Focus on Energy Evaluated Deemed Savings Changes

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Deemed Savings Analysis

This report contains measure-specific findings from evaluating the CY 2016 Wisconsin Focus on Energy programs. These findings are the result of individual project-level evaluation activities, such as billing analyses, supporting research, and engineering reviews.

The CY 2016 evaluation activities revealed the following values and practices for key input variables and algorithms (specific details regarding these inputs are described further in this document):

1. Solar Photovoltaics:
   a. DerateFactor: 88.6%
   b. ShadeFactor: 2.7%
2. Residential Ground-Source Heat Pumps:
   a. Btu/h_{COOL}: 56,020 Btu/h
   b. Btu/h_{HEAT}: 45,680 Btu/h
   c. EER_{EE}: 18.51
   d. COP_{EE}: 3.80
3. Steam Trap Repairs:
   a. Derating factor: 5.9%
4. Smart Thermostats:
   a. Algorithm greatly altered based on billing analysis results
5. Boilers:
   a. $AFUE_{EFF}$ (≥90% measures): 95%
   b. $AFUE_{EFF}$ (≥85% measure): 91%
   c. ISR: 95%

The Evaluation Team[1] recommends updating the savings calculations for solar photovoltaics, ground-source heat pumps, steam trap repairs, smart thermostats, and boilers to reflect these assumptions and algorithm changes. This report identifies the affected measures, the *ex ante* savings assumptions for those measures in the SPECTRUM database during CY 2016, and the revised savings values calculated based on those recommended savings updates.

Table 1 lists the current measures affected by the Evaluation Team's recommendations. The Team also recommends using these updated assumptions for any new, similar measures proposed by Program Implementers, as well as for any custom and hybrid projects where these measures are used.

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

Table 1. Measures Requiring an Update

Measure Category	SPECTRUM Name and MMID
Solar Photovoltaics	Solar PV, 2819
Ground-Source Heat Pumps	Ground Source Heat Pump, Electric Back-Up, 2820 Ground Source Heat Pump, Natural Gas Back-Up, 2821
Steam Trap Repair	Steam Trap Repair, <10 psig, Radiator, 2772 Steam Trap Repair, <10 psig, General Heating, 7/32" or Smaller, 4004 Steam Trap Repair, < 10 psig, General Heating, 1/4", 4005 Steam Trap Repair, < 10 psig, General Heating, 5/16", 4006 Steam Trap Repair, < 10 psig, General Heating, 3/8" or Larger, 4007 Steam Trap Repair, 10-49 psig, General Heating, 7/32" or Smaller, 4008 Steam Trap Repair, 10-49 psig, General Heating, 1/4", 4009 Steam Trap Repair, 10-49 psig, General Heating, 5/16", 4010 Steam Trap Repair, 10-49 psig, General Heating, 3/8" or Larger, 4011 Steam Trap Repair, 50-124 psig, General Heating, 7/32" or Smaller, 4012 Steam Trap Repair, 50-124 psig, General Heating, 1/4", 4013 Steam Trap Repair, 50-124 psig, General Heating, 5/16", 4014 Steam Trap Repair, 50-124 psig, General Heating, 3/8" or Larger, 4015 Steam Trap Repair, 125-225 psig, General Heating, 7/32" or Smaller, 4016 Steam Trap Repair, 125-225 psig, General Heating, 1/4", 4017 Steam Trap Repair, 125-225 psig, General Heating, 5/16", 4018 Steam Trap Repair, 125-225 psig, General Heating, 3/8" or Larger, 4019 Steam Trap Repair, >225 psig, General Heating, 7/32" or Smaller, 4020 Steam Trap Repair, >225 psig, General Heating, 1/4", 4021 Steam Trap Repair, >225 psig, General Heating, 5/16", 4022 Steam Trap Repair, >225 psig, General Heating, 3/8" or Larger, 4023
Smart Thermostats	Smart Thermostat, Existing Natural Gas Boiler, 3609 Smart Thermostat, Existing Natural Gas Furnace, 3610 Smart Thermostat, Existing Air-Source Heat Pump, 3611
Boilers	Boiler, Hot Water, Modulating, ≥90% AFUE, <300 MBh, 2218 Boiler, Hot Water, Modulating, ≥90% AFUE, ≤ 300 MBh, 2743 Boiler, Hot Water, Near Condensing, ≥85% AFUE, ≥300 MBh, 3277 Boiler, Condensing, ≥90% AFUE, ≥300 MBh, 3276

Throughout the CY 2016 evaluation, the Team also determined (through workpaper review and other nonevaluation activities) other measures with variables and algorithms in need of revision. Because these issues were not discovered through the CY 2016 evaluation itself, they are included in *Appendix A: Nonevaluation Findings*.

During CY 2016 and CY 2017, Cadmus authored the *Focus on Energy 2016 Energy Efficiency Potential Study*.[2] Among other activities for this study, Cadmus collected data from hundreds of residential and nonresidential sites, and used these data to inform inputs for several measures. These findings are discussed in *Appendix B: Potential Study Findings*.

CY 2016 Deemed and Evaluated Savings Values

The CY 2016 deemed savings values (or adjusted gross savings values per unit) and the evaluated savings values are listed in Table 2.

Table 2. Deemed and Evaluated Savings Values

Measure Category	SPECTRUM Name and MMID	Deemed	Evaluated	Units
Solar Photovoltaics	Solar PV, 2819	1,121	1,321	kWh per year
		0.45	0.46	kW
		0	0	Therms per year
Ground-Source Heat Pumps	Residential - single family: Ground Source Heat Pump, Electric Back-Up, 2820; Ground Source Heat Pump, Natural Gas Back-Up, 2821	3,999	5,102	kWh per year
		0.9286	1.0331	kW
		0	0	Therms per year
Steam Trap Repair	Steam Trap Repair, < 10 psig, Radiator, 2772	0	0	kWh per year
		0	0	kW
		107	113	Therms per year
	Steam Trap Repair, < 10 psig, General Heating, 7/32" or Smaller, 4004	0	0	kWh per year
		0	0	kW
		82	86	Therms per year
	Steam Trap Repair, < 10 psig, General Heating, 1/4", 4005	0	0	kWh per year
		0	0	kW
		107	113	Therms per year
	Steam Trap Repair, < 10 psig, General Heating, 5/16", 4006	0	0	kWh per year
		0	0	kW
		167	176	Therms per year
	Steam Trap Repair, < 10 psig, General Heating, 3/8" or Larger, 4007	0	0	kWh per year
		0	0	kW
		241	253	Therms per year
	Steam Trap Repair, 10-49 psig, General Heating, 7/32" or Smaller, 4008	0	0	kWh per year
		0	0	kW
		12.6	4.4	Therms per year, per psia

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[2] Cadmus. *Focus on Energy 2016 Energy Efficiency Potential Study*. June 30, 2017. Available online: https://focusonenergy.com/sites/default/files/WI%20Focus%20on%20Energy%20Potential%20Study%20Final%20Report-30JUNE2017.pdf

Measure Category	SPECTRUM Name and MMID	Deemed	Evaluated	Units
	Steam Trap Repair, 10-49 psig, General Heating, 1/4", 4009	0	0	kWh per year
		0	0	kW
		16.5	5.7	Therms per year, per psia
	Steam Trap Repair, 10-49 psig, General Heating, 5/16", 4010	0	0	kWh per year
		0	0	kW
		25.7	8.9	Therms per year, per psia
	Steam Trap Repair, 10-49 psig, General Heating, 3/8" or Larger, 4011	0	0	kWh per year
		0	0	kW
		37.1	12.9	Therms per year, per psia
	Steam Trap Repair, 50-124 psig, General Heating, 7/32" or Smaller, 4012	0	0	kWh per year
		0	0	kW
		12.1	4.2	Therms per year, per psia
	Steam Trap Repair, 50-124 psig, General Heating, 1/4", 4013	0	0	kWh per year
		0	0	kW
		15.7	5.5	Therms per year, per psia
	Steam Trap Repair, 50-124 psig, General Heating, 5/16", 4014	0	0	kWh per year
		0	0	kW
		24.6	8.5	Therms per year, per psia
	Steam Trap Repair, 50-124 psig, General Heating, 3/8" or Larger, 4015	0	0	kWh per year
		0	0	kW
		35.4	12.3	Therms per year, per psia
	Steam Trap Repair, 125-225 psig, General Heating, 7/32" or Smaller, 4016	0	0	kWh per year
		0	0	kW
		11.5	4.0	Therms per year, per psia
	Steam Trap Repair, 125-225 psig, General Heating, 1/4", 4017	0	0	kWh per year
		0	0	kW
		15	5.2	Therms per year, per psia
	Steam Trap Repair, 125-225 psig, General Heating, 5/16", 4018	0	0	kWh per year
		0	0	kW
		23.5	8.1	Therms per year, per psia
	Steam Trap Repair, 125-225 psig, General Heating, 3/8" or Larger, 4019	0	0	kWh per year
		0	0	kW
		33.8	11.7	Therms per year, per psia
	Steam Trap Repair, >225 psig, General Heating, 7/32" or Smaller, 4020	0	0	kWh per year
		0	0	kW
		11.2	3.9	Therms per year, per psia
	Steam Trap Repair, >225 psig, General Heating, 1/4", 4021	0	0	kWh per year
		0	0	kW
		14.7	5.1	Therms per year, per psia
	Steam Trap Repair, >225 psig, General Heating, 5/16", 4022	0	0	kWh per year
		0	0	kW
		22.9	8.0	Therms per year, per psia

Measure Category	SPECTRUM Name and MMID	Deemed	Evaluated	Units
	Steam Trap Repair, >225 psig, General Heating, 3/8" or Larger, 4023	0	0	kWh per year
		0	0	kW
		33.0	11.5	Therms per year, per psia
Smart Thermostats	Smart Thermostat, Existing Natural Gas Boiler, 3609	0	325	kWh per year
		0	0	kW
		136	53	Therms per year
	Smart Thermostat, Existing Natural Gas Furnace, 3610	76	439	kWh per year
		0.1270	0	kW
		92	30	Therms per year
	Smart Thermostat, Existing Air Source Heat Pump, 3611	430	466	kWh per year
		0.1750	0	kW
		0	0	Therms per year
Boilers	Boiler, Hot Water, Modulating, ≥90% AFUE, <300 MBh, 2218	0	0	kWh per year
		0	0	kW
		4.22	6.50	Therms per year, per MBh
	Boiler, Hot Water, Modulating, ≥90% AFUE, ≤300 MBh, 2743	0	0	kWh per year
		0	0	kW
		3.39	5.22	Therms per year, per MBh
	Boiler, Condensing, ≥90% AFUE, ≥300 MBh, 3276	0	0	kWh per year
		0	0	kW
		2.33	3.42	Therms per year, per MBh
	Boiler, Hot Water, Near Condensing, ≥85% AFUE, ≥300 MBh, 3277	0	0	kWh per year
		0	0	kW
		1.03	1.77	Therms per year, per MBh

Evaluation Savings Analysis

The algorithms presented in this section show how the Team applied evaluation results to generate deemed savings values for specific measures.

Solar Photovoltaics

For solar photovoltaic measures, the Evaluation Team suggests lowering the shade factor from 10% to 2%, and increasing the derating factor—which accounts for the amount of power maintained in the conversion from DC to AC—from 80% to 89%.

Shade Factor

Based on desktop reviews and site visits, the actual shading of installed PV systems under the Renewable Rewards Program is lower than expected. The Evaluation Team found an actual average shading loss of 2.7%, compared with the 10% loss assumed in the Spring 2016 Wisconsin TRM.

Derating Factor

During the impact evaluation, the Team reviewed the energy yield estimates for Renewable Rewards projects and found that they generally follow the approach stipulated in the Focus TRM. In the Focus TRM, the calculation method specifies an assumed derate factor of 20%, based on the version of PVWATTS[3] at the time. Since that version of the TRM, the National Renewable Energy Laboratory has released a new version of PVWATTS, with significantly updated assumptions for system losses that are more closely aligned with empirical studies. The updated DC/AC conversion loss factor is 11.4% (derate factor of 88.6%), without accounting for shading, which indicates that a system modeled in the new version of PVWATTS will have an estimated yield much higher (and more accurate) than the same system modeled under the previous version.

Annual Energy-Savings Algorithm

The energy savings for residential PV systems can be calculated using PVWATTS, a tool that uses typical meteorological year (TMY2) 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. Table 3 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 photovoltaic systems installed in Wisconsin.

System Derate Factor = DerateFactor * (1 - ShadeFactor) * (1 - SnowFactor)

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[3] PVWATTS is a free, publicly available tool, produced by the National Renewable Energy Laboratory, used to predict the annual energy yield of solar photovoltaic systems.

Where:

DerateFactor = Amount of power maintained in DC to AC conversion (= 88.6%)

ShadeFactor = Percentage of time system is shaded (= 2.7%)

SnowFactor = Percentage of time system in covered in snow (= 2% for 34° tilt)[4]

Table 3. Installed Solar Photovoltaic Capacity by City

Reference City	Reference ZIP Code	AC kWh/kWDC Installed Capacity
Milwaukee	53220	1,356
Madison	53706	1,319
Green Bay	54302	1,287
Average		**1,321**

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = Peak Period kWh Product / Peak Period Hours

Table 4 shows peak hours and kW by city.

Table 4. Peak Hours by City

Reference City	Reference ZIP Code	Peak Hours AC kWh (June, July, August)	kW
Milwaukee	53220	87	0.46
Madison	53706	92	0.47
Green Bay	54302	85	0.45
Average		**88**	**0.46**

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (= 25 years)[5]

Evaluated Savings

Table 5 shows the annual and lifecycle savings and peak demand reduction for the solar photovoltaic measure.

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[4] Tetra Tech. *State of Wisconsin Public Service Commission Focus on Energy Evaluation: Standard Calculation Recommendations for Renewable Energy Systems*. January 18, 2011. Available online: https://focusonenergy.com/sites/default/files/standardcalculationrecommendationsCY10_evaluationreport.pdf

[5] National Renewable Energy Laboratory. System Useful Life. Available online: http://www.nrel.gov/analysis/tech_footprint.html

Table 5. Solar Photovoltaics Evaluated Savings

Measure	MMID	Annual Energy Savings (kWh)	Lifecycle Energy Savings (kWh)	Coincident Peak Demand Reduction (kW)
Solar PV	2819	1,321	33,950	0.46

Residential Ground-Source Heat Pumps

In CY 2016, the Evaluation Team found that the average size of ground-source heat pumps was larger than the size deemed in the fall 2015 Wisconsin TRM.

Ground-Source Heat Pump Capacity

The Evaluation Team reviewed documentation for 10 ground-source heat pump projects (MMIDs 2820 and 2821). The Team found an average heating capacity of 45,680 Btu/h and an average cooling capacity of 56,020 Btu/h, which are higher than the deemed values of 30,579 Btu/h and 40,089 Btu/h, respectively.

The Team also found an average efficient EER of 18.51 and an average efficient coefficient of performance (COP) of 3.80, which are lower than the respective deemed values of 22.43 and 4.18. The Team therefore recommends changing the deemed values to the average values observed in the project reviews. These changes only apply to residential single-family instances of these measures, and not to commercial or multifamily instances.

Annual Energy-Savings Algorithm

$$kWh_{SAVED} = (EFLH_{COOL} * Btu/h_{COOL} * (1 / SEER_{BASE} – 1 / (EER_{EE} * 1.02))) / 1,000 + (EFLH_{HEAT} * Btu/h_{HEAT} * (1 / HSPF_{BASE} – 1 / (COP_{EE} * 3.412))) / 1,000$$

Where:

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 410)[6]

Btu/h_{COOL} = Cooling capacity of equipment (= 56,020 Btu/h)[8]

$SEER_{BASE}$ = Seasonal energy efficiency ratio of baseline equipment (= 13)[7]

EER_{EE} = Energy efficiency ratio of efficient equipment (= 18.51 kBtu/kWh)[8]

1.02 = Conversion from EER to SEER

1,000 = Kilowatt conversion factor

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[6] Several Cadmus metering studies reveal that the ENERGY STAR calculator equivalent full-load hours are over-estimated by 30% for heat pump cooling, and by 25% for heat pump heating. The heating and cooling equivalent full-load hours values used were adjusted by population-weighted cooling degree day and heating degree day TMY3 values.

[7] *International Energy Conservation Code*. Table 503.2.3(1). 2009.

[8] This is based on Cadmus' CY 2016 review of 10 residential projects for MMIDs 2820 and 2821.

$EFLH_{HEAT}$ = Equivalent full-load heating hours (= 1,890)[6]

Btu/h_{HEAT} = Heating capacity of equipment (= 45,680 Btu/h)[8]

$HSPF_{BASE}$ = Heating seasonal performance factor of baseline equipment (= 7.7 kBtu/kWh)[7]

COP_{EE} = Coefficient of performance of efficient equipment (= 3.80)[8]

3.412 = Conversion from watts to Btu

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Btu/h_{COOL} * (1 / EER_{BASE} – 1 / EER_{EE})) / 1,000 * CF$

Where:

EER_{BASE} = Energy efficiency ratio of baseline equipment (= 11)[7]

CF = Coincidence factor (= 0.5)[9]

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (= 18 years)[10]

Evaluated Savings

Table 6 shows the annual and lifecycle savings and peak demand reduction for ground-source heat pump measures.

Table 6. Ground-Source Heat Pump Evaluated Savings

Measure	Annual Energy Savings (kWh/yr)	Demand Reduction (kW)	Lifecycle Energy Savings (kWh)
Residential- single family: Ground Source Heat Pump, Electric Back-Up, 2820; Ground Source Heat Pump, Natural Gas Back-Up, 2821	5,102	1.0331	91,837

Steam Trap Repairs

In CY 2016, the Evaluation Team examined steam trap repair measures in some detail, scrutinizing the savings methodologies for accuracy and updating them. In addition, the Team conducted a billing

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[9] Ground-source heat pumps are more likely to be installed in the northern part of the state due to the lack of available natural gas. A lower coincidence factor than residential (0.68) and nonresidential (0.80) air conditioning is used to account for the reduced occurrence of operation.

[10] Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual.* 2012. Available online: http://www.ilsag.info/technical-reference-manual.html

analysis and compared the results to calculated results using the updated methodologies. The Team updated the derating factors for steam trap repair measures—to 5.6% for measures <10 psig and 17% for those ≥10 psig—so that calculated savings matched billing analysis savings. These derating factors represent the average values in each pressure bin that produce savings that match the billing analysis, assuming the same distribution of system pressures across projects as in previous years.

The disparate values of these two derating factors results in a large step change in therm savings at 10 psig, a pressure value close to that identified in many Focus on Energy projects, which may cause substantially different savings values for similar projects. Therefore, the Evaluation Team recommends instead using a single derating factor of 5.9% for all residential steam trap measures, both <10 psig and ≥10 psig. Assuming that the distribution of system pressures is the same for future evaluation years as it was in CY 2016, applying this value across all steam trap repair measures will produce calculated savings that match the CY 2016 billing analysis results.

Note that this derating factor is quite close to the old value of 5.6% used for steam trap repair measures <10 psig, because a large majority of submitted projects were <10 psig, so this pressure range disproportionately affected that weighted average.

Energy-Savings Algorithm, Low-Pressure Steam Traps for Heating Systems

$$\text{Therm}_{\text{SAVED}} = 1.9 * K * 60 * (\pi * D^2/4) * \sqrt{}([P_{ABS} – \{P_1 – P_2\}] * [P_1 – P_2]) * h_{FG} * HOU * DF / (100{,}000 * eff)$$

Where:

1.9 = Constant based on units and fluid flow equation[11]

K = Discharge coefficient (= 0.55)[12]

60 = Conversion from minutes to hours

D = Steam trap orifice diameter (= 7/32 inches, 1/4 inches, 5/16 inches, or 3/8 inches)

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[11] Hornaday, William T. “Steam: Its Generation and Use.” Equation 50. Merchant Books, 2007. Available online: http://www.gutenberg.org/files/22657/22657-h/chapters/flow.html#page_321. This formula applies to subsonic flow, which occurs when steam flows through an orifice where P2 ≥ 58% of P1.

[12] Manczyk Energy Consulting. “Estimating the Cost of Steam Loss Through the Orifice of a Steam Trap.” Available online: http://invenoinc.com/wp-content/uploads/2017/05/Estimating-the-Steam-Loss-through-a-Orifice-of-a-Steam-Trap.pdf. The Evaluation Team determined the discharge coefficient by converging flow rates with the Napier equation at P2 = 0.58 * P1. The Napier equation is used to determine flow rate through an orifice when P2 ≤ 0.58 * P1. 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 P2 = 0.58 * P1, produces this equality: $1.9 * (\pi/4 * D2) * K * \sqrt{}([P1 – 0.42 * P1] * 0.42 * P1) * 60 = 24.24 * P1 * D2$. Note that 60 is inserted to convert lb/min to lb/hr, and that P1 and P2 are treated as absolute pressures. Solving this produces K = 0.55.

P_{ABS} = System absolute pressure in pounds per square inch (= 20.7 psia; steam gage pressure at trap inlet (6 psig) + atmospheric pressure at sea level in pounds per square inch (14.7 psi))[13]

P_1 = Steam pressure at trap inlet (= 6 psig)[13]

P_2 = Steam pressure at trap outlet, condensate tank pressure (= 0 psig)

h_{FG} = Latent heat of steam at P_{ABS} (= 959 Btu/lb)[14]

HOU = Annual hours of operation the boiler is on and the system is at design pressure (= 5,510)[15]

DF = Derating factor to account for the average percentage of time the trap fails in the open position and actual versus theoretical energy loss (= 5.9%)[13]

100,000 = Conversion factor from Btu to therms

eff = Boiler efficiency (= 80%)

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[13] Cadmus. “Focus on Energy Steam Trap Study.” 2016. Unpublished.
In the study, Cadmus determined realized savings from billing data for 35 sites that had applied for steam trap incentives during CY 2012 to CY 2014. 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 64% (using algorithms in this workpaper with site-specific values and the previous derating factor of 50%), suggesting that a derating factor of 32% would be more appropriate. The 50% derating factor came from: Enbridge Steam Saver Program. 2005.

[14] The Engineering Toolbox. “Properties of Saturated Steam - Imperial Units.” Available online: http://www.engineeringtoolbox.com/saturated-steam-properties-d_273.html

[15] Appendix B, and 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. Available online: https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
Since the hours of use are dependent on trap type, the Team calculated a weighted average HOU 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.

Lifecycle Energy-Savings Algorithm, Low-Pressure Steam Traps for Heating Systems

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

Where:

EUL = Effective useful life (= 6 years)[16]

Evaluated Savings, Low-Pressure Steam Traps for Heating Systems

Table 7 shows the annual and lifetime savings for low-pressure steam trap measures.

Table 7. Evaluated Savings for Low-Pressure Steam Trap Repair Measures

Measure Name	MMID	Energy Savings (therms)	
		Annual	Lifetime
Steam Trap Repair, <10 psig, General Heating, 7/32 inches or Smaller	4004	86	517
Steam Trap Repair, <10 psig, General Heating, 1/4 inches	4005	113	676
Steam Trap Repair, <10 psig, General Heating, 5/16 inches	4006	176	1,056
Steam Trap Repair, <10 psig, General Heating, 3/8 inches or Larger	4007	253	1,521

Energy-Savings Algorithm, High-Pressure Steam Traps for Heating Systems

The Team determined the steam leakage rate following the Napier equation.[17]

$Therm_{SAVED} = 24.24 * P_{ABS} * D^2 * h_{FG} * HOU * DF / (100,000 * eff)$

Where:

24.24 = Constant from Napier equation when units for absolute system pressure are in psia and units of diameter are in inches

P_{ABS} = System absolute pressure at steam trap inlet in pounds per square inch (= steam gauge pressure at trap inlet + atmospheric pressure at sea level in pounds per square inch (= psig + 14.7); to be input by Program Implementers)

D = Steam trap orifice diameter (= 7/32 inches, 1/4 inches, 5/16 inches, or 3/8 inches)

h_{FG} = Latent heat of vaporization for water at P_{ABS} (= varies by measure; see Table 8)

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[16] 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. Available online: https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

[17] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. "Steam Pressure Reduction: Opportunities and Issues." November 2005. Available online: https://energy.gov/eere/amo/downloads/steam-pressure-reduction-opportunities-and-issues

HOU = Annual hours of operation when the boiler is on and the system is at design pressure (= 5,510)[15]

DF = Derating factor to account for the average percentage of time a trap fails in the open position, and to account for actual versus theoretical energy loss (= 5.9%)[13]

100,000 = Conversion factor from Btu to therms

eff = Boiler efficiency (= 80%)

The amount of therms saved varies based on system pressure (the system absolute pressure at trap inlet is to be recorded by implementers) and orifice diameter.

The latent heat of vaporization value (h_{FG}) corresponds to the assumed system absolute pressures (P_{ABS}), as shown in Table 8. The Evaluation Team determined the latent heat of vaporization values for each measure's pressure range using assumed mid-range pressures. The Program Implementers are to input the absolute system pressure at trap inlet when calculating savings.

The following is a simplified algorithm to calculate annual savings:

$Therm_{SAVED}$ = System Absolute Pressure * Annual Savings Multiplier

= [System Gauge Pressure + 14.7] * Annual Savings Multiplier

Lifecycle Energy-Savings Algorithm, High-Pressure Steam Traps for Heating Systems

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

Where:

EUL = Effective useful life (= 6 years)[16]

Evaluated Savings, High-Pressure Steam Traps for Heating Systems

Table 8 shows the annual and lifecycle savings for high-pressure steam trap repair measures. It also shows the pressure assumed for each value of h_{FG}, and the resulting value of h_{FG}, within each pressure bin.

Table 8. Evaluated Savings for High-Pressure Steam Trap Repair Measures

Measure Name	MMID	Assumed P_{ABS} for h_{FG}[3]	Deemed h_{FG} Latent Heat of Steam (Btu/lb)[5]	Annual Savings Multiplier (therms/psia)	Lifetime Savings Multiplier (therms/psia)
Steam Trap Repair, 10-49 psig, General Heating					
7/32" or Smaller	4008	44.7	929	4.4	26.3
1/4"	4009	44.7	929	5.7	34.3
5/16"	4010	44.7	929	8.9	53.6
3/8" or Larger	4011	44.7	929	12.9	77.2
Steam Trap Repair, 50-124 psig, General Heating					
7/32" or Smaller	4012	102.2	887.5	4.2	25.1
1/4"	4013	102.2	887.5	5.5	32.8
5/16"	4014	102.2	887.5	8.5	51.2
3/8" or Larger	4015	102.2	887.5	12.3	73.8
Steam Trap Repair, 125-225 psig, General Heating					
7/32" or Smaller	4016	190.2	846.8	4.0	23.9
1/4"	4017	190.2	846.8	5.2	31.3
5/16"	4018	190.2	846.8	8.1	48.9
3/8" or Larger	4019	190.2	846.8	11.7	70.4
Steam Trap Repair, > 225 psig, General Heating					
7/32" or Smaller	4020	240.7	827.8	3.9	23.4
1/4"	4021	240.7	827.8	5.1	30.6
5/16"	4022	240.7	827.8	8.0	47.8
3/8" or Larger	4023	240.7	827.8	11.5	68.8

Smart Thermostats

For the CY 2016 Focus on Energy evaluation, the Team conducted a billing analysis to examine savings for 2,427 natural gas and 2,110 electric participants who installed smart thermostats as part of MMIDs 3609, 3610, and 3611. The Team filtered weather-sensitive electric and natural gas consumption from total electric and natural gas usage, and determined smart thermostat savings as a percentage of this consumption.

The Evaluation Team found that baseline natural gas consumption for participant houses with natural gas furnaces was 653 therms, and that the savings fraction from installing a smart thermostat was 4.6% (30 therms). For participant houses with natural gas boilers, this consumption was 1,050 therms with a savings fraction of 5.0%. Precision for all these values was ≤9%.

The Team also found that baseline electric consumption for participant houses with natural gas furnaces was 2,392 kWh. This consisted of 1,584 kWh in the cooling season and 808 kWh in the heating season. Heating season consumption may be from furnace motors and participant sites with electric space heating. The Team found savings factors of 20.5% for cooling season consumption and 14.2% for heating season consumption, with an overall electric savings factor of 18.4%. Precision for heating and cooling consumption and cooling savings are ≤8%. Precision for heating savings is 24%.

Electric data for boilers is limited, since the Evaluation Team only had billing analysis electric data for three sites. However, while the results are imprecise due to the small sample (at 55% to 75% precision), these sites did display cooling consumption and savings. Therefore, the Team applied the cooling consumption and savings for participants with furnaces to the smart thermostat with boiler measure.

The Evaluation Team examined data for 18 sites with air-source heat pumps (ASHPs). Consumption and savings values for these sites were generally imprecise, with precision ranging from 34% to 352%. Therefore, the Team used the cooling consumption and savings values for furnaces, as these values generally reflect sites with air conditioners. Previously, the ASHP consumption value was 2,902 kWh, based on the heat pump providing all heat during winter. However, the billing analysis revealed an ASHP heating consumption of value of 962 kWh. This value is also imprecise, with a precision of 60%, but it still indicates that ASHPs are not generally providing all a participant's home winter heating needs. Therefore, the Evaluation Team used 962 kWh for the baseline ASHP heating consumption. The Team then obtained the ASHP heating savings percentage from a different study.[18]

All the above values reflect the average of three participants, and represent an average split of system AFUE and SEER values, and of houses with and without air conditioning, space heating, manual and programmable thermostats, and other variables.

Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}} = \text{CONS}_{\text{THERM}} * \text{ESF}_{\text{THERM}}$

$\text{kWh}_{\text{SAVED}} = \text{CONS}_{\text{KWh,COOL}} * \text{ESF}_{\text{KWh,COOL}} + \text{CONS}_{\text{KWh,HEAT}} * \text{ESF}_{\text{KWh,HEAT}}$

Where:

$\text{CONS}_{\text{THERM}}$ = Annual therms consumed by smart thermostat participants before smart thermostat installation (= 653 therms for furnace; = 1,050 therms for boiler; = 0 therms for ASHP)

$\text{ESF}_{\text{THERM}}$ = Therm energy savings fraction (= 4.6% for furnace; = 5.0% for boiler)

$\text{CONS}_{\text{KWh,COOL}}$ = Annual cooling kWh consumed by smart thermostat participants before smart thermostat installation (= 1,584 kWh for furnace and boiler; = 1,712 kWh for ASHP)

$\text{ESF}_{\text{KWh,COOL}}$ = kWh energy savings fraction for cooling (= 20.5% for furnace, boiler, and ASHP)

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[18] Apex Analytics. *Nest Thermostat Heat Pump Control Pilot Evaluation*. Prepared for Energy Trust of Oregon. October 10, 2014. Available online: https://nest.com/downloads/press/documents/energy-trust-of-oregon-pilot-evaluation-whitepaper.pdf

$CONS_{KWh,HEAT}$ = Annual heating kWh consumed by smart thermostat participants before smart thermostat installation (= 808 kWh for furnace; = 0 kWh for boiler; = 962 kWh for ASHP)

$ESF_{KWh,HEAT}$ = kWh energy savings fraction for heating (= 14.2% for furnace; = 0% for boiler; = 12% for ASHP)[18]

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure. It is assumed that only a small minority of participants have regular behavioral patterns that would produce demand reduction. These patterns entail not being at home during the peak period and not already setting the temperature back during that time.

Lifecycle Energy-Savings Algorithm

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

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

Where:

EUL = Effective useful life (= 10 years)[19]

Evaluated Savings

Table 9 shows evaluated annual savings, lifecycle savings, and demand reduction for smart thermostat measures.

Table 9. Annual and Lifecycle Savings for Smart Thermostat Measures

Measure	MMID	Peak kW	Annual kWh	Lifecycle kWh	Annual therms	Lifecycle therms
Smart Thermostat, Home Heated by Natural Gas Boiler	3609	0	325	3,250	53	530
Smart Thermostat, Home Heated by Natural Gas Furnace	3610	0	439	4,390	30	300
Smart Thermostat, Home Heated by Air Source Heat Pump	3611	0	466	4,660	0	0

Boilers

The Evaluation Team reviewed 30 boiler upgrade measure projects, and found that for many projects, these measures had actual efficiencies that were higher than their deemed efficiencies. The Team also found that the installation rate was less than 100% for these measures.

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[19] GDS Associates. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures. Available online:http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf. Table 1, HVAC Controls. 2007. Used programmable thermostat EUL as the closest proxy for smart thermostats.

Boiler Efficiencies

The three boiler measures with AFUE ≥90% (MMIDs 2218, 2743, and 3276) all have a deemed AFUE of 90%. However, the Evaluation Team reviewed 28 projects for these measures and found an average installed AFUE of 94.6%, with a standard deviation of 1.6% absolute. Therefore, the Evaluation Team recommends a deemed AFUE of 95% for these ≥90% AFUE boiler measures.

The Evaluation Team reviewed two projects for MMID 3277 (Boiler, Hot Water, Near Condensing, ≥85% AFUE, ≥300 MBh). These projects had actual boiler AFUEs of 97% and 85%, with an average AFUE of 91%. Therefore, the Team recommends a deemed AFUE of 91% for this measure.

Installation Rate

The Evaluation Team reviewed 26 projects for MMID 3276 (Boiler, Hot Water, Condensing, ≥90% AFUE, ≥300 MBh). These 26 projects totaled 75 units, with up to five boilers per project. However, four of these boilers were serving domestic hot water and not space heat applications. The measure requires that incentivized boilers be used for space heating. Therefore, the Team recommends a 95% installation rate for this measure ((75 - 4) / 75).

Annual Energy-Savings Algorithm

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

Where:

BC = Boiler rated capacity (MBtu/h)

OF = Oversizing factor (= varies by measure; see Table 10)

Table 10. Boiler Oversize Factor by Measure[1]

Description	MMID	Oversize Factor
Boiler, Hot Water, Modulating, ≥ 90% AFUE, ≤ 300 MBh	2743	164%
Boiler, Hot Water, Modulating, ≥ 90% AFUE, < 300 MBh	2218	204%
Boiler, Condensing, ≥ 90% AFUE, ≥ 300 MBh	3276	113%
Boiler, Hot Water, Near Condensing, ≥ 85% AFUE, ≥ 300 MBh	3277	77%

[1] Cadmus. “Focus on Energy Boiler Measure Study.” 2016. The study determined realized savings from billing data for sites that had applied for boiler incentives during the 2012-2014 program years. The oversize factors in this workpaper align each measure’s calculated savings, in conjunction with assumed EFLH and AFUE values, with the savings calculated from billing data results. There were 17 sites examined for MMID 2743, 26 sites for MMID 2218, and 33 sites for MMID 3276.

EFLH = Effective full-load hours (= 1,909)[20]

ISR = In-service rate (= 95% for MMID 3276; = 100% for MMIDs 2218, 2743, and 3277)

$AFUE_{BASE}$ = Baseline boiler thermal efficiency (= 82%)[21]

$AFUE_{EFF}$ = Efficient boiler thermal efficiency (= 95% for MMIDs 2218, 2743, and 3276; = 91% for MMID 3277)

100 = Conversion factor from MBtu to therm

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (= 20 years)[22]

Evaluated Savings

Table 11 shows annual and lifetime therm savings for these boiler measures.

Table 11. Evaluated Savings for Boiler Measures (therms per MBtu/h)

Description	MMID	Annual	Lifecycle
Boiler, Hot Water, Modulating, ≥ 90% AFUE, ≤ 300 MBh	2743	5.22	104.49
Boiler, Hot Water, Modulating, ≥ 90% AFUE, < 300 MBh	2218	6.50	129.98
Boiler, Condensing, ≥ 90% AFUE, ≥ 300 MBh	3276	3.42	68.40
Boiler, Hot Water, Near Condensing, ≥ 85% AFUE, ≥ 300 MBh	2377	1.77	35.46

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[20] 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. Available online: 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 Evaluation Team adjusted the heating EFLH by population-weighted heating degree days and typical meteorological year values, then averaged for the state of Wisconsin.

[21] 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. Available online: 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. Available online: https://www.regulations.gov/document?D=EERE-2006-STD-0102-0009

[22] 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. Available online: https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

Appendix A: Nonevaluation Findings

The algorithms presented in this appendix show how Cadmus applied findings originating from general workpaper and TRM review processes to generate updated deemed savings values for specific measures. These activities revealed the following values for key input variables and algorithms (specific details regarding these inputs are described further in this appendix):

1. Natural Gas Furnaces:
    a. Peak electrical savings: 0.0792 kW
2. CFL Bulbs, Retail Markdown:
    a. HOU: 996
    b. CF: 0.1162
3. Exterior LED Fixtures:
    a. Savings values slightly corrected
4. Compressed Air Mist Eliminators, Cycling Thermal Mass Air Dryers, and Controllers:
    a. HOU: 5,702
5. Compressed Air and Vacuum Pump Heat Recovery:
    b. HOU: 3,812

Table 12 lists the current measures affected by these recommendations. Cadmus also recommends using these updated assumptions for any new similar measures proposed by Program Implementers, as well as for any custom and hybrid projects where these measures are used.

Table 12. Measures Requiring an Update

Measure Category	SPECTRUM Name and MMID
Natural Gas Furnaces	LP Furnace with ECM, 90%+ AFUE (Existing), 3679
	LP Furnace with ECM, Income-Qualified (Tier 2), 90%+ AFUE (Existing), 3781
	Natural Gas Furnace with ECM, 95%+ AFUE (Existing), 1981
	NG Furnace with ECM, 95%+ AFUE, Income Qualified (Tier 2), 3782
	NG Furnace with ECM, 96%+ AFUE, 3868
	NG Furnace with ECM, 96%+ AFUE, Income Qualified (Tier 2), 3870
	NG Furnace with ECM, 97%+ AFUE, 3440
	NG Furnace with ECM, 97%+ AFUE, Income Qualified (Tier 2), 3871
	NG Furnace with ECM, 98%+ AFUE, 3869
	NG Furnace with ECM, 98%+ AFUE, Income Qualified (Tier 2), 3872
CFL Bulbs, Retail Markdown	CFL, Standard Bulb, 310-749 Lumens, Retail Store Markdown, 3548
	CFL, Standard Bulb, 750-1049 Lumens, Retail Store Markdown, 3549
	CFL, Standard Bulb, 1050-1489 Lumens, Retail Store Markdown, 3550
	CFL, Standard Bulb, 1490-2600 Lumens, Retail Store Markdown, 3551
	CFL, Reflector, 15 watt, Retail Store Markdown, 3552

Measure Category	SPECTRUM Name and MMID
Exterior LED Fixtures	LED Fixture, Replacing 150-175 Watt HID, Exterior, 3099
	LED Fixture, Replacing 250 Watt HID, Exterior, 3102
	LED Fixture, Replacing 320 Watt HID, Exterior, 3105
	LED Fixture, Replacing 320-400 Watt HID, Exterior, 3106
	LED Fixture, Replacing 400 Watt HID, Exterior, 3107
	LED Fixture, Replacing 70-100 Watt HID, Exterior, 3108
	LED Fixture, Replacing 150-175 Watt HID, Exterior, SBP A La Carte, 3289
	LED Fixture, Replacing 250 Watt HID, Exterior, SBP A La Carte, 3301
	LED Fixture, Replacing 400 Watt HID, Exterior, SBP A La Carte, 3303
	LED Fixture, Replacing 70-100 Watt HID, Exterior, SBP A La Carte, 3304
	LED Fixture, Replacing 150-175 Watt HID, Exterior, Agriculture, 3824
	LED Fixture, Replacing 250 Watt HID, Exterior, Agriculture, 3825
	LED Fixture, Replacing 320-400 Watt HID, Exterior, Agriculture, 3826
	LED Fixture, Replacing 400 Watt HID, Exterior, Agriculture, 3827
	LED Fixture, Replacing 70-100 Watt HID, Exterior, Agriculture, 3828
Compressed Air Measures, General	Compressed Air Controller, Pressure/Flow Controller, 2255
	Compressed Air, Cycling Thermal Mass Air Dryers, 2264
	Compressed Air Mist Eliminators, 2258
	Compressed Air Condensate Drains, No Loss Drain, 2254
Compressed Air Measures, Heat Recovery	Compressed Air Heat Recovery, Space Heating, 2257
	Vacuum Pump Heat Recovery, Space Heating, 3928

CY 2016 Deemed and Evaluated Savings Values, Nonevaluation

The CY 2016 deemed savings values and evaluated savings values are listed in Table 13. These savings updates derive from findings obtained through general workpaper and TRM review processes.

Table 13. Deemed and Evaluated Savings Values

Measure Category	SPECTRUM Name and MMID	Deemed	Evaluated	Units
Natural Gas Furnaces	LP Furnace with ECM, 90%+ AFUE (Existing), 3679	416	416	kWh per year
		0.0759	0.0792	kW
		0	0	Therms per year
	LP Furnace with ECM, Income-Qualified (Tier 2), 90%+ AFUE (Existing), 3781	416	416	kWh per year
		0.0759	0.0792	kW
		0	0	Therms per year
	NG Furnace with ECM, 95%+ AFUE (Existing), 1981	416	416	kWh per year
		0.0759	0.0792	kW
		21	21	Therms per year
	NG Furnace with ECM, 95%+ AFUE, Income Qualified (Tier 2), 3782	416	416	kWh per year
		0.0759	0.0792	kW
		165	165	Therms per year

Measure Category	SPECTRUM Name and MMID	Deemed	Evaluated	Units
	NG Furnace with ECM, 96%+ AFUE, 3868	416	416	kWh per year
		0.0759	0.0792	kW
		30	30	Therms per year
	NG Furnace with ECM, 96%+ AFUE, Income Qualified (Tier 2), 3870	416	416	kWh per year
		0.0759	0.0792	kW
		174	174	Therms per year
	NG Furnace with ECM, 97%+ AFUE, 3440	416	416	kWh per year
		0.0759	0.0792	kW
		39	39	Therms per year
	NG Furnace with ECM, 97%+ AFUE, Income Qualified (Tier 2), 3871	416	416	kWh per year
		0.0759	0.0792	kW
		183	183	Therms per year
	NG Furnace with ECM, 98%+ AFUE, 3869	416	416	kWh per year
		0.0759	0.0792	kW
		48	48	Therms per year
	NG Furnace with ECM, 98%+ AFUE, Income Qualified (Tier 2), 3872	416	416	kWh per year
		0.0759	0.0792	kW
		191	191	Therms per year
CFL Bulbs, Retail Markdown	CFL, Standard Bulb, Retail Store Markdown, 3548–3551	As discussed in the CY 2016 *Deemed Savings Memo*		
Exterior LED Fixtures	Exterior LED replacing 70-watt to 100-watt HID Average, 3108, 3828, 3304	344	353	kWh per year
		0	0	kW
		0	0	Therms per year
	Exterior LED replacing 150-watt to 175-watt HID Average, 3099, 3824, 3289	594	593	kWh per year
		0	0	kW
		0	0	Therms per year
	Exterior LED replacing 250-watt HID Average, 3102, 3825, 3301	870	898	kWh per year
		0	0	kW
		0	0	Therms per year
	Exterior LED replacing 320-watt HID, 3105	859	911	kWh per year
		0	0	kW
		0	0	Therms per year
	Exterior LED replacing 400-watt HID, 3106, 3826, 3107, 3827, 3290, 3303	1,215	1,248	kWh per year
		0	0	kW
		0	0	Therms per year
Compressed Air Measures, Heat Recovery	Compressed Air Controller, Pressure/Flow Controller, 2255	178	199	kWh per year per hp
		0.035	0.035	kW per hp
		0	0	Therms per year
	Compressed Air, Cycling Thermal Mass Air Dryers, 2264	1,430	1,604	kWh per year per 100 CFM
		0.281	0.281	kW per 100 CFM
		0	0	Therms per year

Measure Category	SPECTRUM Name and MMID	Deemed	Evaluated	Units
	Compressed Air Mist Eliminators, 2258	71	80	kWh per year per hp
		0.014	0.014	kW per hp
		0	0	Therms per year
	Compressed Air Condensate Drains, No Loss Drain, 2254	1,525	1,711	kWh per year
		0.24	0.24	kW
		0	0	Therms
Compressed Air Measures, General	Compressed Air Heat Recovery, Space Heating, 2257	0	0	kWh per year per hp
		0	0	kW per hp
		48.93	73.39	Therms per year per hp
	Vacuum Pump Heat Recovery, Space Heating, 3928	0	0	kWh per year per hp
		0	0	kW per hp
		48.93	73.39	Therms per year per hp

Nonevaluation Savings Analysis

The algorithms presented in this section show how Cadmus applied findings from the general TRM and workpaper review processes to generate deemed savings values for specific measures.

Natural Gas Furnace Measures

Cadmus found an error in the displayed value for demand reduction for several furnace measures. In the Fall 2016 Wisconsin TRM, a demand reduction value of 0.0759 is displayed in the workpaper text and in the heading table for the workpaper. However, this value should be 0.0792 according the demand equation in the workpaper, replicated below.

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = tons * 12\ kBtu/ton * (1/EER_{BASE} – 1/EER_{ECM}) * CF * AC\%$

Where:

tons = Cooling capacity in tons (= 2.425)[23]

EER_{BASE} = Baseline SEER (= 10.5)[23]

EER_{ECM} = EER of unit with ECM (= 11)[23]

CF = Coincidence factor (= 68%)[23]

AC% = Percentage of non-air conditioner furnace measures that also had an air conditioner installed (= 92.5%)[23]

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[23] Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. October 27, 2014. Available online: https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

Evaluated Savings

Table 14 provides the evaluated demand reduction.

Table 14. Evaluated Savings for Natural Gas Furnace Measures (kW)

Tier	Measure	kW Savings
Income Qualified (Tier 2)	LP Furnace with ECM, Income-Qualified (Tier 2), 90%+ AFUE (Existing), 3781	0.0792
	NG Furnace with ECM, 95%+ AFUE, Income Qualified (Tier 2), 3782	0.0792
	NG Furnace with ECM, 96%+ AFUE, Income Qualified (Tier 2), 3870	0.0792
	NG Furnace with ECM, 97%+ AFUE, Income Qualified (Tier 2), 3871	0.0792
	NG Furnace with ECM, 98%+ AFUE, Income Qualified (Tier 2), 3872	0.0792
Standard Baseline	LP Furnace with ECM, 90%+ AFUE (Existing), 3679	0.0792
	NG Furnace with ECM, 95%+ AFUE (Existing), 1981	0.0792
	NG Furnace with ECM, 96%+ AFUE, 3868	0.0792
	NG Furnace with ECM, 97%+ AFUE, 3440	0.0792
	NG Furnace with ECM, 98%+ AFUE, 3869	0.0792

CFL Bulbs, Retail Markdown

Cadmus updated details of changes to CFL bulb measures, along with upstream LED measures, in the CY 2016 *Deemed Savings* report.[24] Cadmus updated cross-sector sales and delta watts values based on CY 2015 evaluation findings. However, for CFLs, these changes were not added to the Wisconsin TRM: they should be incorporated into future evaluations.

Exterior LED Fixtures

The Spring 2016 Wisconsin TRM displays savings values for exterior LED fixtures that are slightly incorrect, based on the savings algorithms presented. The algorithms and calculated savings are presented below.

Annual Energy-Savings Algorithm

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

Where:

$Watts_{BASE}$ = Wattage of standard HID fixture (= varies by measure; see Table 15)

$Watts_{EE}$ = Wattage of efficient LED fixture (= varies by measure; see Table 15)

1,000 = Kilowatt conversion factor

HOU = Hours of use (= 4,380)

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[24] Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. September 12, 2016. Available online: https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2016_v1%207.pdf

Table 15. Wattages Used for Deemed Savings Calculations

Measure	$Watts_{BASE}$	$Watts_{EE}$
Exterior LED replacing 70-watt to 100-watt HID Average	111.5	31
Exterior LED replacing 150-watt to 175-watt HID Average	194.5	59
Exterior LED replacing 250-watt HID Average	299.0	94
Exterior LED replacing 320-watt HID	368.0	160
Exterior LED replacing 400-watt HID	463.0	178

Source: Focus on Energy Default Wattage Guide 2013, Version 1.0

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (= 13 years)[25]

Evaluated Savings

Table 16 and Table 17 show annual and lifecycle deemed energy savings, respectively, for these measures.

Table 16. Average Annual Deemed Savings for Exterior LED Fixtures

Measure	MMID	kWh	kW
Exterior LED replacing 70-watt to 100-watt HID Average	3108, 3828, 3304	353	0
Exterior LED replacing 150-watt to 175-watt HID Average	3099, 3824, 3289	593	0
Exterior LED replacing 250-watt HID Average	3102, 3825, 3301	898	0
Exterior LED replacing 320-watt HID	3105	911	0
Exterior LED replacing 400-watt HID	3106, 3826, 3107, 3827, 3290, 3303	1,248	0

Table 17. Average Lifecycle Deemed Savings for Exterior LED Fixtures

Measure	MMID	kWh
Exterior LED replacing 70-watt to 100-watt HID Average	3108, 3828, 3304	4,589
Exterior LED replacing 150-watt to 175-watt HID Average	3099, 3824, 3289	7,709
Exterior LED replacing 250-watt HID Average	3102, 3825, 3301	11,674
Exterior LED replacing 320-watt HID	3105	11,843
Exterior LED replacing 400-watt HID	3106, 3826, 3107, 3827, 3290, 3303	16,224

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[25] DesignLights Consortium. Qualified Product List, accessed August 2017. Available online: https://www.designlights.org/lighting-controls/download-the-qpl/. Average rated life of models participating in exterior HID to LED measures is 57025 hours. With an HOU of 4380, EUL = 13 years

Compressed Air Measures, General

The newly developed workpaper for Vacuum Pump Heat Recovery (MMID 3928) usescompressed air measures in the Wisconsin TRM. The value comes from a U.S. Department of Energy report from 2002[26] and represents an average value for motors in manufacturing facilities, rather than a specific value for compressed air systems. Version 5 of the Illinois TRM[27] uses a more appropriate value for compressed air system yearly hours of use of 5,702, which represents a weighted average based on various facilities' hours of operation as collected from an operator survey, as shown in Table 18.

Table 18. Compressed Air Hours[1]

Shift	Fraction of Facilities[2]	Hours
Single Shift, 7 a.m. to 3 p.m. weekdays, minus some holidays and scheduled down time	16%	1,976
Two Shifts, 7 a.m. to 11 p.m. weekdays, minus some holidays and scheduled down time	23%	3,952
Three Shifts, 24 hours per weekday, minus some holidays and scheduled down time	25%	5,928
Continual Operation, 24 hours per day, 7 days a week, minus some holidays and scheduled down time	36%	8,320
Weighted Average		**5,702**

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

[2] U.S. Department of Energy. Evaluation of the Compressed Air Challenge, section 2.1.5 Facility Operating Schedules. Available online: https://www.nrel.gov/docs/fy04osti/36103.pdf

This recommended update to the value for compressed air system hours of use applies to compressed air controllers (MMID 2255), cycling thermal mass air dryers (MMID 2264), compressed air mist eliminators (MMID 2258), and compressed air no-loss drains (MMID 2254).

Annual Energy-Savings Algorithm

kWh_{SAVED} = hp * 0.746 / Motor Eff. * Load Factor * HOU * % decrease (MMID 2255)

kWh_{SAVED} = SF_{2264} * Load Factor * CFM * HOU (MMID 2264)

kWh_{SAVED} = hp * 0.746 / Motor Eff. * Load Factor * HOU * % savings (MMID 2258)

kWh_{SAVED} = SF_{2254} * HOU (MMID 2254)

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[26] U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy. *United States Industrial Electric Motor Systems Market Opportunities Assessment*. p. 42. December 2002. Available online: https://www.energy.gov/sites/prod/files/2014/04/f15/mtrmkt.pdf

[27] Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Volume 2*. February 11, 2016. Available online: http://www.ilsag.info/technical-reference-manual.html

Where:

hp = Compressor motor size in horsepower

0.746 = Conversion factor from kilowatts to horsepower

Motor Eff. = Compressor motor efficiency (= 95%)[28]

Load Factor = Average load on compressor motor (= 89%)[28]

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

% decrease = Percentage decrease in power input (= 5%)[29]

SF_{2264} = Savings factor in kW per CFM (= varies by dryer capacity; see Table 19)

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

% savings = Percentage of energy saved (= 2%)[30]

SF_{2254} = Saving factor in kilowatts per drain (= 0.3)[31]

Table 19. Savings Factors for MMID 2264

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

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

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = hp * 0.746 / Motor Eff. * Load Factor * % decrease * CF (MMID 2255)

kW_{SAVED} = SF * Load Factor * CFM * CF (MMID 2264)

kW_{SAVED} = hp * 0.746 / Motor Eff. * Load Factor * % savings * CF (MMID 2258)

kW_{SAVED} = SF * CF_{2254} (MMID 2254)

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

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

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

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

Where:

CF = Coincidence factor (= 1)[32]

CF_{2254} = Coincidence factor for MMID 2254 (= 0.8)[31]

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (= 15 years for MMID 2255[33] and 2264[34]; =5 years (new construction) or 3 years (retrofit) for MMID 2258[35]; = 20 years for MMID 2254[36])

Evaluated Savings

Table 20 and Table 21 show annual and lifetime energy savings, respectively, for these measures.

Table 20. Evaluated Annual Savings for General Compressed Air Measures

Description	MMID	kWh	kW
Compressed Air Controller, Pressure/Flow Controller	2255	199 per hp	0.035
Compressed Air, Cycling Thermal Mass Air Dryers	2264	1,604 per 100 CFM	0.281
Compressed Air Mist Eliminators	2258	80 per hp	0.014
Compressed Air Condensate Drains, No Loss Drain	2254	1,711	0.240

Table 21. Evaluated Lifetime Savings for General Compressed Air Measures

Description	MMID	kWh
Compressed Air Controller, Pressure/Flow Controller	2255	2,989 per hp
Compressed Air, Cycling Thermal Mass Air Dryers	2264	24,062 per 100 CFM
Compressed Air Mist Eliminators	2258	400 per hp (new construction) 240 per hp (retrofit)
Compressed Air Condensate Drains, No Loss Drain	2254	34,200

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[32] 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. www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA384166

[33] Estimate from product representative.

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

[35] Massachusetts TRM 2013. http://ma-eeac.org/wordpress/wp-content/uploads/TRM_PLAN_2013-15.pdf. Savings based on low pressure "mist eliminator" filters; Based on typical replacement schedules for low pressure filters (NSTAR staff estimates).

[36] Xcel Energy. *2011 Demand Side Management Plan*. March 2011. Available online: https://www.xcelenergy.com/staticfiles/xe/Regulatory/Regulatory%20PDFs/2011-CO-DSM-Plan.pdf

Compressed Air Measures, Heat Recovery

In addition to the recommended change to the value for compressed air hours of use (discussed above), Cadmus also recommends refining the method used to calculate hours of use for compressed air heat recovery measures. This method also incorporates the hours of use and facility type splits shown in Table 18. Compressed air heat recovery measures (MMIDs 2257 and 2258) should have an effective hours of use value that reflects when the building is being heated and when the compressed air system is operating at the same time. The Spring 2016 Wisconsin TRM uses a value of 5,083 hours of use, representing when compressed air systems are operating, in conjunction with a 50% factor that very roughly accounts for the percentage of time the air systems' operation coincides with space heating. However, the operating hours table from the Illinois TRM (Table 18), combined with the temperature bins in the Wisconsin TRM, can be used to produce a more detailed value for heat recovery hours.

As shown in Table 22, based on Wisconsin temperature bins, there are 5,392 total hours of heating for commercial facilities. For sites with continual (24/7) operation, 100% of these heating hours coincide with compressed air operation. Likewise, for sites with three shift (24/5) operation, five-sevenths of these heating hours coincide with compressed air operation, resulting in 3,851 hours of compressed air heat recovery per year. Analogous assumptions can be made for two-shift and single-shift operation. Averaging these totals using the weights for each facility type produces an average compressed air heat recovery hours of use value of 3,812 hours.

Table 22. Derivation of Compressed Air Heat Recovery Hour Value

Shift	Heating Hours[1]	Fraction of Heating Hours Coinciding with Compressed Air Operation	Hours of Heat Recovery	Fraction of Facilities[2]
Single Shift	5,392	1/3	1,797	16%
Two Shifts		1/2	2,696	23%
Three Shifts		5/7	3,851	25%
Continual Operation		100%	5,392	36%
Weighted Average			**3,812**	

[1] This value is from Appendix B of the Wisconsin TRM.

[2] Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Volume 2*. February 11, 2016. Available online: http://www.ilsag.info/technical-reference-manual.html

Annual Energy-Savings Algorithm

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

Where:

hp = Compressor or vacuum pump motor horsepower size

Load Factor = Average load on compressor or vacuum pump motor (= 89%)Error! Bookmark not defined.

2,545 = Conversion factor from horsepower to Btu/h

HR = Heat recoverable as a percentage of brake horsepower (= 85%)[37]

HOU = Average annual run hours of the compressor or vacuum pump (= 3,812)

100,000 = Conversion from Btus to therms

Summer Coincident Peak Savings Algorithm

There are no peak coincident savings for this measure.

Lifecycle Energy-Savings Algorithm

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

Where:

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

Evaluated Savings

Table 23 shows evaluated savings for these measures.

Table 23. Evaluated Savings for General Compressed Air Measures

Description	MMID	kWh	kW
Compressed Air Heat Recovery, Space Heating	2257	73.39 per hp	0
Vacuum Pump Heat Recovery, Space Heating	3928	73.39 per hp	0

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[37] Moskowitz, Frank. “Compressed Air Challenge™, Heat Recovery and Compressed Air Systems.” September 2010. Available online: https://www.compressedairchallenge.org/data/sites/1/media/library/factsheets/factsheet10.pdf

Appendix B: Potential Study Findings

During the summer of CY 2016, as part of the *Focus on Energy 2016 Energy Efficiency Potential Study*, Cadmus collected data from on-site visits to 103 single-family homes, 92 multifamily units, 70 schools, 70 offices, 70 restaurants, and 70 retail sites. Cadmus collected a wide range of data types—including equipment capacities, efficiencies, category splits, fuel type splits, and counts—then performed an extensive examination of this data in order to inform savings for measures in the Wisconsin TRM. In most cases, these data points did not serve as inputs for calculating measure savings; did serve as calculation inputs but did not significantly differ from existing values; or could not be used because a code baseline was already in use for a particular measure. However, key input variables and algorithms for several measures were influenced by this data (specific details regarding these inputs are described further in this appendix):

1. Boiler Tune-Ups:
    a. Boiler AFUE, multifamily and small business: 84%
2. Boiler Outside Air Temperature Reset Controls:
    a. Boiler AFUE, multifamily: 84%
    b. Boiler AFUE, nonresidential: 85%
3. Aerators:
    a. Fraction of water heaters that are natural gas/electric, single family: 73%/20%
    b. Average energy factor of natural gas water heaters, single family: 61%
    c. Average energy factor of electric water heaters, single family: 94%
4. Water Heaters:
    a. Hot water setpoint, nonresidential: 130°F
5. Attic and Wall Insulation:
    a. Heating efficiency, multifamily: 84%
6. Air Sealing:
    a. Natural gas heating efficiency, noncondensing, multifamily: 80%

Table 24 lists the current measures affected by these recommendations. The Team recommends using these updated assumptions for any new, similar measures proposed by Program Implementers, as well as for any custom and hybrid projects where these measures are used.

Table 24. Measures Requiring an Update

Measure Category	SPECTRUM Name and MMID
Boiler Tune-Ups	Boiler Tune-Up, 2744, 4058
Boiler Outside Temperature Reset Controls	Boiler, Outside Temperature Reset/Cutout Control, 2221
Aerators, Single Family	Faucet Aerator: Pack Based, 1.5 GPM, Kitchen, 3862

Measure Category	SPECTRUM Name and MMID
	Pack Based, 1.0 GPM, Bathroom, Residential, 3863 Direct Install, 1.0 GPM, Bathroom, Residential: Natural Gas, 2137 Showerhead, Pack Based, 1.5 GPM, 3864 Faucet Aerator: 1.5 GPM, Kitchen, 3026 (Electric) Faucet Aerator: 1.5 GPM, Kitchen, 3025 (Natural Gas) Faucet Aerator: 1.0 GPM, Kitchen, 3506 (Electric), Faucet Aerator: 1.0 GPM, Kitchen, 3507 (Natural Gas) Faucet Aerator: 0.5 GPM, Kitchen, 3509 (Electric), Faucet Aerator: 0.5 GPM, Kitchen, 3510 (Natural Gas) Faucet Aerator: 1.5 GPM, Bathroom, 3028 (Electric), Faucet Aerator: 1.5 GPM, Bathroom, 3027 (Natural Gas) Faucet Aerator: 1.0 GPM, Bathroom, 2143 (Electric) Faucet Aerator: 0.5 GPM, Bathroom, 3508 (Natural Gas) Faucet Aerator: 1.5 GPM, Shower, 3030 (Electric), Faucet Aerator: 1.5 GPM, Shower, 3029 (Natural Gas) Faucet Aerator: Direct Install, 0.5/1.0/1.5 Variable GPM, Kitchen, Electric, 3919 Direct Install, 0.5/1.0/1.5 Variable GPM, Kitchen, Natural Gas, 3920 Showerhead, Direct Install, 1.25 GPM, Electric, 3921 Showerhead, Direct Install, 1.25 GPM, Natural Gas, 3922
Commercial Water Heaters	Water Heater, High Usage: ≥ 90% TE, K-12 School, 3684 Water Heater, High Usage: ≥ 90% TE, Natural Gas, 3045 Water Heater, High Usage: ≥ 0.82 EF, Tankless, Natural Gas, 3046 Water Heater, High Usage: ≥ 2 EF, Heat Pump Storage, Electric, 3047
Attic and Wall Insulation	Insulation, Wall: Natural Gas Heat with Cooling, 3703 Natural Gas Heat without Cooling, 3704 Insulation, Attic: Natural Gas Heat with Cooling, Existing Insulation ≤ R-11, 3707 Natural Gas Heat without Cooling, Existing Insulation ≤ R-11, 3708 Natural Gas Heat with Cooling, Existing Insulation R-12 to R-19, 3709 Natural Gas Heat, without Cooling, Existing Insulation R-12 to R-19, 3710
Air sealing	Air Sealing, 2745

CY 2016 Deemed and Evaluated Savings Values, Potential Study

The CY 2016 deemed and evaluated savings values are listed in Table 25. These savings updates derive from findings obtained through the review of CY 2016 *Potential Study* data.

Table 25. Deemed and Evaluated Savings Values

Measure Category	SPECTRUM Name and MMID	Deemed	Evaluated	Units
Boiler Tune-Ups	Boiler Tune-Up, 2744	0	0	kWh per year
		0	0	kW
		129	126	Therms per year
	Boiler Tune-Up, 4058	0	0	kWh per year
		0	0	kW
		129	125	Therms per year
Boiler Outside Air Temperature Reset Controls	Boiler, Outside Temperature Reset/Cutout Control, 2221 (multifamily)	0	0	kWh per year per MBh
		0	0	kW
		1.617	1.675	Therms per year per MBh
	Boiler, Outside Temperature Reset/Cutout Control, 2221 (nonresidential, Green Bay)	0	0	kWh per year per MBh
		0	0	kW
		1.703	1.764	Therms per year per MBh
	Boiler, Outside Temperature Reset/Cutout Control, 2221 (nonresidential, La Crosse)	0	0	kWh per year per MBh
		0	0	kW
		1.808	1.872	Therms per year per MBh
	Boiler, Outside Temperature Reset/Cutout Control, 2221 (nonresidential, Madison)	0	0	kWh per year per MBh
		0	0	kW
		1.778	1.842	Therms per year per MBh
	Boiler, Outside Temperature Reset/Cutout Control, 2221 (nonresidential, Milwaukee)	0	0	kWh per year per MBh
		0	0	kW
		1.731	1.793	Therms per year per MBh
Aerators	Aerator deemed and evaluated savings are compared in Table 26.			
Commercial Water Heaters	Water Heater, High Usage: ≥ 90% TE, K-12 School, 3684	Savings for these hybrid measures vary with facility type and size, and water heater type and efficiency, but the adjustment to hot water setpoint raises savings by 6.9%.		
	Water Heater, High Usage: ≥ 90% TE, Natural Gas, 3045			
	Water Heater, High Usage: ≥ 0.82 EF, Tankless, Natural Gas, 3046			
	Water Heater, High Usage: ≥ 2 EF, Heat Pump Storage, Electric, 3047			
Attic and Wall Insulation	Insulation, Wall: Natural Gas Heat with Cooling, 3703	0.117	0.117	kWh per year per sq ft
		0.0002	0.0002	kW per sq ft
		0.257	0.245	Therms per year per sq ft
	Insulation, Wall: Natural Gas Heat without Cooling, 3704	0	0	kWh per year per sq ft
		0	0	kW per sq ft
		0.257	0.245	Therms per year per sq ft
	Insulation, Attic: Natural Gas Heat with Cooling, Existing Insulation ≤ R-11, 3707	0.0674	0.0674	kWh per year per sq ft
		0.0001	0.0001	kW per sq ft
		0.1476	0.1406	Therms per year per sq ft
		0	0	kWh per year per sq ft

Measure Category	SPECTRUM Name and MMID	Deemed	Evaluated	Units
	Insulation, Attic: Natural Gas Heat without Cooling, Existing Insulation ≤ R-11, 3708	0	0	kW per sq ft
		0.1476	0.1406	Therms per year per sq ft
	Insulation, Attic: Natural Gas Heat with Cooling, Existing Insulation R-12 to R-19, 3709	0.0274	0.0274	kWh per year per sq ft
		0.0001	0.0001	kW per sq ft
		0.0601	0.0573	Therms per year per sq ft
	Insulation, Attic: Natural Gas Heat, without Cooling, Existing Insulation R-12 to R-19, 3710	0	0	kWh per year per sq ft
		0	0	kW per sq ft
		0.0601	0.0573	Therms per year per sq ft
Air Sealing	Air Sealing, 2745	Savings for this measure depend on the results of a blower door test, but the adjustment to multifamily natural gas noncondensing heating AFUE decreases therm savings by 2.5% for residences with noncondensing natural gas heating		

Table 26. Deemed and Evaluated Savings Values, Aerators

Measure	MMID	Sector	Annual kWh		Peak kW		Annual therms	
			Deemed	Evaluated	Deemed	Evaluated	Deemed	Evaluated
Faucet Aerator, Pack Based, 1.5 GPM, Kitchen	3862	SF	30.1	33.1	0.0014	0.0016	5.7	6.3
Faucet Aerator, Direct Install, 1.0 GPM, Bathroom, Residential: Natural Gas	2137	SF	0	0	0	0	3.1	3.8
		MF	0	0	0	0	4.5	4.5
Faucet Aerator, Pack Based, 1.0 GPM, Bathroom, Residential	3863	SF	7.1	7.8	0.0007	0.0008	1.3	1.5
Showerhead, Pack Based, 1.5 GPM	3864	SF	39.3	43.2	0.0021	0.0023	7.4	8.3
Faucet Aerator: 1.5 GPM, Kitchen, Electric	3026	SF	294	306	0.0136	0.0144	0	0
		MF	225	225	0.0136	0.0138	0	0
Faucet Aerator: 1.5 GPM, Kitchen, Natural Gas	3025	SF	0	0	0	0	12.9	16.1
		MF	0	0	0	0	9.9	9.9
Faucet Aerator: 1.0 GPM, Kitchen, Electric	3506	SF	504	525	0.0234	0.0247	0	0
		MF	386	386	0.0234	0.0237	0	0
Faucet Aerator: 1.0 GPM, Kitchen, Natural Gas	3507	SF	0	0	0	0	22.2	27.6
		MF	0	0	0	0	17.0	17.0
Faucet Aerator: 0.5 GPM, Kitchen, Electric	3509	SF	713	744	0.0331	0.0350	0	0
		MF	546	546	0.0331	0.0336	0	0
Faucet Aerator: 0.5 GPM, Kitchen, Natural Gas	3510	SF	0	0	0	0	31.4	39.1
		MF	0	0	0	0	24.0	24.0
Faucet Aerator: 1.5 GPM, Bathroom, Electric	3028	SF	41	42	0.0039	0.0042	0	0
		MF	60	60	0.0039	0.0041	0	0

Measure	MMID	Sector	Annual kWh		Peak kW		Annual therms	
			Deemed	Evaluated	Deemed	Evaluated	Deemed	Evaluated
Faucet Aerator: 1.5 GPM, Bathroom, Natural Gas	3027	SF	0	0	0	0	1.8	2.2
		MF	0	0	0	0	2.6	2.6
Faucet Aerator: 1.0 GPM, Bathroom, Electric	2143	SF	70	73	0.0066	0.0073	0	0
		MF	102	102	0.0066	0.0070	0	0
Faucet Aerator: 0.5 GPM, Bathroom, Natural Gas	3508	SF	0	0	0	0	4.3	5.4
		MF	0	0	0	0	6.4	6.4
Faucet Aerator: 1.5 GPM, Shower, Electric	3030	SF	318	332	0.0284	0.0178	0.0	0.0
		MF	400	400	0.0284	0.0170	0.0	0.0
Faucet Aerator: 1.5 GPM, Shower, Natural Gas	3029	SF	0	0	0	0	14.0	17.5
		MF	0	0	0	0	17.6	17.6
Faucet Aerator, Direct Install, 0.5/1.0/1.5 Variable GPM, Kitchen, Electric	3919	SF	504	525	0.0234	0.0247	0	0
		MF	386	386	0.0234	0.0237	0	0
Faucet Aerator, Direct Install, 0.5/1.0/1.5 Variable GPM, Kitchen, Natural Gas	3920	SF	0	0	0	0	22.2	27.6
		MF	0	0	0	0	17.0	17.0
Faucet Aerator, Showerhead, Direct Install, 1.25 GPM, Electric	3921	SF	398	373	0.0213	0.0120	0	0
		MF	500	450	0.0213	0.0115	0	0
Faucet Aerator, Showerhead, Direct Install, 1.25 GPM, Natural Gas	3922	SF	0	0	0	0	17.5	19.6
		MF	0	0	0	0	22.0	19.8

Potential Data Savings Analysis

The algorithms presented in this section show how the Team applied findings from the *Focus on Energy 2016 Energy Efficiency Potential Study* to generate deemed savings values for specific measures.

Boiler Tune-Ups

Cadmus visited hundreds of multifamily and nonresidential sites as part of the *Potential Study*. Cadmus obtained boiler AFUEs from many of these sites, revealing the building stock averages shown in Table 27.

Table 27. Sites and Average Boiler AFUE

Site Type	Site Count	Average AFUE
Multifamily	23	84%
School, Office, Restaurant, Retail	43	84%
Office, Restaurant, Retail (Small Businesses)	18	85%

Boiler upgrade measures use a code AFUE as a baseline and should not be updated with these building stock AFUEs. However, boiler tune-up measures (MMIDs 2744 and 4058) can employ them. These measures use the algorithm from the *Deemed Saving Manual V1.0*,[38] updated with an unsourced AFUE of 82% to produce a savings value of 0.346 therms per MBh. This section presents the algorithm from the *Deemed Savings Manual V1.0* with the new AFUE of 84%.

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}} = \text{BOF} * \text{CAP} * \text{SF} * \text{HDD} * 24 / [(\text{T}_{\text{INDOOR}} – \text{T}_{\text{OUTDOOR}}) * \text{AFUE}_{\text{PRE}} * 100]$

Where:

BOF = Boiler oversize factor (= 77%, deemed)

CAP = Size of the boiler being tuned (= 373 MBh)[39]

SF = Savings factor (= 1.6%, deemed)

HDD = Heating degree days (= 7,699)

T_{INDOOR} = Indoor design temperature (= 65°F)

$\text{T}_{\text{OUTDOOR}}$ = Outdoor design temperature (= -15°F)

AFUE_{PRE} = AFUE of boiler prior to tune-up (= 84% for multifamily;[40] = 84% for small business[41])

100 = Conversion factor from MBh to therm

Annual Energy-Savings Algorithm

There are no annual energy savings for this measure.

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (= 2 years)[42]

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[38] 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. Available online: https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

[39] This is the average size of boilers that were tuned and cleaned in the ACES Program from CY 2008 to CY 2010.

[40] This is the average AFUE of 23 boilers at multifamily sites, recorded as part of the *Focus on Energy 2016 Energy Efficiency Potential Study*.

[41] This 84% is the average AFUE of 18 boilers at office, restaurant, and retail sites, recorded as part of the *Focus on Energy 2016 Energy Efficiency Potential Study*.

[42] Navigant Consulting. *NYSERDA Commercial/Industrial Natural Gas Market Characterization*. October 3, 2012. Available online: http://www.nyserda.ny.gov/-/media/Files/Publications/PPSER/Program-Evaluation/2012ContractorReports/2012-CI-Natural-Gas-Report.pdf

Evaluated Savings

Table 28 shows annual and lifetime therm savings for these boiler tune-up measures.

Table 28. Evaluated Therm Savings for Boiler Tune-Up Measures

Measure Name	MMID	Annual Energy Savings (therms)	Lifetime Energy Savings (therms)
Boiler Tune-Up	2744	126	252
Boiler Tune-Up	4058	126	252

Boiler Outside Temperature Reset/Cutout Control

The building stock boiler AFUEs presented in Table 27 can also be applied to the boiler temperature reset control measure (MMID 2221). Savings calculations for this measure are presented below.

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}} = \text{BC} * \text{EFLH}_{\text{HEAT}} / (\text{Eff} * 100) * \text{SF}$

Where:

BC = Boiler capacity in MBh (= 1)

$\text{EFLH}_{\text{HEAT}}$ = Equivalent full-load heating hours (= 1,759 for multifamily; = varies by city for commercial, industrial, agriculture, and schools and government sectors, see Table 29).)

Eff = Combustion efficiency of the boiler (= 84%)[43]

100 = Conversion factor from therm to MBtu

SF = Savings factor (= 8%)[44]

Table 29. Equivalent Full-Load Heating and Cooling Hours by City

City	$\text{EFLH}_{\text{HEAT}}$[1]
Green Bay	1,852
La Crosse	1,966
Madison	1,934
Milwaukee	1,883

[1] Several Cadmus metering studies have revealed that the ENERGY STAR calculator EFLH are overestimated by 25%. The Evaluation Team adjusted $\text{EFLH}_{\text{HEAT}}$ by population-weighted heating degree day and TMY3 values.

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[43] This 84% is the average AFUE of 43 boilers at school, office, restaurant, and retail sites, recorded as part of the *Focus on Energy 2016 Energy Efficiency Potential Study*.

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

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (= 5 years)[45]

Evaluated Savings

Table 30 shows annual and lifetime therm savings for these boiler tune-up measures.

Table 30. Evaluated Therm Savings for Boiler Tune-Up Measures

Measure Name	MMID	Sector	Energy Savings (therms per MBh)	
			Annual	Lifetime
Boiler, Outside Temperature Reset/Cutout Control	2221	Multifamily	1.675	8.376
		Nonres, Green Bay	1.764	8.819
		Nonres, La Crosse	1.872	9.362
		Nonres, Madison	1.842	9.210
		Nonres, Milwaukee	1.793	8.967

Aerators

The Evaluation Team visited 103 single-family sites as part of the *2016 Potential Study*, and collected water heating fuel types and energy factors from these sites. Per the data, 73% of these homes have natural gas water heaters, 20% have electric water heaters, and the remaining 7% have propane water heaters. This is a different fuel split from the 81% natural gas and 19% electric currently used for pack-based aerator measures (MMIDs 3862, 3863, and 3864), and the Team recommends using these new, updated split values for these measures.

In addition, data on natural gas water heater energy factors for 40 sites revealed a building stock energy factor of 61%, rather than the Spring 2016 Wisconsin TRM value of 76%. Data on electric water heaters from six sites reveals a building stock energy factor of 94%, rather than the value of 98% in that TRM. The current values for energy factor were obtained from an external benchmark definition,[46] and it is recommended that they be updated to reflect these building stock energy factors.

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[45] Average of Cadmus database March 2013 and Fannie Mae Estimated Useful Life Table: https://www.fanniemae.com/content/guide_form/4099f.pdf

[46] U.S. Department of Energy, National Renewable Energy Laboratory. *Building America Research Benchmark Definition*. p. 12. January 2010. Available online: http://www.nrel.gov/docs/fy10osti/47246.pdf

Finally, Cadmus noted that the workpapers for these aerator measures contained two types of calculation error. First, the coincidence factors were applied unevenly across measure types. For kitchen aerators, the coincidence factor should be 0.0033 but is instead 0.0032. For pack-based showerheads, the coincidence factor considers the number of showers per day and is 0.0023. But for other showerheads have a coincidence factor of 0.0039, which is calculated without considering the number of showers per day and is incorrect. Second, the savings calculations for direct install showerhead measures do not assume an install rate of 0.9, as the text implies.

Update energy savings algorithms are presented below.

Annual Energy-Savings Algorithm

Aerators

$\text{Gallons}_{\text{SAVED}} = (\text{GPM}_{\text{EXISTING}} – \text{GPM}_{\text{NEW}}) * \text{PH} / \text{FH} * \text{LU} * 365 * \text{IR}$

$\text{kWh}_{\text{SAVED}} = \text{Gallons}_{\text{SAVED}} * 8.33 * 1 * (\text{T}_{\text{POINT OF USE}} – \text{T}_{\text{ENTERING}}) / \text{EF}_{\text{ELECTRIC}} / 3{,}412$

$\text{Therm}_{\text{SAVED}} = \text{Gallons}_{\text{SAVED}} * 8.33 * 1 * (\text{T}_{\text{POINT OF USE}} – \text{T}_{\text{ENTERING}}) / \text{EF}_{\text{GAS}} / 100{,}000$

Showerheads

$\text{Gallons}_{\text{SAVED}} = (\text{GPM}_{\text{EXISTING}} – \text{GPM}_{\text{NEW}}) * \text{PH} * \text{SPD} / \text{FH} * \text{SLU} * 365 * \text{IR}$

$\text{kWh}_{\text{SAVED}} = \text{Gallons}_{\text{SAVED}} * 8.33 * 1 * (\text{T}_{\text{POINT OF USE}} – \text{T}_{\text{ENTERING}}) / \text{EF}_{\text{ELECTRIC}} / 3{,}412$

$\text{Therm}_{\text{SAVED}} = \text{Gallons}_{\text{SAVED}} * 8.33 * 1 * (\text{T}_{\text{POINT OF USE}} – \text{T}_{\text{ENTERING}}) / \text{EF}_{\text{GAS}} / 100{,}000$

Where:

$\text{Gallons}_{\text{SAVED}}$ = First-year water savings in gallons

$\text{GPM}_{\text{EXISTING}}$ = Baseline flow rate (= 2.2 GPM for kitchen and bathroom aerators; = 2.5 GPM for showerheads)[47]

GPM_{NEW} = Efficient flowrate (= 0.5, 1.0, or 1.5 GPM for kitchen and bathroom aerators; = 1.25 or 1.5 GPM for showerheads)

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[47] Alliance Water Efficiency. *National Efficiency Standards and Specifications for Residential and Commercial Water-Using Fixtures and Appliances*. August 2011. Available online: http://www.allianceforwaterefficiency.org/uploadedFiles/Resource_Center/Library/codes_and_standards/US-Water-Product-Standard-Matrix-Aug-2011.pdf

PH = People per house (= 2.52 single family; = 1.93 multifamily)[48]

FH = Fixtures per house (for single family: = 1.0 for kitchen aerator; = 2.13 for bathroom aerators; = 1.64 for showerheads. for multifamily: = 1.0 for kitchen aerators; = 1.11 for bathroom aerators; = 1.0 for showerheads)[48]

LU = Fixture length of use in minutes per person per day (= 4.5 for kitchen aerators; = 1.6 for bathroom aerators)[49]

365 = Conversion from days to years

IR = Installation rate (= 1.0 for aerators direct install and prescriptive; =1.0 for showerheads prescriptive; = 0.90 for showerheads direct install;[50] = 0.54 for aerators pack based;[51,52] = 0.65 for showerheads pack based)[52,53]

8.33 = Density of water, lbs/gallon

1 = Specific heat of water, Btu/lb °F

$T_{\text{POINT OF USE}}$ = Temperature of water at point of use (= 93°F for kitchen aerators; = 86°F for bathroom aerators; = 101°F for showerheads)[49]

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[48] California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." February 4, 2014. Available online: http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx
GDS Associates, Inc. *Natural Gas Energy Efficiency Potential in Massachusetts.* Prepared for GasNetworks. Table B-2a, measure C-WH-15. 2009. Available online: http://ma-eeac.org/wordpress/wp-content/uploads/5_Natural-Gas-EE-Potenial-in-MA.pdf

[49] Cadmus. "Michigan Water Meter Study." 2012.

[50] Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. September 14, 2015. Available online: https://focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2015_final.pdf

[51] Cadmus. *Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2014*. May 15, 2015. Available online: https://www.efis.psc.mo.gov/mpsc/commoncomponents/view_itemno_details.asp?caseno=EO-2012-0142&attach_id=2015027784

[52] Cadmus. *Colorado Energy Savings Kits Program Evaluation*. August 28, 2012. Available online: https://www.xcelenergy.com/staticfiles/xe/Regulatory/Regulatory%20PDFs/CO-DSM/CO-2012-Energy-Savings-Kits-Final-Evaluation.pdf

[53] Cadmus. *Colorado Showerhead Program Evaluation*. December 7, 2011. Available online: https://www.xcelenergy.com/staticfiles/xe/Regulatory/Regulatory%20PDFs/CO-DSM/2011-CO-Showerhead-Program-Evaluation.pdf

$T_{ENTERING}$ = Temperature of water entering water heater (= 52.3°F)[54]

$EF_{ELECTRIC}$ = Energy factor of electric water heater (= 94% for single family;[55] = 98% for multifamily)[46]

3,412 = Conversion from Btus to kWhs

EF_{GAS} = Energy factor of natural gas water heater (= 61% for single family;[56] = 76% for multifamily)[46]

100,000 = Conversion from Btus to therms

SPD = Showers per person per day (= 0.6)[49]

SLU = Shower length in minutes (= 7.8)[54]

Summer Coincident Peak Savings Algorithm

Aerators

$kW_{SAVED} = kWh_{SAVED} * CF / (PH * LU * 365 / 60 / FH)$

$CF = \%Peak_{AERATOR} * LU / 180$

Showerheads

$kW_{SAVED} = kWh_{SAVED} * CF / (PH * SPD * SLU * 365 / 60 / FH)$

$CF = \%Peak_{SHOWER} * SLU * SPD / 180$

Where:

kWh_{SAVED} = Calculated savings per faucet

CF = Coincidence factor (= 0.0033 for kitchen aerators; = 0.0012 for bathroom aerators; = 0.0023 for showerheads)

60 = Conversion from minutes to hours

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[54] U.S. Department of Energy. “Domestic Hot Water Scheduler.” Available online: 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.

[55] This is the average energy factor of six electric water heaters at single-family sites, recorded as part of the *Focus on Energy 2016 Energy Efficiency Potential Study*.

[56] This is the average energy factor of 40 natural gas water heaters at single-family sites, recorded as part of the *Focus on Energy 2016 Energy Efficiency Potential Study*.

$\%Peak_{AERATOR}$ = Amount of time faucet aerator is used during peak period (= 13%)[57]

180 = Number of minutes during peak period

$\%Peak_{SHOWER}$ = Amount of time shower is used during peak period (= 9%)[57]

Lifecycle Energy-Savings Algorithm

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

Where:

EUL = Effective useful life (= 10 years)[58]

Assumptions

For pack-based measures, 54% is the average installation rate for aerators,[51,52] while 65% is the average installation rate for showerheads.[52,53] These installation rates were applied to account for some water measures not actually being installed. Direct install measures are typically assumed to have an in-service rate of 100%, but showerhead assumptions were adjusted to 90% to account for evaluation survey findings indicating that some showerheads were removed or never installed.[50]

Pack-based measures claim both natural gas and electric savings, weighted at 73% and 20%, respectively, as found in the 2016 *Potential Study*[59] (7% of single-family homes had propane water heaters). 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.[57] The peak values were taken from the time period from 1 p.m. to 4 p.m.

The shower length was determined using the U.S Department of Energy's "Domestic Hot Water Scheduler,"[54] using the average water main temperature of all locations measured in Wisconsin, weighted by city populations.

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[57] DeOreo, William B. *The End Uses of Hot Water in Single Family Homes From Flow Trace Analysis*. Figure 2. Available online: http://s3.amazonaws.com/zanran_storage/www.aquacraft.com/ContentPages/47768067.pdf
The peak percentage values of 9% and 13% for showerheads and aerators, respectively, determined from the load shape in Figure 2 for the hours between 1 p.m. and 4 p.m.

[58] New York Department of Public Service. *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs: Selected Residential & Small Commercial Gas Measures*. March 25, 2009. http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/766a83dce56eca35852576da006d79a7/$FILE/60_DAy_Gas_TecMarket_Energy_Savings_Manual_Final_1-0.pdf

[59] In the *Potential Study*, of 95.8 site-weighted single-family homes visited, 70.0 had natural gas hot water, 19.2 had electric hot water, and 6.6 had propane hot water.

The variable kitchen aerator can be changed by the user to 0.5, 1.0, or 1.5 GPM depending on the flow needed for the task. It assumed that equal time would be spent at each flow rate, and that the average GPM would be the average of 0.5, 1.0, and 1.5, or 1.0 GPM.

Evaluated Savings

Table 31 shows annual and lifetime savings for these aerator measures.

Table 31. Evaluated Savings for Aerator Measures

Measure	MMID	Sector	Peak kW	Annual kWh	Lifecycle kWh	Annual therms	Lifecycle therms
Faucet Aerator, Pack Based, 1.5 GPM, Kitchen	3862	SF	0.0016	33.1	331	6.3	63
Faucet Aerator, Direct Install, 1.0 GPM, Bathroom, Residential: Natural Gas	2137	SF	0	0	0	3.8	38
		MF	0	0	0	4.5	45
Faucet Aerator, Pack Based, 1.0 GPM, Bathroom, Residential	3863	SF	0.0008	7.8	78	1.5	15
Showerhead, Pack Based, 1.5 GPM	3864	SF	0.0023	43.2	432	8.3	83
Faucet Aerator: 1.5 GPM, Kitchen, Electric	3026	SF	0.0144	306	3,060	0	0
		MF	0.0138	225	2,250	0	0
Faucet Aerator: 1.5 GPM, Kitchen, Natural Gas	3025	SF	0	0	0	16.1	160
		MF	0	0	0	9.9	100
Faucet Aerator: 1.0 GPM, Kitchen, Electric	3506	SF	0.0247	525	5,250	0	0
		MF	0.0237	386	3,860	0	0
Faucet Aerator: 1.0 GPM, Kitchen, Natural Gas	3507	SF	0	0	0	27.6	280
		MF	0	0	0	17.0	170
Faucet Aerator: 0.5 GPM, Kitchen, Electric	3509	SF	0.0350	744	7,440	0	0
		MF	0.0336	546	5,460	0	0
Faucet Aerator: 0.5 GPM, Kitchen, Natural Gas	3510	SF	0	0	0	39.1	390
		MF	0	0	0	24.0	240
Faucet Aerator: 1.5 GPM, Bathroom, Electric	3028	SF	0.0042	42	420	0	0
		MF	0.0041	60	600	0	0
Faucet Aerator: 1.5 GPM, Bathroom, Natural Gas	3027	SF	0	0	0	2.2	20
		MF	0	0	0	2.6	30
Faucet Aerator: 1.0 GPM, Bathroom, Electric	2143	SF	0.0073	73	730	0	0
		MF	0.0070	102	1,020	0	0
Faucet Aerator: 0.5 GPM, Bathroom, Natural Gas	3508	SF	0	0	0	5.4	50
		MF	0	0	0	6.4	60
Faucet Aerator: 1.5 GPM, Shower, Electric	3030	SF	0.0178	332	3,320	0.0	0
		MF	0.0170	400	4,000	0.0	0
Faucet Aerator: 1.5 GPM, Shower, Natural Gas	3029	SF	0	0	0	17.5	170
		MF	0	0	0	17.6	180
Faucet Aerator, Direct Install, 0.5/1.0/1.5 Variable GPM, Kitchen, Electric	3919	SF	0.0247	525	5,250	0	0
		MF	0.0237	386	3,860	0	0
	3920	SF	0	0	0	27.6	280

Measure	MMID	Sector	Peak kW	Annual kWh	Lifecycle kWh	Annual therms	Lifecycle therms
Faucet Aerator, Direct Install, 0.5/1.0/1.5 Variable GPM, Kitchen, Natural Gas		MF	0	0	0	17.0	170
Faucet Aerator, Showerhead, Direct Install, 1.25 GPM, Electric	3921	SF	0.0120	373	3,730	0	0
		MF	0.0115	450	4,500	0	0
Faucet Aerator, Showerhead, Direct Install, 1.25 GPM, Natural Gas	3922	SF	0	0	0	19.6	200
		MF	0	0	0	19.8	200

Commercial Water Heaters

Cadmus recorded hot water setpoints for 132 schools, offices, restaurants, and retail sites as part of the 2016 *Potential Study*. The average hot water setpoint of 130°F can affect savings for nonresidential hot water heater measures (MMIDs 3045, 3046, and 3684). Currently, in cases where the setpoint is not known, these measures assume a hot water setpoint of 125°F. The new savings algorithms for these measures are presented below.

Annual Energy-Savings Algorithm

$\text{Btu}_{\text{SAVED}} = \text{GPY} * 8.33 * 1.0 * \Delta T * [(1 / \text{EF}_{\text{BASELINE}}) – (1 / \text{EF}_{\text{EFFICIENT}})]$

For electric water heaters: $\text{kWh}_{\text{SAVED}} = \text{Btu}_{\text{SAVED}} / 3{,}412$

For natural gas water heaters: $\text{Therm}_{\text{SAVED}} = \text{Btu}_{\text{SAVED}} / 100{,}000$

Where:

GPY = Gallons per year of domestic hot water usage (= derived from days per year of operation and gallons per day shown in Table 32)

8.33 = Density of water in pounds per gallon

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

ΔT = Water temperature change produced by the domestic hot water heater (= 52.3°F as user-defined on application.[54] If actual water heater setpoint temperature is unknown, = 130°F as default)[60]

$\text{EF}_{\text{BASELINE}}$ = Efficiency metric for baseline domestic hot water heater

$\text{EF}_{\text{EFFICIENT}}$ = Efficiency metric for efficient domestic hot water heater

3,412 = Conversion factor for Btu per kWh

100,000 = Conversion factor for Btu per therm

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[60] This is the average hot water setpoint of 130°F for water heaters at schools, offices, restaurants, and retail sites, recorded as part of the *Focus on Energy 2016 Energy Efficiency Potential Study*.

Table 32. 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 2011, Chapter 50, Table 7[1]
Motels and Hotels ≤20 rooms/suites 21 to 99 rooms/suites ≥100 rooms/suites	20 per room 14 per room 10 per room	ASHRAE HVAC Applications 2011, Chapter 50, Table 7
Dormitories	12.7 per student	ASHRAE HVAC Applications 2011, Chapter 50, Table 7 (average of 13.1 for male dormitory and 12.3 for female dormitory)
Prison Housing	12.7 per inmate	ASHRAE HVAC Applications 2011, Chapter 50, Table 7 (average of 13.1 for male dormitory and 12.3 for female dormitory; prison housing water usage is assumed to be similar to the dormitories category)
Hospital	50 per bed	http://smud.apogee.net/comsuite/content/ces/?id=971 (report lists a range of 25 to 90 gallons/day/bed, used 50, which is conservative based on the 57.5 midpoint)[2]
Nursing Homes	18.4 per bed	ASHRAE HVAC Applications 2011, Chapter 50, Table 7
Food Service Full Service Restaurant Cafeteria Fast Food	2.4 per meal 2.4 per meal 350 per day	Full service and cafeteria: ASHRAE HVAC Applications 2011, Chapter 50, Table 7 Fast food: ASHRAE HVAC Applications 2011, Chapter 50, page 50.15 (report lists range of 250 to 500, use 350 as the midpoint)
Supermarket	650 per day	ASHRAE HVAC Applications 2011, Chapter 50, page 50.15 (report lists range of 300 to 1,000, use average of 650)
Laundry	21 per wash	ASHRAE HVAC Applications 2011, Chapter 50, page 50.12 (for low-flow clothes washer)

[1] American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc. *ASHRAE Handbook, HVAC Applications*. Chapter 50 “Service Water Heating.” 2011.

[2] U.S. Department of Energy. “Domestic Hot Water Scheduler.”

Summer Coincident Peak Savings Algorithm

Water heater demand reduction is a function of building type, because it is a function of whether or not—at the time of participant interest—the units are operating intermittently to compensate for heat losses through the tank and surrounding insulation, or if they are operating at a constant level to heat the incoming water that is replacing hot water.

A careful study to analyze demand reduction in various facility types has not been performed, largely because the amount of reduction will be quite small. For this reason, and because the power rating of storage type electric water heaters is the same for the baseline and efficient models, zero demand reduction is assumed for all storage type heaters. For heat pump DHW heaters, there will be savings due to different power ratings.

Electric and Natural Gas Storage Domestic Hot Water Heaters

There are no summer coincident peak savings for storage domestic hot water heaters.

Electric Heat Pump Domestic Hot Water Heaters

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

Where:

CF = Coincidence factor, or the ratio of expected power demand at utility peak system demand to the maximum connected load of an item of equipment (= varies by facility type; see Table 33)

FUF = Facility use factor, or the ratio of facility use at the time of utility peak system demand to the maximum facility use; this is a function of facility type. For dormitories, it should reflect summer occupancy relative to maximum occupancy. Similarly, for other facility types, it should account for summer weekday occupancy factors that affect domestic hot water usage (= project-specific values; otherwise use the set of typical FUF values shown in Table 33)

$kW_{BASELINE}$ = Power rating of the baseline domestic hot water heater

Table 33. Coincidence Factors and Facility Use Factors[1]

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[2]	0.25	1.00
Nursing Homes	0.35	1.00
Hospital (assume same values as nursing home)	0.35	1.00
Office Buildings	0.15	0.90
Food Service	0.40	1.00
Apartment Houses	0.25	0.90
Supermarkets	0.15	1.00
Laundry	0.50	1.00

[1] Coincidence factors and facility use factors were developed by seeking consensus among a small group of seven engineers with experience performing energy audits in commercial and industrial facilities.

[2] These values exclude motel and hotel restaurants, kitchens, and laundries.

Lifecycle Energy-Savings Algorithm

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

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

Where:

EUL = Effective useful life (= 15 years for natural gas storage, freestanding water heaters; = 13 years for natural gas tankless and electric heat pump)[61,62]

Attic and Wall Insulation

Ninety-two multifamily sites were visited as part of the 2016 *Potential Study*, and the heating AFUE (for natural gas furnaces or boilers) was recorded at many of these sites. Cadmus obtained central heating AFUE values for 23 sites, revealing an average of 83.6%. Cadmus obtained in-unit AFUE values for 15 sites, revealing an average of 85.6%. Of the 92 sites visited, 58.7% had central heating and 41.3% had in-unit heating. Therefore, the average AFUE for natural gas heating in multifamily sites is 84%.

This value can inform the savings for wall and attic insulation. The recommended updates to savings algorithms are shown below.

Annual Energy-Savings Algorithm, Wall Insulation Measures

$Therm_{SAVED} = ((1 / R_{BASE} - 1 / R_{EE}) * Area * (1 - FramingF)) * 24 * HDD / (100,000 * AFUE)$

$kWh_{SAVED} = kWh_{SAVED\_HEAT} + kWh_{SAVED\_COOL}$

$kWh_{SAVED\_HEAT} = ((1 / R_{BASE} – 1 / R_{EE}) * Area * (1 – FramingF)) * 24 * HDD / (1,000 * HSPF)$

$kWh_{SAVED\_COOL} = ((1 / R_{BASE} - 1 / R_{EE}) * Area * (1 - FramingF)) * 24 * CDD / (1,000 * SEER)$

Where:

R_{BASE} = Existing condition insulation R-value (= 5)

R_{EE} = Efficient condition insulation R-value (= 20)

Area = Wall area to be insulated in square feet

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[61] California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." EUL Table. 2014. Available online: http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx

[62] U.S. Department of Energy. *2010 Residential Heating Products, Final Rule*. p. 8-52. Available online: http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch8.pdf Used by Illinois TRM, Version 5.0: http://www.ilsag.info/il_trm_version_5.html

FramingF = Adjustment to account for area of framing (= 25%)[63]

HDD = Heating degree days (= 7,616; see Table 34)

AFUE = Natural gas heating system efficiency (= 84%)[64]

HSPF = Electric heating system efficiency (= 3.412 for electric resistant heat)

CDD = Cooling degree days (= 565; see Table 34)

SEER = Cooling system efficiency (= 13)[65]

Table 34. Heating and Cooling Degree Days by Location

Location	HDD[1]	CDD[1]
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**

[1] Wisconsin *Focus on Energy. Deemed Savings Changes*. November 14, 2014. Available online: https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

Summer Coincident Peak Savings Algorithm, Wall Insulation Measures

$kW_{SAVED} = (kWh_{SAVED\_COOL} / EFLH_{COOL}) * CF$

Where:

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 410)[6]

CF = Coincidence factor (= 0.68)[66]

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[63] ASHRAE Estimation of Degree-Days: Fundamentals, Chapter 14. (TMY3 weather files of the seven Wisconsin locations)
2010 US Census data for Wisconsin. (statewide weighted values)

[64] This is the average natural gas AFUE for 38 multifamily sites, recorded as part of the *Focus on Energy 2016 Energy Efficiency Potential Study*. Twenty-three sites had an average central heating AFUE of 83.6% while 15 sites had an in-unit heating AFUE of 85.6%, and sites had a 58.7%/41.3% split of central/in-unit heating.

[65] Appliance Standards Awareness Project. "Central Air Conditioners and Heat Pumps." Available online: http://www.appliance-standards.org/product/central-air-conditioners-and-heat-pumps

[66] Wisconsin Focus on Energy. Deemed Savings Changes. November 14, 2014. Available online: https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

Lifecycle Energy-Savings Algorithm, Wall Insulation Measures

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

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

Where:

EUL = Effective useful life (=25 years)[67]

Evaluated Savings, Wall Insulation Measures

Table 35 shows annual and lifetime savings for these wall insulation measures.

Table 35. Evaluated Savings for Wall Insulation Measures (per sq ft)

Measure	MMID	Peak kW	Annual kWh	Lifecycle kWh	Annual therms	Lifecycle therms
Insulation, Wall: Natural Gas Heat with Cooling	3703	0.0002	0.117	2.934	0.245	6.120
Insulation, Wall: Natural Gas Heat without Cooling	3704	0	0	0	0.245	6.120

Annual Energy-Savings Algorithm, Attic Insulation Measures

$Therm_{SAVED} = ((1 / R_{BASE} – 1 / R_{EE}) * HDD * 24 * Area) / (100,000 * AFUE)$

$kWh_{SAVED} = kWh_{SAVED\_HEAT} + kWh_{SAVED\_COOL}$

$kWh_{SAVED\_HEAT} = ((1 / R_{BASE} – 1 / R_{EE}) * HDD * 24 * Area) / (1,000 * HSPF)$

$kWh_{SAVED\_COOL} = ((1 / R_{BASE} – 1 / R_{EE}) * CDD * 24 * Area) / (1,000 * SEER)$

Where:

R_{BASE} = Existing R-value of attic (= 11 or = 19)

R_{EE} = Proposed R-value of attic after retrofit (= 38)

HDD = Heating degree days (= 7,616; see Table 35)

24 = Hours per day

Area = Attic area to be insulated (in square feet)

100,000 = Conversion from Btu to therms

AFUE = Natural gas heating system efficiency (= 84%)[64]

1,000 = Kilowatt conversion factor

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[67] GDS Associates. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*. Table 1, Insulation. June 2007. Available online: https://library.cee1.org/system/files/library/8842/CEE_Eval_MeasureLifeStudyLights%2526HVACGDS_1Jun2007.pdf

HSPF = Electric heating system efficiency (= 3.412 for electric resistance heat, the number of Btu in a watt-hour)

CDD = Cooling degree days (= 565; see Table 35)

SEER = Cooling system efficiency (= 13)[65]

Summer Coincident Peak Savings Algorithm, Attic Insulation Measures

$kW_{SAVED} = (kWh_{SAVED\_COOL} / EFLH_{COOL}) * CF$

Where:

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 410)[6]

CF = Coincidence factor (= 0.68)[66]

Lifecycle Energy-Savings Algorithm, Attic Insulation Measures

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

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

Where:

EUL = Effective useful life (= 25 years)[67]

Evaluated Savings, Attic Insulation Measures

Table 36 shows annual and lifetime savings for these wall insulation measures.

Table 36. Evaluated Savings for Attic Insulation Measures (per sq ft)

Measure	MMID	Peak kW	Annual kWh	Lifecycle kWh	Annual therms	Lifecycle therms
Natural Gas Heat with Cooling, Existing Insulation ≤R-11	3707	0.0001	0.0674	1.6844	0.1406	3.5139
Natural Gas Heat without Cooling, Existing Insulation ≤R-11	3708	0	0	0	0.1406	3.5139
Natural Gas Heat with Cooling, Existing Insulation R-12 to R-19	3709	0.0001	0.0274	0.6862	0.0573	1.4316
Natural Gas Heat, without Cooling, Existing Insulation R-12 to R-19	3710	0	0	0	0.0573	1.4316

Air Sealing

The savings algorithms for air sealing measures are similar to those used for insulation measures. One difference is that the AFUE values are split into condensing (AFUE <90%) and noncondensing (AFUE ≥90%) groups. Of the multifamily AFUE data points outlined for the wall and attic insulation measures, 17 sites had known central noncondensing AFUE values, with an average of 80.81%. Eight sites had known in-unit noncondensing AFUE values, with an average of 79.79%. These groups combine, using the central versus in-unit weighting outlined above, for an average noncondensing multifamily AFUE of 80%. This differs from the currently assumed value of 78% for air sealing measures.

Of the multifamily AFUE data points outlined for the wall and attic insulation measures, six sites had known central condensing AFUE values, with an average of 91.67%. Seven sites had known in-unit condensing AFUE values, with an average of 92.21%. These groups combine, using the central versus in-unit weighting outlined above, for an average condensing multifamily AFUE of 92%. This is the same as the value currently assumed in the Wisconsin TRM.

Updated savings algorithms for the air sealing measure are presented below.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{SAVED\ COOL} + kWh_{SAVED\ HEAT}$

Systems with Cooling Installed

$kWh_{SAVED\ COOL} = [\{((CFM50_{PRE} - CFM50_{POST}) / N_{COOL}) * 60 * 24 * CDD * 0.018\} / (1{,}000 * Cool_{EFF})] * LM$

Systems with Electric Heat

$kWh_{SAVED\ HEAT} = [((CFM50_{PRE} - CFM50_{POST}) / N_{HEAT}) * 60 * 24 * HDD * 0.018] / (3{,}412 * Heat_{EFF})$

Systems with Natural Gas Heat

$Therm_{SAVED} = [((CFM50_{PRE} - CFM50_{POST}) / N_{HEAT}) * 60 * 24 * HDD * 0.018] / (100{,}000 * Heat_{EFF})$

Where:

$CFM50_{PRE}$ = Blower door test result before air sealing is performed

$CFM50_{POST}$ = Blower door test result after air sealing is performed

N_{COOL} = Conversion factor for CFM from 50 Pascal to natural conditions (= 18.5 assuming normal shielding)

60 = Conversion from minutes to hours

24 = Hours per day

CDD = Cooling degree days (= 565; see Table 34)

0.018 = Specific heat capacity of air (Btu/cubic feet – °F)

1,000 = Kilowatt conversion factor

$Cool_{EFF}$ = Cooling system efficiency in Btu/(W * hr) (= 10 SEER if manufactured before 2006; = 13 SEER if manufactured in 2006 or later)

LM = Latent multiplier to convert the calculated sensible cooling savings to a value representing sensible and latent cooling loads (= 6.6 as an average of Chicago and Minneapolis)[68]

N_{HEAT} = Conversion factor for CFM from 50 Pascal to natural conditions, assuming normal shielding (= 18.5 if one story; = 16.5 if 1.5 stories; = 15.0 if two stories; = 14.1 if 2.5 stories; = 13.3 if three stories)[69]

HDD = Heating degree days (= 7,616; see Table 34)

3,412 = Conversion factor from kWh to Btu

$Heat_{EFF}$ = Heating system efficiency (fraction of heat output per unit of energy input expressed as a decimal)

100,000 = Conversion factor from Btu to therms

For systems with electric heat, $Heat_{EFF}$ = HSPF/3.412

- Heat pumps manufactured before 2006, $Heat_{EFF}$ = 6.8/3.412 = 1.99
- Heat pumps manufactured in 2006 or later, $Heat_{EFF}$ = 7.7/3.412 = 2.26
- Electric resistance, $Heat_{EFF}$ = 1.0

Installed AFUE for systems with natural gas heat:

- $Heat_{EFF}$ = 0.92 for condensing systems[70]
- $Heat_{EFF}$ = 0.80 for noncondensing systems[71]

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[68] Harriman et al. “Dehumidification and Cooling Loads From Ventilation Air.” ASHRAE Journal.
Cadmus added the latent and sensible loads to determine the total (using averages from Chicago and Minneapolis to represent Wisconsin), then divided by the sensible load.

[69] Lawrence Berkeley National Laboratory. *Building Performance Institute Building Analyst Technical Standards.* Available online: http://www.bpi.org/tools_downloads.aspx?selectedTypeID=1&selectedID=2

[70] This is the average natural gas condensing AFUE for 13 multifamily sites, recorded as part of the *Focus on Energy 2016 Energy Efficiency Potential Study*. Six sites had an average central heating condensing AFUE of 91.7% while seven sites had an in-unit heating condensing AFUE of 92.2%, and sites had a 58.7%/41.3% split of central/in-unit heating. Cadmus considered units with AFUE ≥90% as condensing.

[71] This is the average natural gas noncondensing AFUE for 25 multifamily sites, recorded as part of the *Focus on Energy 2016 Energy Efficiency Potential Study*. Seventeen sites had an average central heating noncondensing AFUE of 80.8% while eight sites had an in-unit heating non-condensing AFUE of 79.8%, and sites had a 58.7%/41.3% split of central/in-unit heating. Cadmus considered units with AFUE <90% as noncondensing.

Summer Coincident Peak Savings Algorithm

Systems with Central Air Conditioning

$kW_{SAVED} = (kWh_{SAVED\ COOL} / EFLH_{COOL}) * CF$

Where:

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 380; see table below)

CF = Coincidence factor (= 0.66)[72]

Table 37. Supporting Inputs for Load Hours in Several Wisconsin Cities

Location	$EFLH_{COOL}$[1]
Green Bay	344
La Crosse	323
Madison	395
Milwaukee	457
Wisconsin Average	**380**

[1] Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. November 14, 2014. Available online: https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

Lifecycle Energy-Savings Algorithm

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

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

Where:

EUL = Effective useful life (= 20 years)[67]

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[72] Opinion Dynamics Corporation. *Delaware Technical Resource Manual*. April 30, 2012. Available online: http://www.dnrec.delaware.gov/energy/information/otherinfo/Documents/EM-and-V-guidance-documents/DELAWARE_TRM_August%202012.pdf