UEF, the true UEF 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.[6] The fitted equation is GPD = -0.0089 * x2 + 16.277 * x + 3.25, where x is the average number of occupants per home.

Revision History

Version Number	Date	Description of Change
01	01/2012	Initial TRM entry
02	10/2014	Updated therms based on 72.7°F temperature
03	12/2018	Updated gallons per day calculation
04	12/2021	Added 90% AFUE measure.

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[1] 2009 GDS Residential Study, MA Natural Gas Potential http://ma-eeac.org/wordpress/wp-content/uploads/5_Natural-Gas-EE-Potenial-in-MA.pdf

[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

[3] Public Service Commission of Wisconsin. Focus on Energy Evaluation, Residential Programs: CY09 Deemed Savings Review. March 26, 2010.

[4] Code of Federal Regulations. Title 10, Chapter II, Subchapter D, Part 430, Subpart C, § 430.32. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32

[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] U.S. Census Bureau. "Demographic Profile for Wisconsin." May 12, 2011. https://www.census.gov/newsroom/releases/archives/2010_census/cb11-cn137.html

[7] Air-Conditioning, Heating, and Refrigeration Institute. https://www.ahridirectory.org/NewSearch?programId=24&searchTypeId=3. Average RE for 476 gas storage water heaters with UEF between 0.58 and 0.62.

[8] Assumed the combustion efficiency is a proxy for AFUE, with program minimum of 90% or 95% AFUE.

[9] U.S. Department of Energy. Technical Support Document: Energy Efficiency Standards for Consumer Products, Residential Water Heaters, Including Regulatory Impact Analysis. 2000.

[10] *New York Technical Reference Manual.* Indirect Water Heaters, p. 87. 2010.

Natural Gas Storage Water Heater, 0.64 UEF

	Measure Details
Measure Master ID	Water Heater, NG, UEF of 0.64 or Greater, 5265
Workpaper ID	W0301
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)	9.84
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	128.0
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 ≤ 75,000 Btuh and a storage volume from 20 to 55 gallons. There is a program incentive for participants who install a small storage water heater that has an efficiency rating ≥ 0.64 Uniform Energy Factor (UEF).

Description of Baseline Condition

The base case is a residential, natural gas–fueled storage water heater with a UEF of 0.60 (see Assumptions).[3]

Description of Efficient Condition

The efficient condition is a higher efficiency natural gas storage-type water heater with a UEF compliant with ENERGY STAR qualification criteria.

Annual Energy-Savings Algorithm

$$Therm_{\text{SAVED}} = [(GPD * 365 * 8.33 * C_{\text{P,WATER}} * \Delta Tw) / 100{,}000] * [(1 / UEF_{\text{BASE}}) - (1 / UEF_{\text{EE}})]$$

Where:

Variable	Description	Units	Value
GPD	Average daily hot water consumption	Gal/day	42.8 gallons per day; see Assumptions
365	Days per year	Days/yr	365
8.33	Density of water	Lbs/gal	8.33
$C_{P,WATER}$	Specific heat of water	Btu/lb °F	1
ΔT_w	Average difference between cold water inlet temperatures (52.3°F)[4] and hot water delivery temperature (125°F)	°F	72.7°F[5]
100,000	Conversion factor	Btu/therm	100,000
UEF_{BASE}	Energy factor of baseline water heater		0.60
UEF_{EE}	Energy factor of efficient water heater		0.64

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

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

Where:

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

Assumptions

The federal standard baseline is calculated by taking an average of the UEF_{BASE} calculated using 40- and 50-gallon water heaters, for medium and high water draw patterns. This produces a baseline uniform energy factor of 0.60. See workpaper W0267 for more details. 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.

Revision History

Version Number	Date	Description of Change
01	01/2012	Initial TRM entry
02	10/2014	Updated therm based off 72.7°F for the change in temperature
03	04/2017	Updated therms based on new federal baseline and other figures
04	12/2021	Restored measure, updated to UEF

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[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 Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 10.0. Volume 3: Residential Measures*. September 24, 2021. https://ilsag.s3.amazonaws.com/IL-TRM_Effective_010122_v10.0_Vol_3_Res_09242021.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] 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.

[5] 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

[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] U.S. Census Bureau. *2010 Demographic Profiles*. Accessed May 15, 2017.

Natural Gas Instant Water Heater

	Measure Details
Measure Master ID	5165
Workpaper ID	W0267
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)	49
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	637
Water Savings (gal/year)	0
Effective Useful Life (years)	20[1]
Measure Incremental Cost ($/unit)	$1,096.60[2]

Measure Description

This measure is for the replacement of failed or working domestic natural gas–fired storage water heaters in residential and multifamily buildings and for the installation of natural gas–fired instantaneous water heaters.

Description of Baseline Condition

The baseline condition is a natural gas–fueled, residential-duty commercial storage water heater with a 0.60 UEF. See the Assumptions for more details.

Description of Efficient Condition

The efficient condition is a natural gas–fired, residential, natural gas–fired instantaneous water heater meeting ENERGY STAR criteria.

Annual Energy-Savings Algorithm

$$Therm_{\text{SAVED}} = \left[(GPD \ * \ 365 \ * \ 8.33 \ * \ C_{\text{P,WATER}} * \ \Delta Tw) \ / \ 100{,}000\right] \ * \ \left[(1 \ / \ UEF_{\text{BASE}}) - (1 \ / \ UEF_{\text{EE}})\right]$$

Where:

Variable	Description	Units	Value
GPD	Average daily hot water consumption	Gal/day	42.75 gallons per day; see Assumptions[3,4]
365	Days per year	Days/yr	365
8.33	Density of water	Lbs/gal	8.33
$C_{P,WATER}$	Specific heat of water	Btu/lb °F	1
ΔT_w	Difference between average cold water inlet temperature and hot water delivery temperature (= T_{OUT} - T_{IN})	°F	T_{IN} = 52.3°F[5] T_{OUT} = 125°F[6]
100,000	Conversion factor	Btu/therm	100,000
UEF_{BASE}	Energy factor of baseline water heater based on tank size		See Assumptions, Baseline Efficiency table
UEF_{EE}	Energy factor of efficient water heater		0.87[7]

Summer Coincident Peak Savings Algorithm

Natural gas–fired instantaneous water heaters consume no electrical energy, aside from a combustion air fan; therefore, they have a negligible impact on demand reduction.

Lifecycle Energy-Savings Algorithm

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

Where:

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

Deemed Savings

Energy Savings for Instantaneous Natural Gas–Fired Water Heater

Measure	MMID	Baseline Rated Storage	Draw Pattern	Annual Therm	Lifecycle Therms
Instantaneous Natural Gas–Fired Water Heater	5165	<2 gallons and >50,000 Btu/h	Medium/High	49	980

Assumptions

The baseline is assumed to be a new, nautral gas–fired, residential storage water heater that meets or exceeds minimum federal efficiency standards.

Based on data of available products and as defined in the federal standard,[1] water heaters are assumed to have a medium or high draw pattern. Reviewing water heater models with a tank size ≤55 gallons in the AHRI database[8] shows 12 low-use models, 435 medium-use models, and 583 high-use models. It also shows the majority of units as between 40 gallons and 50 gallons.

The baseline efficiency was derived from federal standard for water heaters[1] and generally follows the form UEF = 0.6597 – (0.0009 * V), where V is the tank size volume. Several sets of coefficients exist across water heater types, tank size ranges, and draw patterns, as shown in the Baseline UEF Values table below. Therefore, for the baseline UEF, a value of 0.60—which is the average for medium and high draw for a 50 gallon tank—was chosen. This reflects an average of 40 gallons to 50 gallons, with medium- and high-draw pattern values.

Baseline UEF Values

Tank Size	Fuel	Draw Pattern	UEF Formula	UEF Value for Tank Size (Gallons)			
				30	40	50	55
≥20 gallons and ≤55 gallons	Natural gas	Very Small	0.3456 – (0.0020 * V)	0.2856	0.2656	0.2456	0.2356
		Low	0.5982 – (0.0019 * V)	0.5412	0.5222	0.5032	0.4937
		Medium	0.6483 – (0.0017 * V)	0.5973	0.5803	0.5633	0.5548
		High	0.6920 – (0.0013 * V)	0.6530	0.6400	0.6270	0.6205

Revision History

Version Number	Date	Description of Change
01	12/2020	Initial TRM entry
02	07/2022	EUL Update

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[1] U.S. Department of Energy. Technical Support Document: Energy Efficiency Program for Residential Water Heaters, Direct Heating Equipment. p. 56; 8-50. https://downloads.regulations.gov/EERE-2006-STD-0129-0170/attachment_9.pdf

[2] U.S. Department of Energy. *2010 Residential Heating Products Final Rule Technical Support Document*. Tables 8.2.13-14, 8.2.16. http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch8.pdf

[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] U.S. Census Bureau. "Demographic Profile for Wisconsin." May 12, 2011. https://www.census.gov/newsroom/releases/archives/2010_census/cb11-cn137.html

[5] 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.

[6] Wisconsin State Legislature. Chapter 704. Landlord and Tenant. Section 704.06. https://docs.legis.wisconsin.gov/statutes/statutes/704/06
National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy12osti/55074.pdf
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.

[7] ENERGY STAR. "ENERGY STAR Product Specification for Residential Water Heaters." Version 3.2. Effective April 16, 2015. https://www.energystar.gov/sites/default/files/Water%20Heaters%20Final%20Version%203.2_Program%20Requirements_1.pdf

[8] Air-Conditioning, Heating, & Refrigeration Institute. *AHRI Directory of Certified Product Performance*. Accessed December 2019. https://www.ahridirectory.org/Search/SearchHome

HVAC

Room Air Conditioner, ENERGY STAR

	Measure Details
Measure Master ID	Room Air Conditioner, ENERGY STAR, 4035
Workpaper ID	W0202
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)	10[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.[3]

Description of Efficient Condition

The efficient condition is ENERGY STAR-certified room air conditioners that meet ENERGY STAR Version 4.0 requirements.[4] 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.

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = UEC_{\text{BASE}} - UEC_{\text{EE}}$$

Where:

Variable	Description	Units	Value
UEC_{BASE}	Annual unit energy consumption of baseline unit	kWh	442.11 kWh[4,2]
UEC_{EE}	Annual unit energy consumption of measure unit	kWh	401.79 kWh[4]

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = (kWh_{\text{SAVED}} / Hours) * CF$$

Where:

Hours = Hours of operation per year (543)[3]

CF = Coincidence factor (0.3)[3]

Lifecycle Energy-Savings Algorithm

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

Where:

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

Revision History

Version Number	Date	Description of Change
01	06/24/2016	Initial TRM entry
02	07/2022	EUL Update

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[1] U.S. Department of Energy. Technical Support Document: Energy Efficiency Program For Consumer Products And Commercial And Industrial Equipment: Room Air Conditioners. p. 237; 8-29. https://www.regulations.gov/document/EERE-2014-BT-STD-0059-0013

[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

[3] RLW Analytics. *Final Report Coincidence Factor Study Residential Room Air Conditioners.* June 23, 2008. http://www.puc.state.nh.us/electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/124_SPWG%20Room%20%20AC%20Evaluation%20FINALReport%20June%2023%20ver7.pdf

[4] 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.

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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.

Smart Thermostat, Residential

	Measure Details
Measure Master ID	Smart Thermostat, Gas and Electric, 10052 Smart Thermostat, Electric only, 10053 Smart Thermostat, Gas only, 10054
Workpaper ID	W0314
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)	9[1]
Incremental Cost ($/unit)	$207.67[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. This workpaper is intended to replace previous TRM workpapers: W0205, W0258, W0297, and W0298.

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.

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, electric baseboard, air-source heat pump (ASHP), or other HVAC system. The measures reflect a weighted average of the three systems analyzed in Cadmus' CY 2022 evaluation's smart thermostat billing analysis. The estimated savings for each have been updated to reflect this weighted average.

Description of Efficient Condition

The efficient condition is a smart thermostat 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 Meet the following requirements:

- 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

$$Therm_{\text{SAVED}} = therms_{HEAT}$$

$$kWh_{\text{SAVED}} = kWh_{COOL} + kWh_{HEAT}$$

Where:

Variable	Description	Units	Value
$\text{therms}_{\text{HEAT}}$	Annual gas heating savings for an average smart thermostat installation[3]	therms/yr	32
kWh_{COOL}	Annual electric cooling savings for an average smart thermostat installation[3]	kWh/yr	258
kWh_{HEAT}	Annual electric heating savings for an average smart thermostat installation[3]	kWh/yr	224

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

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

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

Where:

EUL = Effective useful life (9 years)[1]

Deemed Savings

DEEMED SAVINGS FOR RESIDENTIAL SMART THERMOSTATS

Measure Description	MMID	Sector	Peak kW	Annual		Lifecycle	
				kWh	Therms	kWh	Therms
Smart Thermostat, gas and electric	10052	SF/MF	0	482	32	4,338	288
Smart Thermostat, electric only	10053	SF/MF	0	482	0	4,338	0
Smart Thermostat, gas only	10054	SF/MF	0	0	32	0	288

Assumptions

- For the 2022 Focus on Energy evaluation, Cadmus conducted a billing analysis to examine savings for participants who installed smart thermostats as part of the heating and cooling offering and the Online Marketplace Offering under the Direct to Customer Solutions. The 2022 Focus on Energy Evaluation Report[3] discusses these findings, and results from that billing analysis are analyzed further in the updated workpaper for these MMIDs.
- The results shown in the workpaper reflect the savings experienced by the average smart thermostat participant.
- There is no in-service rate for this workpaper as that is accounted for in the billing analysis.

Revision History

Version Number	Date	Description of Change
01	10/2023	Consolidating smart thermostat measures to reflect the 2022 smart thermostat billing analysis

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[1] Cadmus. *EUL Analysis of Residential Smart Communicating Thermostat—Vendor A and B*. February 1, 2019. https://www.caetrm.com/media/reference-documents/SWHC039-01_A8_-_EUL_Analysis.pdf

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 39,243 projects and 39,984 units from January 2018 to July 2020 is $246.78 (MMIDs 3612 - 3615, 4054 - 4056, and 4301 - 4303 in single family sectors). Minus the cost of a manual thermostat, which is $39.11 based on online lookups from July 2018.

[3] Cadmus. *Appendix F. Measure Analysis. Focus on Energy Calendar Year 2022 Evaluation Report, Volume III*. May 22, 2023. https://assets.focusonenergy.com/production/inline-files/Evaluation_CY_2022-Vol-III_final.pdf

Gas Furnaces

	Measure Details
Measure Master ID	NG Furnace, Multi-Stage+, 95% AFUE, 4962 NG Furnace, Multi-Stage+, 96% AFUE, 4963 NG Furnace, Multi-Stage+, 97% AFUE, 4964 NG Furnace, Multi-Stage+, 98%+ AFUE, 4965 NG Furnace, Multi-Stage+, Tier 2, 95% AFUE, 4966 NG Furnace, Multi-Stage+, Tier 2, 96% AFUE, 4967 NG Furnace, Multi-Stage+, Tier 2, 97% AFUE, 4968 NG Furnace, Multi-Stage+, Tier 2, 98%+ AFUE, 4969 NG Furnace, Single-Stage, 95% AFUE, 4970 NG Furnace, Single-Stage, 96% AFUE, 4971 NG Furnace, Single-Stage, 97% AFUE, 10046 NG Furnace, Single-Stage, Tier 2, 95% AFUE, 4972 NG Furnace, Single-Stage, Tier 2, 96% AFUE, 4973 NG Furnace, Single-Stage, Tier 2, 97% AFUE, 10047 MF NG Furnace, Multi-Stage+, 95% AFUE, 4950 MF NG Furnace, Multi-Stage+, 96% AFUE, 4951 MF NG Furnace, Multi-Stage+, 97% AFUE, 4952 MF NG Furnace, Multi-Stage+, 98%+ AFUE, 4953 MF NG Furnace, Multi-Stage+, Tier 2, 95% AFUE, 4954 MF NG Furnace, Multi-Stage+, Tier 2, 96% AFUE, 4955 MF NG Furnace, Multi-Stage+, Tier 2, 97% AFUE, 4956 MF NG Furnace, Multi-Stage+, Tier 2, 98%+ AFUE, 4957 MF NG Furnace, Single-Stage, 95% AFUE, 4958 MF NG Furnace, Single-Stage, 96% AFUE, 4959 MF NG Furnace, Single-Stage, 97% AFUE, 10048 MF NG Furnace, Single-Stage, Tier 2, 95% AFUE, 4960 MF NG Furnace, Single-Stage, Tier 2, 96% AFUE, 4961 MF NG Furnace, Single-Stage, Tier 2, 97% AFUE, 10049
Workpaper ID	W0207
Measure Unit	Per furnace
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Furnace
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Varies by heating stage, tier, and sector
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by AFUE, tier, and sector
Lifecycle Energy Savings (kWh)	Varies by rated input heating capacity and AFUE
Lifecycle Therm Savings (Therms)	Varies by AFUE, tier, and sector
Water Savings (gal/year)	0
Effective Useful Life (years)	23[1]
Incremental Cost ($/unit)	Varies by measure, see Deemed Savings and Costs table below

Measure Description

Conventional natural gas furnaces produce by-products, such as water vapor and carbon dioxide, that 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 natural gas than conventional furnaces.

In addition to natural gas savings, furnaces can save electricity through more efficient blower motors. These are commonly ECMs and can generally be constant-torque or constant airflow (true variable speed). Additional electric savings can be achieved by employing these motor types with a burner staging strategy that allows for the furnace blower to run at lower speed when the full heating capacity of the furnace is required. While the blower may run for longer on these furnaces, the reduced electrical use at these lower speeds creates significant savings.

Multifamily measures are for in-unit furnaces, as opposed to MMIDs 3491 and 3492, which are considered common area furnaces.

Description of Baseline Condition

The current federal furnace standard is an 80% AFUE single-stage furnace with a blower motor that meets a fan energy rating (FER) performance requirement.[2,3] However, based on the results of 2023 Wisconsin HVAC contractor surveys, data on furnace sales in Wisconsin indicate a higher AFUE market baseline for natural gas furnaces[4]. Non-income eligible measures (Tier 1) use a 90.6% AFUE furnace as the baseline, while the Single family income eligible measures (Tier 2) use an 88.3% AFUE baseline[4]. Multifamily measures are assumed to have a baseline AFUE of 81.8%, and the low-income AFUE value of 80.7% which are also based on results of 2023 Wisconsin HVAC contractor surveys[4].

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 either a single family or a multifamily residential application.

Annual Energy-Savings Algorithm

$$Therm_{\text{SAVED}} = CAP * hours_{\text{HEATING}} * (AFUE_{\text{EE}} / AFUE_{\text{BASE}} - 1) / 100$$

$$kWh_{\text{SAVED}} = kWh_{\text{BASE}} - kWh_{\text{EE}}$$

Where:

Variable	Description	Units	Value
CAP	Rated input heating capacity	MBtu/h	Varies by measure, see Deemed Inputs table below, see Assumptions[5]
$hours_{HEATING}$	Hours of heating operation	Hrs	1,158 hours[5]
$AFUE_{EE}$	Efficient AFUE	%	Varies by measure, see Deemed Inputs table below
$AFUE_{BASE}$	Baseline AFUE	%	80.7% (multifamily Tier 2); [4] 81.8% (multifamily Tier 1); [4] 88.3% (single family Tier 2; [4] 90.6% (single family Tier 1). [4]
100	Conversion factor	Mbtu/therm	100
kWh_{BASE}	Electric energy consumed for baseline motor	kWh	482.8 for Tier 1 multi-stage; 468.5 for Tier 2 multi-stage, see Assumptions
kWh_{EE}	Electric energy consumed for efficient furnace motor upgrade	kWh	Varies by measure, see Deemed Inputs table below, see Assumptions

Deemed Inputs[5]

Measure	MMID	CAP	$AFUE_{BASE}$	$AFUE_{EE}$	kWh_{BASE}	kWh_{EE}
NG Furnace, Multi-stage+, 95% AFUE	4962	62.3	90.6	95.0	482.8	317.4
NG Furnace, Multi-stage+, 96% AFUE	4963	70.0	90.6	96.1	482.8	353.9
NG Furnace, Multi-stage+, 97% AFUE	4964	76.5	90.6	97.2	482.8	359.1
NG Furnace, Multi-stage+, 98%+ AFUE	4965	75.1	90.6	98.2	482.8	317.6
NG Furnace, Multi-stage+, Tier 2, 95% AFUE	4966	65.6	88.3	95.0	468.5	325.8
NG Furnace, Multi-stage+, Tier 2, 96% AFUE	4967	64.5	88.3	96.1	468.5	331.1
NG Furnace, Multi-stage+, Tier 2, 97% AFUE	4968	69.1	88.3	97.1	468.5	303.1
NG Furnace, Multi-stage+, Tier 2, 98%+ AFUE	4969	63.3	88.3	98.0	468.5	285.6
NG Furnace, Single-stage, 95% AFUE	4970	62.9	90.6	95.0	0	0
NG Furnace, Single-stage, 96% AFUE	4971	64.5	90.6	96.2	0	0
NG Furnace, Single-stage, Tier 2, 95% AFUE	4972	61.2	88.3	95.0	0	0
NG Furnace, Single-stage, Tier 2, 96% AFUE	4973	61.8	88.3	96.1	0	0
MF NG Furnace, Multi-stage+, 95% AFUE	4950	63.0	81.8	95.0	482.8	372.5
MF NG Furnace, Multi-stage+, 96% AFUE	4951	55.6	81.8	96.1	482.8	289.0
MF NG Furnace, Multi-stage+, 97% AFUE	4952	63.0	81.8	97.3	482.8	274.1
MF NG Furnace, Multi-stage+, 98%+ AFUE	4953	66.0	81.8	98.1	482.8	295.0
MF NG Furnace, Multi-stage+, Tier 2, 95% AFUE	4954	60.0	80.7	95.0	468.5	321.0
MF NG Furnace, Multi-stage+, Tier 2, 96% AFUE	4955	50.8	80.7	96.1	468.5	269.0
MF NG Furnace, Multi-stage+, Tier 2, 97% AFUE	4956	60.0	80.7	97.4	468.5	213.0
MF NG Furnace, Multi-stage+, Tier 2, 98% AFUE	4957	51.4	80.7	98.0	468.5	267.7
MF NG Furnace, Single-stage, 95% AFUE	4958	57.5	81.8	95.0	0	0
MF NG Furnace, Single-stage, 96% AFUE	4959	55.3	81.8	96.3	0	0
MF NG Furnace, Single-stage, Tier 2, 95% AFUE	4960	42.0	80.7	95.0	0	0
MF NG Furnace, Single-stage, Tier 2, 96% AFUE	4961	44.0	80.7	96.5	0	0
NG Furnace, Single-stage, 97% AFUE	10046	69.4	90.6	97.0	0	0
NG Furnace, Single-stage, Tier 2, 97% AFUE	10047	64.3	88.3	97.0	0	0
MF NG Furnace, Single-stage, 97% AFUE	10048	60.1	81.8	97.0	0	0
MF NG Furnace, Single-stage, Tier 2, 97% AFUE	10049	51.4	80.7	97.0	0	0

Summer Coincident Peak Savings Algorithm

No demand savings are claimed for this measure.

Lifecycle Energy-Savings Algorithm

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

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

Where:

EUL = Effective useful life (23 years)[1]

Assumptions

Previously, savings from ECM furnace motor upgrades were derived from a 2014 Cadmus study. As reviewed in the 2014 Deemed Savings memo,[6] this study metered the furnace motors of 67 Focus on

Energy participants who had received furnaces with ECMs. There was no federal standard for furnace blower motors at that time, and savings were estimated over a PSC motor, deemed to be a reasonable baseline. This study showed an average of 1,158 hours of heating with an average savings of 0.116 kW in that mode, over an assumed PSC motor baseline—therefore 1,158 * 0.116 kW = 134.3 kWh of heating mode savings. The study also showed an average of 1,020 hours in circulation mode with an average 0.207 kW savings in that mode, for 211.1 kWh of savings in circulation mode. Assuming a SEER upgrade from 12 to 13 as a result of the ECM produces cooling savings of 70.7 kWh. Therefore, the total rounded savings for a PSC to ECM upgrade were 134.3 + 211.1 + 70.7 = 416 kWh.

As of July 3, 2019, the U.S. Department of Energy required residential furnace blower motors to meet a fan energy rating (FER) performance standard that can generally only be met by ECMs, rendering the 2014 study's savings historical. However, as discussed in the Measure Description section and elaborated in the Final Rule Technical Support Document (FRTSD) for furnace fans,[6] there are multiple efficiency levels of ECMs—constant torque, constant torque with a multi-stage furnace burner, constant airflow, and constant airflow with a multi-stage furnace burner. A majority of Focus on Energy furnaces are constant airflow, and therefore offer some electrical savings over a code baseline furnace blower motor.

However, FER information for furnace models have only recently been found to be publicly available, which makes it difficult to determine savings. In addition, FER may not reflect actual energy usage and savings in Wisconsin, due to a few possible issues. First, different assumed versus actual heating, cooling, and circulation mode hours. Additionally, the performance of constant torque blower motors may have improved over the assumptions made in the FRTSD,[7] since the final required FER levels align with its assumptions for constant torque motors with multi-stage burners, but many furnace models with constant torque motors and single stage burners are being manufactured today. These issues may be supported by the fact that results from the 2014 Cadmus study do not align with assumed consumption values in the FRTSD.

As an alternative to FER, the average annual auxiliary electrical energy consumption (E_{AE}; referred to as kWh_{BASE} or kWh_{EE} in algorithm) is used to estimate the potential savings from staging during heating and from more efficient motors. E_{AE} is the electrical consumption for the furnace for all heating-related consumption and any standby use,[7] and it is available for most furnace models in the AHRI database.[8] E_{AE} does not include electrical use in cooling or circulation mode. There may be some additional savings for qualified furnaces in these modes, but without better reporting of FER, or a study, no electrical savings is assumed for cooling or continuous modes. Electrical savings are only deemed for multi-stage furnaces because the bulk of these savings come from operating the furnace fan in the low-fire heating stage. Because furnace capacity (MBh), blower capacity (CFM), and motor type and staging are significant factors in furnace electrical energy consumption, savings should be re-evaluated when there is more data on E_{AE} values for delivered Focus on Energy furnaces.

The efficient E_{AE} for each measure is deemed to be the average value delivered in the PY2020 evaluation year. These values can be seen in the Deemed Inputs table above.

The Tier 1 baseline E_{AE} value is estimated as the average for furnace models that are not Focus on Energy–qualified and have an AFUE in the range of the Tier 1 market baseline of 90.6%. This includes 92% to 94% AFUE single- or multi-stage and 95%+ AFUE single-stage. The average E_{AE} from the AHRI database for 1,010 such models is 482.8 kWh. The Tier 2 baseline E_{AE} value is estimated to be the average for noncondensing furnace models that do not otherwise meet Focus on Energy requirements. The average E_{AE} for 1,961 such models is 468.5 kWh.

Incremental costs come from a 2020 dealer and distributor survey effort.[9]

Deemed Savings

Deemed Savings and Costs by Measure

Measure	MMID	kW	Annual		Lifecycle		Incremental Cost[5]
			kWh	Therms	kWh	therms	
NG Furnace, Multi-stage+, 95% AFUE	4962	0	165	35	3,795	805	$1,407.50
NG Furnace, Multi-stage+, 96% AFUE	4963	0	129	49	2,967	1,127	$541.31
NG Furnace, Multi-stage+, 97% AFUE	4964	0	124	65	2,852	1,495	$1,207.92
NG Furnace, Multi-stage+, 98%+ AFUE	4965	0	165	73	3,795	1,679	$2,308.33
NG Furnace, Multi-stage+, Tier 2, 95% AFUE	4966	0	143	58	3,289	1,334	$2,311.57
NG Furnace, Multi-stage+, Tier 2, 96% AFUE	4967	0	137	66	3,151	1,518	$1,445.38
NG Furnace, Multi-stage+, Tier 2, 97% AFUE	4968	0	165	80	3,795	1,840	$2,111.98
NG Furnace, Multi-stage+, Tier 2, 98%+ AFUE	4969	0	183	81	4,209	1,863	$3,212.40
NG Furnace, Single-stage, 95% AFUE	4970	0	0	35	0	805	$0.00
NG Furnace, Single-stage, 96% AFUE	4971	0	0	46	0	1,058	$48.06
NG Furnace, Single-stage, 97% AFUE	10046	0	0	57	0	1,311	$96.12
NG Furnace, Single-stage, Tier 2, 95% AFUE	4972	0	0	54	0	1,242	$542.68
NG Furnace, Single-stage, Tier 2, 96% AFUE	4973	0	0	63	0	1,449	$952.12
NG Furnace, Single-stage, Tier 2, 97% AFUE	10047	0	0	73	0	1,679	$1,361.56
MF NG Furnace, Multi-stage+, 95% AFUE	4950	0	110	118	2,530	2,714	$2,296.76
MF NG Furnace, Multi-stage+, 96% AFUE	4951	0	194	113	4,462	2,599	$1,430.57
MF NG Furnace, Multi-stage+, 97% AFUE	4952	0	209	138	4,807	3,174	$2,097.18
MF NG Furnace, Multi-stage+, 98%+ AFUE	4953	0	188	152	4,324	3,496	$3,197.59
MF NG Furnace, Multi-stage+, Tier 2, 95% AFUE	4954	0	148	123	3,404	2,829	$2,553.57
MF NG Furnace, Multi-stage+, Tier 2, 96% AFUE	4955	0	200	112	4,600	2,576	$1,687.38
MF NG Furnace, Multi-stage+, Tier 2, 97% AFUE	4956	0	256	144	5,888	3,312	$2,353.98
MF NG Furnace, Multi-stage+, Tier 2, 98% AFUE	4957	0	201	127	4,623	2,921	$3,454.40
MF NG Furnace, Single-stage, 95% AFUE	4958	0	0	107	0	2,461	$708.57
MF NG Furnace, Single-stage, 96% AFUE	4959	0	0	114	0	2,622	$937.32
MF NG Furnace, Single-stage, 97% AFUE	10048	0	0	129	0	2,967	$1,166.07
MF NG Furnace, Single-stage, Tier 2, 95% AFUE	4960	0	0	86	0	1,978	$784.68
MF NG Furnace, Single-stage, Tier 2, 96% AFUE	4961	0	0	100	0	2,300	$1,194.12
MF NG Furnace, Single-stage, Tier 2, 97% AFUE	10049	0	0	120	0	2,760	$1,603.56

Revision History

Version Number	Date	Description of Change
01	03/2012	Initial release
02	11/2012	Updated memo
03	02/2013	Reviewed and updated for new formatting
04	08/2014	Updated to new format, changed from 2014 Baseline Study and ECM Study
05	09/2014	Revised to reflect final results from the 2014 ECM study
06	10/2014	Revised to reflect additions from 2014 Cadmus ECM study and Deemed Savings report
07	04/2016	Added 96%, 97%, 98% AFUE measures
08	04/2017	Fixed discrepancies in kilowatts, LC kilowatt-hours, and EUL
09	10/2017	Updated EUL
10	12/2018	Updated savings algorithm
11	05/2019	Updated costs for Tier 1 measures
12	01/2020	Reconfigured to reflect new measure mix, added in-unit multifamily measures, and updated furnace fan savings. Deleted details of MMIDs 3679, 3781, 3783, 1981, 3782, 3868, 3870, 3440, and 3871.
13	12/2021	Updated with actual CAP, $AFUE_{EE}$, EAE_{EE}, updated costs and EUL
14	09/2022	Updated EUL and corrected AFUE headings
15	09/2023	Added single-stage, 97% AFUE measures
16	12/2023	Updated AFUE base with latest furnace baseline and contractor survey results

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[1] U.S. Department of Energy. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Consumer Furnaces*. June 2022. Table 8.3.7. https://downloads.regulations.gov/EERE-2014-BT-STD-0031-0320/content.pdf.
22.5 years listed for North region, rounded to 23 years

[2] Electronic Code of Federal Regulations. Title 10, Chapter II, Subchapter D, Part 430, Subpart C, §430.32. Table 1—Energy Conservation Standards for Covered Residential Furnace Fans. https://www.ecfr.gov/cgi-bin/text-idx?SID=0423028877ce42bb0c3e0e2529ac80ba&mc=true&node=se10.3.430_132&rgn=div8

[3] Regulations.gov. *2014-07-03 Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Furnace Fans; Final Rule*. Table I.1. https://www.regulations.gov/document?D=EERE-2010-BT-STD-0011-0117

[4] Cadmus. *Heating and Cooling Program Furnace Baseline Findings and Contractor Survey Results*. November 29th 2023 Updated with latests furnace baseline and contractror survey results meeting. November 11, 2023. Presentation and notes available in measure Huddle folder.

[5] Focus on Energy. *Deemed Savings Report.* October 27, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

[6] U.S Department of Energy. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnace Fans*. June 2014. https://www.regulations.gov/document?D=EERE-2010-BT-STD-0011-0111

[7] Electronic Code of Federal Regulations. Title 10, Chapter II, Subchapter D, Part 430 Subpart B, Appendix N. https://www.govinfo.gov/app/details/CFR-2013-title10-vol3/CFR-2013-title10-vol3-part430-subpartB-appN

[8] Air-Conditioning, Heating, and Refrigeration Institute. “Directory of Certified Product Performance.” www.ahridirectory.org

[9] CLEAResult. Survey of trade allies. Summer 2020.

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
Workpaper ID	W0209
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, 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.[4]

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

$$Therm_{\text{SAVED}} = CAP * Hours_{\text{HEATING}} * (\eta_{\text{EE}} / \eta_{\text{BASE}} - 1) * (1/100)$$

$$kWh_{\text{SAVED}} = kWh_{\text{SAVED HEATING}} + kWh_{\text{SAVED CIRC}} + kWh_{\text{SAVED COOLING}}$$

$$kWh_{\text{SAVED HEATING}}\ (applies\ to\ all\ systems\ as\ ECM\ savings\ from\ heating\ season) = Hours_{\text{HEATING}} * \Delta kW_{\text{HEAT}}$$

$$kWh_{\text{SAVED CIRC}}\ (applies\ to\ all\ systems\ as\ ECM\ savings\ from\ cooling\ season,\ since\ AHRI\ data\ indicates\ that\ all\ listed\ natural\ gas\ single\ package\ vertical\ units\ have\ cooling) = Hours_{\text{CIRC}} * \Delta kW_{\text{CIRC}}$$

$$kWh_{\text{SAVED COOLING}}\ (applies\ if\ the\ system\ meets\ the\ requirement\ for\ high-efficiency\ cooling) = Tons * EFLH_{\text{COOL}} * Cooling_{\text{QUALIFIES}} * 12\ kBtu/ton * (1/EER_{\text{BASE}} - 1/EER_{\text{ECM}})$$

Where:

Variable	Description	Units	Value
CAP	Rated input heating capacity	Mbtu/hr	40.4 MBtu/hr[3]
$Hours_{\text{HEATING}}$	Heating hours	Hrs	1,158[5]
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	Therm to Mbtu	100
ΔkW_{HEAT}	Heating demand	kW	0.116 kW[5]
$Hours_{\text{CIRC}}$	Annual hours on circulate setting	Hrs/yr	1,020[5]
ΔkW_{CIRC}	Demand on circulate setting	kW	0.207 kW[5]
Tons	Cooling capacity	Tons	1.548 tons[3]
$EFLH_{\text{COOL}}$	Equivalent full-load cooling hours	Hrs	410[5]
$Cooling_{\text{QUALIFIES}}$	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	kBtu/ton to kW/ton	12
EER_{BASE}	Energy efficiency rating of efficient unit		9.0[4]
EER_{ECM}	Energy efficiency rating of efficient unit		10.7[3]

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED COOLING}} = Tons * 12\ kBtu/ton * (1/EER_{\text{BASE}} - 1/EER_{\text{ECM}}) * CF$$

Where:

CF = Coincidence factor (68%)[4]

Lifecycle Energy-Savings Algorithm

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

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

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)	5,182	7,200
Lifecycle Therm Savings (Therms)	780	780

Revision History

Version Number	Date	Description of Change
01	10/2015	Initial entry
02	01/2016	Revised per Cadmus comments
03	01/2016	Revised per PSC comments
04	12/2018	Updated savings algorithm

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[1] Energy Efficiency and Customer-Sited Renewable Energy: Achievable Potential in Wisconsin 2006-2015, Volume II: Technical Appendix. Energy Center of Wisconsin, November 2005, page 192. Available Online: 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] ASHRAE Standard 90.1-2007, Table 6.8.1D for SPVAC (single package vertical air conditioning).

[5] Cadmus. “Focus on Energy Evaluated Deemed Savings Changes.” November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

Ductless Mini-Split Heat Pump

	Measure Details
Measure Master ID	Ductless Mini-Split: Replacing Electric Resistance and CAC, 3874 Replacing Electric Resistance and CAC, Tier 2, 3891 Replacing Electric Resistance and Room AC, 3875 Replacing Electric Resistance and Room AC, Tier 2, 3892 Replacing Electric Furnace and CAC, 3876 Replacing Electric Furnace and CAC, Tier 2, 3893 Replacing Electric Resistance and No AC, 3877 Replacing Electric Resistance and No AC, Tier 2, 3894 Replacing Gas Furnace and CAC, 5022 Replacing Gas Boiler and CAC, 5023
Workpaper ID	W0210
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Other
Sector(s)	Residential- single family, Residential- multifamily, Commercial
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	$2,889.00[2]

Measure Description

This measure is a residential-sized variable speed mini-split and multi-split heat pump system (MSHPs) with an output capacity of ≤ 65,000 Btu per hour.[3] This workpaper documents energy savings for MSHPs with energy efficiency performance of 14.3 SEER2 and 7.5 HSPF2 or greater that has inverter technology.

Description of Baseline Condition

Qualifying baseline scenarios involve electric heat (baseboard, furnace), electric cooling (central AC, room AC), and natural gas heat (furnace or boiler). The new MSHP 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.

Description of Efficient Condition

The efficient condition is a MSHP with an efficiency of at least SEER2 15.2, EER2 9.0, and HSPF2 8.5 or greater, based on proposed CEE Specification (10/18/22) – Tier 1, Ducted Split HP.

The savings calculation is dependent on the baseline heating fuel type and whether an incentive for the installation has been provided by both a natural gas and electric utility, just an electric utility, or just a natural gas utility.

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = kWh_{\text{HEAT}} + kWh_{\text{COOL}}$$

$$kWh_{\text{HEAT}} = CAP_{\text{HEAT}} * HOU_{\text{HEAT-EE}} * (Elec_{\text{BASE}} * DLF_{\text{BASE}} / HSPF2_{\text{BASE}} - 1 / HSPF2_{\text{EE}}) / 1{,}000$$

$$kWh_{\text{COOL}} = CAP_{\text{COOL}} * HOU_{\text{COOL-EE}} * (AC_{\text{BASE}} * DLF_{\text{BASE}} / SEER2_{\text{BASE}} - 1 / SEER2_{\text{EE}}) / 1{,}000$$

$$Therms_{\text{SAVED}} = Gas_{\text{BASE}} * CAP_{\text{EE}} * HOU_{\text{HEAT-EE}} * DLF_{\text{BASE}} / (AFUE_{\text{BASE}} * 100{,}000)$$

Where:

Variable	Description	Units	Value
CAP_{HEAT}	Heating capacity of efficient equipment	Btu/hr	19,110 Btu/hour[4]
$HOU_{HEAT-EE}$	Hours of use for efficient equipment heating	Hrs	1,940[5]
$Elec_{BASE}$	Factor indicating whether baseline case was electric heat		0 if baseline natural gas heat, 1 if baseline electric heat
DLF_{BASE}	Duct leakage factor of baseline equipment that accounts for percentage of energy lost to duct leakage and conduction for ducted systems		See Duct Leakage Factor of Baseline Equipment table below[3]
$HSPF2_{BASE}$	Baseline heating seasonal performance factor		3.412 for electric baseboard, 3.242 for electric furnace[3]
$HSPF2_{EE}$	Efficient measure heating seasonal performance factor		10.6[4]
1,000	Conversion factor	W/kW	1,000
CAP_{COOL}	Cooling capacity of efficient equipment	Btu/hr	21,193; see Assumptions[4]
$HOU_{COOL-EE}$	Hours of use for efficient equipment cooling	Hrs	369; see Assumptions[6]
AC_{BASE}	Factor indicating whether baseline case had AC		0 if no baseline AC, 1 if baseline AC
$SEER2_{BASE}$	Baseline seasonal energy efficiency ratio		13.4 for central AC,[7] 11.3 for room AC[3]
$SEER2_{EE}$	Efficient measure seasonal energy efficiency ratio		20.2[4]
Gas_{BASE}	Factor indicating whether baseline case had natural gas heat		0 if electric resistance or heat pump baseline, 1 if natural gas heat baseline
$AFUE_{BASE}$	Natural gas heating baseline AFUE	%	91.4% if furnace, 80% if boiler[8]
100,000	Conversion factor	Btu/therms	

Duct Leakage Factor of Baseline Equipment

Existing HVAC Type	DLF
Central AC	1.15
Electric or natural gas furnace	1.15
Natural gas boiler	1.00
Electric resistance (baseboard, space heaters)	1.00
Room AC	1.00

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = CAP_{\text{EE}} * (AC_{\text{BASE}} * DLF_{\text{BASE}} / EER2_{\text{BASE}} - 1 / EER2_{\text{EE}}) / 1{,}000 * CF$$

Where:

$EER2_{BASE}$ = Energy efficiency ratio of baseline unit (9.8 for room AC, 10.5 for central AC)[3]

$EER2_{EE}$ = Energy efficiency ratio of efficient unit (12.4)[4]

CF = Coincidence factor (0.68)[6]

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (18 years)[1]

Deemed Savings

Annual and Lifecycle Savings for Ductless Mini-Split Heat Pumps

Base Heating	Base Cooling	Tier	MMID	Annual		kW	Lifecycle	
				kWh	Therms		kWh	Therms
Electric baseboard	Central AC	1	3874	7,652	0	0.4162	137,736	0
		2	3891					
	Room AC	1	3875	7,673	0	0.3083	138,114	0
		2	3892					
Electric furnace	Central AC	1	3876	9,937	0	0.4162	178,866	0
		2	3893					
Electric baseboard	None	1	3877	6,981	0	-1.1622	125,658	0
		2	3894					
Natural gas furnace	Central AC	N/A	5022	-3,213	466	0.4162	-57,834	8,388
Natural gas boiler	Central AC	N/A	5023	-3,213	463	0.4162	-57,834	8,334

Assumptions

Full-load cooling hours were reduced by 10% from the 410 hours found in the *Wisconsin Deemed Savings Review*,[6] producing 369 hours based on an assessment of assumed EFLH for ductless heat pumps in other states.

Revision History

Version Number	Date	Description of Change
01	05/2016	Initial TRM entry
02	01/2020	Added natural gas heating baseline
03	01/2021	Updated capacities, efficiencies, and cost
06	11/2022	Efficiencies updated to SEER2, EER2, HSPF2

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[1] GDS Associates. *Measure Life Report, Residential and Commercial/Industrial HVAC Measures*. Table A-2, "Residential Heating and Cooling." June 2007.
https://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf
The table shows 18 years as the median measure life from multiple heat pump sources.

[2] Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 8.0, Volume 3*. October 17, 2019. p. 142. https://www.icc.illinois.gov/programs/illinois-statewide-technical-reference-manual-for-energy-efficiency
Full install cost for 10.0 HSPF to 10.9 HSPF units is $1,605 per ton. With a cooling capacity of 21,193 / 12,000 = 1.77 tons was used. $1,605 * 1.77 = $2,835.

[3] Pennsylvania Public Utility Commission. *Technical Reference Manual*. June 2016. Section 2.2.3, p. 53.
http://www.puc.pa.gov/pcdocs/1350348.docx

[4] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. 2020. Average AHRI-rated capacities and efficiencies for 489 installations in 2020. For heating capacity, the average of the capacites at 17°F and 47°F was used.

[5] Hours of use calculated by comparing TMY average weather data from four Wisconsin cities (Green Bay, La Crosse, Madison, and Milwaukee) to aggregate meter data collected by Cadmus from 70 cold-climate ductless heat pumps in Vermont, and evaluated against Vermont run-time variance to determine hours of use at various external temperatures.

[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] Electronic Code of Federal Regulations. Title 10, Chapter II, Subchapter D, Part 430, Subpart C, §430.32(c)(5).
https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32

[8] 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. Only three sites had boilers; 80% is an engineering assumption.

Air Source Heat Pump

	Measure Details
Measure Master ID	Air-Source Heat Pump, ≥15.2 SEER2, 2992 Air-Source Heat Pump Replacing Gas and CAC, 5163 Air-Source Heat Pump Replacing Gas and No CAC, 5164 Air-Source Heat Pump Replacing Electric Resistance, 10050 MF, Air Source Heat Pump, ≥ 15.2 SEER2, 5191 MF, Air Source Heat Pump replacing gas and CAC, 5192 MF, Air Source Heat Pump replacing gas no CAC, 5193 MF, Air-Source Heat Pump replacing Electric Resistance, 10051
Workpaper ID	W0237
Measure Unit	Per heat pump
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Other
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)	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)	18[1]
Incremental Cost ($/unit)	Varies by measure[2]

Measure Description

This measure is a residential-sized air-source heat pump with an input capacity of ≤ 65,000 Btu/hour. Heat pumps are installed for different reasons depending on the existing heating fuels:

- For propane customers, heat pumps can represent a significant cost savings over base fuel, and are often installed based on customer's request or the contractor's offering. In the cases where propane is the existing heating fuel, the measure baseline is a heat pump meeting the federal minimum efficiency requirements.
- For electric customers, heat pumps are often overlooked as not able to meet the heating load of the home. This fallacy leads to heat pumps not being installed.
- For natural gas customers a large increase in electricity usage and a large decrease in natural gas usage is created, reducing the overall net energy use. Heat pumps are less likely to be installed due to the availability and cost of natural gas.

Description of Baseline Condition

For heat pumps not installed with natural gas or electric resistance, the baseline measure is a federal standard baseline air-source heat pump.

For heat pumps installed with natural gas, the baseline is a market average furnace with or without federal standard central air conditioning unit.

For heat pumps installed with electric resistance, the baseline is electric resistance without federal standard central air conditioning unit.

Description of Efficient Condition

The efficient measure is a residential-sized air-source heat pump of SEER2 17.0 and HSPF2 8.0.[3]

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = kWh_{\text{HEAT}} + kWh_{\text{COOL}}$$

$$kWh_{\text{HEAT}} = CAP_{\text{HEAT}} * EFLH_{\text{HEAT}} * (HPH_{\text{BASE}} / HSPF2_{\text{BASE}} - 1 / HSPF2_{\text{EE}}) / 1{,}000$$

$$kWh_{\text{COOL}} = CAP_{\text{COOL}} * EFLH_{\text{COOL}} * (Cooling_{\text{BASE}} / SEER2_{\text{BASE}} - 1 / SEER2_{\text{EE}}) / 1{,}000$$

$$Therms_{\text{SAVED}} = Gas_{\text{BASE}} * CAP_{\text{HEAT}} * EFLH_{\text{HEAT}} / (AFUE_{\text{BASE}} * 100{,}000)$$

Where:

Variable	Description	Unit	Value
CAP_{HEAT}	Heating capacity	Btu/hr	29,518 Btu/hour[3]
$EFLH_{HEAT}$	Equivalent full-load heating hours	Hrs	1,890[5]
HPH_{BASE}	Factor indicating whether baseline case is heat pump heat	none	1 if baseline is heat pump or electric resistance heat, 0 if baseline is natural gas heat
$HSPF2_{BASE}$	Baseline heating seasonal performance factor	Btu/Wh	7.5 for heat pump baseline,[4] 3.413 for electric resistance baseline
$HSPF2_{EE}$	Efficient measure heating seasonal performance factor	Btu/Wh	8.0[3]
1,000	Conversion factor	W/kW	1,000
CAP_{COOL}	Cooling capacity	Btu/hr	30,222 Btu/hour[3]
$EFLH_{COOL}$	Equivalent full-load cooling hours	Hrs	395; see assumptions[5]
$Cooling_{BASE}$	Factor indicating whether baseline case had cooling	none	1 if baseline cooling, 0 if no baseline cooling
$SEER2_{BASE}$	Baseline seasonal energy efficiency ratio	Btu/Wh	13.4 for baseline air conditioning, 14.3 for baseline air-source heat pump heat[4]
$SEER2_{EE}$	Efficient seasonal energy efficiency ratio	Btu/Wh	17.0[3]
Gas_{BASE}	Factor indicating whether baseline case had natural gas heat	none	1 if natural gas furnace baseline, 0 if heat pump or electric resistance baseline
$AFUE_{BASE}$	Furnace baseline AFUE	%	91.4%[6]
100,000	Conversion factor	Btu/therm	100,000

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = CAP_{\text{COOL}} * (Cooling_{\text{BASE}} / EER2_{\text{BASE}} - 1 / EER2_{\text{EE}}) / 1{,}000 * CF$$

Where:

$EER2_{\text{BASE}}$ = Baseline energy efficiency ratio (10.0 for baseline natural gas heat, 10.5 for baseline air-source heat pump heat)[7]

$EER2_{\text{EE}}$ = Efficient energy efficiency ratio (11.0)[3]

CF = Coincidence factor (0.68)[8]

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (18 years)[1]

Assumptions

The capacity of residential heat pumps is assumed to be 2.52 tons for equipment installed in the Wisconsin market, based on analysis of 920 air-source heat pumps installed between 2016 and 2022 through the Focus on Energy Residential Prescriptive program. The assumed average capacity is 30,222 Btu/hr for cooling and 29,518 Btu/hr for heating.[3]

These capacity values were reduced by a factor of 20% to approximate the average multifamily size. This value comes from an analysis of furnaces (W0207) delivered in 2020.

Supporting inputs for heating load hours in several Wisconsin cities are shown in the table below.

Equivalent Full-Load Heating Hours by Location

Location	$EFLH_{\text{HEAT}}$[5]
Green Bay	1,852
La Crosse	1,966
Madison	1,934
Milwaukee	1,883
Wisconsin Average	1,909
Weighted Average	**1,890**

Cooling hours are based on an air conditioner in the Deemed Savings Report,[5] adjusted for the larger capacity system (410 hours at 2.425 tons is equivalent to 395 hours at 2.52 tons).

Deemed Savings and Costs

Deemed Savings and Costs

MMID	Annual		kW	Lifecycle		Cost
	kWh	Therms		kWh	Therms	
2992	597	0	0.0890	10,746	0	$620
5163	-6,785	610	0.0890	-122,130	10,980	$1,804.45
5164	-7,675	610	-1.8683	-138,150	10,980	$1,804.45
10050	8,671	0	-1.8683	156,078	0	$1,804.45
5191	478	0	0.0890	8,604	0	$620
5192	-5,428	488	0.0890	-97,704	8,784	$1,804.45
5193	-6,140	488	-1.8683	-110,520	8,784	$1,804.45
10051	6,936	0	-1.8683	124,848	0	$1,804.45

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
04	2/2021	Updated workpaper based on SPECTRUM data and added natural gas furnace baseline measures
05	07/2022	EUL Update
06	11/2022	Efficiencies updated to SEER2, EER2, HSPF2
07	9/22/2023	Added Electric Resistance heat baseline

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[1] Average of two reported EULs from two different sources. Measure Life report EUL report 16 years while MichaelsEnergy report 20 years, therefore the average of the two is 18 years of EUL.
GDS Associates. Measure Life Report, Residential and Commercial/Industrial HVAC Measures. June 2007. Equivalent full-load cooling hours Table A-2, “Residential Heating and Cooling,” gives 18 years as a median measure life found from multiple heat pump sources. MichaelsEnergy. June 03 2022. X2001A: Final Evaluation Report for: X2001A: Connecticut Measure Life/EUL Update. Study-Residential Measures.
https://energizect.com/sites/default/files/documents/Measure%20Life%20Report%202007.pdf
https://energizect.com/sites/default/files/documents/CT%20X2001A%20EUL%20Res%20Measure%20Report%20DRAFT%20REVIEW_Technical%20Consultants%20comments.pdf

[2] Illinois Energy Efficiency Statewide Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 8.0, Volume 3*. pp. 66 and 79. October 17, 2019. https://www.icc.illinois.gov/programs/illinois-statewide-technical-reference-manual-for-energy-efficiency
The air-source heat pump baseline has an incremental cost of $724.00 for a time-of-sale 17 SEER unit versus a less-efficient heat pump. For the furnace baseline, the heat pump is installed instead of an air conditioner, with a full cost of $1,381 * 2.52 tons + $724 = $4,202.08. The baseline cost is deemed at $952 per ton, which is an approximation for a 13 SEER air conditioner, or $952 * 2.52 = $2,397.63. This leads to a total cost of $4,202.08 - $2,397.63 = $1,804.45.

[3] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average capacities and efficiencies of 920 units from January 2016 to September 2022. The AHRI number, efficiencies, and capacities are all collected in SPECTRUM. Where no AHRI data is available the following is entered into SPECTRUM:
a. Where the distributor or manufacturer has provided a letter/email stating the combination meets or exceeds the offering

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requirements – Letter / 15.2 SEER2 / 10.0 EER2/ 8.1 HSPF2.
b. Where there is no combination and no letter is provided – AHRI unavailable / 12.2 SEER2 / 8.0 EER2 / 6.5 HSPF2.

[4] Electronic Code of Federal Regulations. Title 10, Chapter II, Subchapter D, Part 430, Subpart C, §430.32(c)(5). https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32

[5] Opinion Dynamics and Cadmus. Residential HVAC Metering Study Results. Recommendation 5a. February 28, 2018. https://ilsag.s3.amazonaws.com/AIC_HVAC_Metering_Study_Memo_FINAL_2018-02-28.pdf
This value is also used in the Illinois TRM.

[6] Cadmus. Focus on Energy Calendar Year 2015 Evaluation Report. May 20, 2016. Table J-4. https://www.focusonenergy.com/sites/default/files/Evaluation%20Report%20-%202015%20Appendices%20%28High%20Resolution%29.pdf

[7] Pennsylvania Public Utility Commission. Technical Reference Manual. June 2016. Section 2.2.3, p. 53. http://www.puc.pa.gov/pcdocs/1350348.docx

[8] Cadmus. Focus on Energy Evaluated Deemed Savings Changes. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

Ground Source Heat Pump, Residential, Natural Gas and Electric Backup

	Measure Details
Measure Master ID	Ground Source Heat Pump, No Gas Service, 5320 Ground Source Heat Pump, With Gas Service, 5321
Workpaper ID	W0244
Measure Unit	Per heat pump
Measure Type	Prescriptive
Measure Group	Renewable Energy
Measure Category	Geothermal
Sector(s)	Residential- single family
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)	25[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

For systems installed in a home without natural gas service, the baseline measure is deemed to be a federal standard air-source heat pump with a SEER of 14 and HSPF of 8.2. For systems installed in a home with natural gas service, the baseline is a 91.4% AFUE furnace with 13 SEER central air conditioning. This matches assumptions made in the air source heat pump workpaper, W0237. This measure is ineligible when replacing existing ground-source heat pumps.

Description of Efficient Condition

A qualifying product must be an ENERGY STAR listed unit with a minimum efficiency of:

- 17.1 EER / 3.6 COP for Water-to-Air systems
- 16.1 EER / 3.1 COP for for Water-to-Water systems
- 16.0 EER / 3.6 COP for Direct Ground Exchange (DGX) systems

EER and COP are based on a closed loop system 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. Savings are based on average efficiency of actual installations.

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = kWh_{\text{HEAT}} + kWh_{\text{COOL}}$$

$$kWh_{\text{HEAT}} = CAP_{\text{HEAT}} * EFLH_{\text{HEAT}} * [HPH_{\text{BASE}} / HSPF_{\text{BASE}} - 1 / (COP_{\text{EE}} * 3.412)] / 1{,}000$$

$$kWh_{\text{COOL}} = CAP_{\text{COOL}} * EFLH_{\text{COOL}} * [1 / SEER_{\text{BASE}} - 1 / EER_{\text{EE}}] / 1{,}000$$

$$Therms_{\text{SAVED}} = Gas_{\text{BASE}} * CAP_{\text{HEAT}} * EFLH_{\text{HEAT}} / (AFUE_{\text{BASE}} * 100{,}000)$$

Where:

Variable	Description	Units	Value
CAP_{HEAT}	Heating output capacity of equipment	Btu/hr	48,205[2]
$EFLH_{\text{HEAT}}$	Equivalent full-load heating hours	Hrs	1,890[3]
HPH_{BASE}	Factor indicating whether baseline case is heat pump heat		1 for no gas service, 0 if with gas service
$HSPF_{\text{BASE}}$	Heating seasonal performance factor of baseline equipment	kBtu/kWh	8.2 for no gas service[4]
COP_{EE}	Coefficient of performance		4.05[2]
3.412	Conversion factor	Btu/Wh	3.412
1,000	Conversion factor	W/kW	1,000
CAP_{COOL}	Cooling capacity of equipment	Btu/h	48,205[2]
$EFLH_{\text{COOL}}$	Equivalent full-load cooling hours	Hrs	410[3]
$SEER_{\text{BASE}}$	Seasonal energy efficiency ratio of baseline equipment	Btu/Wh	13 for homes with gas service, 14 for homes with no gas service[4]
EER_{EE}	Energy efficiency ratio of efficient equipment	kBtu/kWh	22.3[2]
Gas_{BASE}	Factor indicating whether baseline case is assumed to have had natural gas heat		0 for no gas service, 1 for with gas service
$AFUE_{\text{BASE}}$	Furnace baseline AFUE	%	91.4% for single family[5]
100,000	Conversion factor	Btu/therm	100,000

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = (Btu/h_{\text{COOL}} * (1 / EER_{\text{BASE}} - 1 / EER_{\text{EE}})) / 1{,}000 * CF$$

Where:

EER_{BASE} = Energy efficiency ratio of baseline equipment (11 for no gas service, 10.5 for gas service)[6]

CF = Coincidence factor (0.5)[7]

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (25 years)[1]

Deemed Savings

Annual and Lifecycle Savings

Measure	MMID	Annual		kW	Lifecycle	
		kWh	Therms		kWh	Therms
Ground Source Heat Pump:						
No Gas Service	5320	5,043	0	1.1103	126,075	0
With Gas Service	5321	-5,959	997	1.2146	-148,975	24,925

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.[3]

Equivalent Full-Load Cooling and Heating Hours by City

Location	$EFLH_{COOL}$[3]	$EFLH_{HEAT}$[3]
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**

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
04	08/2020	Updated based on evaluation findings
05	12/2021	Updated with gas baseline, updated capacities and efficiencies
06	07/2023	Updated EUL

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[1] Office of Energy and Effifciency & Renewable Energy. *Geothermal Heat Pumps.* 2017. https://www.energy.gov/eere/articles/5-things-you-should-know-about-geothermal-heat-pumps. Indoor equipment EUL is 25 years, but ground equipment will have a much longer life. An EUL of 25 years is deemed.

[2] Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 112 systems for MMID 2820 and 20 systems for MMID 2821, from January 2020 through June 2021.

[3] 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.

[4] U.S. Code of Federal Regulations. 10 CFR Ch. 11, §430.32. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32

[5] 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.

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[6] Opinion Dynamics and Cadmus. Residential HVAC Metering Study Results. Recommendation 5a. February 28, 2018. https://ilsag.s3.amazonaws.com/AIC_HVAC_Metering_Study_Memo_FINAL_2018-02-28.pdf
This value is also used in the Illinois TRM.

[7] Energy Center of Wisconsin. *Update of Geothermal Analysis*. p. 19–21. August 31, 2009.

Residential Air Conditioning Tune Up - Coil Cleaning and Filter Replacement

	Measure Details
Measure Master ID	Residential AC Tune-Up, 4838
Workpaper ID	W0211
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[2]

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

$$kWh_{\text{SAVED}} = CAP * 12 * EFLH / [SEER * (1 - SF)] * SF$$

Where:

Variable	Description	Units	Value
CAP	Unit capacity	Tons	2.425 tons[3]
12	Conversion factor	kBtuh/ton	12
EFLH	Equivalent full load cooling hours	Hrs	410[3]
SEER	Seasonal energy efficiency ratio	kBtu/kWh	12.1[4]
SF	Savings factor	%	7.4%[5]

Summary Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = CAP * 12 * EFLH / [EER * (1 - SF)] * SF * CF$$

Where:

EER = Energy efficiency ratio (10.6)[6]

CF = Coincidence factor (0.68)[3]

Lifecycle Energy-Savings Algorithm

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

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.

Revision History

Version Number	Date	Description of Change
01	12/2018	Initial TRM entry

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[1] EUL reflects engineering judgment, and the baseline condition requirement that the system has not been maintained in the last two years.

[2] Average cost based on responses from 12 residential HVAC contractors in Wisconsin. Costs ranged from $98 to $150. January 2019.

[3] Wisconsin Focus on Energy. *Deemed Savings Report*. October 27, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

[4] 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.

[5] 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

[6] Wassmer, M. *A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations.* Masters Thesis, University of Colorado at Boulder. 2003.

Furnace Tune-Up, Single Family

	Measure Details
Measure Master ID	Furnace Tune-Up, Single Family, 4660
Workpaper ID	W0212
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

$$Thermf = CAP * SF * EFLH_{\text{HEAT}} / (AFUE_{\text{PRE}} * 100)$$

Where:

Variable	Description	Units	Value
CAP	Size of boiler being tuned	MBh	70.7[3]
SF	Savings factor	%	1.6%[4]
$EFLH_{HEAT}$	Equivalent full-load hours	Hrs	1,158[5]
$AFUE_{PRE}$	AFUE of boiler prior to tune-up	%	91%[3]
100	Conversion factor	MBtu/therm	100

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

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

Where:

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

Revision History

Version Number	Date	Description of Change
01	05/2018	Initial TRM entry

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[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. "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

Thermostatic Radiator Valve (TRV)

	Measure Details
Measure Master ID	Thermostatic Radiator Valve - 10045
Workpaper ID	W0316
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	Boilers & Burners
Measure Category	Controls
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	11
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	167
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$250[2]

Measure Description

This measure is for the addition of a thermostatic valve installed on a hydronic or steam radiator. The Thermostatic Radiator Valve (TRV) is a thermostatically controlled, self-regulating valve that allows an occupant to set the temperature in the space. By limiting/blocking the flow of hot water or steam, the TRV prevents run-away heat and is particularly effective in multifamily buildings to prevent tenants from leaving windows open to control temperature in their unit.

Description of Baseline Condition

The baseline equipment is a radiator with no TRV.

Description of Efficient Condition

The efficient condition is a radiator with a TRV installed.

Annual Energy-Savings Algorithm

$$Therm_{\text{SAVED}} = \ (CAP * EFLH_{\text{HEATING}} * EFF/100)\ /R * \%Savings$$

Where:

Variable	Description	Units	Value
CAP	Boiler input capacity	MBtu/h	117[3]
$EFLH_{HEAT}$	Equivalent full load hours heating	hrs	1,158[4]
EFF	Boiler efficiency, AFUE	%	82%[5]
100	Conversion factor	MBtu/therm	100
R	Number of radiators in MF unit	none	5 (see Assumptions)
%Savings	Savings factor	%	5%[6]

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

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

Where:

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

Deemed Savings

Average Annual Deemed Savings

Measure	MMID	Therm
Thermostatic Radiator Valve	10045	11

Average Lifecycle Deemed Savings

Measure	MMID	Therm
Thermostatic Radiator Valve	10045	167

Assumptions

It is assumed that there are five radiators in a multifamily unit and the heating load is divided evenly between them.

The savings factor of 5% comes from the Illinois TRM (v12) and reflects the savings estimate for TRV projects that don't include system balancing. This value is based on a review of the following research reports.

- Department of Energy, Dentz et al, "Thermostatic Radiator Valve Evaluation," January 2015.[1]
- NYSERDA "Thermostatic Radiator Valve Demonstration Project," 1995.[3]
- Lublin University of Technology Cholewa, et al "Actual energy savings from the use of thermostatic radiator valves in residential buildings – Long term field evaluation," July 2017.

Revision History

Version Number	Date	Description of Change
01	09/2023	Initial TRM entry

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[1] Estimate based on assumption used in DOE's 2015 Thermostatic Radiator Valve Evaluation. Dentz, Jordan, & Ansanelli, Eric. *Thermostatic Radiator Valve Evaluation. United States*. https://doi.org/10.2172/1170337

[2] Estimate based on values found in Table 2, Page 7. Dentz, Jordan, & Ansanelli, Eric. Thermostatic Radiator Valve Evaluation. United States. https://doi.org/10.2172/1170337

[3] Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average input capacity of 1,012 boilers delivered between January 2020 and June 2021.

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[4] 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.

[5] U.S. Department of Energy (DOE). Energy and water conservation standards. January 15, 2021. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32

[6] Illinois TRM v12.0 (Page 218). September 22, 2023. https://www.icc.illinois.gov/downloads/public/il-trm-12/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf

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
Workpaper ID	W0213
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 DHW fuel source
Peak Demand Reduction (kW)	Varies by DHW fuel source
Annual Therm Savings (Therms)	Varies by DHW fuel source
Lifecycle Energy Savings (kWh)	Varies by DHW fuel source
Lifecycle Therm Savings (Therms)	Varies by DHW fuel source
Water Savings (gal/year)	15,337
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$87.00[2]

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.

Description of Baseline Condition

The baseline condition is a non-ENERGY STAR commercial clothes washer.

Minimum Performance Standards for Commercial Clothes Washers[3]

Washer Type	Modified Energy Factor (ft^3/kWh/cycle)	Integrated Water Factor (gal/ft^3/cycle)
Top-Loading	1.35	8.8
Front-Loading	2.00	4.1

Description of Efficient Condition

The efficient condition is an ENERGY STAR commercial clothes washer.

Minimum ENERGY STAR Performance Standards for Commercial Clothes Washers[4]

Washer Type	Modified Energy Factor (ft^3/kWh/cycle)	Integrated Water Factor (gal/ft^3/cycle)
Top-Loading	2.20	4.0
Front-Loading		

Annual Energy-Savings Algorithm[2]

$$kWh_{SAVED} = [Cap * 1/MEF_{BASE} * n * (\%CW_{BASE} + \%WH_{BASE} * (1 - \%WH_{GAS}) + \%Dryer_{BASE} * (1 - \%Dryer_{GAS})) - Cap * 1/MEF_{EE} * n * (\%CW_{EE} + \%WH_{EE} * (1 - \%WH_{GAS}) + \%Dryer_{EE} * (1 - \%Dryer_{GAS})] + Gallon_{SAVED} / 1{,}000 * kWh_{WATER}$$

$$Therm_{SAVED} = [Cap * 1/MEF_{BASE} * n * (\%WH_{BASE} / Eff_{WH} * (\%WH_{GAS}) + \%Dryer_{BASE} * (\%Dryer_{GAS}))] - [Cap * 1/MEF_{EE} * n * (\%CW_{EE} + \%WH_{EE} * (\%WH_{GAS}) + \%Dryer_{EE} * (\%Dryer_{GAS})]$$

$$Gallon_{SAVED} = Cap * n * (IWF_{BASE} - IWF_{EE})$$

Where:

Variable	Description	Units	Value
Cap	Clothes washer capacity	Ft^3	3.5 ft^3 (estimated)
MEF	Modified energy factor of washer	Ft^3/kWh/cycle	
n	Cycles per year	Cycles/yr	1,241[1]
%CW	Percentage of total energy consumption for clothes washer operation	%	Varies between baseline and efficient unit
%WH	Percentage of total energy consumption used for water heating	%	Varies between baseline and efficient unit
%Dryer	Percentage of total energy consumption for dryer operation	%	Varies between baseline and efficient unit
$\%WH_{GAS}$	Percentage of units with gas water heating	%	80% [1]
$\%Dryer_{GAS}$	Percentage of units with gas water heating	%	60% [1]
Eff_{WH}	Water heater efficiency	%	Electric = 100%; Gas = 75% [1]
1,000	Gallons to kilogallon conversion factor	Gal/kgal	1,000
kWh_{WATER}	Energy saved from water and wastewater utilities	kWh/kgal	3.89 kWh/kgal[5]
IWF	Integrated water factor	Gallons/ft^3/cycle	

Summer Coincident Peak Savings Algorithm

$$kW_{SAVED} = kWh_{SAVED} / (n * t_{CYCLE}) * CF$$

Where:

t_{CYCLE} = 1 hour per cycle (estimated)

CF = Coincidence factor (0.038)[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

Annual (kWh), Life Cycle Energy Savings (LC kWh) and Demand Reduction Savings (kW) by Measure

Measure	MMID	kW	kWh	LC kWh
Clothes Washer, Common Area, ENERGY STAR, Electric	2756	0.017	615	6,765
Clothes Washer, Common Area, ENERGY STAR, Natural Gas	2757	0.012	453	4,985

Annual (therms) and Life Cycle Gas Savings (LC therms) by Measure

Measure	MMID	therms	LC therms
Clothes Washer, Common Area, ENERGY STAR, Electric	2756	14	154
Clothes Washer, Common Area, ENERGY STAR, Natural Gas	2757	21	231

Annual (gallons) and Life Cycle Water Savings (LC gallons) by Measure

Measure	MMID	gallons	LC gallons
Clothes Washer, Common Area, ENERGY STAR, Electric	2756	15,337	168,706
Clothes Washer, Common Area, ENERGY STAR, Natural Gas	2757	15,337	168,706

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	09/2022	Overhauled algorithm, updated ES criteria, and IMC
03	10/2023	Updated electric energy savings factor for W/WW utilities

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[1] Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Dishwashers, Dehumidifiers, and Cooking Products, and Commercial Clothes Washers. U.S. Department of Energy. October 2009. Tables 8.2.23 and 8.2.12 and their footnotes. https://downloads.regulations.gov/EERE-2006-STD-0127-0101/attachment_10.pdf

[2] Algorithm format and incremental cost used from the Illinois TRM, v10. 5.1.2 ENERGY STAR Clothes Washers. https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010122_v10.0_Vol_3_Res_09242021.pdf

[3] 10 CFR 431.156(b) https://www.ecfr.gov/current/title-10/part-431#p-431.156(b)

[4] ENERGY STAR Program Requirements Product Specification for Clothes Washers, Version 8.0. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%208.0%20Clothes%20Washer%20Partner%20Commitments%20and%20Eligibility%20Criteria_0.pdf

[5] Water-Related Energy Savings using updated CMAR (2016-2020) and WI Water Utility databases (2015-2022). A weighted average was used for the calculation of the water energy savings factor for groundwater/surface water, and for facilities with 0-1 MGD/ >1 MGD. Calculations and data provided in Huddle folder of this workpaper.

Electric Clothes Dryer, ENERGY STAR

	Measure Details
Measure Master ID	Electric Clothes Dryer, ENERGY STAR, 4038
Workpaper ID	W0214
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)	14[1]
Incremental Cost ($/unit)	$224.91[2]

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.[2]

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.[3]

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.[2]

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = UEC_{\text{BASE}} - UEC_{\text{EE}}$$

Where:

Variable	Description	Units	Value
UEC_{BASE}	Annual unit energy consumption of baseline unit	kWh/yr	768.92 kWh[2]
UEC_{EE}	Annual unit energy consumption of measure unit	kWh/yr	608.49 kWh[2]

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = (kWh_{\text{SAVED}} \,/\, Hours) * CF$$

Where:

Hours = Assumed annual run hours of clothes dryer (= 283; Ncycles * 1 Hour)

CF = Coincidence factor (2.9%)[4]

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (14 years)[1]

Revision History

Version Number	Date	Description of Change
01	06/2016	Initial TRM entry
02	07/2022	EUL Update

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[1] U.S. Department of Energy. Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment. p. 212; 8-27. https://downloads.regulations.gov/EERE-2017-BT-STD-0014-0030/content.pdf

[2] 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.

[3] 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

[4] 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

Natural Gas Clothes Dryer, ENERGY STAR

	Measure Details
Measure Master ID	Natural Gas Clothes Dryer, ENERGY STAR, 4039
Workpaper ID	W0215
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

$$Therm_{\text{SAVED}} = UEC_{\text{BASE}} - UEC_{\text{EE}}$$

$$kWh_{\text{SAVED}} = UEC_{\text{BASE}} - UEC_{\text{EE}}$$

Where:

Variable	Description	Units	Value
UEC_{BASE}	Annual unit energy consumption of baseline unit	kWh/yr, therm/yr	42.1 kWh/year, 27.2 therm/year[1]
UEC_{EE}	Annual unit energy consumption of measure unit	kWh/yr, therm/yr	34.36 kWh/year, 22.2 therm/year[1]

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = (\Delta kWh/Hours) * CF$$

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

$$Therm_{\text{LIEFCYCLE}} = Therm_{\text{SAVED}} * EUL$$

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

Where:

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

Revision History

Version Number	Date	Description of Change
01	06/2016	Initial TRM entry

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[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

LIGHTING

Interior Lighting Controls, CALP

	Measure Details
Measure Master ID	Lighting Controls, Interior, CALP, 3969
Workpaper ID	W0216
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

$$kWh_{\text{SAVED}} = Watts\ /\ 1{,}000\ *\ SF\ *\ HOU$$

Where:

Variable	Description	Units	Value
Watts	Controlled lighting wattage	Watts	Provided for each project
1,000	Conversion factor	W/kW	1,000
SF	Savings factor, deemed	%	41%[3]
HOU	Hours of use	Hrs	6,614[4]

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = Watts\ *\ SF\ /1{,}000\ *\ CF$$

Where:

CF = Coincidence factor (0.77)[5]

Lifecycle Energy-Savings Algorithm

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

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

Revision History

Version Number	Date	Description of Change
01	11/2016	Initial TRM entry

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[1] PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. Appendix B. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

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[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. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. 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] Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

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
Workpaper ID	W0219
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

$$kWh_{\text{SAVED}} = kWh_{\text{8' T12}} - kWh_{\text{HP/RW}}$$

Where:

Variable	Description	Units	Value
$\text{kWh}_{8'\ \text{T12}}$	Annual electricity consumption of an 8-foot, T12, T12HO, or T12VHO lamp linear fluorescent fixture	kWh/yr	
$\text{kWh}_{\text{HP/RW}}$	Annual electricity consumption of an 8-foot, T12, T12HO, or T12VHO lamp linear fluorescent fixture	kWh/yr	

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = Wattage\ /\ 1{,}000\ *\ CF$$

Where:

Wattage = Wattage used

1,000 = Conversion factor, W/kW

CF = Coincidence factor (1.0)[2]

Lifecycle Energy-Savings Algorithm

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

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[3]

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

Revision History

Version Number	Date	Description of Change
01	12/2012	Initial TRM entry
02	01/2019	Removed MMIDs 3144–3147, 3149–3151, and 3154–3156

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[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. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

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
Workpaper ID	W0222
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[2]

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

$$kWh_{\text{SAVED}} = kWh_{\text{59wattT8}} - kWh_{\text{RWLamp}}$$

Where:

Variable	Description	Units	Value
$kWh_{59wattT8}$	Annual electricity consumption of standard 59-watt 8-foot T8 lamp	kWh/yr	
kWh_{RWLamp}	Annual electricity consumption of reduced wattage 8-foot T8 lamp	kWh/yr	

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = Wattage\ /\ 1{,}000\ *\ CF$$

Where:

Wattage = Wattage of installed fixture; (ballast factor * lamp wattage)

1,000 = Conversion factor, W/kW

CF = Coincidence factor (0.77)[3]

Lifecycle Energy-Savings Algorithm

$$kWh_{\text{LIFECYCLE}} = (kWh_{\text{59wattT8}} - kWh_{\text{RWLamp}})\ *\ EUL$$

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.

Revision History

Version Number	Date	Description of Change
01	12/2012	Updated savings values

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[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] 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] Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

LED, Omnidirectional, Connected Lighting

	Measure Details
Measure Master ID	Connected Lighting Bulb, Non-Hub, BR30, Online Store, 5391 Connected Lighting Bulb, Non-Hub, Omnidirectional A-19, Pop-Up Retail, 5389 Connected Lighting Bulb, Non-Hub, BR30, Pop-Up Retail, 5390
Workpaper ID	W0302
Measure Unit	Per bulb
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)	3 for MMID 5389, 1 for MMIDs 5390, 5391 (see Assumptions)[1,2]
Incremental Cost ($/unit)	Varies by measure. See table Measure Costs table[3]

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; however, the increased energy usage of the hub outweighs the savings attributed to the connectivity of the lamp, and therefore are not included in this measure.[4] 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 Wi-Fi connectivity, 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,[4] 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 lightbulb for the omnidirectional A19 bulb, in accordance with the lumen equivalence method as specified in the *Uniform Methods Project*.[5]

For the BR30 bulb, the baseline equipment is a 65-watt incandescent BR30 reflector lamp, based on CFR 430.32(6)(ii).

In April 2022, the U.S. Department of Energy (DOE) issued its final rulemaking[3,6] to expand the definition of general service lamps (GSLs) and require all GSLs to meet a 45 lumen per watt minimum efficiency by July 31, 2023. Based on this ruling, baseline wattages for any LEDs distributed or discounted after July 31, 2023 should be adjusted to reflect the new 45 lumens per watt requirement.

Description of Efficient Condition

The efficient equipment is a Wi-Fi connected lightbulb that can communicate with users via smart phone applications.

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = (\Delta kWh_{\text{LED}} * ISR_{\text{LED}}) + (\Delta kWh_{\text{APP}} * ISR_{\text{LED}} * ISR_{\text{APP}})$$

$$\Delta kWh_{\text{LED}} = (Watts_{\text{BASE}} - Watts_{\text{EE}}) / 1{,}000 * HOU * N_{\text{LAMPS}}$$

$$\Delta kWh_{\text{APP}} = (\Delta kWh_{\text{DIM}} + \Delta kWh_{\text{HOU}} - \Delta kWh_{\text{STBY}}) * N_{\text{LAMP}}$$

$$\Delta kWh_{\text{DIM}} = Watts_{\text{EE}} / 1{,}000 * \%\Delta Watts_{\text{DIM}} * [HOU * (1 - \%\Delta\text{HOU})]$$

$$\Delta kWh_{\text{HOU}} = [Watts_{\text{EE}} * (1 - \%\Delta Watts_{\text{DIM}})] / 1{,}000 * HOU * \%\Delta\text{HOU}$$

$$\Delta kWh_{\text{STBY}} = Watts_{\text{STBY}} / 1{,}000 * HOU_{\text{STBY}}$$

Where:

Variable	Description	Units	Value
ΔkWh_{LED}	Reduction in annual energy consumption from upgrading a single bulb	kWh/yr	
ISR_{LED}	In-service rate	%	See Installation Rates table and Assumptions
ΔkWh_{APP}	Reduction in annual energy consumption from using all connected lighting features and standby and hub energy usage	kWh/yr	
ISR_{APP}	Usage rate of the smart lighting app	%	84%, see Assumptions[4]
$Watts_{BASE}$	Baseline wattage	Watts	43 for A19 bulb, 65 for BR30 bulb. To be updated by July 31, 2023. See Description of Baseline Condition.
$Watts_{EE}$	Efficient wattage	Watts	9 for A19 bulb,[6] 8 for BR30 bulb[7]
1,000	Conversion factor	W/kW	1,000
HOU	Hours of use	Hrs	829 for single-family, 734 for multifamily[8]
N_{LAMPS}	Number of lamps installed		1

Variable	Description	Units	Value
ΔkWh_{DIM}	Reduction in annual energy consumption from app-induced dimming	kWh/yr	
ΔkWh_{HOU}	Reduction in annual energy consumption from app-induced HOU reduction	kWh/yr	
ΔkWh_{STBY}	Increase in annual energy consumption from standby power	kWh/yr	
$\%\Delta Watts_{DIM}$	Average app-induced percentage decrease in power	%	11%[4]
%ΔHOU	Average app-induced percentage decrease in HOU	%	4%[4]
$Watts_{STBY}$	Bulb standby wattage	Watts	0.5, see Assumptions
HOU_{STBY}	Bulb standby hours of use	Hrs	160[4]

Installation Rates

Measure Name	MMID	Sector	ISR_{LED}[9]
A19 Omnidirectional, Non-Hub, Wi-Fi Connected Bulb, Pop-Up Retail	5389	SF/MF	92%
BR30, Non-Hub, Wi-Fi Connected Bulb, Pop-Up Retail	5390	SF/MF	90%
BR30, Non-Hub, Wi-Fi Connected Bulb, Online Marketplace	5391	SF/MF	89%

Summer Coincident Peak Savings Algorithm

$$kW_{SAVED} = (\Delta kW_{LED} * ISR_{LED}) + (\Delta kW_{APP} * ISR_{APP})$$

$$\Delta kW_{LED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * CF * N_{LAMPS}$$

$$\Delta kW_{APP} = (\Delta kW_{DIM} - \Delta kW_{STBY}) * N_{LAMPS}$$

$$\Delta kW_{DIM} = Watts_{EE} * \%\Delta Watts_{DIM} * CF / 1{,}000$$

$$\Delta kW_{STBY} = Watts_{STBY} * CF_{STBY} / 1{,}000$$

Where:

CF = Coincidence factor for bulb usage time (12%)[4]

CF_{STBY} = Coincidence factor for bulb standby time (2%)[4]

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (3 years for MMID 5389, 1 year for MMIDs 5390, 5391, see Assumptions)[1,2]

Deemed Savings

Savings for Pack-Based Connected Lighting Bulbs

Delivery/Sector		Measure	MMID	Annual Savings (kWh)	Demand Reduction (kW)	Lifecycle Savings (kWh)
Online Store	SF	BR30, Non-Hub, Wi-Fi Connected Bulb	5391	43	0.0062	43
	MF			38	0.0062	38
Pop-Up Retail		A19 Omnidirectional, Non-Hub, Wi-Fi Connected Bulb	5389	26	0.0038	79
		BR30, Non-Hub, Wi-Fi Connected Bulb	5390	44	0.0064	44

Assumptions

The savings are based on data used in a study conducted by Cadmus on behalf of the Wisconsin Focus on Energy program.[4] 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 81 participants in Wisconsin, 68 of which were confirmed to have used the technology. The study revealed that 84% of participants who installed the bulbs also installed the hub, which was used as a proxy for usage of the connected features of the bulbs (ISR_{APP}).

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 %ΔHOU 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 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.[8] The value for %ΔHOU, derived from the study, is maintained as a percentage rather than an absolute.

Standby wattage information for the EarthTronics bulbs was not available, but similar Wi-Fi bulbs state a standby power draw of 0.5,[10] so this workpaper uses that value. Because this power is used to power the Wi-Fi connection, it is assumed that the standby power is the same for both EarthTronics models.

In April 2022, the U.S. Department of Energy (DOE) issued its final rulemaking[1,2] to expand the definition of general service lamps (GSLs) and require all GSLs to meet a 45 lumen per watt minimum efficiency by July 2023. Based on this mandate, Focus on Energy updated EULs for LED measures that are affected by the DOE ruling using HOU from the 2022 TRM and technical life of baseline equipment for each measure.

Incremental Costs

Base costs for each lumen bin were estimated for the Wisconsin market using data from the Consortium for Retail Energy Efficiency Data.[11] Efficient costs are calculated based on the bulk pricing costs incurred by Focus on Energy.

Measure Costs[3]

Delivery/ Sector	Measure	MMID	Base Cost	Efficient Cost	Incremental Cost
Online Store	BR30, Non-Hub, Wi-Fi Connected Bulb	5391	$2.90	$13.99	$11.09
Pop-Up Retail	A19 Omnidirectional, Non-Hub, Wi-Fi Connected Bulb	5389	$1.51	$9.99	$8.48
	BR30, Non-Hub, Wi-Fi Connected Bulb	5390	$2.90	$13.99	$11.09

Pop-Up Retail Sector Split

For Pop-Up Retail measures, savings are weighted by approximate single-family / multifamily participant counts, from 2020 program year Pop-Up Retail Survey results. Nine out of 120 respondents (7.5%) receiving an Energy and Water Savings Kit (containing showerheads, aerators, bulbs, pipe wrap, and a DHW turndown card) were multifamily participants. Nine out of 147 respondents receiving an LED Starter Kit, containing omnidirectional bulbs and a desk lamp, were multifamily participants. A rounded value of 7% is applied for these types of Pop-Up Retail measures, including pipe insulation.

Revision History

Version Number	Date	Description of Change
01	01/2018	Initial TRM entry
02	04/2018	Added multifamily sector
03	09/2022	Overhauled entire measure. Removed hub-based options, changed EUL, changed cost, changed specific bulb offerings.

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[1] U.S. Department of Energy Appliance and Equipment Standards Rulemakings and Notices. April 2022. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=4. https://www.regulations.gov/document/EERE-2021-BT-STD-0012-0022

[2] Apex Analytics conducted unpublished research in 2020 and found that most halogen lamps offered for sale at that time had a rated life of only 1,000 hours. However, actual lifetimes are dependent on available lamps and what is purchased, therefore while 2,000 hours may be a generous assumption, it is reasonable given the uncertainty of package offerings and availabilities as well as other uncertain variables in the calculation. EULs were calculated as:
LED EUL = Technical Life (hours) / Hours of Use (HOU). MMID 5389 technical life is 2000 hours and HOU was the weighted average of the split of SF and MF (97/7) , while MMIDs 5390, 5391 technical life and HOU are 1,000 (incandescent) and 829 for SF/734 for MF, giving 3 years EUL for MMID 5389 and 1 year EUL for MMIDs 5390, 5391.

[3] Apex Analytics and Cadmus. Base costs derived from data from the Consortium for Retail Energy Efficiency Data, see W0228 and W0229. Efficient costs for Online Store and Pop-up Retail reflect bulk pricing to Focus for the bulbs, i.e., the discount plus the customer out-of-pocket price. The efficient costs do not include the incentives offered by Focus on Energy.

[4] 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/

[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. Table 3. February 2015. http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf

[6] EarthTronics. "Smart LED A19 80CRI Specification Sheet." https://cdn.earthtronics.com/wp-content/uploads/2021/06/06114720/11484-LA199RGBWES-Spec-Sheet-1.6.pdf

[7] EarthTronics. "Smart LED BR30 90+CRI Specification Sheet." https://www.earthtronics.com/wp-content/uploads/2020/09/11449-LBR38RGBW-Spec-Sheet-10.7.pdf

[8] Cadmus. *Focus on Energy Evaluated Deemed Savings*. June 10, 2016. https://focusonenergy.com/sites/default/files/2016%20Deemed%20Savings%20Review.pdf

[9] Cadmus. *Focus on Energy Calendar Year 2020 Evaluation Report Volume II*. pp. 14,22. May 21, 2021. https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_II.pdf

[10] Ikea. "Wireless Dimmable LED Bulb" https://www.ikea.com/us/en/p/tradfri-led-bulb-e26-1000-lumen-wireless-dimmable-white-spectrum-globe-opal-70408492/ See product specification information for standby power draw

[11] Apex Analytics. *COVID-19 and EISA Challenges Lead to Uncertainty in the Lighting Market: LED Market Update, Analysis, and Implications for Energy Efficiency Programs.* May 1, 2020. http://www.creedlighttracker.com/wp-content/uploads/2020/05/Spring-2020-Lighting-Update_050520_PDF.pdf

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
Workpaper ID	W0231
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[1]

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

$$KWh_{\text{SAVED}} = (Watts_{\text{INCANDESCENT}} - Watts_{\text{LED}})\ /\ 1{,}000\ *\ HOU$$

Where:

Variable	Description	Units	Value
$\text{Watts}_{\text{INCANDESCENT}}$	Power consumption of baseline measure	Watts	63.7; see Baseline Wattage table below[2]
$\text{Watts}_{\text{LED}}$	Power consumption of efficient measure	Watts	20.93; see Efficient Wattage table below[3]
1,000	Kilowatt conversaion factor	kW	1,000
HOU	Average annual hours of use	Hrs/yr	4,380 for 12-hour use; 8,760 for 24-hour use

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**

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**

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = (Watts_{\text{INCANDESCENT}} - Watts_{\text{LED}})\ /\ 1{,}000\ *\ CF$$

Where:

CF = Coincidence factor (0.0 to 1.0 for 24-hour use)

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = (11 years for 12 hour fixtures; 6 years for 24 hour fixtures)[4]

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.

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	03/2015	Revised and combined 12 hour and 24 hour workpapers
03	10/2017	Updated EUL

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[1] Online research. March 2016. Material cost is average sales price of LED downlight. https://www.1000bulbs.com/category/led-downlights/

[2] EISA equivalent wattages for common incandescent lamps.

[3] Average wattage of equivalent qualifying ENERGY STAR and DLC-listed LED fixtures as of January 30, 2015.

[4] 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.

LED Upgrades, CALP

	Measure Details
Measure Master ID	CALP Interior 12+ Hours, 3967 CALP Exterior, 3968
Workpaper ID	W0233
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

$$kWh_{\text{SAVED}} = (Watts_{\text{REDUCED}}) * HOU / 1{,}000 = Watts_{\text{REDUCED}} * HOU / 1{,}000$$

Where:

Variable	Description	Units	Value
$\text{Watts}_{\text{REDUCED}}$	$\text{Watts}_{\text{BASE}}$ - $\text{Watts}_{\text{LED}}$	Watts	
$\text{Watts}_{\text{BASE}}$	Power consumption of currently installed lighting	Watts	Actual; provided by Trade Ally for each project
$\text{Watts}_{\text{LED}}$	Power consumption of efficient LED product	Watts	Actual; provided by Trade Ally for each project
1,000	Conversion factor	W/kW	1,000
HOU	Hours of use	Hrs	6,614 for MMID 3967,[3] 4,380 for MMID 3968)[4]

Summer Coincident Peak Savings Algorithm

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

Where:

CF = Coincidence factor (0.77 for MMID 3967[5]; 0.00 for MMID 3968)

Lifecycle Energy-Savings Algorithm

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

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

Revision History

Version Number	Date	Description of Change
01	11/2016	Initial TRM entry
02	10/2017	Updated EUL

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[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] Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

REFRIGERATION

Freezer, ENERGY STAR

	Measure Details
Measure Master ID	Freezer, Chest, ENERGY STAR, 4036 Freezer, Upright, ENERGY STAR, 4037
Workpaper ID	W0242
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)	16[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

$$kWh_{\text{SAVED}} = UEC_{\text{BASE}} - UEC_{\text{EE}}$$

Where:

Variable	Description	Units	Value
UEC_{BASE}	Annual unit energy consumption of baseline unit	kWh	Based on unit type, see Annual Energy Savings table below[1]
UEC_{EE}	Annual unit energy consumption of measure unit	kWh	Based on unit type, see Annual Energy Savings table below[1]

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = (kWh_{\text{SAVED}} / 8{,}760) * TAF * LSAF$$

Where:

TAF = Temperature adjustment factor (1.23)[4]

LSAF = Load shape adjustment factor (1.15)[4]

Lifecycle Energy-Savings Algorithm

$$kWh_{\text{LIFE-CYCLE}} = kWh_{\text{SAVED}} * EUL$$

Where:

EUL = Effective useful life (16 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	16	384
Upright, 4037	44	16	704

Revision History

Version Number	Date	Description of Change
01	06/2016	Initial TRM entry
02	07/2022	EUL Update

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[1] ENERGY STAR. *Retail Products Platform: Product Analysis for Clothes Dryers*. Effective May 11, 2016. https://drive.google.com/open?id=0B9Fd3ckbKJp5OEpWSHg1eksyZ1U
For EUL, an average between ENERGY STAR and U.S. Department of Energy Technical Support Document sources was calculated. Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment uses 21 years. p. 235; 1-5. https://downloads.regulations.gov/EERE-2017-BT-STD-0003-0020/content.pdf. ENERGY STAR assumes 11 years based on Appliance Magazine, U.S. Appliance Industry: Market Value, Life Expectancy & Replacement Picture for 2005-2012, 2011.

[2] U.S. Department of Energy, 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).

Refrigerator and Freezer Recycling

	Measure Details
Measure Master ID	Refrigerator, Recycling and Replacement, 2955 Freezer, Recycling and Replacement, 2956
Workpaper ID	W0243
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[2]

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

$$kWh_{\text{SAVED}} = Unadjusted\ gross\ annual\ kWh\ savings/unit\ *\ Part\_Use$$

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.[3]

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

$$kW_{\text{SAVED}} = [(kWh\ savings/unit) \ / \ HOURS] * P * Part\_Use$$

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)[3]

Part_Use = Part-use factor determined by Evaluation Team (0.86 for refrigerators; 0.76 for freezers)

Lifecycle Energy-Savings Algorithm

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

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).

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	01/2015	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

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[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] Cost to implementer for appliance pick-up.

[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

RENEWABLE ENERGY

Solar Photovoltaic

	Measure Details
Measure Master ID	Solar PV, 2819
Workpaper ID	W0245
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)	28[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 a direction other than south 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 ≥ 135 degrees and ≤ 225 degrees). East-facing PV arrays may be installed within 45 degrees of straight east (azimuth angle ≥ 45 degrees and < 135 degrees). West-facing PV arrays may be within between 45 degrees of straight west (azimuth angle > 225 degrees and ≤ 315 degrees). North-facing systems may be installed within 45 degrees of due north (azimuth angle > 315 degrees and < 45 degrees). All panels are to be installed in a safe area, where there is 15% or less shading.

Arrays can have a tilt between 5 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,[3] 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:

Variable	Description	Units	Value
DerateFactor	Amount of power maintained in DC to AC conversion	%	88.6%; see Assumptions
ShadeFactor	Percentage of time system is shaded	%	4.5%; see Assumptions
SnowFactor	Percentage of time system in covered in snow	%	2% for 28° tilt[4]

Installed Capacity by City

Reference City	Reference Zip Code	AC kWh/kWDC Installed Capacity			
		South Facing	East Facing	West Facing	North Facing
Milwaukee	53220	1,324	1,065	1,074	755
Madison	53706	1,310	1,048	1,054	738
Green Bay	54302	1,331	1,070	1,061	740
Average		**1,346**	**1,322**	**1,061**	**1,063**

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 2 p.m. to 6 p.m. on weekdays from June through September then dividing by the number of hours in that period.

$kW_{SAVED} = kWh_{PEAK,\ TOTAL} / Hours_{PEAK,\ TOTAL}$

Where:

$kWh_{PEAK,\ TOTAL}$ = Total kilowatt-hours generated during peak hours

$Hours_{PEAK,\ TOTAL}$ = Total peak period hours (= 348.57; see Assumptions)

Installed Capacity by City

Direction	Reference City	Total Peak Period (kWh)	Amount Reduced (kW)
South	Milwaukee	93.5	0.27
	Madison	94.1	0.27
	Green Bay	92.0	0.26
	Average	93.2	0.27
East	Milwaukee	42.5	0.12
	Madison	43.9	0.13
	Green Bay	40.8	0.12
	Average	42.4	0.12
West	Milwaukee	136.2	0.39
	Madison	133.5	0.38
	Green Bay	134.3	0.38
	Average	134.7	0.39
North	Milwaukee	77.7	0.22
	Madison	76.6	0.22
	Green Bay	75.2	0.22
	Average	76.5	0.22

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (28 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[4] or, where available, are Residential Rewards program-specific data:

- Array azimuth of 180° for south facing, 90° for east facing, 270° for west facing, 0° for north facing
- Fixed (non-tracking) array
- Array tilt of 28° (reference 6)

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.[5]

A shade factor of 4.5% was used based on program year 2019 desktop reviews,[6] and reflect a higher permitted shading value. The 2019 desk reviews showed an average ShadeFactor of 1.0% for 10 nonresidential sites and 3.4% for 89 residential sites, an overall average of 3.2%. These values reflected a cutoff of 10% shading. For PY2022, installations have shading of up to 15%. Adding a rough projection of site counts from 10% to 15% shading, based on the existing 2019 trend in site counts observed from 0% to 10%, produces an average ShadeFactor of 4.5%.

The overall System Losses factor used in PV Watts is 1 - [System Derate Factor] = 1 - DerateFactor * (1 - ShadeFactor) * (1 - SnowFactor) = 1 - 88.6% * (1 - 4.5%) * (1 - 2%) = 1 - 84.4836% = 17.0793%.

Peak period hours were calculated as follows: there are 30 + 31 + 31 + 30 = 122 days in June, July, August, and September. Five out of every seven days are weekdays, with four peak hours per weekday. Therefore, $\text{Hours}_{\text{PEAK}}$ = 122 * (5 / 7) * 4 = 348.57.

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
04	12/2021	Added north facing, updated to 28 degree tilt and 4.5% Shadefactor
05	06/2023	EUL and peak demand savings

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[1] The average estimation of the effective useful life (EUL) has risen to a median of 32.5 years. It's important to note that these estimates are based on utility-scale solar projects, which differ from the majority of the Focus on Energy PV participation. Considering this, a proposed EUL of 30 years is being suggested as the standard. Additionally, we propose adjusting the EUL to incorporate the degradation of solar PV generation. By assuming a nominal EUL of 30 years and an annual degradation rate of 0.5%, the adjusted EUL is approximately 28 years (27.8).

[2] Cadmus. Analysis of 2016 Renewable Rewards program data for 24 funded PV systems.

[3] National Renewable Energy Laboratory. *PVWatts Calculator*. https://pvwatts.nrel.gov/pvwatts.php

[4] 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

[5] 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

[6] Average tilt of 92 residential and 10 nonresidential Focus on Energy solar PV installations in program year 2019. Average ShadeFactor of 3.2% (with shading limit of 10%).

VENDING & PLUG LOADS

Advanced Power Strip

	Measure Details
Measure Master ID	Advanced Power Strip, Pack-Based, APS Tier 1, 3895 Advanced Power Strip, APS Tier 1, Online Store, 4917 Advanced Power Strip, APS Tier 2, Online Store, 4918
Workpaper ID	W0246
Measure Unit	Per advanced power strip
Measure Type	Prescriptive
Measure Group	Vending & Plug Loads
Measure Category	Controls
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)	6[1,2] (see Assumptions)
Incremental Cost	Tier 1 Online and Pack = $22.00 (MMIDs 4917)[3] Tier 2 Online = $50.00 (MMID 4918)[3]

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 because 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 in to the switched outlets and main loads (such as a DVR, router, or clock) being plugged in to 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 on 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

The efficient condition is efficient use of an APS.

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = kWh_{\text{BASE}} * SF * ISR$$

Where:

Variable	Description	Units	Value
kWh_{BASE}	Baseline consumption	kWh	356[4]
SF	Savings factor	%	19% for Tier 1;[5] see Assumptions, 33% for Tier 2[4]
ISR	Installation rate	%	90% for Pack-Based Tier 1, 93% for Online Store Tier 1, 70% for Online Store Tier 2[6]

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = kWh_{\text{SAVED}} * CF / HOU$$

Where:

CF = Coincidence factor (0.87; see Assumptions)[2]

HOU = Hours of use (6,588; see Assumptions)[5]

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (6 years; see Assumptions)[1,2]

Deemed Savings

Deemed Savings by Measure

Delivery	APS Type	MMID	Annual Energy Savings (kWh)	Lifecycle Energy Savings (kWh)	Coincident Peak Demand Reduction (kW)
Pack-Based	Tier 1	3895	61	366	0.0077
Online Store	Tier 1	4917	60	360	0.0076
	Tier 2	4918	103	618	0.0130

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 an Illume study showing 75 kWh of savings and 391.5 kWh of baseline consumption (75 / 391.5 = 19%).[5]

Installation rates for all types of APS are updated based on 2020 participant survey results.[6]

For hours of use, the Illume whitepaper cites a 2014 Nielsen study that reports an average daily television operation time of 5.95 hours.[5] 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 coincidence factor of 17.0% for televisions, which employs a peak period of four hours.[2] 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]

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 Tier 1 and Tier 2 workpapers and added multifamily sector
04	01/2021	Added Online Store measures, updated cost
05	07/2021	Updated ISRs and removed unused retail and pack-based MMIDs
06	07/2023	Updated ISRs for OLM power strips

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[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

[2] Efficiency Vermont. *Technical Reference User Manual (TRM): Measure Savings Algorithms and Cost Assumptions.* pp. 15, 16, and 391. March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf

[3] All packs are assumed to have no baseline, and therefore no baseline cost—the incremental cost is the full cost of the pack to Focus, whether it is a free pack or a discounted Online Store purchase. The cost of the Tier 1 APS to Focus is $22.00, and the cost of the Tier 2 APS is $50.00.

[4] Iaccarino, Joseph, C. Kelly, S. Cofer, and J. Fontaine. "Only as Smart as Its Owner: A Connected Device Study." July 2018. https://cadmusgroup.com/papers-reports/only-as-smart-as-its-owner-a-connected-device-study/

[5] Illume. "Overview of the Tier 1 Advanced PowerStrip: Potential Savings and Programmatic Uses." Whitepaper. pp. 10 and 14. September 15, 2014. http://www.amconservationgroup.com/wp-content/uploads/2014/12/Illume-Advanced-Powerstrip-Case-Study.pdf

[6] Cadmus. *Focus on Energy Calendar Year 2020 Evaluation Report Volume II.* p. 14, 17. May 21, 2021. https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_II.pdf

Room Air Cleaner, ENERGY STAR

	Measure Details
Measure Master ID	Smoke CADR 100 ≤ Smoke CADR < 150 MMID 5401 Smoke CADR 150 ≤ Smoke CADR < 200 MMID 5402 Smoke CADR ≥ 200 MMID 5403 Smoke CADR ≤ 200 5404
Workpaper ID	W0238
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	Vending and Plug Loads
Measure Category	Filtration
Sector(s)	Residential- multifamily, Residential- single family
Annual Electricity Savings (kWh)	Varies by unit size
Peak Demand Reduction (kW)	Varies by unit size
Annual Natural Gas Savings (therms)	0
Lifecycle Electricity Savings (kWh)	Varies by unit size
Lifecycle Natural Gas Savings (therms)	0
Annual Water Savings (gallons)	0
Effective Useful Life (years)	9[1]
Incremental Cost ($/unit)	Varies by unit size. See Assumptions.

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 2.0 requirements. ENERGY STAR-certified units are 25% more efficient that non-qualified models.[2] Energy savings are derived from more efficient operation as well as increased efficiency in "partial on mode" which includes the constant energy consumption necessary for general operation and Wi-Fi connectivity (when applicable).

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 2.0 requirements.[2]

Annual Energy-Savings Algorithm

$$kWh_{SAVED} = UEC_{\text{BASE}} - UEC_{\text{EE}}$$

$$\text{UEC}_{\text{BASE}} = \left[\text{Hours} * \frac{\text{CADR}_{\text{BASE}}}{(\text{CPW}_{\text{BASE}} * 1{,}000)}\right] + \left[(8{,}760 - \text{Hours}) * \frac{\text{PartialPwr}_{\text{BASE}}}{1{,}000}\right]$$

$$\text{UEC}_{\text{EE}} = \left[\text{Hours} * \frac{\text{CADR}_{\text{EE}}}{(\text{CPW}_{\text{EE}} * 1{,}000)}\right] + \left[(8{,}760 - \text{Hours}) * \frac{\text{PartialPwr}_{\text{EE}}}{1{,}000}\right]$$

Where:

Variable	Description	Units	Value
UEC_{BASE}	Annual unit energy consumption of baseline unit	kWh	
UEC_{EE}	Annual unit energy consumption of efficient unit	kWh	
Hours	Annual active operating hours	Hrs	5,840[3]
$\text{CADR}_{\text{BASE}}$	Smoke clean air delivery rate (CADR) in cubic feet per minute for baseline units.	Ft^3/min	Use actual values. If unknown, see Parameter Assumptions for Baseline Units by CADR Range below
CPW_{BASE}	Smoke CADR per watt for baseline units.	CADR/watt	Use actual values. If unknown, see Parameter Assumptions for Baseline Units by CADR Range below
1,000	Conversion factor	W/kW	1,000
8,760	Conversion factor	Hrs/yr	8,760
$\text{PartialPwr}_{\text{BASE}}$	Partial On power consumption for baseline units.		Use actual values. If unknown, see Parameter Assumptions for Baseline Units by CADR Range below
CADR_{EE}	Smoke CADR in cubic feet per minute for efficient units.	Ft^3/min	Use actual values. If unknown, see Parameter Assumptions for Efficient Units by CADR Range below
CPW_{EE}	Smoke CADR per watt for baseline units.	Watts	Use actual values. If unknown, see Parameter Assumptions for Efficient Units by CADR Range below
$\text{PartialPwr}_{\text{EE}}$	Partial On power consumption for efficient units.		Use actual values. If unknown, see Parameter Assumptions for Efficient Units by CADR Range below

Parameter Assumptions for Baseline Units by CADR Range[4]

CADR Range	CADR (CFM)	Smoke CADR per Watt	Partial On Mode Power (Watts)	Annual Energy Use (kWh)
30 ≤ Smoke CADR < 100	83.3	1.64	2.0	302
100 ≤ Smoke CADR < 150	127.6	1.83	2.0	413
150 ≤ Smoke CADR < 200	175.2	1.94	2.0	533
200 ≤ Smoke CADR	292.9	1.89	2.0	911

Parameter Assumptions for Efficient Units by CADR Range[5]

CADR Range	CADR (CFM)	Smoke CADR per Watt	Partial On Mode Power (Watts)	Annual Energy Use (kWh)
30 ≤ Smoke CADR < 100	83.3	2.90	0.478	169
100 ≤ Smoke CADR < 150	127.6	4.08	0.325	184
150 ≤ Smoke CADR < 200	175.2	4.47	0.562	231
200 ≤ Smoke CADR	292.9	5.05	0.638	341

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = (UEC_{\text{BASE}} - UEC_{\text{EE}}) \;/\; Hours \,*\, CF$$

Where:

CF = Coincidence factor (0.67)[5]

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (9 years)[1]

Deemed Savings

Deemed Savings per Unit

Measure	MMID	Peak Savings (kW)	Annual Savings (kWh)	Lifecycle Savings (kWh)
30 ≤ Smoke CADR < 100	5401	0.015	133	1,197
100 ≤ Smoke CADR < 150	5402	0.026	229	2,061
100 ≤ Smoke CADR < 150	5403	0.035	302	2,718
200 ≤ Smoke CADR	5404	0.065	570	5,130

Incremental Cost

Incremental Cost by CADR Range

Measure	MMID	Average Purchase Cost ($)	Average Incremental Cost ($)
30 ≤ Smoke CADR < 100	5401	$82.49	$8.44
100 ≤ Smoke CADR < 150	5402	$140.43	$22.33
150 ≤ Smoke CADR < 200	5403	$349.00	$92.34
200 ≤ Smoke CADR	5404	$264.49	$44.50

Revision History

Version Number	Date	Description of Change
01	06/2016	First draft
02	09/2022	Updating measure to reflect ENERGY STAR v2.0 criteria, reference IL TRM V10.0

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[1] 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. https://eta-publications.lbl.gov/publications/2008-status-report-savings-estimates

[2] *ENERGY STAR Version 2.0 Product Specification for Room Air Cleaners.* Accessed November 4, 2022. ENERGY STAR Version 2.0 Room Air Cleaners Specification (Rev. May 2022)
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*. 2021 Version 10.0 . Accessed November 4, 2022. IL-TRM_Effective_010122_v10.0_Vol_3_Res_09242021.pdf (ilsag.info)
These values are consistent with ENERGY STAR Qualified Room Air Cleaner Calculator assumption of 16 hours per day (16 * 365.25 = 5,840). 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%).

[4] *Illinois Technical Reference Manual*. Version 10. Accessed October 4, 2022.

[5] Cadmus. *2016 Potential Study for Focus on Energy.* Data maintained by Cadmus and Wisconsin PSC. Data includes information from 103 single-family sites and 92 multifamily units.

Soundbar, ENERGY STAR

	Measure Details
Measure Master ID	Soundbar, ENERGY STAR, 4033
Workpaper ID	W0241
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	Vending & Plug Loads
Measure Category	Other
Sector(s)	Residential- upstream
Annual Energy Savings (kWh)	52
Peak Demand Reduction (kW)	0.0033
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	364
Lifecycle 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.[2]

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.[3]

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.[4]

Annual Energy-Savings Algorithm

$$kWh_{\text{SAVED}} = UEC_{\text{BASE}} - UEC_{\text{EE}}$$

Where:

Variable	Description	Units	Value
UEC_{BASE}	Annual unit energy consumption of baseline unit	kWh	77[1]
UEC_{EE}	Annual unit energy consumption of efficient unit	kWh	25[1]

Summer Coincident Peak Savings Algorithm

$$kW_{\text{SAVED}} = kW_{\text{SAVED, ACTIVE}} + kW_{\text{SAVED, IDLE/SLEEP}}$$

$$kW_{\text{SAVED, ACTIVE}} = (UEC_{\text{BASE, ACTIVE}} - UEC_{\text{EE, ACTIVE}}) \,/\, 8{,}760 \,*\, CF_{\text{ACTIVE}}$$

$$kW_{\text{SAVED, IDLE/SLEEP}} = (UEC_{\text{BASE, IDLE/SLEEP}} - UEC_{\text{EE, IDLE/SLEEP}}) \,/\, 8{,}760 \,*\, CF_{\text{IDLE/SLEEP}}$$

Where:

Variable	Description	Units	Value
$UEC_{\text{BASE, ACTIVE}}$	Yearly baseline consumption in active mode	kWh	36.09, which is 4.3 * 8.62 * 2.65 * 365 / 1,000[1]
$UEC_{\text{EE, ACTIVE}}$	Yearly efficient consumption in active mode	kWh	3.62, which is 4.3 * 8.62 * 365 / 1,000[1]
CF_{ACTIVE}	Coincidence factor for the active condition	%	10%[3]
8,760	Hours per year	Hrs/yr	8,760
$UEC_{\text{BASE, IDLE/SLEEP}}$	Yearly baseline consumption in idle and sleep modes	kWh	40.61, which is [2.0 * 8.42 * 2.65 + 17.7 * 1.42 * 2.65] * 365 / 1,000[1]
$UEC_{\text{EE, IDLE/SLEEP}}$	Yearly efficient consumption in idle and sleep modes	kWh	11.23, which is [0.4 * 8.42 + 19.3 * 1.42] * 365 / 1,000[1]
$CF_{\text{IDLE/SLEEP}}$	Coincidence factor for the idle and sleep conditions	%	90%[3]

Lifecycle Energy-Savings Algorithm

$$kWhL_{\text{IFECYCLE}} = kWh_{\text{SAVED}} * EUL$$

Where:

EUL = Effective useful life (7 years)[1]

Revision History

Version Number	Date	Description of Change
01	06/2016	Initial TRM entry

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[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] 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.

[3] The coincidence factor for soundbars in active use is assumed to be 10%, based on engineering judgment. The coincidence factor for idle and sleep modes is therefore 100% - 10% = 90%.

[4] *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

Appendix A: List of Acronyms

Acronym	Definition
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

Acronym	Definition
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)[1]

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. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use in Commercial Applications. 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)[2]

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

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[1] 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

[2] 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

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%[3]
- Multifamily Weighting, 25.3%[4]
- Single Family HOU, 2.27 hours per day[5]
- Multifamily HOU, 2.01 hours per day[6]
- Residential Weighting 93%[7]
- Commercial Weighting 7%[8]
- Residential HOU Average, 2.20
- Commercial HOU Average, 10.2[9]
- Single Family Coincidence Factor 7.5%[10]

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[3] U.S. Census Bureau. Percentage of Wisconsin housing stock that is single family. 2013 Estimates.

[4] U.S. Census Bureau. Percentage of Wisconsin housing stock that is multifamily. 2013 Estimates.

[5] Cadmus. Single family light logger study, 2013.

[6] Cadmus. Multifamily light logger study. 2013.

[7] Cadmus. In-store intercept surveys. 2012.

[8] Ibid.

[9] *Wisconsin Business Deemed Savings*. 2010.

[10] U.S. Census Bureau. Percentage of Wisconsin housing stock that is single family. 2013 Estimates.

- Multifamily Coincidence Factor 5.5%[11]
- Residential, Averaged, Coincidence Factor 6.99%
- Commercial Coincidence Factor 77%[12]

Average annual HOU based on weighting metrics outlined above = 1,011

Coincidence factor based on weighting metrics outline above = 0.1189

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. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Coincidence Factor for Lighting in Commercial Applications. 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[13]

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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[11] U.S. Census Bureau. Percentage of Wisconsin housing stock that is multifamily. 2013 Estimates.

[12] PA Consulting Group Inc. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Lighting in Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

[13] 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)[14]

Low-Flow Showerheads

$GPM_{EXISTING}$ = Baseline flow rate (= 2.5 GPM)[15]

Temperature (Water)

Water Heaters

T_{WH} = Water heater temperature setpoint (= 125°F)[16]

$T_{ENTERING}$ = Temperature of water entering water heater (= 52.3°F)[17]

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[14] Federal minimum at 80 psi.

[15] Federal minimum at 80 psi.

[16] 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.)

[17] 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.

Faucet Aerators (Kitchen)

$T_{\text{POINT OF USE}}$ = Temperature of water at point of use (= 93°F)[18]

Faucet Aerators (Bathroom)

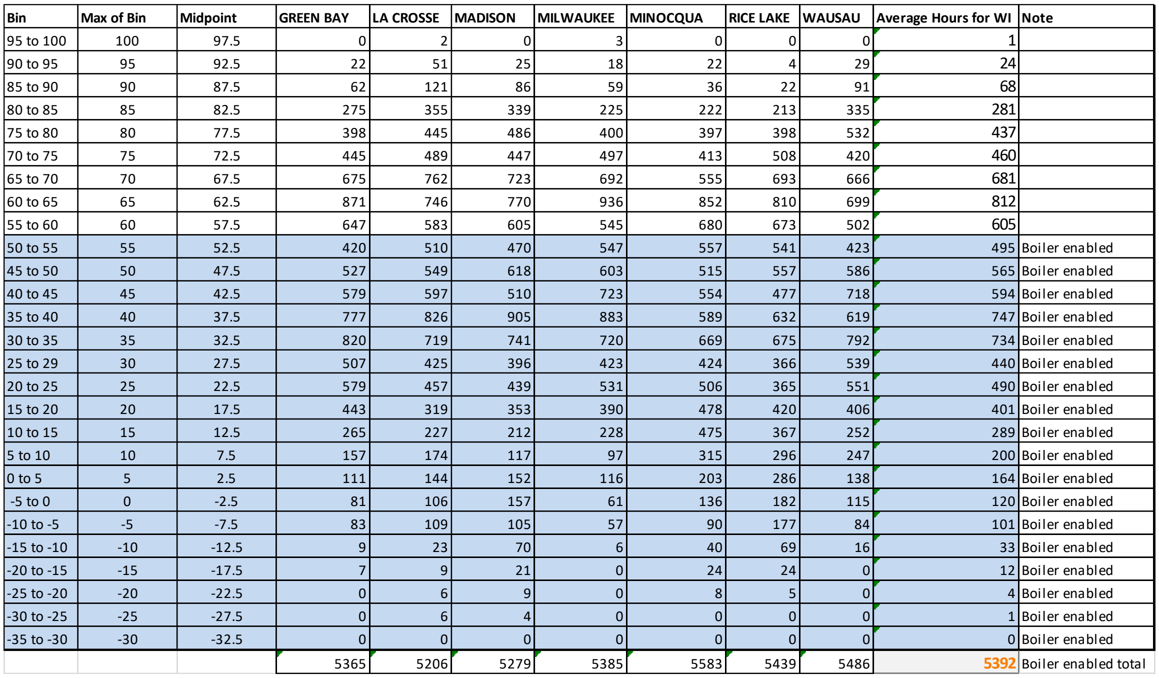
$T_{\text{POINT OF USE}}$ = Temperature of water at point of use (= 86°F)[18]

Low-Flow Showerheads

$T_{\text{POINT OF USE}}$ = Temperature of water at point of use (= 101°F)[18]

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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[18] 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

The workpapers above define savings and EULs for a vast majority of active measures. This appendix defines effective useful life values for measures that are not described in the workpapers above.

MMID	Measure Name	EUL
224	Cycling Air Dryer (See W0021)	15
284	Exhaust Air Heat Recovery System	15
285	Ventilation Filtration vs Make Up Air System	15
296	Chiller Optimization Controls	10
299	Replace Constant Volume HVAC with VAV	15
2220	Boiler, Not Otherwise Specified	25
2228	Building Envelope, Glazing Retrofit	20
2229	Building Envelope, Not Otherwise Specified	25
2230	Building Envelope, Reduce Air Infiltration	20
2232	Building Envelope, Window Replacement	20
2247	Chiller System, Not Otherwise Specified	20
2248	Chiller System, Water Free Cooling Controls and Equipment	10
2260	Compressed Air System Isolation	15
2265	Compressed Air, Not Otherwise Specified	15
2266	Compressed Air, Process Load Reduction (See W0282)	15
2267	Compressor, Duct in Outside Air	10
2275	Delamping, Not Otherwise Specified	12
2279	Destratification	15
2304	Domestic Hot Water, Not Otherwise Specified	13
2319	Fans, High Volume Low Speed (HVLS), Not Otherwise Specified (See W0053	15
2369	Greenhouse Roof Vents	10
2370	Greenhouse Thermal blanket	10
2382	HVAC Controls, Scheduling/Setpoint Optimization	5
2383	HVAC Energy Management System	15
2386	HVAC, Not Otherwise Specified	15
2387	HVAC, Variable Refrigerant Flow/Volume Systems	15
2420	Induction Lighting, Not Otherwise Specified	15
2421	Industrial Oven or Furnace, Not Otherwise Specified	15
2425	Insulation, Boiler Plumbing	15
2426	Insulation, Ceiling	25
2428	Insulation, Roof	25
2431	Insulation, Wall, Not Otherwise Specified	25
2434	Irrigation Pressure Reduction, Nozzle Installation & Motor Downsizing	15
2436	IT Systems, Not Otherwise Specified	5
2438	IT Systems, Server Consolidation	5
2441	IT Systems, Uninterruptible Power Supply	20
2443	Laundry Equipment - Not Otherwise Specified	15
2455	LED, Not Otherwise Specified	15
2461	Lighting Controls, Not Otherwise Specified	8
2462	Lighting Layout Reconfiguration	10
2463	Lighting, Not Otherwise Specified	12
2464	Mechanical Sub-Cooling	10

MMID	Measure Name	EUL
2470	Motor, Not Otherwise Specified	15
2492	Plate Heat Exchanger, Milk Pipeline, VFD On Milk Vacuum Pump, Ag	15
2493	Pool, Not Otherwise Specified	15
2497	Process Heat Recovery, Condensing Heat Exchanger	15
2498	Process Heat Recovery, Not Otherwise Specified	15
2499	Process, Not Otherwise Specified	15
2504	Pumping and Piping System Efficiency Improvement	15
2511	Refrigeration Economizer, Ambient Subcooling	15
2517	Refrigeration, Central Parallel Rack System Replacing Individual Units	10
2518	Refrigeration, Defrost Controls	10
2520	Refrigeration, Not Otherwise Specified	15
2539	Rooftop Unit	15
2589	T8, CEE, Not Otherwise Specified	15
2600	Thermal Curtain, Not Otherwise Specified	5
2609	Unit Heater, Not Otherwise Specified (See W0048)	15
2619	Ventilation Controls, Kitchen Exhaust Hood	10
2645	VFD, Not Otherwise Specified	15
2650	Waste Water Treatment, Not Otherwise Specified	20
2654	Water Heater, >90% TE, Condensing, Residential	15
2659	Water Heater, Not Otherwise Specified	13
2661	Waterer, Livestock, Not Otherwise Specified, Ag (See W0006)	10
2663	Welder, Replace w/ High Efficiency Unit	13
2680	HVAC Controls, Not Otherwise Specified	15
2690	Insulation, Attic (See W0189)	32
2722	Ventilation Controls, Demand Controlled Ventilation	10
2724	Ventilation Controls, Exhaust/Supply For Paint/Spray Booth	10
2727	Aeration, Not Otherwise Specified	20
2773	Windows, Energy Star	20
2853	Ventilation Controls, Demand Control Ventilation For Air Handling Units	10
2919	Domestic Hot Water, Not Otherwise Specified	13
2922	HVAC, Not Otherwise Specified	15
2927	Process, Not Otherwise Specified	NULL
2928	Refrigeration, Not Otherwise Specified	15
2970	Project Savings Verification	0
3383	Retrocommissioning, Audit, Part 1 Incentive	0
3384	Retrocommissioning, Implementation, Part 2 Incentive	6
3622	Water-Related Energy Savings	NULL
3663	Outside Air Intake Optimization	5
3675	Valve Repair, Chilled Water	5
3676	Valve Repair, Hot Water	5
3995	Water Heater, Dual Thermostat, Ag, NG	15
3996	Water Heater, Dual Thermostat, Ag, Electric (<150 milking cows)	15
3997	Water Heater, Dual Thermostat, Ag, Electric (>=150 milking cows)	15
4407	Weekday Heating Schedule Optimization	5
4408	Weekday Cooling Schedule Optimization	5
4409	Weekend Heating Schedule Optimization	5
4410	Weekend Cooling Schedule Optimization	5

MMID	Measure Name	EUL
4420	Certification (Electric) - Level 1-25 to 29.9% Better Than Code	30
4421	Certification (Electric) - Level 2-30 to 34.9% Better Than Code	30
4422	Certification (Electric) - Level 3-35 to 99.9% Better Than Code	30
4423	Certification (Electric) - Level 4-Energy Neutral	30
4424	Certification (Gas) - Level 1-25 to 29.9% Better Than Code	30
4425	Certification (Gas) - Level 2-30 to 34.9% Better Than Code	30
4426	Certification (Gas) - Level 3-35 to 99.9% Better Than Code	30
4427	Certification (Gas) - Level 4-Energy Neutral	30
4678	SEM Operational Savings, Industrial	NULL
4680	SEM Operational Savings, Commercial	NULL
4821	Project Savings Verification, Baseline: 2015 IECC (90.1-2013)	NULL
4841	LED Horticultural Fixture, Replacing or instead of HPS/MS/Fluorescent, Vertical Farming, Agriculture	11
4842	LED Horticultural Fixture, Replacing or instead of HPS/MS/Fluorescent, Non-Stacked Indoor, Agriculture	13
4843	LED Horticultural Fixture, Replacing or instead of HPS/MS/Fluorescent, Supplemented Greenhouse, Agriculture	20
4845	Project Savings Verification, Baseline: 2015 IECC (90.1-2013), We Energies Program	NULL
4851	Greenhouse Climate Controls, Propane	NULL
4877	Water Heater, Dual Thermostat, Ag, Propane	NULL
4882	Propane, Not Otherwise Specified	NULL
5003	EDA - Project Savings Verification	NULL
5004	EDR - Project Savings Verification - Energy Design Review	NULL
5056	EDA - Project Savings Verification, We Energies Program	NULL
5058	EDR - Project Savings Verification - Energy Design Review, We Energies Program	NULL
5107	Certification Level 1, NG or Elec Heat, 25-29.9% SOC	30
5108	Certification Level 2, NG or Elec Heat, 30-34.9% SOC	30
5109	Certification Level 3, NG or Elec Heat, 35-39.9% SOC	30
5110	Certification Level 4, NG or Elec Heat, 40%+ SOC	30
5111	Certification Level 1, Other Heat, 25-29.9% SOC	30
5112	Certification Level 2, Other Heat, 30-34.9% SOC	30
5113	Certification Level 3, Other Heat, 35-39.9% SOC	30
5114	Certification Level 4, Other Heat, 40%+ SOC	30
5119	EDA - Project Savings and Verification	NULL
5121	EDR - Project Savings and Verification	NULL
5123	EDA - Project Savings and Verification, VDAP	NULL
5161	SEM Operational Savings, Higher Ed	NULL
5188	PEP, Multifamily, New Construction	20
5189	Virtual Commissioning	5
5194	Biogas	20
5250	Biogas, Biodigester	0
5251	Biomass	20
5252	Solar Thermal	20
5361	Hot Water System Cutout Optimization, Building Tune-up	4
5362	Chilled Water Reset Controls, Building Tune-up	4
5363	Chiller Schedule Optimization, Building Tune-up	4
5364	Morning Warmup Optimization, Building Tune-up	4

MMID	Measure Name	EUL
5365	Adaptive Optimal Start, Building Tune-up	4
5366	HVAC Fan Static Pressure Reset, Building Tune-up	4
5367	Zone-Based Scheduling, Building Tune-up	4
5368	Triple Duty Valve Optimization, Building Tune-up	4
5381	Air Compressor Replacement or Upgrade, Not Otherwise Specified	13

Appendix D: Incremental Costs

The workpapers above define savings and incremental costs for a vast majority of active measures. This appendix defines incremental cost values for measures that are not described in the workpapers above. These are in the Non-Workpaper Measure Costs table.

In addition, some workpapers above do not define costs for their measures—costs for such measures are defined in this appendix as well. These are in the Workpaper Measure Costs table below.

Non-Workpaper Measure Costs

MMID	Measure Name	Incremental Cost	Source
598	Greenhouse Climate Controls, Hybrid	$0.11	Historical Project Data, 2016. Agriculture, Schools and Government Program; 4 Projects, 01/2016 to 06/2016. Average Cost is $0.11 per square foot.
1989	Water Heater, Electric, EF 0.93 or greater	$25.16	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.
2139	Low-flow Showerhead, 1.5 gpm, Gas	$5.00	$5.00 = WESCO Distribution Pricing ($3.11) + Labor ($1.89)
2145	Low-flow Showerhead, 1.5 gpm, Electric MF	$5.00	$5.00 = WESCO Distribution Pricing ($3.11) + Labor ($1.89)
2211	Boiler Tune-up - service buy down	$0.83	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
2434	Irrigation Pressure Reduction, Nozzle Installation	$6.92	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
2494	Pre-Rinse Sprayer, <=.65 gpm, Electric	$51.74	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.
2495	Pre-Rinse Sprayer, <=.65 gpm, NG	$51.74	
2556	T8 1L-4 ft Reduced Wattage with CEE Ballast - 25 Watts (Low BF)	$2.45	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.
2557	T8 1L-4 ft Reduced Wattage with CEE Ballast - 28 Watts (Low BF)	$2.07	

MMID	Measure Name	Incremental Cost	Source
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	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.
2573	T8 3L-4 ft Reduced Wattage with CEE Ballast - 28 Watts (Low BF)	$6.20	
2574	T8 3L 4', 28W, CEE, BF > 0.78	$6.20	
2579	T8 4L-4 ft Reduced Wattage with CEE Ballast - 28 Watts (Low BF)	$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	$1.50	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
2603	Thermal Curtain, Single Pane Glass Walls and Ceiling, Overhead Heating	$1.50	
2608	Unit Heater, >= 90% thermal efficiency, per input MBh, for retrofit	$18.00	Actual Program Data, 2015-2016. 49 projects with average actual cost of $18.00 per MBh.
2635	Agricultural Exhaust Fan, High Efficiency - 55"	$1,139.00	Similar to measure 2634. Historical Focus on Energy project data, 2012-2013. 12 projects, 289 fans; fan average total cost is $1,139.00.
2637	Agricultural Exhaust Fan, High Efficiency - 60"	$2,010.00	Historical Focus on Energy project data, 2012-2013. 3 projects, 141 fans; fan average total cost is $2,010.00.
2651	Storage Water Heater EF >0.67	$400.00	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
2711	Insulation, Project Based, Attic	$2.69	Illinois Technical Reference Manual. p. 141. 2013. This measure includes air sealing costs. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Versio

MMID	Measure Name	Incremental Cost	Source
			n_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf
2712	Insulation, Sidewall, Foam	$0.94	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.
2713	Insulation, Foundation - Interior	$2.93	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
2714	Insulation, Sill Box	$5.97	
2764	Furnace, with ECM fan motor, for space heating (AFUE >= 95%)	$1,667.84	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
2902	Water Heater, Power Vented, EF = .67-.82, Storage, NG	$400.00	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
3022	Split System A/C	$82.34	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)
3121	Programmable Thermostat, RTU Optimization Standard	$150.00	California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com/
3586	Water Heater, Electric, EF of 0.93 or greater, Claim Only	$25.16	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.
3587	Water Heater, >= 0.67 EF, Storage, NG, Claim Only	$400.00	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
3588	Water Heater, >= 0.82 EF, Tankless, Residential, NG, Claim Only	$605.00	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

MMID	Measure Name	Incremental Cost	Source
3761	A/C Split or Packaged System, High Efficiency, Multifamily	$100.00	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
3767	Circulation Fan, HS/HE, 36"-47", Ag	$150.00	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
3768	Circulation Fan, HS/HE, 48"-52", Ag	$150.00	
3769	Circulation Fan, HS/HE, ≥ 53", Ag	$150.00	
3770	Ventilation Fan, HS/HE, 24"-35", Ag	$150.00	
3771	Ventilation Fan, HS/HE, 36"-47", Ag	$150.00	
3772	Ventilation Fan, HS/HE, 48"-52", Ag	$150.00	
3773	Ventilation Fan, HS/HE, ≥ 53", Ag	$150.00	
3785	Insulation, Tier 2, Project Based, Attic	$2.69	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
3786	Insulation, Tier 2, Project Based, Foundation	$0.94	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.
3787	Insulation, Tier 2, Project Based, Sillbox	$2.93	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
3788	Insulation, Tier 2, Project Based, Wall	$5.97	
3799	T8 2L 4', HPT8, CEE, BF <= 0.78, Agriculture	$15.40	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.
3806	LED Fixture, <155 Watts, Replacing 250 Watt HID, High Bay, Agriculture	$204.99	Online research. March 2016. Average cost of LED round high bay fixtures under 155-watt replacement. https://www.1000bulbs.com/category/round-high-bays/

MMID	Measure Name	Incremental Cost	Source
3807	LED Fixture, <250 Watts, Replacing 400 Watt HID, High Bay, Agriculture	$387.82	
3810	LED Fixture, <250 Watts, Replacing 320-400 Watt HID, High Bay, Agriculture	$387.82	
3831	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 320-400 Watt HID, Exterior, Agriculture	$290.00	2015 Implementer assessment of measure cost.
3834	Lighting Controls, Photocell with Internal Timer or Wireless Schedule, Exterior, Agriculture	$101.56	Actual cost from 2015-16 program data, 7 applications.
3842	Air Sealing, Tier 2, Project Based	$0.00	Implementer findings
3861	LED, 10 Watt, Pack-based	$5.90	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.
3897	LED, Pack-based, 10 Watt, BR30	$7.85	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
3984	Refrigeration System Tune-Up Without Milk Pre-Cooler	$260.86	"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
3985	Refrigeration System Tune-Up With Milk Pre-Cooler	$260.86	
3986	Refrigeration System Tune-Up With Milk Pre-Cooler and VFD Milk Pump	$260.86	
4052	TLED Trial, Replacement of 4' T8 Lamps utilizing existing ballast	$4.10	Cost for particular product for the TLED Trial special offering, per accepted proposal. Price valid through December 31, 2017.

Workpaper Measure Costs

MMID	Measure Name	Incremental Cost	Source
2280	Dishwasher, Low Temp, Door Type, Energy Star, Energy Star, Electric	$662.00	ENERGY STAR. "Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment." Calculator. October 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx
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	ENERGY STAR. "Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment." Calculator. October 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx
2285	Dishwasher, High Temp, Electric Booster, Single Tank Conveyor, Energy Star, Electric	$2,050.00	
2286	Dishwasher, High Temp, Electric Booster, Single Tank Conveyor, Energy Star, NG	$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	

MMID	Measure Name	Incremental Cost	Source
2293	Dishwasher, Low Temp, Door Type, Energy Star, NG	$662.00	
2294	Dishwasher, Low Temp, Multi Tank Conveyor, Energy Star, Electric	$970.00	ENERGY STAR. "Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment." Calculator. October 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx
2295	Dishwasher, Low Temp, Multi Tank Conveyor, Energy Star, NG	$970.00	
2296	Dishwasher, Low Temp, Single Tank Conveyor, Energy Star, Electric	$0.00	
2298	Dishwasher, Low Temp, Under Counter, Energy Star, Electric	$234.00	
2299	Dishwasher, Low Temp, Under Counter, Energy Star, NG	$234.00	
3136	Dishwasher, High Temp, Electric Booster, Pots/Pans Type, Energy Star, Electric	$1,710.00	
3137	Dishwasher, High Temp, Electric Booster, Pots/Pans Type, Energy Star, NG	$1,710.00	
3138	Dishwasher, High Temp, Gas Booster, Pots/Pans Type, Energy Star, NG	$1,710.00	
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	
3139	Dishwasher, Low Temp, Pots/Pans Type, Energy Star, Electric	$1,710.00	
3140	Dishwasher, Low Temp, Pots/Pans Type, Energy Star, NG	$1,710.00	
2471	Occupancy Sensors - Ceiling Mount <= 500 Watts	$120.00	WESCO Distribution Pricing, 2013 ($95.00)+ Labor ($25.00) = $120.00
2472	Occupancy Sensors - Ceiling Mount >= 1001 Watts	$120.00	

MMID	Measure Name	Incremental Cost	Source
2473	Occupancy Sensors - Ceiling Mount 501-1000 Watts	$120.00	
2474	Occupancy Sensors - Fixture Mount <= 200 Watts	$95.00	WESCO Distribution Pricing. 2013. ($70.00) + Labor ($25.00) = $95.00
2475	Occupancy Sensors - Fixture Mount > 200 Watts	$95.00	
2483	Occupancy Sensors - Wall Mount <= 200 Watts	$35.00	WESCO Distribution Pricing, 2013 ($18.75) + Labor ($16.25) = $35.00
2484	Occupancy Sensors - Wall Mount >= 201 Watts	$35.00	
3201	Occupancy Sensor, Wall or Ceiling Mount <=200 Watts, CALP	$77.50	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.
3605	Occupancy Sensor, Fixture Mount, <=200 Watts, CALP	$115.00	Similar to MMID 2474. WESCO Distribution Pricing ($70.00) + Labor ($25.00) = $95.00
3606	Occupancy Sensor, Fixture Mount, >200 Watts, CALP	$115.00	
3619	Occupancy Sensor, Fixture Mount, ≤ 60 Watts, SBP Package	$200.00	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
3621	Occupancy Sensor, Fixture Mount, ≤ 60 Watts, SBP After A La Carte	$200.00	
3122	T8 2L 4', HPT8 or RWT8, Replacing T12 1L 8', 0.78 < BF < 1.00	$4.90	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.
3123	T8 2L 4', HPT8 or RWT8, Replacing T12 1L 8', BF <= 0.78	$4.90	
3124	T8 2L 4', HPT8 or RWT8, Replacing T12HO 1L 8', 0.78 < BF < 1.00	$4.90	
3125	T8 2L-4ft High Performance HBF Replacing T12HO 1L-8 ft	$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	

MMID	Measure Name	Incremental Cost	Source
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	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.
3801	T8 2L 4', HPT8 or RWT8, Replacing T12HO 1L 8', 0.78 < BF < 1.00, Agriculture	$4.90	
3802	T8 2L 4', HPT8 or RWT8, Replacing T12HO 1L 8', BF > 1.00, Agriculture	$4.90	
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	$9.80	
3805	T8 4L 4', HPT8 or RWT8, Replacing T12HO 2L 8', BF > 1.00, Agriculture	$9.80	
3097	LED Fixture, Bilevel, Stairwell and Passageway	$215.15	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 1,939 units over 101 projects, from 2016 to 2018.
3251	Lighting Controls, Bilevel, Exterior and Parking Garage Fixtures, Dusk to Dawn	$81.41	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 800 units over 38 projects, from 2016 to 2018.

MMID	Measure Name	Incremental Cost	Source
3252	Lighting Controls, Bilevel, Parking Garage Fixtures, 24 Hour	$47.54	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 5,321 units over 21 projects, from 2016 to 2018.
2276	DELAMPING, DIRECT INSTALL, 4 FOOT LAMP	$51.75	Actual program cost from 2015-16 program data, where available, 23 applications.
2277	Delamping, T8 to T8	$11.59	
3320	Delamping, T12 to T8, 8', SBP A La Carte	$10.80	Mid-Atlantic TRM Version 6.0. p. 323. http://www.neep.org/mid-atlantic-technical-reference-manual-v6
3099	LED Fixture, Replacing 150-175 Watt HID, Exterior	$257.06	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.
3102	LED Fixture, Replacing 250 Watt HID, Exterior	$340.05	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 608 projects and 3,948 units from April 2018 to September 2019 is $349.67. Base cost of $9.62 from August 2018 online lookups of 6 base models. $349.67 - $9.62 = $340.05.
3107	LED Fixture, Replacing 400 Watt HID, Exterior	$461.62	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.
3108	LED Fixture, Replacing 70-100 Watt HID, Exterior	$214.57	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.
3824	LED Fixture, Replacing 150-175 Watt HID, Exterior, Agriculture	$328.01	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.
3825	LED Fixture, Replacing 250 Watt HID, Exterior, Agriculture	$371.94	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.
3826	LED Fixture, Replacing 320-400 Watt HID, Exterior, Agriculture	$94.27	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 1000bulbs.com search for "320 Watt HID, Exterior = $243.06.

MMID	Measure Name	Incremental Cost	Source
			Incremental Cost is $408-$243.06 =$164.94. Incremental Cost is $337.33 - $243.06 = $94.27
3827	LED Fixture, Replacing 400 Watt HID, Exterior, Agriculture	$404.66	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.
3828	LED Fixture, Replacing 70-100 Watt HID, Exterior, Agriculture	$259.73	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.
3811	T8 4L Replacing 250-399 W HID, Agriculture	$129.00	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.
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	
3084	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 320 Watt HID, Exterior	$340.00	2015 Implementer assessment of measure cost.
3829	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 150-175 Watt HID, Exterior, Agriculture	$284.48	Actual cost from 2015-16 program data, 8 applications.
3830	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 250 Watt HID, Exterior, Agriculture	$244.76	Actual cost from 2015-16 program data, 15 applications.
3832	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 400 Watt HID, Exterior, Agriculture	$316.61	Actual cost form 2015-16 program data, 15 applications.
3833	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 70-100 Watt HID, Exterior, Agriculture	$50.00	2015 Implementer assessment of measure cost.
3815	Induction, PSMH/CMH, Replacing 250 Watt HID, High Bay	$100.00	Actual cost from 2015-16 program data, 1 application.
3816	Induction, PSMH/CMH, <=250 Watt, Replacing	$290.00	2015 Implementer assessment of measure cost.

MMID	Measure Name	Incremental Cost	Source
	320-400 Watt HID, High Bay, Agriculture		
3817	Induction, PSMH/CMH, <=250 Watt, Replacing 400 Watt HID, High Bay, Agriculture	$159.74	Online research. March 2016. and Program Data. 2015. 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.
1988	Water Heater, Indirect	$988.50	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
3585	Water Heater, Indirect, Claim Only	$1,294.00	NEEP Regional Evaluation, Measurement & Verification Forum, A Report on Costs in Six Northeast & Mid-Atlantic Markets. 2011. Navigant Consulting. p. 11. Mid-sized (60 MBh and 48 gals) Residential Indirect Water Heater Incremental Cost Results ($ per unit) Non-Regional Specific.
3784	Water Heater, Indirect, Tier 2	$988.50	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
3148	T8 2L 4', HPT8 or RWT8, Replacing T12HO 1L 8', BF > 1.00, Parking Garage	$9.80	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.
3152	T8 4L 4', HPT8 or RWT8, Replacing T12HO 2L 8', 0.78 < BF < 1.00, Parking Garage	$9.80	
3153	T8 4L 4', HPT8 or RWT8, Replacing T12HO 2L 8', BF <= 0.78, Parking Garage	$9.80	