State of Minnesota Technical Reference Manual for Energy Conservation Optimization Programs

VERSION 5.0

FINAL

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COMMERCE DEPARTMENT

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Acknowledgements

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Purpose and Use of Manual

The purpose of this technical reference manual (TRM) is to put forth standard methodologies and inputs for calculating the savings impacts and cost-effectiveness of Energy Conservation and Optimization (ECO) Programs in Minnesota.

The TRM is not intended to define a single set of approved calculation methods; rather, the TRM is a standard set of methodologies and inputs that ECO administrators may reference when developing, implementing, and reporting on ECO programs. Each measure herein represents a pre-approved calculation method when correctly applied in a program. While Commerce encourages utilities to use the TRM measure designs, utilities may propose, with justification, variations that reflect different program designs or enhanced calculation methods that will result in more accurate savings estimations. Utilities may also use the TRM to generate tables of unitary "deemed savings" figures for pre- and post-installation values for predefined equipment combinations if their current tracking software requires this format.

Similarly, the TRM does not represent an exclusive set of measures that may be applied in ECO programs. Minnesota utilities may propose additional measures as standard offerings in their ECO plans or implement custom measures without pre-approval from Commerce.

Summary of Changes from TRM v4.2

Measure	Version/Description
Overarching Modifications	
ENERGY STAR	Clarified throughout (primarily Res Appliances and C/I Food Service) that compliant efficient appliances do not need to be ENERGY STAR qualified through the EPA program but would need to meet the current ENERGY STAR performance criteria specifications, specified within each measure by product type. Removed "ENERGY STAR" from titles
Measure IDs	Added numeric IDs to each measure. Level 1 number is sector (Res, C/I), level 2 number is category (HVAC, Lighting) and category numbers the same across sectors, level 3 number aligned sequentially to each measure within each category. Some minor reorganization of measures and categories occurred in this version prior to numbering.
Incremental Costs	Minor updates to incremental costs throughout where data available from MN stakeholders, primarily limited to this summary of measures modified.
Definitions	Added a “Definitions” Section inclusive of definitions for “Prescriptive Measure”, “Custom Project,” And baseline definitions for “New Construction,” “Replace on Fail,” and “Early Replacement.”
Residential $EFLH_{HEAT}$	Updated the $EFLH_{HEAT}$ value for Climate Zone 2 (Central MN) to match the $EFLH_{HEAT}$ value for Climate Zone 3 (Southern MN/Twin Cities) for applicable residential HVAC measures.
Install Rate	Included Install Rates for the below measures: • Residential HVAC – Thermostats, • Residential Hot Water – Electric Water Heater Setback, • Residential Hot Water – Faucet Aerator with Electric Water Heater, • Residential Hot Water – Faucet Aerator with Gas Water Heater, • Residential Hot Water – Gas Water Heater Setback, • Residential Hot Water – Low Flow Showerheads with Elec WH • Residential Hot Water – Low Flow Showerheads with Gas Water • Heater, Residential Hot Water – Pipe Insulation with Electric Water • Heater, Residential Hot Water – Pipe Insulation with Gas Water • Heater, Residential Misc – Plug Load - Tier 1 Advanced Power Strips, • Residential Misc – Plug Load - Tier 2 Advanced Power Strips, • Commercial Plug Load – Tier 1 Advanced Power Strips, • Commercial Plug Load – Tier 2 Advanced Power Strips
Res Single Family Default Baseline Furnace Efficiency	The default baseline furnace efficiency has been modified from 80% to 90%. See Methodology in Res HVAC – Furnaces and Boilers measure for more detail as to the context and references. The baseline change has been made in the following measures in version 5.0: • Res HVAC – Furnace and Boilers • Res HVAC – Furnace Quality Install and Maintenance • Res HVAC – ASHP • Res HVAC – GSHP

Measure	Version/Description
	• Res Envelope – Insulation There are additional measures that use a current furnace baseline of 80% that were unable to be updated fully in version 5.0 due to resource constraints. The following measures are planned for res furnace baseline update to 90% in version 5.1, but remain at 80% in version 5.0: • Res Envelope – Low E Storm Windows • Res Envelope – Cellular Shades
Residential Measures	
Residential HVAC - Window or Room A/C or ASHP	Expanded measure to include window ASHP units, clarified scope of eligible equipment and baseline conditions. Expanded algorithm to allow for kWh heating savings for ASHPs replacing electric resistance heating.
Residential HVAC - A/C or ASHP Tune Up	Split actions and savings factors for the more enhanced actions. Reduced EUL for general maintenance actions to 1 year (from 2 years). Clarified algorithm operation for the Savings Factor metrics
Residential HVAC – Air Source Heat Pump Systems (ASHP)	Updated the $EFLH_{HEAT}$ value for Climate Zone 2 (Central MN) to match the $EFLH_{HEAT}$ value for Climate Zone 3 (Southern MN/Twin Cities) Updated the baseline efficiency for Furnaces in single-family homes to 90% in some applications with a caveat in the algorithm based methodology. This update will be included in the BEopt modeled methodology prior to the end of Q1 2026 when an updated Appendix G will be published.
Residential HVAC - Air to Water Heat Pumps (AWHP)	New measure developed.
Residential HVAC - Ground Source Heat Pumps (GSHP)	Clarification to inputs definitions, updates to incremental costs, updates to resources referenced, EFS baseline added to measure. Updated the $EFLH_{HEAT}$ value for Climate Zone 2 (Central MN) to match the $EFLH_{HEAT}$ value for Climate Zone 3 (Southern MN/Twin Cities). Updated the baseline efficiency for Furnaces in single-family homes to 90% in some applications with a caveat.
Residential HVAC – ECM Blower Motors	Updated the information required from Customer/Contractor to include the "AFUE of the existing furnace." No default value can be assumed if this information is not provided.
Residential HVAC - ECM Circulators	Updated several references to more current sources of data. Modified algorithm layout and variables for clarity. Modified deemed savings based on smaller motor more applicable to residential application. Updated Algorithm formatting.
Residential HVAC - ERV	New measure developed.
Residential HVAC – Furnaces and Boilers	Updated the $EFLH_{HEAT}$ value for Climate Zone 2 (Central MN) to match the $EFLH_{HEAT}$ value for Climate Zone 3 (Southern MN/Twin Cities). Updated the baseline efficiency for Furnaces in single-family homes to 90% in Replace on Fail and Replace Early applications with a caveat.

Measure	Version/Description
Residential HVAC – Furnace Quality Installation/Maintenance	Updated the $EFLH_{HEAT}$ value for Climate Zone 2 (Central MN) to match the $EFLH_{HEAT}$ value for Climate Zone 3 (Southern MN/Twin Cities). Updated the baseline efficiency for Furnaces in single-family homes to 90% in some applications with a caveat.
Residential Envelope – Insulation and Air Sealing	Updated the baseline efficiency for Furnaces in single-family homes to 90% in some applications with a caveat.
Residential Hot Water - Heat Pump Water Heater	Edits to input variable $Energy_{HEATWATER}$ to reference water consumption in gallons per day uniformly, some references to consumption in gallons per person remained from last update in 4.2. The examples were modified to align with using the average MN climate zone rather than a specific zone.
Residential Hot Water - Desuperheater	New measure developed in coordination with updates to Res HVAC GSHP measure.
Residential Appliances - Air Purifiers	Updated ENERGY STAR reference standard to version 3.0.
Residential Appliances - Clothes Washers	Updated ENERGY STAR reference standard to version 9.0.
Residential Appliances - Clothes Dryers	Updated ENERGY STAR reference standard to version 2.0.
Residential Appliances - Induction Ranges and Cooktops	New measure developed
Commercial and Industrial Measures	
C/I Food Service - Electric Cooktops, Ovens and Ranges	Simplified algorithm inputs, removed HVAC interactive effects and aligned building type metrics with other commercial food service measures.
C/I Compressed Air - VFD Air Compressors	Modified upper limit for this measure to 200 HP from 50 HP
C/I HVAC – ECM Fan Motors	Modified upper limit for this measure to 3 HP from 1 HP. Minor clarifications made within measure
C/I HVAC – ECM Circulators	Updated several references to more current. Modified algorithm layout for clarity. Modified deemed savings based on different sized motors
C/I HVAC – Heat Pump RTU	Added 'Other / Unknown' category with data from the study team's expanded findings
C/I HVAC - Heat Pump Systems	Added performance criteria tables for GSHP and PTHP, update to incremental costs.
C/I HVAC – Mini Split Ductless Systems (A/C or Heat Pump)	Measure title change and minor description updates, updates to example
C/I HVAC – ERV	Added CARD study reference to support updates to metrics presented in measure. Added kWh heating savings for ASHP electric heating systems.
C/I Refrigeration - Demand Defrost Controls	Corrected the conflicting default values between variable input list and Methodology write up. Corrected algorithm discrepancy between primary algorithm and example algorithm. Added missing variable definitions. Checked reference notations. Aligned referenced COP value to other C&I Refrigeration measures.

Measure	Version/Description
C/I Refrigeration - Door Gasket Replacements	New measure developed
C/I Misc - Electric Forklifts	New measure developed
C/I Lighting – LED Grow Lights	New measure developed
Electric Utility Infrastructure Measures	
N/A	N/A
Appendices	
Appendix B – Commercial Lighting Tables	Corrected Proposed Wattage values, incorrectly identified as 16Ws.
Appendix F – Standard Conversion Factors	Updates to emissions values based on updated source data (MROW, GWP factors). Ensured consistent calculation and representation of CO2e (distinct from CO2) with original EPA sources, for stationary versus mobile combustion sources. Modifications made to emissions values in Appendix F in turn resulted in modifications to deemed emissions tables within several EFS measures.
Appendix G – Residential HVAC – ASHP Model and Calculator	Updated the $EFLH_{HEAT}$ value for Climate Zone 2 (Central MN) to match the $EFLH_{HEAT}$ value for Climate Zone 3 (Southern MN/Twin Cities) Update to emissions values to align with Appendix F. Addition of AWHP calculation tab. Updated the baseline efficiency for Furnaces in single-family homes to 90% in some applications with a caveat in the algorithm based methodology. This update will be included in the BEopt modeled methodology prior to the end of Q1 2026 when an updated Appendix G will be published.

Definitions

Prescriptive Measure

Energy or load reduction or load management measure that provides efficiency solutions to situations that are amendable to fully or partially deemed savings calculations or values. Typically, they are one-for-one replacements for existing equipment or the equipment that would have been installed in lieu of the associated prescriptive measure.

Custom Project

Energy or load reduction or load management project with one or more non-prescriptive measures or a project with multiple interactive prescriptive measures such that the operation of each measure is affected by one or more of the other measures.

Replace on Failure Baseline

For equipment being replaced upon failure (which is unresolvable or cost prohibitive to resolve) or after the end of its measure life, the comparative baseline to the newly installed equipment is defined:

- at the current building or energy code, or equipment standard applicable to the equipment, or
- at a higher threshold when research suggests standard practice is higher than building or energy code or equipment standard.

Early Replacement Baseline

For equipment being replaced before the end of its measure life, the comparative baseline to the newly installed equipment is the specification of the existing equipment.

Existing equipment should be in operational order or require nominal repair expenses to return the equipment to functional order, as confirmed by the contractor servicing/replacing the equipment.

Where the existing equipment efficiency specification is not known or cannot be attained, the default baseline of the “New Construction” and “Replace on Failure” baseline scenarios should be used.

New Construction Baseline

For newly installed equipment in ground up new construction or major renovations, where there is no existing equipment, the comparative baseline to the newly installed equipment is defined:

- at the current building or energy code, or equipment standard applicable to the equipment, or
- at a higher threshold when research suggests standard practice is higher than building or energy code or equipment standard.

Residential

Lighting

Residential Lighting – Lighting End Use

Measure Detail	Measure Value
Measure ID	1.01.01
Target Market Segments	Residential, Commercial, Multifamily
Target End Uses	Lighting
Required from Customer/Contractor	Existing fixtures and quantities (retrofits only), installed fixtures and quantities, space type (interior living quarters, multifamily (2+ units) common areas, or exterior/unconditioned space), HVAC system (heating only, heating & cooling, exterior/unconditioned)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	See each technology section
Unit Participant Incremental Cost	See each technology section

Measure Description

The residential lighting measures use a standard set of variables for hours of use, HVAC cooling interaction effects, in service rates (ISRs), and coincident factors. The following section provides the algorithms used for energy savings and the tables of supporting information.

Algorithms

Unit kWh Savings per Year = (kW_Base – kW_EE) x Hrs x HVAC_cooling_kWhsavings_factor x Install Rate

Unit Peak kW Savings = (kW_Base – kW_EE) x CF x HVAC_cooling_kWsavings_factor x Install Rate

Unit Dth Savings per Year = (kW_Base – kW_EE) x Hrs x HVAC_heating_penalty_factor x Install Rate

Where:

kW_EE = Deemed average wattage efficient luminaire per each section

kW_Base = Deemed average wattage of baseline luminaire per each section

Hrs = Deemed annual operating hours from Table 2 based on building type.

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in Table 2.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting (Ref. 3).

ISR = In service rate, the average percentage of product installed as intended depending on the method of distribution and installation, See Table 3.

Example:

A customer purchases at a retail store and installs an LED to replace an incandescent lamp in a single-family home with Central A/C.

kWh = (0.0467-0.019) x 938 *1.075 x 73% = 20.4 kWh

kW = 0.095 *(0.0467-0.019) x 1.248 x 73% = 0.0024 kW

Deemed Input Tables

Table 1. HVAC Interactive Factors by HVAC System (Ref. 1)

Space Type	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only or Heating & Cooling
Interior Living Quarters	1.00	1.248	1.00	1.075	-0.0029
Multifamily Common Areas	1.00	1.248	1.00	1.075	-0.0029
Exterior/Unconditioned Space	1.00	1.00	1.00	1.00	0
Interior Living Quarters – Cooling Unknown	1.16		1.048		-0.0029
Multifamily Common Areas – Cooling Unknown	1.11		1.034		-0.0029

*For non-direct install delivery methods use the Cooling Unknown HVAC values.

Table 2. Deemed Peak Demand Coincidence Factors (Ref. 2 and 5) and Annual Operating Hours by Space Type

Space Type	CF	Hrs	Reference
Interior Living Quarters	9.5%	938	3
Multifamily Common Areas	75%	5,950	4
Exterior/Unconditioned Space	0%	1,825	3

Table 3. Install Rate based on Delivery Method

Delivery Method	Install Rate	Reference
Direct Install	97%	6
Retail	73%	7
Distributed School Efficiency Kit	61%	8
Requested Kit	66%	9

Methodology and Assumptions

HVAC cooling and heating interactive factor data based on DOE2/eQuest building simulation.

The prototypes building models are based on the California DEER study prototypes and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

References

1. Calculated through energy modeling by FES 2012
2. Based on lighting logger study conducted as part of the PY3 ComEd Residential Lighting Program evaluation. "ComEd Residential Energy Star Lighting Program Metering Study: Overview of Study Protocols" http://www.icc.illinois.gov/downloads/public/edocket/303835.pdf
   "Memo RE: Lighting Logger Study Results – Version 2, Date: May 27, 2011, To: David Nichols and ComEd Residential Lighting Interested Parties, From: Amy Buege and Jeremy Eddy; Navigant Evaluation Team" http://www.icc.illinois.gov/downloads/public/edocket/303834.pdf
3. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 7.5 based on lighting logger study conducted as part of the PY3 ComEd Residential Lighting Program evaluation.
4. Multifamily common area lighting assumption is 16.3 hours per day (5950 hours per year) based on Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010.
5. Coincidence factor is based on healthcare/clinic value (used as proxy for multifamily common area lighting with similar hours of use) developed using eQuest models for various building types averaged across five climate zones for Illinois for the following building types.
6. Based upon review of the Illinois PY2 and PY3 ComEd Direct Install program surveys and consistent with the annualization of savings for the first-year savings claim; http://www.icc.illinois.gov/downloads/public/edocket/287090.pdf

7. First-year ISR is based upon review of PY4-6 evaluations from ComEd and PY5-6 for Ameren. The average first-year ISR for each utility was calculated weighted by the number of bulbs in each year's survey. This was then weighted by annual sales to give a statewide assumption. http://www.ilsag.info/evaluation-documents.html
8. In service rates provided for the CFL and LED lamps in a kit only. Kits provided free to students through the school, with education program. http://ilsagfiles.org/SAG_files/Evaluation_Documents/Ameren/AIU%20Evaluation%20Reports%20EPY6/AIC_PY6_EEKits_Report_FINAL_2015-07-20.pdf
9. Opt-in program to receive kits via mail, with little or no education. Based on 'Impact and Process Evaluation of 2013 (PY6) Ameren Illinois Company Residential Efficiency Kits Program', table 10. http://ilsagfiles.org/SAG_files/Evaluation_Documents/Ameren/AIU%20Evaluation%20Reports%20EPY6/AIC_PY6_EEKits_Report_FINAL_2015-07-20.pdf

Revision History

Version	Description	Author	Date

Residential Lighting – LED Ceiling Fan

Measure Detail	Measure Value
Measure ID	1.01.02
Target Market Segments	Residential, Multifamily
Target End Uses	Lighting
Applicable To	Residential and multifamily customers
Actions	Replace on Failure, New Construction
Delivery Methods	Direct Install, Coupon, Giveaway, Upstream, Kits
Required from Customer/Contractor	Space type (Single Family/Multifamily in Unit, Multifamily Common Area, Exterior/Unconditioned Space), HVAC System (Heating Only or Heating & Cooling)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	10 (Ref. 1)
Unit Participant Incremental Cost	See Table 8

Measure Description

ENERGY STAR qualified ceiling fan/light combination units are 60% more efficient than conventional fan/light units because they use improved motors and blade designs and meet strict energy efficiency, quality, and performance criteria set by the U.S. Environmental Protection Agency, tested by accredited labs, and certified by a third party. As the ENERGY STAR lighting certification program sunsets due to EISA baseline standards, qualifying fixtures for this measure do not need to be ENERGY STAR qualified but will need to be LED technology and must meet the ENERGY STAR v4.0 criteria outlined below with regard to wattage per CFM.

There are several defined fan types, including low-speed small-diameter (LSSD), high-speed small-diameter (HSSD), very small diameter (VSD), and hugger fans. Federal and ENERGY STAR requirements for energy use depend on fan type and diameter. The ENERGY STAR Certified Product List was analyzed to calculate average savings for each fan category, as well as a weighted average savings across all categories.

Algorithms

Unit kWh Savings per Year = Fan Energy Savings + Lighting Energy Savings

Unit kW Savings per Year = Fan Demand Savings + Lighting Demand Savings

Unit Dth Savings per Year = Lighting Dth Penalty

Where:

Fan Energy Savings = $[[(W_{BASE,HIGH} * OH_{HIGH}) + (W_{BASE,LOW} \times OH_{LOW}) + (W_{BASE,STBY} \times OH_{STBY})] - [(W_{EFF,HIGH} \times OH_{HIGH}) + (W_{EFF,LOW} \times OH_{LOW}) + (W_{EFF,STBY} \times OH_{STBY})]] / 1{,}000 \times 365$

Fan Demand Savings = $[(W_{BASE,HIGH}) - (W_{ES,HIGH})] / 1{,}000 \times CF_{FAN}$

If ceiling fan has a built-in light kit or has a lighting component:

Lighting Energy Savings = $(kW_{BASE} - kW_{EFF}) \times Hrs \times SF_{HVAC,COOL,kWh}$

Lighting Demand Savings = $(kW_{BASE} - kW_{EFF}) \times CF_{LIGHT}$ x HVAC_cooling_kWsavings_factor

Lighting Dth Savings = $(kW_{BASE} - kW_{EFF}) \times Hrs$ x HVAC_heating_penalty_factor

Where:

$W_{BASE,HIGH}$	= Baseline fan wattage (W per fan) operating on high mode, see Table 10 in Notes
OH_{HIGH}	= Fan daily operating hours on high mode, see Table 2
$W_{BASE,LOW}$	= Baseline fan wattage (W per fan) operating on low mode, see Table 10 in Notes
OH_{LOW}	= Fan daily operating hours on low mode, see Table 2
$W_{BASE,STBY}$	= Baseline fan wattage (W per fan) operating on standby mode, see Table 10 in Notes
OH_{STBY}	= Fan daily operating hours on standby mode, see Table 2
$W_{EFF,HIGH}$	= Efficient fan wattage (W per fan) operating on high mode, see Table 10 in Notes
$W_{EFF,LOW}$	= Efficient fan wattage (W per fan) operating on low mode, see Table 10 in Notes
$W_{EFF,STBY}$	= Efficient fan wattage (W per fan) operating on standby mode, see Table 10 in Notes
1,000	= Conversion from W to kW
365	= Days per year
CF_{FAN}	= Coincidence factor of the fan, the probability that peak demand of the fan will coincide with peak utility system demand, 0.75 (Ref. 6)
kW_{BASE}	= Total lighting wattage of baseline ceiling fan, see Table 11 or Residential Lighting – Lighting End Use section
kW_{EFF}	= Total lighting wattage of efficient ceiling fan, see Table 11
Hrs	= Deemed annual lighting operating hours from Table 3 in Lighting End Use based on building type, see Table 4

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1 in Lighting End Use. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning, see Table 5.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1 in Lighting End Use. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning, see Table 5.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting, see Table 5.

CF_{LIGHT} = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in Table 2 in Lighting End Use, or see Table 4.

Example:

Install an LED ceiling fan meeting ENERGY STAR v4.0 criteria in an interior space.

kWh = 108.20 + 35.70 = 143.90 kWh

kW = 0.0507 + 0.0040 = 0.0547 kW

Dth/year = - 0.10 Dth

Deemed Input Tables

Table 1. ENERGY STAR Ceiling Fan and Baseline Ceiling Fan Standards (Ref. 2, Ref. 3)

Ceiling Fan Type	Blade Span Category	Baseline Standard (CFM/W)*	ENERGY STAR 4.0 Standard Criteria (CFM/W)
Standard	Diameter (D) ≤ 36 inches	0.65 x D + 38.03	0.72 x D + 41.93
	36 inches < D < 78 inches		2.63 x D – 26.83
	D ≥78 inches		2.63 x D – 26.83
Low Mount HSSD	D ≤ 36 inches	4.16 x D + 0.02	0.72 x D + 41.93
	36 inches < D < 78 inches		2.63 x D – 26.83
	D ≥78 inches		2.63 x D – 26.83
Hugger	D ≤ 36 inches	0.29 x D + 34.46	0.31 x D + 36.84
	36 inches < D < 78 inches		1.75 x D – 15
	D ≥78 inches		1.75 x D – 15

* There are other categories of ceiling fans that have minimum federal standards but do not have ENERGY STAR standards. Those are excluded here.

Table 2. Ceiling Fan Daily OH for Different Fan Modes (Ref. 4)

Fan Mode	LSSD (Standard and Hugger Fans)	HSSD Fans
High	3.4	12
Low	3	0
Standby	17.6	12

Table 3. Ceiling Fan with Light Kit Lighting Standards (Ref. 2, Ref. 3)

Lumens	Baseline Lumens/Watt Requirement	ENERGY STAR 4.0 Lumens/Watt Requirement*
< 120 Lumens	50	65.0 for separable light sources 70.0 with integrated circuitry
≥ 120 Lumens	$(74.0 – 29.42 \times 0.9983^{lumens})$. Minimum baseline of 45 lumens/watt if calculation results in lower value.	

* ENERGY STAR ceiling fans with lighting kits must output 800 lumens

Table 4. Ceiling Fan Lighting Hours of Use and CF (Ref. 7)

Space Type	Hrs	CF_Light
Interior Living Quarters	938	9.50%
Multifamily Common Areas	5,950	75%
Exterior/Unconditioned Space	1,825	0%

Table 5. HVAC Interactive Factors by HVAC System (Ref. 7)

Space Type	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only or Heating & Cooling
Interior Living Quarters	1.00	1.248	1.00	1.075	-0.0029
Multifamily Common Areas	1.00	1.248	1.00	1.075	-0.0029
Exterior/Unconditioned Space	1.00	1.00	1.00	1.00	0
Interior Living Quarters – Cooling Unknown	1.16		1.048		-0.0029
Multifamily Common Areas – Cooling Unknown	1.11		1.034		-0.0029

Table 6. Efficient Case Ceiling Fan Default Fan Savings

Ceiling Fan Type	Blade Span Category	Fan Energy Savings Based on ENERGY STAR Certified Products List (kWh/yr)	Fan Peak Demand Savings Based on ENERGY STAR Certified Products List (kW/yr)	Weight in ENERGY STAR Certified Products List
Standard	D ≤ 36 inches	17.9	0.009	1%
	36 inches < D < 78 inches	111.0	0.052	82%
	D ≥78 inches	181.8	0.090	4%
Low Mount HSSD	D ≤ 36 inches	N/A, none in ES List	N/A, none in ES List	0%
	36 inches < D < 78 inches	23.1	0.004	5%
	D ≥78 inches	N/A, none in ES List	N/A, none in ES List	0%
Hugger	D ≤ 36 inches	N/A, none in ES List	N/A, none in ES List	0%
	36 inches < D < 78 inches	103.1	0.047	9%
	D ≥78 inches	N/A, none in ES List	N/A, none in ES List	0%
Weighted Average		**108.2**	**0.051**	

Table 7. Efficient Case Ceiling Fan Default Lighting Savings

Ceiling Fan Type	Installation Location	Lighting kWh	Lighting kW	Lighting Dth
Weighted Average Ceiling Fan with Light Kit	Interior Living Quarters – Unknown Cooling	52.1	0.0068	(0.14)
	Multifamily Common Areas – Unknown Cooling	325.8	0.044	(0.91)
	Exterior/Unconditioned Space	95.0	-	-
Weighted Average Ceiling Fan with Unknown Light Kit*	Interior Living Quarters – Unknown Cooling	35.7	0.004	(0.10)
	Multifamily Common Areas – Unknown Cooling	223.4	0.030	(0.63)
	Exterior/Unconditioned Space	65.2	-	-

* The ENERGY STAR Certified Products List analyzed found that 68% of all ceiling fans had light kits.

Table 8. Efficient Ceiling Fan Incremental Cost (Ref. 1)

Ceiling Fan Type	Incremental Cost
Ceiling Fan with Light Kit	$46.00
Ceiling Fan without Light Kit	$30.71
Ceiling with Unknown Light Kit	$41.20

Notes

Ceiling fan federal energy standards are based on CFM/W. However, CFM/W is not *directly* the means to calculate energy and demand savings. As shown in the algorithms above, fan energy is calculated via summing the wattages at different operating modes multiplied by the daily hours at each respective operating mode.

The ENERGY STAR Certified Products List for ceiling fans reports each of the wattages at different operating modes. To determine the wattages at different operating modes for the baseline fan, the ratio of the ENERGY STAR CFM/W to Baseline CFM/W is applied to each of the reported ENERGY STAR wattages at different operating modes. See Table 9.

Table 9. CFM/W to Different Wattage Operating Modes Estimate

Ceiling Fan Type	Blade Span Category	Average Blade Span in ES Certified Products List (Inches)	Average ENERGY STAR CFM/W	Federal Standard CFM/W	Federal Standard to ENERGY STAR CFM/W Ratio
Standard	D ≤ 36”	26.33	72.50	55.15	76%
	36”< D < 78”	57.63	229.59	75.49	33%
	D ≥ 78”	83.75	315.01	92.47	29%
Low Mount HSSD	D ≤ 36”	N/A	N/A	N/A	N/A
	36” < D < 78”	58.80	286.55	244.63	85%
	D ≥78”	N/A	N/A	N/A	N/A
Hugger	D ≤ 36”	N/A	N/A	N/A	N/A
	36” < D < 78”	50.58	159.57	49.13	31%
	D ≥78”	N/A	N/A	N/A	N/A

Table 10 shows the fan wattages at different fan modes for ENERGY STAR and baseline fans.

Table 10. CFM/W to Different Wattage Operating Modes Estimate

Ceiling Fan Type	Blade Span Category	Efficient Case			Baseline		
		W_{HIGH}	W_{LOW}	W_{STBY}	W_{HIGH}	W_{LOW}	W_{STBY}
Standard	D ≤ 36”	37.10	4.10	1.00	48.77	5.39	1.31
	36” < D < 78”	34.20	4.69	1.06	104.01	14.28	3.22
	D ≥78”	49.72	4.81	1.33	169.38	16.38	4.54
Low Mount HSSD	D ≤ 36”	N/A	N/A	N/A	N/A	N/A	N/A
	36” < D < 78”	29.36	3.00	1.47	34.39	3.51	1.72
	D ≥78”	N/A	N/A	N/A	N/A	N/A	N/A
Hugger	D ≤ 36”	N/A	N/A	N/A	N/A	N/A	N/A
	36” < D < 78”	28.09	3.90	1.05	91.25	12.66	3.40
	D ≥78”	N/A	N/A	N/A	N/A	N/A	N/A

Table 11 shows the lumens of ENERGY STAR fans with ceiling light kits from the same ENERGY STAR analysis. Note that the weights below reflect the ENERGY STAR ceiling fans with light kits.

Table 11. Efficient Case Ceiling Fan Default Watts

Ceiling Fan Type	Blade Span Category	Lumens Efficient Ceiling Fan with Light Kit Based on ENERGY STAR Certified Products List	Watts Efficient Ceiling Fan with Light Kit Based on ENERGY STAR Certified Products List	Watts of Baseline Ceiling Fan with Light Kit	Weight in ENERGY STAR Certified Products List
Standard	D ≤ 36”	1,870.67	23.57	72.78	1%
	36” < D < 78”	1,447.69	18.50	71.49	82%
	D ≥78”	1,465.40	20.05	71.57	3%
Low Mount HSSD	D ≤ 36”	N/A	N/A	N/A	0%
	36” < D < 78”	1,633.00	22.67	72.17	2%
	D ≥78”	N/A	N/A	N/A	1%
Hugger	D ≤ 36”	N/A	N/A	N/A	0%
	36” < D < 78”	1,493.66	18.43	71.68	11%
	D ≥78”	N/A	N/A	N/A	0%
Weighted Average			**18.73**	**71.55**	

Ceiling fans that allow for lights but don’t come with lights will have calculated savings based on Residential Lighting - Lighting End Use section.

References

1. Illinois Stakeholder Advisory Group. 2021 Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 9.0. Volume 3: Residential Measures. September 25, 2020. https://data.energystar.gov/Active-Specifications/ENERGY-STAR-Certified-Ceiling-Fans/2te3-nmxp/data
2. ENERGY STAR. Program Requirements for Residential Ceiling Fans and Ceiling Fan Light Kits. Version 4.0. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Ceiling%20Fans%20and%20Ceiling%20Fan%20Light%20Kits%20Version%204.0_Program%20Requirements_0.pdf
3. Code of Federal Regulations. Title 10, Chapter II, Subchapter D, Part 430, Subpart C, §430.32. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32
4. Code of Federal Regulations. Title 10, Chapter II, Subchapter D, Part 430, Subpart B, Appendix U. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-B
5. ENERGY STAR. Certified Product List for ENERGY STAR Ceiling Fans. Downloaded 9/2/2021. https://data.energystar.gov/Active-Specifications/ENERGY-STAR-Certified-Ceiling-Fans/2te3-nmxp/data
6. Value for room air conditioners used as an approximation of when ceiling fans are operated.
7. Lighting hours and coincidence factor taken from residential Lighting End Use measure.

Revision History

Version	Description	Author	Date
3.3	Updated to match current ENERGY STAR standards and federal standards	Cadmus	9/2021
4.1	Removed ENERGY STAR Qualified as required product criteria given sunset of program, however same ENERGY STAR criteria must be met by qualifying fixtures.	Cadmus	11/2023

Residential Lighting – LED Lamps and Fixtures

Measure Detail	Measure Value
Measure ID	1.01.03
Target Market Segments	Residential, Commercial
Target End Uses	Lighting
Applicable To	Single family, duplex, townhome, and multifamily (3+ units) customers
Actions	Replace on Failure, Replace Working, New Construction
Delivery Methods	Direct Install, Coupon, Giveaway, Upstream, Kits
Measure Energy Type	Electric
Unit kWh Savings per Year	Refer to the algorithm and tables provided in the Lighting End Use section
Unit Peak kW Savings	Refer to the algorithm and tables provided in the Lighting End Use section
Unit Dth Savings per Year	Refer to the algorithm and tables provided in the Lighting End Use section

Measure Description

ENERGY STAR LED lamps and fixtures provide an energy-efficient alternative to traditional incandescent, halogen, and CFL lamps. All LED lamps and fixtures must meet ENERGY STAR criteria v2.2 for lumens per watt, but do not need to be ENERGY STAR Qualified. Criteria for ENERGY STAR qualified LED products vary by product type and include specifications for: light output (lumens), efficacy (lumens per Watt), zonal lumen density, correlated color temperature (CCT), lumen maintenance (lifetime), color rendering index (CRI), and power factor, among others. LED bulbs also have three-year (or longer) warranties covering material repair or replacement from the date of purchase and must turn on instantly. As the ENERGY STAR lighting certification program sunsets due to EISA baseline standards, qualifying fixtures for this measure do not need to be ENERGY STAR qualified but will need to be LED technology and must meet the ENERGY STAR v2.2 criteria (Ref. 10) outlined below with regard to lumens per watt. This measure applies to screw-in and hardwired LED lamps and fixtures, including:

- A-line lamps are the most commonly used type of general lighting service (GLS) bulbs, characterized by a pear shape, omnidirectional light and typically a screw-in base. The most common bulb shape of this type is A19, but the category includes many other shapes and sizes beyond A19. LED A line lamps typically replace incandescent and CFL technology.
- Globes lamps are commonly used in restroom vanity fixtures and other specialty applications, and are characterized by a circular globe shape bulb and narrow screw-in base. This type of bulb provides omnidirectional light. G30 size bulbs are the most common of this type, with the numeric value representing the measurement of the diameter at the widest point. LED globes typical replace incandescent and halogen technology.
- Directional lamps (PAR/Flood/Reflector) are triangular in shape, providing a unidirectional light beam. The most common applications for these bulbs is within recessed downlight fixtures, track lighting fixtures, and exterior spotlight fixtures. These bulbs can be screw in or pin based. Directional bulbs are numbered according to the diameter of the lens, with PAR30 being one of the more common bulbs of this type. Directional bulbs typically replace CFL, metal halide, halogen, and incandescent technology. .

- Decorative/Specialty lamps come in a variety of shapes and serve specialty applications not addressed by the applications above. Examples might include candelabra bulbs.

The baseline wattage for all screw-in bulbs is determined by a minimum 45 lumens per watt efficacy.

Algorithm

Refer to the algorithm and tables provided in the Lighting End Use section.

Deemed Input Tables

Table 1. Fixture Wattage (Ref. 2, 10, 11) and Costs (Ref. 3)

Type	Wattage Equivalence (Reference to incandescent)	Efficient Case – LED Replacement Bulb				Baseline Deemed Wattage	Incremental Cost ($)
		Deemed Wattage	Wattage Range	Deemed Lumens	Lumen Range		
A Line	100	16	15 – 18	1650	>1300	37	$8.66
A Line	75	13	11 – 14.9	1100	1000 - 1299	24	$8.66
A Line	60	9	8 – 10.9	800	600 - 999	18	$4.84
A Line	40	5	4 – 7.9	450	350 - 599	10	$3.73
A Line	25	3	1 – 3.9	250	<350	6	$1.45
Globe	100	13	>10	1100	>900	24	$8.66
Globe	60	7	6-9.9	680	550-899	15	$4.84
Globe	40	5	4.5 – 5.9	500	<550	11	$3.73
Directional	325	30	>27	3000	>2500	67	$10.00
Directional	250	22	19 – 26.9	2100	1800-2499	47	$10.00
Directional	150	15	13 – 18.9	1500	1300-1799	33	$10.00
Directional	90	11	10 – 12.9	1000	900-1299	22	$7.52
Directional	75	9	8 – 9.9	700	600-899	16	$6.02
Directional	50	6	<8	500	<600	11	$9.58
Specialty	100	6.5	>6	900	>700	20	$3.73
Specialty	60	5	4.6 – 6	500	450 - 699	11	$3.73
Specialty	40	4	3 – 4.5	350	300-450	8	$5.87
Specialty	25	2.5	<3	200	<300	4	$5.87

Table 2. Measure Life (Ref. 1, 5, 6, 7, 8, 9)

Equipment Type	Measure Life (Years)		Ref.
	Screw or Pin Based Interior	Integrated Interior	
LED Lamps - Single Family/Unit	16.0		1
LED Lamps - Multifamily Common Area	2.5		5
LED Decorative or Directional Lamps - Single Family/Unit	20.0		7
LED Decorative or Directional Lamps - Multifamily Common Area	4.2		8
LED Fixtures - Single Family/Unit	20.0	20.0	10
LED Fixtures - Multifamily Common Area	4.2	8.4	11

Methodology and Assumptions

The option to collect the existing wattage and efficient wattage is available to input customer-specific values in the algorithm. If actual existing efficacy is less than 45 lumens per watt, a minimum efficacy of 45 lumens per watt must be utilized for the baseline to determine savings. Pricing for LED technology is falling rapidly; use incremental costs if known. If not provided, use the deemed values provided in Table 1.

References

1. ENERGY STAR LED Lamp Version 2.0 has a rated minimum life of 15,000 hours for screw-based general lamps. 15,000 divided by 938 hours of operation = 16 years.
2. Baseline wattages are from EISA minimum 45 lumen/watt efficiency requirements. ENERGY STAR efficient wattages are from product information and available qualified products.
3. Costs are based on manufacturer product surveys and Midwest program data, on field data collected by CLEAResult and provided by ComEd, on Wisconsin Focus on Energy historical data obtained from Spectrum, and from Consortium of Retail Energy Efficiency Data (CREED) 2019.
4. ENERGY STAR LED Lamp Version 2.0 has a rated minimum life of 15,000 hours for screw-based general lamps. 15,000 hours divided by 5,950 hours for multifamily common areas = 2.5 years.
5. ENERGY STAR LED Lamp Version 2.0 has a rated minimum life of 15,000 hours for screw-based general lamps. 15,000 hours divided by 1,825 hours for exterior lighting = 8.2 years.
6. ENERGY STAR LED Lamp Version 2.0 has a rated minimum life of 25,000 hours for screw-based Decorative or Directional Lamps. 25,000 divided by 5,950 hours for multifamily common area = 4.2 years.
7. ENERGY STAR LED Lamp Version 2.0 has a rated minimum life of 25,000 hours for screw-based Decorative or Directional Lamps. 25,000 divided by 1,825 hours for exterior = 13.7 years.
8. ENERGY STAR LED Fixture Version 2.0 has a rated minimum life of 25,000 hours for screw-based fixtures. 25,000 divided by 5,950 hours for multifamily common area = 4.2 years.
   ENERGY STAR LED Fixture Version 2.0 has a rated minimum life of 50,000 hours for integrated fixtures. 50,000 divided by 5,950 hours for multifamily common area = 8.4 years.
9. ENERGY STAR LED Fixture Version 2.0 has a rated minimum life of 35,000 hours for screw-based fixtures. 35,000 divided by 1,825 hours for exterior = 19.2 years.
   ENERGY STAR LED Fixture Version 2.0 has a rated minimum life of 50,000 hours for integrated fixtures. 50,000 divided by 1,825 hours for exterior = 27.4 years. This is capped at 20 years as the maximum eligible lifetime for Minnesota.
10. EPA ENERGY STAR. Luminaires v2.2 Criteria. Effective August 15, 2019. https://www.energystar.gov/products/light_fixtures/partners
11. EPA ENERGY STAR. Lamps v2.1 Criteria. Effective January 2, 2017. https://www.energystar.gov/products/light_bulbs/partners

Revision History

Below is a summary of the revision history for the entire Residential Lighting section.

Version	Description	Author	Date
2.0	Updated format, baseline and efficient wattages, costs, energy standards, and requirements where applicable through the lighting section. Added residential occupancy sensors and outdoor fixtures. Updated HVAC Heating Penalty Factor. Added default values where appropriate. Added In Service Rate. Added delivery methods.	Franklin Energy Services	11/13/2015
2.1	Added measure lives for LED lamps and fixtures based on ENERGY STAR Qualified Specifications for Lamps and Fixtures	Franklin Energy Services	9/30/2016
4.0	Modified measure outline to incorporate EISA minimum efficacy requirements for baseline bulb, updates to efficient wattages, lumens, and incremental costs.	Cadmus	11/01/2022
4.1	Slight value modification to Table 1 to round deemed baseline values down to nearest whole wattage value. Removed ENERGY STAR Qualified as required product criteria given sunset of program, however same ENERGY STAR criteria must be met by qualifying fixtures.	Cadmus	11/01/2023

Residential Lighting – LED Outdoor Fixtures

Measure Detail	Measure Value
Measure ID	1.01.04
Target Market Segments	Residential, Commercial
Target End Uses	Lighting
Applicable To	Single family, duplex, townhome, and multifamily (3+ units) customers
Actions	Replace on Failure, Replace Working, New Construction
Delivery Methods	Direct Install, Coupon, Giveaway, Upstream
Measure Energy Type	Electric
Unit kWh Savings per Year	Refer to the algorithm and tables provided in the Lighting End Use section
Unit Peak kW Savings	Refer to the algorithm and tables provided in the Lighting End Use section
Unit Dth Savings per Year	Refer to the algorithm and tables provided in the Lighting End Use section

Measure Description

LED Outdoor Fixtures replace less efficient fixtures in retrofits or new construction. Fixtures are hardwired and use either pin-based or screw-in lamps. As the ENERGY STAR lighting certification program sunsets due to EISA baseline standards, qualifying fixtures for this measure do not need to be ENERGY STAR qualified but will need to be LED technology and must meet the ENERGY STAR v2.2 criteria (Ref. 5) outlined below with regard to lumens per watt.

Algorithm

Refer to the algorithm and tables provided in the Lighting End Use section.

Deemed Input Tables

Table 1. Fixture Wattage (Ref. 2, 3, 5, 6) and Costs (Ref. 4)

Type	Wattage Equivalence (Reference to incandescent)	Efficient Case – LED Replacement Bulb				Baseline Deemed Wattage	Incremental Cost ($)
		Deemed Wattage	Wattage Range	Deemed Lumens	Lumen Range		
Outdoor	100	10	>15	1000	1000-1999	23	$40
Outdoor	150	20	15-22.9	2500	2000-3499	56	$40
Outdoor	250	27	23-29.9	4000	3500-4499	90	$40
Outdoor	350	35	30-37.9	5000	4500 - 5499	112	$40
Outdoor	400	40	38-49.9	6000	5500-6999	134	$40
Outdoor	500	56	50-64.9	8000	7000-9000	178	$40
Outdoor	650	73	>65	10000	>9000	223	$40

Table 2. Measure Life (Ref. 1)

Equipment Type	Measure Life (Years)	
	Screw or Pin Based Exterior	Integrated Exterior
LED Lamps - Exterior	8.2	
LED Decorative or Directional Lamps - Exterior	13.7	
LED Fixtures - Exterior	19.2	20.0

Methodology and Assumptions

The option to collect the existing wattage and efficient wattage is available to input customer specific values in the algorithm. If actual existing efficacy is less than 45 lumens per watt, a minimum efficacy of 45 lumens per watt must be utilized for the baseline to determine savings. Pricing for LED technology is falling rapidly, use incremental costs if known. If not provided, use the deemed values in Table 1.

References

1. ENERGY STAR LED Fixture Version 2.0 has a rated minimum life of 35,000 hours for screw-based fixtures. 35,000 divided by 1,825 hours for exterior = 19.2 years. Gas & Electric Company, Southern California Edison Company, 2005
   Measure life: 15 years (capped for persistence), based on 35,000 hour average fixture life.
   ENERGY STAR LED Fixture Version 2.0 has a rated minimum life of 50,000 hours for integrated fixtures. 50,000 divided by 1,825 hours for exterior = 27.4 years. This is capped at 20 years as the maximum eligible lifetime for Minnesota.

   ENERGY STAR LED Lamp Version 2.0 has a rated minimum life of 25,000 hours for screw-based Decorative or Directional Lamps, and fixtures. 25,000 divided by 938 hours for single family = 26.7 years. This is capped at 20 years as the maximum eligible lifetime for Minnesota.

   ENERGY STAR LED Fixture Version 2.0 has a rated minimum life of 50,000 hours for integrated fixtures. 50,000 divided by 938 hours for single family = 53.3 years. This is capped at 20 years as the maximum eligible lifetime for Minnesota.
2. ENERGY STAR Light Fixtures Product List, outdoor category - accessed 09/01/2022. www.energystar.gov
3. Study of costs for baseline fixture options determined an average incremental cost of $40 for ENERGY STAR fixtures.
4. CFL METERING STUDY FINAL REPORT, Prepared for: Pacific Gas & Electric Company, San Diego
5. EPA ENERGY STAR. Luminaires v2.2 Criteria. Effective August 15, 2019. https://www.energystar.gov/products/light_fixtures/partners
6. EPA ENERGY STAR. Lamps v2.1 Criteria. Effective January 2, 2017. https://www.energystar.gov/products/light_bulbs/partners

Revision History

Version	Description	Author	Date
4.0	Modified measure outline to incorporate EISA minimum efficacy requirements for baseline bulb, updates to efficient wattages, lumens, and incremental costs.	Cadmus	11/01/2022
4.1	Removed ENERGY STAR Qualified as required product criteria given sunset of program, however same ENERGY STAR criteria must be met by qualifying fixtures.	Cadmus	11/01/2023

Residential Lighting – LED Decorative String Lighting

Measure Detail	Measure Value
Measure ID	1.01.05
Target Market Segments	Residential, Commercial
Target End Uses	Lighting
Applicable To	Residential customers in single-family homes, duplexes, townhomes, and multifamily units.
Actions	Replace on Fail, Replace Working, New Construction
Delivery Methods	Kits, Retail offering
Required from Customer/Contractor	Number of light strings, number of lights per string, type of each lighting string (C7, C9, mini). HVAC System (if unknown use "Heating Only, No Cooling"). Space Type (if unknown use "Interior"). Delivery method.
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	8 (Ref. 1)
Unit Participant Incremental Cost	$10 (Ref. 3)

Measure Description

This measure applies to mini, C7, and C9 bulb shape types used in residential locations (single-family homes, duplexes, townhomes and multifamily units). Descriptions of the bulb types of string lighting are listed below:

- Mini: Approximately 1/4” wide x 5/8” high with a shape described as a miniature candle with a pointed tip. The mini is the most common type of string light today and shares about 80% of the market. They have a female-to-male push type base.
- C7: Approximately 1” wide x 1-1/2” high with a shape described as a strawberry. The C7 (and C9) are thought of as more “old fashioned” or traditional since they were the first types of string lighting used for decorative purposes. The C7 shares about 7% of the market and has a screw-in E12 candelabra base.
- C9: Similar in shape to the C7, the C9 is slightly larger at 1-1/4” wide x 2-1/2” high. The C9 shares about 5% of the market and has a screw-in E17 intermediate base.

Because it is difficult to verify if this equipment will be used as Holiday Lights or Decorative Lights, the HOU for this measure defaults to 996 annual hours.

Algorithms

Unit kWh Savings per Year = [($Watt_{Baseline}$ x $N_{Baseline}$) - ($Watt_{Efficient}$ x $N_{Efficient}$)] / 1000 x Install Rate x HOU x HVAC Cooling kWh Savings Factor

Unit Dth Savings per Year = [($Watt_{Baseline}$ x $N_{Baseline}$) - ($Watt_{Efficient}$ x $N_{Efficient}$)] / 1000 x Install Rate x HOU x HVAC Heating Penalty Factor

Algorithm Inputs:

Variable	Definition	Units	Ref	Table Ref
$Watt_{Baseline}$	Actual wattage of baseline equipment if known, if unknown use Table 1.	Watts	4,5	
$Watt_{Efficient}$	Actual wattage of LED purchased or installed, if unknown use Table 1.	Watts	4,5	
$N_{Baseline}$	Number of lights in a string. If unknown, assume same as the $N_{Efficient}$.			
$N_{Efficient}$	Number of lights in a string.			
Install Rate	The percentage of light strings rebated that ultimately get installed.	%	2	
HOU	Annual hours of use. (150 hours x 80%) + (4380 hours x 20%) = 996 hours.	Hours	3	
HVAC Cooling kWh Savings Factor	Cooling system energy savings factor resulting from efficient lighting. If the customer has air conditioning, a reduction in lighting energy results in a reduction in cooling energy. If "HVAC System" is unknown use "Heating Only, No Cooling."	Dth/kWh	4	
HVAC Heating Penalty Factor	Heating system penalty factor resulting from efficient lighting. If "Space Type" is unknown, use "Interior."		4	

Example:

A customer received a single (1x) 70-light LED mini light package within a kit. The HVAC system is unknown and the space type is unknown.

Unit kWh Savings per Year = ((0. 45 x 70) – (0. 043 x 70)) / 1,000 x 60% x 996 x 1.048 = 17.8 kWh

Unit Dth Savings per Year = ((0.45 – 70) x (0.043 x 70)) / 1,000 x 60% x 996 x -0.0029 = -0.049 Dth

Deemed Input Tables

Table 1. Post- and Pre-retrofit Wattages per Light (Ref. 4,5)

Post-retrofit Fixture	$Watt_{Efficient}$	Pre-retrofit Fixture	$Watt_{Baseline}$
LED Mini Lights	0.043	Incandescent Mini Holiday Lights	0.45
LED C7 Holiday Lights	0.48	Incandescent C7 Holiday Lights	6.00
LED C9 Holiday Lights	2.00	Incandescent C9 Holiday Lights	7.00

Table 2. Install Rate based on Delivery Method (Ref. 7, 8)

Delivery Method	Install Rate
Retail	84%
Kits	60%

Table 3. HOU based on End Use

End Use	HOU	HOU Methodology	Usage Multiplier (%)	Resulting Deemed HOU combined uses
Holiday Lights	150	5 Hours/Day * 30 Days/year	80%	**996**
Decorative Lights	4380	12 Hours/Day * 365 Days/year	20%	

Table 4. HVAC Interactive Factors by HVAC System (Ref 6)

Space type	HVAC System	HVAC Cooling Savings Factor (kWh)	HVAC Heating Penalty Factor (Dth/kWh)
Interior	Heating and Electric Cooling, or Heating and Cooling **Unknown**	1.048	-0.0029
Interior	Heating Only, No Cooling	1.000	-0.0029
Exterior	NA	1.000	0.0000

Methodology and Assumptions

Light strings are assumed to be operating during winter or as decorative lights used as nightlights. There are no peak kW savings identified for this measure.

References

1. Engineering judgment based on 50% of DEER measure life value (16 years).
2. Southern California Edison Company, “LED, Electroluminescent & Fluorescent Night Lights”, Work Paper WPSCRELG0029 Rev. 1, February 2009, p. 2. and p.3Holiday Lights: LED and Fiber Optics, November 2007. Energy Ideas Clearinghouse.Based on a 70-light string; Pacific Gas & Electric document "Light up the holidays and save", November 2009.Technical Reference Manual State of Pennsylvania Act 129 Energy Efficiency and Conservation Program & Act 213 Alternative Energy Portfolio Standards, June 2014 page 174.
3. Calculated through energy modeling by FES 2012

   1st year in service rate is based upon analysis of ComEd PY7, PY8, and PY9 intercept data. See IL TRM v12 Measure "5.5.10 LED Nightlights" for more information .1st year ISR for school kits based on ComEd PY9 data for the Elementary Energy Education program. See IL TRM v12 Measure "5.5.10 LED Nightlights" for more information.

Revision History

Version	Description	Author	Date
1.1	New Measure “Residential Lighting - LED Holiday Lighting”	MN Department of Commerce	2012
4.2	- Updated Measure Name to “Residential Lighting - LED Decorative Lighting”	MN Department of Commerce	9/1/2024

Residential Lighting – LED Nightlights

Measure Detail	Measure Value
Measure ID	1.01.06
Target Market Segments	Residential, Commercial
Target End Uses	Lighting
Applicable To	Residential customers in single-family homes, duplexes, townhomes and multifamily units.
Actions	Replace on Fail, Replace Working, New Construction
Delivery Methods	Retail, Kits
Required from Customer/Contractor	$Watt_{Efficient}$, Delivery Method, HVAC System (if unknown use "Heating Only, No Cooling"), Space Type (if unknown use "Interior")
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	None
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	8 (Ref. 1)
Unit Participant Incremental Cost	$3.35 (Ref. 2)

Measure Description

This measure describes savings from LED nightlights. This characterization assumes that the LED nightlight is installed in a residential location.

Algorithms

Unit kWh Savings per Year = $(Watt_{Baseline} - Watt_{Efficient}) / 1000 \times$ Install Rate $\times$ HOU $\times$ HVAC Cooling kWh Savings Factor

Unit Dth Savings per Year = $(Watt_{Baseline} - Watt_{Efficient}) / 1000 \times$ Install Rate $\times$ HOU $\times$ HVAC Heating Penalty Factor

Algorithm Inputs:

Variable	Definition	Units	Ref	Table Ref
WattBaseline	Actual wattage if known, if unknown, assume 7W.	Watt	3	
WattEfficient	Actual wattage of LED purchased / installed equipment.	Watt		
Install Rate	The percentage of nightlights rebated that get installed.	%	4	1
HOU	Annual hours of use. Default of 12 * 365 = 4380 hours	Hours		
HVAC Cooling kWh Savings Factor	Cooling system energy savings factor resulting from efficient lighting. If the customer has air conditioning, a reduction in lighting energy results in a reduction in cooling energy. If "HVAC System" is unknown use "Heating Only, No Cooling."	kWh	5	2
HVAC Heating Penalty Factor	= Heating system penalty factor resulting from efficient lighting. If "Space Type" is unknown, use "Interior."	Dth/kWh	5	2

Example:

A customer received a 0.3W LED Nightlight within a kit. The HVAC System is unknown and the space type is unknown.

Unit kWh Savings per Year = (7 - 0.3) / 1000 x 60% x 4380 x 1.00 = 17.6 kWh

Unit Dth Savings per Year = (7 - 0.3) / 1000 x 60% x 4380 x -0.0029 = -0.051 Dth

Deemed Input Tables

Table 1. Install Rate based on Delivery Method (Ref. 4)

Delivery Method	Install Rate
Retail	84.0%
Direct Install	96.9%
Kits	60.0%

Table 2. HVAC Interactive Factors by HVAC System (Ref 5)

Space Type	HVAC System	HVAC Cooling kWh Savings Factor	HVAC Heating Penalty Factor (Dth/kWh)
Interior	Heating and Electric Cooling, or Heating and Cooling Unknown	1.048	-0.0029
Interior	Heating Only, No Cooling	1.000	-0.0029
Exterior	NA	1.000	0.0000

Methodology and Assumptions

The Efficient Equipment must be a qualified LED nightlight. The baseline equipment is assumed to be an incandescent/halogen nightlight. The coincidence factor for this measure is 0 therefore there are no peak kW savings determined for this measure.

References

1. California Edison Company, “LED, Electroluminescent & Fluorescent Night Lights”, Work Paper WPSCRELG0029 Rev. 1, February 2009, p. 2. and p.3.
2. Average cost data provided in Stanley Mertz, “LED Nightlights Energy Efficiency Retail products programs”, March 2018.
3. Based on Stanley Mertz, “LED Nightlights Energy Efficiency Retail products programs”, March 2018.
4. Illinois Statewide Technical Reference Manual v12.0 Vol. 3 – Residential Measures, 5.5.10 LED Nightlights, September 22, 2023.
5. Calculated through energy modeling by FES 2012

Revision History

Version	Description	Author	Date
4.2	New Measure “Residential Lighting - LED Nightlights”	MN Department of Commerce	2024

Residential Lighting – Controls

Measure Detail	Measure Value
Measure ID	1.01.07
Target Market Segments	Residential, Multifamily
Target End Uses	Lighting
Applicable To	Residential Single Family, Multifamily
Actions	Modify
Delivery Methods	Direct Install, Coupon, Giveaway, Upstream, Kits
Required from Customer/Contractor	Control type/quantity, connected load (kW) to each control, building type, HVAC system (heating only, heating & cooling, exterior/unconditioned)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	10 years (Ref. 1)
Unit Participant Incremental Cost	$40 for wall mounted, $100 for ceiling mounted

Measure Description

Occupancy sensors represent an energy-efficient way to control lighting use in low occupancy areas such as halls, storage rooms, and restrooms. Instead of relying on people to remember to switch lights off when they leave a space, occupancy sensors perform this task. They measure the movement of people within a space. When movement is detected, the lights turn on automatically; they then shut off when they no longer sense movement. Each unit's shut-off time can be preset, given needs of space.

Algorithms

Unit kWh Savings per Year = kW controlled x ESF x Hrs x HVAC_cooling_kWhsavings_factor

Unit Dth Savings per Year = kW_connected x ESF x Hrs x HVAC_heating_penalty_factor

Where:

kW_controlled = Total connected fixture load, determined as the sum of stipulated fixture wattages from Appendix B.

Hrs = Hours per day, See Table 2 in Lighting End Use

ESF = Energy savings factor – 40% (Ref 2)

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from lighting from Table 1 in Lighting End Use. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from lighting from Table 1 in Lighting End Use. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from lighting control from Table 1 in Lighting End Use.

Example:

Install a wall mounted occupancy sensor with a connected load of 0.560 kW (10 - 2L 32W T8 fixtures) in a common area.

kWh = 0.560kW x 40% x 938 x 1.075 = 225.87 kWh

kW = There is no demand savings for occupancy controls

References

1. GDS Associates, Inc (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for The New England State Program Working Group.
2. "Residential Lighting Controls Market Characterization" Consortium for Energy Efficiency (CEE), January 9, 2014. Average of lighting on during unoccupied times across multiple room locations.
3. Calculated through energy modeling by FES in 2012
4. As above but using estimate of 64% of single family and multifamily in unit buildings in Minnesota having central cooling (based on data from "Table HC7.1 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009"
5. As above but using estimate of 45% of multifamily buildings in Minnesota having central cooling (based on data from "Table HC7. Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to MN air conditioning prevalence compared to US avg
6. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 7.5 based on lighting logger study conducted as part of the PY3 ComEd Residential Lighting Program evaluation.
7. Multifamily common area lighting assumption is 16.3 hours per day (5950 hours per year) based on Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010.
8. Based on lighting logger study conducted as part of the PY3 ComEd Residential Lighting Program evaluation. "ComEd Residential Energy Star Lighting Program Metering Study: Overview of Study Protocols" http://www.icc.illinois.gov/downloads/public/edocket/303835.pdf
9. "Memo RE: Lighting Logger Study Results – Version 2, Date: May 27, 2011, To: David Nichols and ComEd Residential Lighting Interested Parties, From: Amy Buege and Jeremy Eddy; Navigant Evaluation Team" http://www.icc.illinois.gov/downloads/public/edocket/303834.pdf
10. Coincidence factor is based on healthcare/clinic value (used as proxy for multifamily common area lighting with similar hours of use) developed using eQuest models for various building types averaged across 5 climate zones for Illinois for the following building types.

Revision History

Version	Description	Author	Date

HVAC

Residential HVAC – Efficient Air Conditioning System

Measure Detail	Measure Value
Measure ID	1.02.01
Target Market Segments	Residential
Target End Uses	HVAC
Applicable To	Residential customers in single-family homes, duplexes, townhomes, and multifamily homes (including 3- and 4-family homes) with residential type AC and ASHP systems for cooling.
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Equipment size (tons), SEER or EER of new equipment, SEER or EER of existing equipment (if program includes early replacements), , existing equipment condition (working or failed, if program includes early replacements), building type (single family/multifamily*), project location (county)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	18 years (Ref. 1)
Unit Participant Incremental Cost	See Table 4. Incremental equipment cost only, labor is not included

* Multifamily includes duplexes, townhomes, and multifamily buildings with 3 or more units.

Measure Description

This measure includes replacement of failed or working central AC and ASHP systems in existing homes with high-efficiency units, as well as installation of high-efficiency AC and ASHP systems in new homes. Savings for replacement of working units are in reference to existing unit. Qualifying AC and ASHP systems must meet the efficiency criteria outlined in the current ENERGY STAR performance criteria (v6.1) for Central Air Conditioners and Heat Pumps (Ref. 8), although need not be qualified through the EPA program to be eligible. Electric utilities may provide direct space heating and domestic hot water energy savings measures to low-income delivered fuel customers and low-income small gas utility customers (non- ECO) offered in conjunction with the Weatherization Assistance Program. This measure quantifies the cooling savings resulting from an ASHP upgrade. To quantify heating savings in addition to cooling savings, see MN TRM Measure *Residential HVAC – Air Source Heat Pump Systems (ASHP).*

Algorithms

Unit kWh Savings per Year = (Capacity/12,000) x $EFLH_{COOL}$ x (12 / $SEER_{BASE}$ - 12 / $SEER_{EFF}$)

Unit Peak kW Savings = (Capacity/12,000) x CF x (12/EER_{BASE} - 12/EER_{EFF})

Where:

Capacity	= Output capacity of baseline and efficient unit in btu/hr (1 ton = 12,000 btu/h).
12,000	= 1 ton = 12,000 btu/h
$EFLH_{COOL}$	= Equivalent Full Load Cooling Hours by equipment type and zone. See Table 1.
$SEER_{BASE}$	= SEER of baseline or existing unit provided by customer/contractor if Replace Working. If unknown, Replace on Fail or New Construction see Table 2.
$SEER_{EFF}$	= SEER of new high-efficiency unit provided by customer/contractor. See Table 3 for minimum requirements. Note that if SEER2 is given, either convert to SEER or use SEER2 in both baseline and efficient when making a direct comparison.
EER_{BASE}	= EER of baseline or existing unit provided by customer/contractor. Actuals strongly preferred, particularly for variable speed systems. If unavailable, for single speed systems use EER = 1.12 x SEER – 0.02 x $SEER^2$ if SEER is provided (Ref. 4). If unknown, Replace on Fail or New Construction see Table 2.
EER_{EFF}	= EER of new high-efficiency unit provided by customer/contractor. Actuals strongly preferred, particularly for variable speed systems. If unavailable, for single speed systems use EER = 1.12 x SEER – 0.02 x $SEER^2$ if SEER is provided (Ref. 8). See Table 3 for minimum requirements. Note that if EER2 is given, either convert to EER or use EER2 in both baseline and efficient when making a direct comparison.
CF	= Coincidence factor = 0.75 for standard single-speed compressor equipment, 0.9 for variable-speed compressor equipment (see Notes)

Example:

A single-family home with an A/C unit (42,000 output Btu/hr at SEER 14, EER 11.8) is being retrofit with a 19.5 SEER (EER 14.2) AC unit of the same size in zone 3. The unit is single speed.

Unit kWh Savings per Year = 42,000 / 12,000 x 567 x ((12 / 14) – (12 / 19.5)) = 479.8 kWh

Unit Peak kW Savings = 42,000 / 12,000 x 0.75 x ((12/ 11.8) – (12/14.2)) = 0.45 kW

Deemed Input Tables

Table 1. Effective Full Load Cooling Hours ($EFLH_{COOL}$) by Climate Zone (Ref. 3)

Zone	$EFLH_{COOL}$ Heat Pump Systems	$EFLH_{COOL}$ AC Systems
Zone 1 (Northern MN)	456	312
Zone 2 (Central MN)	512	565
Zone 3 (Southern MN/Twin Cities)	678	567

Note: EFLH values have been derived such that load factor and oversizing factor has been included in the values outlined above. See methodology assumptions and notes on EFLH derivation below.

Table 2. Baseline SEER and EER Values (Ref. 6)

Product Type	$SEER_{BASE}$	$SEER2_{BASE}$	EER_{BASE}*	$EER2_{BASE}$
Split System Air Conditioner	15	13.4	12.5	12.0
Single Package Air Conditioner	15	13.4	12.0	11.4
Split System Heat Pump	15	14.3	12.5	12.0
Single Package Heat Pump	15	14.3	12.0	11.4

Table 3. ENERGY STAR Criteria SEER and EER Values (Ref. 8)

Product Type	$SEER_{EFF}$	$SEER2_{EFF}$	EER_{EFF}*	$EER2_{EFF}$
Split Systems Air Conditioner (ENERGY STAR AC Split System)	≥16.0	≥15.2	≥12.5	≥12.0
Single Package Air Conditioner	≥16.0	≥15.2	≥12.0*	≥11.5*
Split System Heat Pump (ENERGY STAR Heat Pump Split System)	≥16.0	≥15.2	≥12.0	≥11.7
Single Package Heat Pump (ENERGY STAR Heat Pump Single Package)	≥16.0	≥15.2	≥11.0	≥10.6

*Where ENERGY STAR efficiency criteria are lower than the current Federal minimum efficiency standard, eligible equipment must meet or exceed the Federal minimum efficiency indicated in Table 2.

Table 4. Incremental Cost (Ref. 2)

Efficiency Level	AC Cost per Ton	ASHP Cost per Ton
SEER 16	$357	$411
SEER 17	$476	$548
SEER 18	$596	$685
SEER 19	$715	Actuals
SEER 20	$834	Actuals
SEER 21	$908	Actuals
Average	**$650**	

Methodology and Assumptions

Building heating and cooling loads shall be calculated and systems shall be sized in accordance with applicable federal, state, local and municipal codes and standards. The algorithm is not intended to provide direction in appropriately sizing a cooling system.

Installations of ASHPs where the intention is operation in heating and cooling seasons should instead follow the Residential HVAC – ASHP measure algorithm.

$EFLH_{COOL}$ and $EFLH_{HEAT}$ values were determined from a 2022 MN CARD study using PRISM utility billing data analysis, with billing data collected from Minnesota utility customers, and NOAA 2005 - 2020 MN weather data. The EFLH heating calculation uses total heating energy use and equipment input capacity. The total heating energy use was determined from customer billing data, and the input capacity was determined through customer interviews and utility provided data on installations. With this method, the load factor and oversizing factor are already included in the resulting value and are therefore not included as a separate metric in the algorithm.

Effective January 1, 2023, HVAC products will be subject to regional minimum efficiencies, according to Seasonal Energy Efficiency Ratio 2 (SEER2). The nomenclature of SEER2, EER2, and HSPF2 will be used to denote the new M1 ratings. Conversion between the new M1 ratings and original M ratings should be done using an AHRI approved method, using the multipliers in the Tables below.

Table 5. M to M1 Forward Conversion (Ref. 10)

	Multiplier to convert to SEER2*	Multiplier to convert to EER2	Multiplier to convert to HSPF2
Ducted	0.95	0.95	0.85
Ductless	1.00	1.00	0.90
Packaged	0.95	0.95	0.84

Table 6. M1 to M Backward Conversion (Ref. 10)

System Type	Multiplier to convert to SEER*	Multiplier to convert to EER	Multiplier to convert to HSPF2
Split System Air Conditioner	1.05	1.04	N/A
Split System Heat Pump	1.05	1.04	1.18
Packaged Air Conditioner	1.04	1.04	N/A
Packaged Heat Pump	1.04	1.04	1.18
Ductless Heat Pump	1.00	1.00	1.12
Space Constrained System	1.01	1.00	1.17
Small Duct High Velocity System	1.00	1.00	1.18

The value for coincidence factor is derived from a 2016 CARD study (Ref. 5) that examined quality install and maintenance practices for residential furnaces, air conditioners and heat pumps, in part by metering the behavior and performance of 58 cooling systems and 55 furnaces. A follow-on memo was produced (Ref. 7) that recommended coincidence factor be reduced from 90% to 75%. Because the previous 90% value was simply deemed as a typical value worth updating when primary data was available, that update is applied here. However, because the metered systems had single-speed compressors, 90% may still be used for equipment with variable-speed compressors.

References

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc. June 2007 http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf
2. DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com)
3. Cadmus and Minnesota Department of Commerce. "*MN CARD Study: Residential Thermostat Savings and HVAC Equipment Equivalent Full Load Hours*" Accessed July 2022. https://www.cards.commerce.state.mn.us/security/search.do?documentId=%7B3D4A3D02-73F6-480A-B365-D582C35C44CC%7D

4. ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment. https://www.ahrinet.org/search-standards/ahri-210240-2023-2020-performance-rating-unitary-air-conditioning-air-source-heat
5. Seventhwave. *Improving Installation and Maintenance Practices for Minnesota Residential Furnaces, Air Conditioners and Heat Pumps*. September 30, 2016. https://www.cards.commerce.state.mn.us/CARDS/security/search.do?documentId=%7B881DD1B7-1FE4-495A-9FC0-F74A54B99CB6%7D
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Revision History

Version	Description	Author	Date
1.0	New spec to reflect standalone QI measure in DER Smart Measure Library, Added wording to clarify how EER and SEER are calculated	Joe Plummer	
2.0	Changed energy savings equations arrangement, Changed measure life, Changed incremental cost, Changed references, Added incremental cost table	Franklin Energy Services	7/25/2012
2.1	Added to description, added missing customer/contractor inputs	Joe Plummer	3/25/2013
2.2	Add explanation of multifamily buildings under required customer/contractor inputs, corrected ASHP example calculation, added existing HSPF to Required Inputs (if program includes early replacements of working units.), Federal standard grace period note added	Joe Plummer	3/12/2014
3.0	Changed to EFLH algorithm	Franklin Energy Services	11/12/2015
3.1	Updated CF, adjusted HSPF for AHRI climate zone V	Cadmus	10/2019
3.2	Updated baseline SEER, EER, and HSPF	Cadmus	10/2020
4.0	Split ASHP into separate measure. Updated ENERGY STAR qualification criteria. EFLH modifications based on recent CARD study.	Cadmus	11/01/2022
4.1	Clarification to SEER2, EER2, and HSPF2 conversions. Updates to federal and ENERGY STAR criteria for applicable equipment. Added back in ASHP cooling equipment.	Cadmus	11/1/2023

Residential HVAC – Window or Room A/C or ASHP

Measure Detail	Measure Value
Measure ID	1.02.02
Target Market Segments	Residential
Target End Uses	HVAC
Applicable To	Residential customers in single-family homes and multifamily homes including duplexes and townhomes*
Actions	Replace on Failure, Replace Working, New Construction
Required from Customer/Contractor	New unit rated Btuh or tons, new unit EER, new unit type (side louvers or no side louvers), building type (single family/multifamily*), project location (county)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	9 (Ref. 1)
Unit Participant Incremental Cost	See Table 7 (Ref 7)

* Multifamily defined as duplexes, townhomes, and buildings with three or more units.

Measure Description

This measure includes the replacement of failed or working room or wall air conditioners or ASHPs in residential homes, as well as installation of high-efficiency room or wall air conditioners or ASHPs in new homes. This measure is also applicable to the new room or wall AC or ASHP offsetting the heating or cooling being provided by electric resistance heating (such as baseboard heaters) or central A/C system, both of which may remain operational. New units must meet current ENERGY STAR performance criteria specified within this measure, but need not be ENERGY STAR qualified through the EPA program. This measure applies to single-phase powered window mounted and through the wall units that provide cooling (A/C or HP) and optionally could also provide heating (HP only). Efficient units that have electric resistance heat as the primary heating source are not eligible for this measure. Mini split ductless heat pumps would fall under the Residential HVAC – Air Source Heat Pump measure.

Algorithms

Cooling Savings (A/C and HP):

Unit kWh Cooling Savings per Year = Btuh x (1/CEER_base - 1/CEER_eff) / 3,412 x $EFLH_{COOL}$

Unit Peak kW Savings = Btuh x (1/CEER_base - 1/CEER_eff) / 1000 x CF

Where:

Btuh = Cooling capacity of unit in Btu/h, provided by customer. If given in tons, 1 ton = 12,000 Btuh.

CEER_base = Federal minimum standard combined energy efficiency ratio (CEER) of baseline unit. Refer to Table 1.

CEER_eff = Combined energy efficiency ratio (CEER) of new unit. Refer to Table 1, or actuals.

$EFLH_{COOL}$ = Equivalent full load cooling hours. Refer to Table 5.3,412 = Conversion factor Btuh/ kW

1,000 = Conversion factor W/ kW

CF = Peak coincidence factor = 0.75 (see Notes)

Heating Savings (HP and electric resistance):

Unit kWh Heating Savings per Year = Btuh x (1/COP_base - 1/COP_eff) / 3,412 x ($EFLH_{HEAT}$ x DF)

Where:

Btuh = Heating capacity of new unit in Btu/h, provided by customer. If given in tons, 1 ton = 12,000 Btuh.

COP_base = Federal minimum standard coefficient of performance (COP) of electric resistance heater. Refer to Table 4. Baseline is assumed to be electric resistance heating. HSPF x 0.29 = COP, or HSPF2 x 0.34 = COP

COP_eff = Coefficient of performance (COP) of new unit. Actuals, or refer to Table 1. See Table 4 and Notes for conversions and assumptions. HSPF x 0.29 = COP, or HSPF2 x 0.34 = COP

3,412 = Conversion factor Btuh/ kW

$EFLH_{HEAT}$ = Equivalent full load heating hours. Refer to Table 6.

DF = Discount factor by climate zone applied to the ELHF Heating hours to account for situations of partial displacement and/or HP capacity reductions as lower temperatures. The discount factor differs by climate zone, see Table 6 for values and Notes for detailed assumptions.

Example 1:

A 1-ton (12,000 Btuh), 15 CEER ENERGY STAR-rated window air conditioner without reverse cycle and with louvered sides is installed in a Climate Zone 1 Single-Family home. The efficient unit is replacing an existing window A/C unit that did not have any heating capacity. The baseline unit would fall under window unit without reverse cycle without louvered sides in the capacity range of 11,000 to 13,000 Btu/h at a baseline default CEER of 10.9.

Unit kWh Cooling Savings per Year = 12,000 Btuh x (1/ 10.9 CEER - 1/ 15 CEER) / 3,412 x 312 = 27.52 kWh

Unit Peak kW Savings = = 12,000 Btuh x (1/10.9 CEER - 1/15.0 CEER) / 1,000 * 0.75 = 0.226 kW

Example 2:

A 1-ton (12,000 Btuh), 17.6 CEER and 10.12 HSPF2 window heat pump with reverse cycle is installed in a climate zone 3 single family home. The baseline unit would fall under window unit with reverse cycle < 14,000 Btu/h (Table 2) at a baseline default CEER of 9.3. The efficient unit is replacing an existing window A/C unit that had electric resistance heating incorporated.

Unit kWh Cooling Savings per Year = 12,000 Btuh x (1/ 10.9 CEER - 1/ 17.2 CEER) / 3,412 x 567 hrs = 98.49 kWh

Unit Peak kW Savings = 12,000 Btuh x (1/10.9 CEER - 1/17.2 CEER) / 1,000 * 0.75 = 0.44 kW

COP_Base = 1.0

COP_Eff = 10.12 HSPF2 x 0.34 = 3.44

Unit kWh Heating Savings per Year = Btuh x (1/ 1.0 COP - 1/ 3.44 COP) / 3,412 x (1,046 hrs x 87%) x 87%) = 2,270 kWh

Deemed Input Tables

Table 1. Baseline and High-Efficiency CEER Ratings for Units without Reverse Cycle. (Ref. 3, 5)

Capacity (Btu/h)	Window Units (w/ louvered sides)		Sleeve Units (w/o louvered sides)	
	Baseline Minimum Efficiency, CEER	ENERGY STAR Efficiency, CEER	Baseline Minimum Efficiency, CEER	ENERGY STAR Efficiency, CEER
< 6,000	11.0	13.1	10.0	12.8
6,000 to 7,999	11.0	13.7	10.0	12.8
8,000 to 10,999	10.9	14.7	9.6	13.0
11,000 to 13,999	10.9	14.7	9.5	12.8
14,000 to 19,999	10.7	14.4	9.3	12.6
20,000 to 27,999	9.4	12.7	9.4	12.7
≥ 28,000	9.0	12.2	9.4	12.7

Table 2. Baseline and High-Efficiency CEER Ratings for Units with Reverse Cycle (HP). (Ref. 3, 5)

Capacity (Btu/h)	Window Units (w/ louvered sides)		Sleeve Units (w/o louvered sides)	
	Baseline Minimum Efficiency, CEER	ENERGY STAR Efficiency, CEER	Baseline Minimum Efficiency, CEER	ENERGY STAR Efficiency, CEER
< 14,000	N/A	N/A	9.3	12.6
≥ 14,000	N/A	N/A	8.7	11.7
< 20,000	9.8	13.2	N/A	N/A
≥ 20,000	9.3	12.6	N/A	N/A

Table 3. Baseline and High-Efficiency CEER Ratings for Casement Units (Ref. 3,5)

Capacity (Btu/h)	Window Units	
	Baseline Minimum Efficiency, CEER	ENERGY STAR Efficiency, CEER
Casement-Only	9.5	12.8
Casement-Slider	10.4	14.0

Table 4. Baseline and High-Efficiency COP and HSPF Ratings for Units with Reverse Cycle (HP) (Ref 5,8 See Notes)

Capacity (Btu/h)	Window or Sleeve Units, all sizes	
	Baseline Minimum Efficiency	Performance Efficiency
COP	1.0 (Baseline electric resistance)	≥2.3
HSPF (Rated at 47 degrees F)	8.2 (Baseline ASHP)	≥9.2
HSPF2 (Rated at 47 degrees F)	6.7 (Baseline ASHP)	≥7.8

Table 5. Equivalent Full Load Cooling Hours ($EFLH_{COOL}$) by Climate Zone (Ref. 4)

Zone	Heat Pump Systems *(use only when both baseline and efficient cases are heat pump, otherwise use AC System EFLH COOL)*	AC Systems
Zone 1 (Northern MN)	456	312
Zone 2 (Central MN)	512	565
Zone 3 (Southern MN/Twin Cities)	678	567

Table 6. Equivalent Full Load Heating Hours ($EFLH_{HEAT}$) by Climate Zone (Ref. 4, 12 See Notes)

Zone Heat Pump Systems	EFLH Heat ASHP Systems *(use only when both baseline and efficient cases are heat pump, otherwise use elec resistance EFLH HEAT)*	EFLH Heat Electric Resistance	DF
Zone 1 (Northern MN)	2576	1145	79%
Zone 2 (Central MN)	2383	1046	81%
Zone 3 (Southern MN/Twin Cities)	2069	1046	87%

Note: EFLH values have been derived such that load factor and oversizing factor has been included in the values outlined above. See methodology assumptions and notes on EFLH derivation below.

Table 7. Incremental Cost by Capacity (Ref. 7, 10, 11)

Capacity (Btu/h)	AC Window Units (w/ louvered sides)	AC Sleeve Units (w/o louvered sides)	HP Units
< 6,000	$8.45	$8.45	$3,800
6,000 to 7,999	$14.35	$14.35	
8,000 to 13,999	$104.07	$123.13	
14,000 to 19,999	$126.83	$108.38	Actuals
20,000 to 27,999	$138.35	$117.52	
≥ 28,000	$150.27	$117.52	

Methodology and Assumptions

$EFLH_{COOL}$ and $EFLH_{HEAT}$ values were determined from a 2022 MN CARD study using PRISM utility billing data analysis method collected from Minnesota utility customers, and NOAA 2005 - 2020 MN weather data. The EFLH heating calculation uses total heating energy use and equipment input capacity. The total heating energy use was determined from customer billing data and the input capacity was determined through customer interview and utility provided data on installations. In this method, the load factor and oversizing factor are already included in the resulting value derived and are therefore

not additionally included as a separate metric in the algorithm. Deviating from the results from the 2022 CARD study, the $EFLH_{HEAT}$ value for Climate Zone 2 (Central MN) matches the $EFLH_{HEAT}$ value for Climate Zone 3 (Southern MN/Twin Cities) to reflect concerns with unexplored variables influencing the initial results that did not trend as expected due to climate.

The value for coincidence factor is derived from a 2016 CARD study (Ref. 2) that examined quality install and maintenance practices for residential furnaces, air conditioners and heat pumps, in part by metering the behavior and performance of 58 cooling systems and 55 furnaces. A follow-on memo was produced (Ref. 6) that recommended coincidence factor be reduced from 90% to 75%. Because the previous 90% value was simply deemed as a typical value worth updating when primary data was available, that update is applied here.

A discount factor (DF) has been applied to the EFLH Heating hours to account for baseline and performance case both relying on electric resistance heat when the OSA temperature is below 5 degrees. There are relatively few window heat pumps on the market at present, most are cold climate rated and will operate with full capacity down to 5 degrees F with limited reduction in heating efficiency. This measure algorithm assumes the window heat pump will operate to satisfy the full load at the rated capacity at 47 degrees F down to OSA of 5 degrees. Below 5 degrees, it is assumed that supplemental heating will be needed to meet the some or all of the remaining load, presumably electric resistance. This measure quantifies heating savings when the OSA is at or above 5 degrees. While the unit will likely operate below 5 degrees and meet some of the heating load, the savings have not been quantified in this measure. The discount factor applied to EFLH Heat reduces the EFLH to only the portion of heat load at or above 5 degrees, by climate zone, according to Appendix G calculations of load by binned hours. A discount factor has not applied to any other variables in the algorithm.

The minimum heating performance criteria for units with reverse cycle (heat pumps) presented in Table 4 has been determined by the performance criteria in the current ENERGY STAR Performance Criteria for Central Air Conditioners and Heat Pumps (Ref 8) for a single packaged heat pump, outlined in both HSPF and HSPF2, according to the conversion presented in Table 7 below. A potential baseline for this measure could be an existing window heat pump unit, however an electric resistance baseline unit is likely more prevalent. The assumed baseline efficiency for an electric resistance unit is a COP of 1.0. New heat pump units are likely to provide the heating efficiency in HSPF/HSPF2 rather than in COP. The performance COP presented in Table 4 has been calculated from the rated HSPF at 47 degrees F efficiency = 9.2 HSPF x 0.29 = 2.7 COP or = 7.8 HSPF2 x 0.35. Baseline and efficient case efficiency metrics used in the algorithm should be the same.

- To convert given efficient unit HSPF to COP, used HSPF x 0.29 = COP_eff
- To convert given efficient unit HSPF2 to COP, use HSPF2 x 0.34 = COP_eff

Effective January 1, 2023, HVAC products will be subject to regional minimum efficiencies, according to Seasonal Energy Efficiency Ratio 2 (SEER2). The nomenclature of SEER2, EER2 and HSPF2 will be used to denote the new M1 ratings. Conversion between the new M1 ratings and original M ratings should be done using an AHRI approved method, using the multipliers in Table 8 and Table 9 below.

Table 8. M to M1 Forward Conversion (Ref. 9)

System Type	Multiplier to convert to SEER2*	Multiplier to convert to EER2	Multiplier to convert to HSPF2
Ducted	0.95	0.95	0.85
Ductless	1.00	1.00	0.90
Packaged	0.95	0.95	0.84

Table 9. M1 to M Backward Conversion (Ref. 9)

System Type	Multiplier to convert to SEER*	Multiplier to convert to EER	Multiplier to convert to HSPF2
Split System Air Conditioner	1.05	1.04	N/A
Split System Heat Pump	1.05	1.04	1.18
Packaged Air Conditioner	1.04	1.04	N/A
Packaged Heat Pump	1.04	1.04	1.18
Ductless Heat Pump	1.00	1.00	1.12
Space Constrained System	1.01	1.00	1.17
Small Duct High Velocity System	1.00	1.00	1.18

References

1. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values, October 10, 2008.
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3. ENERGY STAR® Program Requirements, Product Specification for Room Air Conditioners. Version 5.0. https://www.energystar.gov/products/room_air_conditioner_specification_version_5_2
4. Cadmus and Minnesota Department of Commerce. "*MN CARD Study: Residential Thermostat Savings and HVAC Equipment Equivalent Full Load Hours*" Accessed July 2022. https://www.cards.commerce.state.mn.us/security/search.do?documentId=%7B3D4A3D02-73F6-480A-B365-D582C35C44CC%7D
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7. ENERGY STAR® v5.0 Room Air Conditioner Final Data & Analysis Package (Excel). Feb 28 2023. https://www.energystar.gov/products/room_air_conditioner_specification_version_5_2.
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9. Consortium for Energy Efficiency. CEE Residential Electric HVAC Specification. Published October 18, 2023. https://cee1.my.site.com/s/resources?id=a0V2R00000sUQbyUAG
10. Gradient Product Specifications for All-Weather 120V Heat Pump unit as of 8/1/2025. https://www.gradientcomfort.com/products/gradient-all-weather-120v-window-heat-pump.
11. Midea Product Specification for PWHP as of 8/1/2025. https://www.mideacomfort.us/packaged.html
12. Engineering assumption to increase the Climate Zone 2 EFLH Heat value to be equal to Zone 3. The original study value determined this value to be 1020 hours, which is lower than zone 3 at 1046 hours.

Revision History

Version	Description	Author	Date
2.3	Updated to new Federal and ENERGY STAR standards, updated incremental costs	Franklin Energy Services	7/31/2014
2.5	Removed mention of existing unit in example, adding EER_Eff to Required Inputs Updated ENERGY STAR standards, example, and notes	Franklin Energy Services	8/25/2016
2.6	Corrected CEER ratings table, added CEER ratings tables for units with reverse cycle and casement	Cadmus	10/2018
4.0	Updated CF, EFLH modifications based on recent CARD study.	Cadmus	11/1/2022
4.2	ENERGY STAR criteria update to v5.0. Modified incremental cost reference and values.	Cadmus	8/1/2024
5.0	Expanded measure to include window ASHP units, clarified scope of eligible equipment and baseline conditions. Expanded algorithm to allow for kWh heating savings for ASHPs replacing electric resistance heating.	Cadmus	8/1/2025
5.0	Updated the $EFLH_{HEAT}$ value for Climate Zone 2 (Central MN) to match the $EFLH_{HEAT}$ value for Climate Zone 3 (Southern MN/Twin Cities)	MN Department of Commerce	2025

Residential HVAC – Air Source Heat Pump Systems (ASHP)

Measure Detail	Measure Value
Measure ID	1.02.03
Target Market Segments	Residential
Target End Uses	HVAC
Applicable To	Residential customers in single-family homes, duplexes, townhomes, and multifamily homes (including 3- and 4-family homes) with residential type central ducted and ductless air source heat pump (ASHP) systems
Actions	Replace on Fail, Early Replacement, New Construction
Required from Customer/Contractor	Equipment size (tons), SEER or EER of new equipment, SEER or EER of existing equipment (if program includes early replacements), HSPF of new equipment, HSPF of existing equipment (if available), existing equipment condition, AHRI certification of system
Measure Energy Type	Gas, Electric, EFS
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	18 years (Ref. 1)
Unit Participant Incremental Cost	See Table 5. Incremental costs between a code minimum ASHP and higher SEER ASHP. Costs are for equipment only, labor is not included. Actual incremental costs should be used whenever possible given the various baseline scenarios possible for this measure.

Measure Description

This measure includes replacement of failed or working central ducted and ductless cooling systems, heating systems, or combination systems with high-efficiency ASHP systems in existing homes, as well as installation of high-efficiency ASHP systems in new homes. Savings for replacement of working units are in reference to the existing unit. An ASHP system can be considered an applicable replacement scenario for electric resistance heating (with or without a cooling system), a less efficient ASHP system, or a fossil fuel fired heating system such as a boiler or furnace (with or without a cooling system). For new construction installations, the baseline should be assumed to be a fuel system most applicable to the location of installation and capacity required.

Systems functioning as the primary heating and cooling system are applicable for savings and rebates. In circumstances where the ASHP heating system is installed in conjunction with existing heating or cooling systems, the existing system must be controlled as the backup heating or cooling system. ASHPs used as backup heating systems are not applicable.

Qualifying ASHP systems must meet the efficiency criteria outlined in the current ENERGY STAR performance criteria (v6.1) for Central Air Conditioners and Heat Pumps (Ref. 7). An AHRI certificate is required for every qualifying system installed. Heat pumps operating as the primary heating system and programmed with a changeover temperature to the backup system of less than 30°F are encouraged to

also meet the Northeast Energy Efficiency Partnerships (NEEP) Cold Climate Air Source Heat Pump (ccASHP) Specification, version 4.0 (Ref. 13, 14). The specification uses AHRI-certified performance ratings and manufacturer reported data to describe the efficiency and capacity of the unit under full and part load conditions. This equipment is rated under ANSI/AHRI 210/240. Cold climate specific ASHP installations will be covered in a separate measure with different operating assumptions and requirements.

The Minnesota Energy Conservation and Optimization Act (Ref. 17, and 18) allows for efficient fuel switching (EFS) improvements where electricity or natural gas replaces another fuel used by the customer (i.e. natural gas, fuel oil, propane, etc) provided that the following criteria are met for each measure pursued:

1. The proposed efficient fuel switching measure results in a net reduction in the amount of source energy consumed for a particular use, measured on a fuel-neutral basis, using the utility's annual system average efficiency, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.
2. The proposed efficient fuel switching measure results in a net reduction of statewide greenhouse gas emissions (Ref. 19), over the lifetime of the improvement. For an efficient fuel-switching improvement installed by an electric utility, the reduction in emissions must be measured using the utility's annual average emissions factor, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.
3. The proposed efficient fuel switching measure is cost-effective, considering the costs and benefits from the perspective of the utility, participants, and society.
4. The proposed efficient fuel switching measure should produce a similar or higher level of quality, service, or output as the technical assumptions identified in the baseline technology to be eligible (Ref. 19).

Utilities can pursue efficient fuel switching energy savings as part of their ECO programs if an applicable incentive/program/rate is offered to customers and has measured participation. Annual participation within the applicable measure should be tracked to claim savings for any efficient fuel switching savings claimed.

This measure potentially includes the efficient fuel switching energy savings resulting from conversion of some or all of the non-electric heating energy of the baseline equipment to electric heating energy in the proposed ASHP equipment.

Baseline equipment for this measure is assumed to include residential-sized furnaces, boilers, air source heat pumps, wood pellet stoves, and electric resistance heating elements. The proposed efficient technology is an air source heat pump. To meet the same quality of service the baseline provides, the ASHP should be sized to serve the entire or partial heating load served by the baseline equipment. In the case of partial displacement, the ASHP will be backed up by other equipment to meet the entire heating load in combination. In most cases, the backup equipment will be the existing baseline equipment left in

place but sequenced to operate as backup, but could also be newly installed equipment sequenced to operate as backup.

Algorithms

Refer to Appendix G for the Residential ASHP Calculator. Within the calculator are several tabs with reference data for a BEopt (Building Energy Optimization Tool) model developed to model energy savings for this measure. Modeled data has been used to determine the inputs for %Backup, default equipment capacities, and the deemed savings shown in Tables 6 and 7. The remaining tabs within the Appendix G calculator are available to assist with determining energy reductions, additions, and net savings by fuel type, cost-effectiveness and emissions ramifications from permutations not modeled. The modeled output data should be relied on as primary and the calculator as secondary given the limited functionality of the Excel-based calculator.

If proposing alternative inputs not modeled for this measure, entities with the resources and customer data to support hourly load model calculations should propose custom approaches to this measure to support rationale for meeting efficient fuel switching requirements. It is expected that as ASHP technology continues to expand in Minnesota, and more studies are conducted on customer installation and operation, the algorithm, model, and metrics within this measure will continue to be revised with the best data available.

Cooling Savings

ASHP replaces AC system: *For cooling savings from ASHP replacing an AC system, use the AC system capacity and EFLH in both baseline and efficient cases such that the efficiency difference between the units is the comparable metric to determine savings.*

Unit kWh Savings per Year = Baseline kWh Consumption – Efficient kWh Consumption

Baseline kWh Consumption per Year = $(Capacity_{BASE} / 1{,}000) \times EFLH_{COOL\ AC} \times (1 / SEER_{BASE})$

Efficient kWH Consumption per Year = $(Capacity_{BASE} / 1{,}000) \times EFLH_{COOL\ AC} \times (1 / SEER_{EFF})$

Unit Peak kW Savings = Baseline Peak kW Demand = Efficient Peak kW Demand

Baseline Peak kW Demand = $(Capacity_{BASE} / 1{,}000) \times CF \times (1 / EER_{BASE})$

Efficient Peak kW Demand = $(Capacity_{BASE} / 1{,}000) \times CF \times (1 / EER_{EFF})$

ASHP replaces less efficient ASHP system:

Unit kWh Savings per Year = Baseline kWh Consumption – Efficient kWh Consumption

Baseline kWh Consumption per Year = $(Capacity_{BASE} / 1{,}000) \times EFLH_{COOL\ HP} \times (1 / SEER_{BASE})$

Efficient kWH Consumption per Year = $(Capacity_{BASE} / 1{,}000) \times EFLH_{COOL\ HP} \times (1 / SEER_{EFF})$

Summer Peak kW Savings = Baseline Summer Peak kW Demand - Efficient Summer Peak kW Demand

Baseline Summer Peak kW Demand = ($Capacity_{BASE}$ / 1,000) x CF x (1 / EER_{BASE})

Efficient Summer Peak kW Demand = ($Capacity_{BASE}$ / 1,000) x CF x (1 / EER_{EFF})

**Note that for ASHP systems sized with capacity exceeding the necessary cooling load, efficient peak summer kW derived from the calculation above will likely exceed actual efficient peak summer kW given the oversize factor. In those situations, efficient peak summer kW will need to be adjusted by the oversized factor to more accurately reflect actual peak summer demand from the ASHP based on cooling load. For this reason, Capacity_Base is referenced for the efficient case algorithm.*

<u>Heating Savings</u>

ASHP replaces Fossil Fuel Furnace/Boiler or Wood Stove:

Unit Net MMBtu Savings per Year = Unit Dth Savings per Year + ((Baseline kWh Consumption per Year - Efficient kWh Consumption per Year) / 293.07)

Unit Dth Savings per Year = Baseline Dth Consumption per Year - Efficient Dth Consumption per Year

Baseline Dth Consumption per Year = ($Capacity_{BASE}$ / 1,000,000) x $EFLH_{HEAT\ BASE}$ x (1/ $\%EFF_{BASE}$)

Baseline kWh Consumption per Year = (Baseline Dth Consumption per Year x FanEnergy%) x 293.07

Efficient Dth Consumption per Year = ($Capacity_{BASE}$ / 1,000,000) x $EFLH_{HEAT\ BASE}$ x (1/ $\%EFF_{BASE)}$ x %BACKUP

Efficient kWh Consumption per Year = ($Capacity_{BASE}$ / 1,000) x $EFLH_{HEAT\ BASE}$ x (1/ $HSPF_{EFF}$) x (1 - %BACKUP)] + ((Efficient Dth Consumption per year x FanEnergy%) x 293.07)

ASHP replaces Electric Resistance Heating:

Unit kWh Savings per Year = Baseline kWh Consumption per Year – Efficient kWh Consumption per Year

Baseline kWh Consumption per Year = ($Wattage_{BASE}$ / 1,000) x $EFLH_{HEAT\ BASE}$ x (1 / $\%EFF_{BASE}$)

Efficient kWh Consumption per Year = [($Capacity_{EFF}$ / 1,000) x $EFLH_{HEAT\ HP}$ x (1 / $HSPF_{EFF}$) x (1 - %BACKUP)]
+[($Wattage_{BASE}$ / 1,000) x $EFLH_{HEAT\ BASE}$ x (1 / $\%EFF_{BASE}$) x %BACKUP]

ASHP replaces Less Efficient ASHP:

Unit kWh Savings per Year = $Capacity_{BASE}$ x $EFLH_{HEAT\ HP}$ x [(12 / $HSPF_{BASE}$) – (12 / $HSPF_{EFF}$)]

Where:

$Capacity_{BASE}$	= Output capacity of baseline unit in btu/hr (1 ton = 12,000 btu/h). If ASHP, use capacity rated at 47°F. If unknown, use deemed values in Table 6 and Table 7.
$Capacity_{EFF}$	= Output capacity of efficient ASHP unit in btu/hr (1 ton = 12,000 btu/h) rated at 47°F.
$Wattage_{BASE}$	= Output wattage of the baseline electric resistance total system. If unknown assume the lesser of 250 watts per linear foot of baseboard heater, or 10 watts per total conditioned square footage of home.
$EFLH_{COOL}$	= Equivalent Full Load Cooling Hours by equipment type and zone. See Table 1.
$EFLH_{HEAT}$	= Equivalent Full Load Hours Heating. See Table 2.
$SEER_{BASE}$	= SEER of baseline or existing unit provided by customer/contractor if Replace Working (Ref. 4). If unknown, Replace on Fail or New Construction see Table 3.
$SEER_{EFF}$	= SEER of new high-efficiency unit provided by customer/contractor (Ref. 4). See Table 4 for minimum requirements. Note that if SEER2 is given, either convert to SEER or use SEER2 in both baseline and efficient when making a direct comparison. See Tables 8 and 9 for conversion.
EER_{BASE}	= EER of baseline or existing unit provided by customer/contractor. Actuals strongly preferred, particularly for variable speed systems. If unavailable, for single speed systems use EER = 1.12 x SEER – 0.02 x $SEER^2$ if SEER given. (Ref. 4). If unknown, Replace on Fail or New Construction see Table 3.
EER_{EFF}	= EER of new high-efficiency unit provided by customer/contractor, or use EER = 1.12 x SEER – 0.02 x $SEER^2$ if SEER given. (Ref. 4). See Table 4 for minimum requirements. Note that if EER2 is given, either convert to EER or use EER2 in both baseline and efficient when making a direct comparison.
CF	= Coincidence factor = 0.75 for standard single-speed compressor equipment, 0.9 for variable-speed compressor equipment (see Notes)
1,000	= Conversion from watt to kW
1,000,000	= Conversion from Btu to Dth
293.07	= Conversion from Dth to kWh
FanEnergy%	= Furnace fan energy use as a percentage of annual fuel consumption, 3.14% (Ref. 16)
$\%EFF_{BASE}$	= Efficiency (%) or AFUE of baseline heating system. See Table 3 for default baseline efficiencies by equipment type.
%BACKUP	= Percentage of heating load served by the backup system, assumed to be the same system as the baseline system. Applicable to heat pump installations

where the heat pump is meant to partially displace the baseline system. Determined by programmed changeover temperature from primary heat pump to backup system. Appendix G has modeled this value as 77.8% in Zone 1, 76.6% in Zone 2, and 71.3% in Zone 3 for ducted furnace backup systems. For other systems or other inputs, see Appendix G.

$HSPF_{EFF}$ = Heating system performance factor of efficient ASHP, provided by customer/contractor. See Table 4 for minimum qualifying requirements. To account for reduced heating efficiency at low outdoor air temperatures, use Appendix G, or alternative resource, to determine the HSPF value for heating season given a set switch over temperature and zone (cell v36). Use the derated HSPF value in the algorithm for heating savings. Note that if HSPF2 is given, either convert to HSPF or use HSPF2 in both baseline and efficient when making a direct comparison.

$HSPF_{BASE}$ = Heating system performance factor of baseline or existing ASHP, provided by customer/contractor, or see Table 3 if unknown, Replace on Fail or New Construction. Note that if HSPF2 is given, either convert to HSPF or use HSPF2 in both baseline and efficient when making a direct comparison.

Example:

A single-family home with an A/C unit (30,000 output Btu/hr at SEER 15, EER 12.5) and natural gas furnace (70,000 output Btu/hr verified at 80% efficiency) is being retrofit with a ducted ASHP, meant to partially displace the furnace in the winter and fully displace the AC unit in the summer. The new ASHP has a HSPF of 9.2, SEER of 16, EER 13 and output capacity of 30,000Btu/hr, with a single-speed compressor. The customer is located in climate zone 3. The switch over temperature has been set at 30 degrees. These parameters fit the Appendix G modeled scenario for partial replacement of existing furnace, therefore deemed values from Table 6 and 7 are used below.

Cooling Savings:

Baseline kWh Consumption per Year = (30,000 / 1,000) x 567 x (1 / 15.0) = 1,134 kWh

Efficient kWH Consumption per Year = (30,000 / 1,000) x 567 x (1 / 16) = 1,063 kWh

Unit kWh Savings per Year = 1,134 kWh – 1,063 kWh = 71 kWh

As calculated by algorithm. Appendix G energy model indicates 282 kWh saved. When input parameters are similar, recommend model is used over linear algorithm

Baseline Peak kW Demand = (30,000 / 1,000) x 0.75 x (1 / 12.5) = 1.8 kW

Efficient Peak kW Demand = (30,000 / 1,000) x 0.75 x (1 / 13) = 1.73 kW

Unit Peak kW Savings = 2.26 kW - 1.88 kW = 0.07 kW

Heating Savings:

Baseline Dth Consumption per Year = (70,000 / 1,000,000) x 1,046 x (1/ 0.80) = 91.5 Dth

Efficient Dth Consumption per Year = (70,000 / 1,000,000) x 1,046 x (1/ 0.80) x 71.3% = 65.2 Dth

Unit Dth Savings per Year = 91.5 Dth – 65.21 Dth = 26.3 Dth

As calculated by algorithm. Appendix G energy model indicates 19 Dth saved. When input parameters are similar, recommend model is used over linear algorithm

Baseline kWh Consumption per Year = ((Baseline Dth x 3.14%) x 293.07) = 842 kWh

Efficient kWh Consumption per Year = ((30,000/ 1,000) x 2,069 x (1/ 8.83) x (100%-71.3%)

+ ((Efficient Dth x 3.14%) x 293.07) = 2,618 kWh

As calculated by algorithm net added kWh is 842 – 2618 = 1,776 kWh added. Appendix G energy model indicates 1,819 kWh added. When input parameters are similar, recommend model is used over algorithm

Unit Net MMBtu Savings per Year, Calculated by algorithm = 26.3 Dth + (842 kWh – 2,618 kWh / 293.07) = 20.2 MMBtu

Unit Net MMBtu Savings per Year, Calculated from Appendix G model = 19 Dth + (1,819 kWh / 293.07) = 25.2 MMBtu. *When input parameters are similar, recommend model is used over algorithm*

Deemed Input Tables

$EFLH_{COOL}$ and $EFLH_{HEAT}$ values were determined from a 2022 MN CARD study using PRISM utility billing data analysis method collected from Minnesota utility customers, and NOAA 2005 - 2020 MN weather data. The EFLH heating calculation uses total heating energy use and equipment input capacity. The total heating energy use was determined from customer billing data and the input capacity was determined through customer interview and utility provided data on installations. In this method, the load factor and oversizing factor are already included in the resulting value derived and are therefore not additionally included as a separate metric in the algorithm. Deviating from the results from the 2022 CARD study, the $EFLH_{HEAT}$ value for Climate Zone 2 (Central MN) matches the $EFLH_{HEAT}$ value for Climate Zone 3 (Southern MN/Twin Cities) to reflect concerns with unexplored variables influencing the initial results that did not trend as expected due to climate. Heat pump heating EFLH values reflect average Minnesota customer heat pump operation, which is a mix of supplemental, primary, and whole-home heating. These values do not solely represent customers who use their heat pump systems as their only heating source. Heat pump systems installed in homes with no other supplemental heating source are expected to have higher annual heating season operating hours than presented in the deemed values table 7 below.

Table 1. Effective Full Load Cooling Hours ($EFLH_{COOL}$) by Climate Zone (Ref. 3)

Zone	ASHP Systems	AC Systems
Zone 1 (Northern MN)	456	312
Zone 2 (Central MN)	512	565
Zone 3 (Southern MN/Twin Cities)	678	567

Note: EFLH values have been derived such that load factor and oversizing factor has been included in the values outlined above. See methodology assumptions and notes on EFLH derivation below.

Table 2. Equivalent Full Load Heating Hours ($EFLH_{HEAT}$) by Climate Zone (Ref. 3, 20)

Zone	ASHP Systems ($EFLH_{HEAT\ HP}$)	Furnace, Boiler, Electric Resistance, and other Systems ($EFLH_{HEAT\ BASE}$)
Zone 1 (Northern MN)	2576	1145
Zone 2 (Central MN)	2383	1046
Zone 3 (Southern MN/Twin Cities)	2069	1046

Note: EFLH values have been derived such that load factor and oversizing factor has been included in the values outlined above. See methodology assumptions and notes on EFLH derivation below.

Table 3. Baseline SEER, EER, and HSPF Values (Ref. 6, 7, 8, 9, 10, 11 and the Methodology and Assumptions Section within Measure ID 1.02.14)

Product Type	$SEER_{BASE}$	$SEER2_{BASE}$	EER_{BASE}*	$EER2_{BASE}$	$HSPF_{BASE}$	$HSPF2_{BASE}$	Fuel Combustion Efficiency % (AFUE)
Split System Air Conditioner	15	13.4	12.5	12.0	N/A	N/A	-
Single Package Air Conditioner	15	13.4	12.0	11.4	N/A	N/A	-
Split System Heat Pump	15	14.3	12.5	12.0	8.5	7.5	-
Single Package Heat Pump	15	13.4	12.0	11.4	8.2	6.7	-
Furnace (all fuel types) - New Construction	-	-	-	-	-	-	90%
Furnace (all fuel types) - Single-family - Replace on Fail or Early Replacement	-	-	-	-	-	-	90%[A]
Furnace (all fuel types) - Duplexes, Townhomes and Multifamily - Replace on Fail or Early Replacement	-	-	-	-	-	-	80%
Boiler (all fuel types)	-	-	-	-	-	-	84%
Electric Resistance	-	-	-	-	-	-	100%
Wood Pellet Stove	-	-	-	-	-	-	75%

[A]The default baseline efficiency for furnaces for single-family homes in this table is set higher than the current Federal minimum standard for Replace on Fail and Early Replacement actions (Ref. 7). If utilities can verify that the actual efficiency of the customer's existing furnace equipment is less than 90%, the Federal minimum standard of

80% AFUE for furnaces can be used (Ref. 9, 10, 11 and Methodology and Assumptions Section within Measure ID 1.02.14).

Table 4. ENERGY STAR Criteria SEER, EER, and HSPF Values (Ref. 12)

Product Type	$SEER_{EFF}$	$SEER2_{EFF}$	EER_{EFF}*	$EER2_{EFF}$	$HSPF_{EFF}$	$HSPF2_{EFF}$
Split Systems Air Conditioner (ENERGY STAR AC Split System)	≥16.0	≥15.2	≥12.5	≥12.0	N/A	N/A
Single Package Air Conditioner	≥16.0	≥15.2	≥12.0*	≥11.5*	N/A	N/A
Split System Heat Pump (ENERGY STAR Heat Pump Split System)	≥16.0	≥15.2	≥12.0	≥11.7	≥9.2	≥7.8
Single Package Heat Pump (ENERGY STAR Heat Pump Single Package)	≥16.0	≥15.2	≥11.0	≥10.6	≥9.2	≥7.8

*Where ENERGY STAR efficiency criteria are lower than the current Federal minimum efficiency standard, eligible equipment must meet or exceed the Federal minimum efficiency indicated in Table 2.

Table 5. Minimum code compliant ASHP to higher SEER ASHP Incremental cost (Ref. 2)

Efficiency Level	Cost per Ton
SEER 16	$411
SEER 17	$548
≥SEER 18	$685

Note: there are many permutations of baseline to efficient cases for this measure, the incremental costs above only apply to the cost differences between a minimum code compliant ASHP to a higher SEER ASHP. Incremental costs for other conversion scenarios will be researched further in later iterations of the TRM. Actual costs should be utilized wherever possible.

Deemed Savings Tables

To determine a set of deemed values for this measure, a BEopt model has been developed to model the baseline and efficient permutations of this measure. Several variables have been held to constant, the inputs, assumptions and limitations of the model are outlined in Appendix G. Baseline system efficiency constants have been derived from those shown in Table 3. The resulting savings from the fixed variables are shown in Table 6 and Table 7 below.

Table 6. Deemed Cooling Energy Savings

Baseline Case	Performance Case	Savings Type	Zone 1	Zone 2	Zone 3
Traditional AC*	New ASHP	kWh Saved	284	279	282
		kW Demand Savings	0.07	0.07	0.07
Less Efficient ASHP**	New ASHP	kWh Saved	57	64	85
		kW Demand Savings	0.07	0.07	0.07

*values derived from BEopt Model in Appendix G, assumes ducted heating and cooling system model

**Values derived from Appendix G Excel-based calculator

Table 7. Deemed Heating Energy Savings for ASHP Partial Replacement

Baseline Case	Efficient Case	Savings Type	Zone 1	Zone 2	Zone 3
Furnace (all fuel types)	*Deemed heating savings from partial replacement are represented in Appendix G.*[1]				
Boiler (all fuel types)	New ASHP serves primary, existing boiler remains as backup	Dth Saved	76	69	67
		kWh Saved (Added)	(7,004)	(6,435)	(5,964)
		Net MMBtu Saved	52	47	46
Wood Pellet Stove[2]	New ASHP serves primary, existing stove remains as backup	Dth Saved	35	35	40
		kWh Saved (Added)	(3,067)	(3,199)	(3,125)
		Net MMBtu Saved	25	24	29
Electric Resistance	New ASHP serves primary, existing electric resistance remains as backup	Net kWh Saved	10,282	9,275	9,210
		Net MMBtu Saved	35	32	31
Less Efficient ASHP[3] (full replacement)	New ASHP installed to replace less efficient ASHP	Net kWh Saved	310	183	125
		Net MMBtu Saved	1.1	0.6	0.4

Methodology and Assumptions

Building heating and cooling loads shall be calculated and systems shall be sized in accordance with applicable federal, state, local, and municipal codes and standards. The algorithm and calculator associated with this measure are not intended to provide direction in appropriately sizing a heat pump.

The algorithm calculates heating savings and cooling savings separately. Installations where ASHP systems are used for only heating or only cooling should claim only the savings associated with the season of use. ASHPs installed with the intention of serving only cooling should not claim heating savings. The algorithm calculates baseline case consumption and performance case consumption separately so

[1] On January 9, 2026, the Assistant Commissioner of the MN Department of Commerce issued a Decision on the final version of the MN TRM v5.0 (this iteration of the MN TRM). This Decision included an update to the default baseline efficiency for furnaces ($\%EFF_{BASE}$) for single-family homes in Replace on Fail and Early Replacement applications at 90% with the caveat that If utilities can verify that the actual efficiency of the customer's existing furnace equipment is less than 90%, an $\%EFF_{Base}$ of 80% AFUE can be used. See Table 3 for more information. This update was completed in the algorithm based energy and demand savings methodology of this measure on January 9, 2026 but was not completed within the BEopt model methodology for this measure. It is expected that the update will be made in the BEopt model methodology for this measure by the end of quarter 1 2026. An updated Appendix G will be issued at that time with this included update.

[2] Wood pellet stove is not able to be modeled in BEopt; the values represented in this table have been generated from Appendix G Excel-based calculator.

[3] ASHP to ASHP not modeled in BEopt; the values represented in this table have been generated from Appendix G Excel-based calculator.

that baseline system and fuel type can be quantified independently. The deemed values assume that in partial replacements, the baseline system becomes the backup system in the performance case.

The measure algorithm relies on weather-dependent variables, incorporated into a BEopt model to estimate savings. Various inputs have been fixed to determine the deemed savings presented in this measure. The inputs can be varied by using the Appendix G Excel-based calculator instead of the deemed BEopt outputs, but resulting savings estimates will be less reliable. As an alternative to using the BEopt outputs or Appendix G calculator to calculate this measure, custom approaches supported by customer collected data can be proposed.

Note that the BEopt model is limited to a single HSPF2 input and therefore has limited ability to account for reduced heating efficiency at low OSA temperatures. The simulation uses a performance curve based on a single HSPF2 input to model part-load efficiency but is limited in the ability to vary the default performance curve to distinguish between standard and cold climate performance. For cold climate equipment and applications where the switch over temperature is significantly lower than 30 degrees, measure savings would more accurately be calculated through custom proposed calculations. When BEopt is able to accurately model this, a cold climate ASHP measure will be developed for inclusion in the TRM. The BEopt model does not currently incorporate variable speed compressors as a parameter but has the ability to be modeled. Future iterations of this measure may incorporate variable speed outputs. BEopt currently uses TMY3 datasets, but will be updated in future with TMY4 (once available) or another recent representative set of weather data agreed upon for all TRM measures. BEopt accepts .epw files, which would need to be created with complete data (solar, wind, etc) to be used in the model as an alternative to TMY3. See Appendix G for a full list of the model inputs, assumptions, model permutations and outputs.

The emissions values presented in appendix G represent emissions from stationary combustion of the specified fuel irrespective of the timing of the combustion or the efficiency of the method of combustion. These values are not derived from hourly emissions models specific to Minnesota or more granular utility territories within Minnesota, as required by the most recent resource plan approved by the commission under section 216B.2422. Hourly emissions models are still under development by utility groups, emissions values currently presented within the TRM will be revisited with hourly modeled data when available. Emissions values currently outlined within the TRM are meant to serve as guardrails and placeholders until more granular data is available. Utilities able to analyze terretory emissions on an hourly basis should utilize hourly emissions specific to their territory in place of TRM provided emissions data.

Effective January 1, 2023, HVAC products will be subject to regional minimum efficiencies, according to Seasonal Energy Efficiency Ratio 2 (SEER2). The nomenclature of SEER2, EER2 and HSPF2 will be used to denote the new M1 ratings. Conversion between the new M1 ratings and original M ratings should be done using an AHRI approved method, using the multipliers in Table 8 and Table 9 below.

Table 8. M to M1 Forward Conversion (Ref. 15)

System Type	Multiplier to convert to SEER2*	Multiplier to convert to EER2	Multiplier to convert to HSPF2
Ducted	0.95	0.95	0.85
Ductless	1.00	1.00	0.90
Packaged	0.95	0.95	0.84

Table 9. M1 to M Backward Conversion (Ref. 15)

System Type	Multiplier to convert to SEER*	Multiplier to convert to EER	Multiplier to convert to HSPF2
Split System Air Conditioner	1.05	1.04	N/A
Split System Heat Pump	1.05	1.04	1.18
Packaged Air Conditioner	1.04	1.04	N/A
Packaged Heat Pump	1.04	1.04	1.18
Ductless Heat Pump	1.00	1.00	1.12
Space Constrained System	1.01	1.00	1.17
Small Duct High Velocity System	1.00	1.00	1.18

The value for coincidence factor is derived from a 2016 CARD study (Ref. 5) that examined quality install and maintenance practices for residential furnaces, air conditioners and heat pumps, in part by metering the behavior and performance of 58 cooling systems and 55 furnaces. A follow-on memo was produced (Ref. 5) that recommended coincidence factor be reduced from 90% to 75%. Because the previous 90% value was simply deemed as a typical value worth updating when primary data was available, that update is applied here. However, because the metered systems had single-speed compressors, 90% may still be used for equipment with variable-speed compressors.

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20. Engineering assumption to increase the Climate Zone 2 EFLH Heat value to be equal to Zone 3. The original study value determined this value to be 1020 hours, which is lower than Zone 3 at 1046 hours.

Revision History

Version	Description	Author	Date
1.0	New spec to reflect standalone QI measure in DER Smart Measure Library. Added wording to clarify how EER and SEER are calculated. Changed energy savings equations arrangement, measure life, incremental costs, and references.	Joe Plummer	7/25/2012
2.0	Add explanation of multifamily buildings under required customer/contractor inputs, corrected ASHP example calculation, added existing HSPF to Required Inputs (if program includes early replacements of working units.). Federal standard grace period note added	Joe Plummer	3/12/2014
3.0	Changed to $EFLH_{HEAT}$ algorithm	Franklin Energy Services	11/12/2015
3.1	Updated CF, adjusted HSPF for AHRI climate zones	Cadmus	10/2019
3.2	Updated baseline SEER, EER, and HSPF	Cadmus	10/2020
4.0	Split the AC and Air Source Heat Pump measure into separate measures, incorporated ducted and ductless heat pumps into one measure for all ASHPs. Updated baseline efficiency requirements, updated performance efficiency requirements, including new SEER2, EER2 and HSPF2 requirements and crosswalk, modified algorithm to incorporate adjustments for backup fuel, added baseline fuel scenarios, added deemed table of savings based on baseline fuel scenarios, added optional	Cadmus	11/1/2022

Version	Description	Author	Date
	calculator tool to aid calculations of savings. EFLH modifications.		
4.1	Updates to the input metrics based on 8,760 modeled data in BEopt. Deemed savings values derived from BEopt model rather than Excel based calculator in v4.0. Clarification to SEER2, EER2 and HSPF2 conversions. Modification to algorithm to simplify. Updates to federal and ENERGY STAR criteria for applicable equipment.	Cadmus	11/1/2023
5.0	Updated the $EFLH_{HEAT}$ value for Climate Zone 2 (Central MN) to match the $EFLH_{HEAT}$ value for Climate Zone 3 (Southern MN/Twin Cities) Updated the baseline efficiency for Furnaces in single-family homes to 90% in some applications with a caveat in the algorithm based methodology. This update will be included in the BEopt modeled methodology prior to the end of Q1 2026.	MN Department of Commerce	2025

Residential HVAC – Air to Water Heat Pump (AWHP)

Measure Detail	Measure Value
Measure ID	1.02.04
Target Market Segments	Residential
Target End Uses	HVAC
Applicable To	Residential customers in single-family homes, duplexes, townhomes and multifamily homes (including 3- and 4-family homes) with residential type hydronic space heating
Actions	Replace on Failure, Replace Working, New Construction
Required from Customer/Contractor	Existing HVAC system type (electric resistance boiler, gas boiler, propane boiler, electric resistance baseboard), Equipment capacity of existing and new equipment, efficiency of existing equipment and COP of new unit, Action Type (Replace on Fail, Replace Working)
Measure Energy Type	Electric, Gas, EFS
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	18 years (Ref. 1)
Unit Participant Incremental Cost	See Table 3, actuals preferred

Measure Description

This measure includes replacement of failed or working hydronic heating system boiler (electric or fossil fuel fired) with high efficiency air-to-water heat pump (AWHP) systems for space heating with or without domestic hot water (DHW) pre heating and space cooling. While AWHP can serve DHW pre heating and cooling applications, the potential energy savings not been quantified in this measure, as cooling savings have not been supported by current findings from MN CARD studies on this topic (Ref 2,3). The measure is applicable to retrofit or new construction single family homes. Savings for replacement of working units are in reference to the existing unit. AWHPs can typically deliver hot water in the range of 80-120°F. Fossil fuel furnaces typically deliver warmer supply air (120-140°F) and traditional radiator hydronic systems are typically designed for supply temperatures of 160-180°F. As a result, AWHPs are not considered a drop in replacement for high temperature hydronic systems or fossil fuel forced air systems. Qualifying applications of AWHPs are in new construction of existing homes utilizing low temperature emitters such as fan coil cassettes, radiant floor heating and central hydronic coils (Ref. 2,3).

An AWHP system can be considered an applicable replacement scenario for electric resistance hydronic heating (with or without a cooling system) or a fossil fuel fired hydronic heating system (with or without a cooling system). For new construction installations, the baseline should be assumed to be a fuel system most applicable to the location of the installation and capacity required.

Systems functioning as the primary space heating system are applicable for savings and rebates. In circumstances where the AWHP heating system is installed in conjunction with existing heating systems, the existing system must be controlled as a supplemental back-up heating system. AWHPs used as back-up heating systems are not applicable.

Qualifying AWHP systems should meet or exceed the efficiency criteria outlined in the Efficiency Vermont Qualified Products List at the time of purchase until a rating standard is available for AWHPs available in Minnesota. The AWHP must be sized to cover most of the heating load with the available distribution system. The building must have a water-based heating distribution system, ideally low temperature radiant heating (generally connected to a boiler if not an AWHP). The rating standard for air-to-water heat pump equipment is AHRI 550/590. However, few products use this standard for product certification or publish these rating conditions in their product literature. As such, the minimum qualification criteria for an air to water heat pump is to generate 110°F supply water at an outdoor temperature of 5°F with a COP of 1.7 or greater (COP @ A5W110), which is a published rating in all qualifying product literature. See references 4 and 5 for a database of qualified products.

The Minnesota Energy Conservation and Optimization Act (Ref. 9,10) allows for efficient fuel switching (EFS) improvements where electricity or natural gas replaces another fuel used by the customer (i.e. natural gas, fuel oil, propane, etc) provided that the following criteria are met for each measure pursued:

1. The proposed efficient fuel switching measure results in a net reduction in the amount of source energy consumed for a particular use, measured on a fuel-neutral basis, using the utility's annual system average efficiency, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.
2. The proposed efficient fuel switching measure results in a net reduction of statewide greenhouse gas emissions (Ref 11), over the lifetime of the improvement. For an efficient fuel-switching improvement installed by an electric utility, the reduction in emissions must be measured using the utility's annual average emissions factor, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.
3. The proposed efficient fuel switching measure is cost-effective, considering the costs and benefits from the perspective of the utility, participants, and society.
4. The proposed efficient fuel switching measure should produce a similar or higher level of quality, service, or output as the technical assumptions identified in the baseline technology to be eligible (Ref. 12).

Utilities can pursue efficient fuel switching energy savings as part of their ECO programs if an applicable incentive/program/rate is offered to customers and has measured participation. Annual participation within the applicable measure should be tracked to claim savings for any efficient fuel switching savings claimed.

This measure potentially includes the efficient fuel switching energy savings resulting from conversion of some or all of the non-electric heating energy of the baseline equipment to electric heating energy in the proposed equipment.

Baseline equipment for this measure is assumed to include residential-sized boilers, and electric resistance heating elements. The proposed efficient technology is an air to water heat pump. To meet the same quality of service the baseline provides, the AWHP should be sized to serve the entire or

partial heating load served by the baseline equipment. In the case of partial displacement, the AWHP will be backed up by other equipment to meet the entire heating load in combination. The backup equipment will be the existing baseline equipment left in place or newly equipment, and will be sequenced to operate as backup.

Algorithms

Refer to Appendix G for the Residential ASHP Calculator, AWHP tab for consumption and savings calculations for this measure based on binned hourly heat load, and utilize capacity and efficiency ratings at different OSA temperatures, which provides a slightly more accurate representation of values than the below algorithms. Binned weather data and a deemed switchover temperature of 5 degrees F has been assumed in the variable inputs to the algorithm below, and the deemed savings shown in Table 5. The Appendix G calculator is available to assist with determining energy reductions, additions, and net savings by fuel type, cost-effectiveness and emissions ramifications from permutations not presented in this measure.

AWHP replaces fossil fuel fired hydronic heating system, backup is fossil fuel:

Unit MMBtu Savings per Year (net) = Unit Dth Savings per Year + ((Baseline kWh Consumption per Year - Efficient kWh Consumption per Year) / 293.07)

Unit Dth Savings per Year = Baseline Dth Consumption per Year - Efficient Dth Consumption per Year

Baseline Dth Consumption per Year = $(Capacity_{BASE} / 1{,}000{,}000) \times EFLH_{HEAT\ BASE} \times (1/ EFF_{BASE})$

Efficient Dth Consumption per Year = $(Capacity_{BACK} / 1{,}000{,}000) \times EFLH_{HEAT\ BASE} \times (1/ EFF_{BACK}) \times \%BACKUP$

Baseline kWh Consumption per Year = 0

Efficient kWh Consumption per Year = $(Capacity_{EFF} / 3{,}412) \times EFLH_{HEAT\ HP} \times (1/ COP_{EFF}) \times (1 - \%BACKUP)]$

AWHP replaces electric resistance hydronic heating system, backup is electric resistance:

Unit kWh Savings per Year = Baseline kWh Consumption per Year – Efficient kWh Consumption per Year

Baseline kWh Consumption per Year = $KW_{BASE} \times EFLH_{HEAT\ BASE} \times (1 / EFF_{BASE})$

Efficient kWh Consumption per Year = $[(Capacity_{EFF} / 3{,}412) \times EFLH_{HEAT\ HP} \times (1 / COP_{EFF}) \times (1 - \%BACKUP)]$
$+[kW_{BACK} \times EFLH_{HEAT\ BASE} \times (1 / EFF_{BACK}) \times \%BACKUP]$

AWHP replaces fossil fuel fired hydronic heating system, backup is electric resistance:

Unit MMBtu Savings per Year (net) = Unit Dth Savings per Year + ((Baseline kWh Consumption per Year - Efficient kWh Consumption per Year) / 293.07)

Unit Dth Savings per Year = Baseline Dth Consumption per Year - Efficient Dth Consumption per Year

Baseline Dth Consumption per Year = $(Capacity_{BASE} / 1{,}000{,}000) \times EFLH_{HEAT\ BASE} \times (1/ \%EFF_{BASE})$

Efficient Dth Consumption per Year = 0

Baseline kWh Consumption per Year = 0

Efficient kWh Consumption per Year = $[(Capacity_{EFF} / 3{,}412) \times EFLH_{HEAT\ HP} \times (1 / COP_{EFF}) \times (1 - \%BACKUP)]$
$+[kW_{BASE} \times EFLH_{HEAT\ BASE} \times (1 / \%EFF_{BACK}) \times \%BACKUP]$

Where:

$Capacity_{BASE}$	= Output capacity of baseline unit in btu/hr (1 ton = 12,000 btu/h). Provided by customer/contractor. If unknown, match output capacity of installed AWHP system.
$Capacity_{BACK}$	= Output capacity of installed backup unit in btu/hr (1 ton = 12,000 btu/h, 1 kW = 3,412 Btu/hr). Provided by customer/contractor.
$Capacity_{EFF}$	= Output capacity of installed AWHP unit in btu/hr (1 ton = 12,000 btu/h) rated at 47°F. Provided by customer/contractor.
KW_{BASE}	= Output power of the baseline electric resistance total system, in kilowatts. Provided by Customer/Contractor. If unknown assume 10 watts per total conditioned square footage of home. (1 kW = 3,412 Btu/hr)
KW_{BACK}	= Output power of the installed backup electric resistance total system, in kilowatts. Provided by Customer/Contractor. (1 kW = 3,412 Btu/hr)
$EFLH_{HEAT\ BASE}$	= Equivalent Full Load Hours Heating of baseline and backup equipment. See Table 1.
$EFLH_{HEAT\ HP}$	= Equivalent Full Load Hours Heating of AWHP equipment. See Table 1.
1,000	= Conversion from watt to kW
1,000,000	= Conversion from Btu to Dth
293.07	= Conversion from Dth to kWh
3,412	= Conversion from Btu to kWh
%BACKUP	= Percentage of heating load served by the backup system at a switch over temperature of 5 degrees. Applicable to heat pump installations where the heat pump is meant to partially displace the baseline system. Determined by programmed changeover temperature from primary heat pump to backup system. Note that even if switch over temperature is set lower than 5, or if no backup system exists, the COP of the AWHP is likely to decrease to the level of the baseline system (approaching COP 1.0), therefore AWHP should be assumed to perform similarly to an electric resistance system at COP 1.0. Appendix G calculates this value as 21.4% in Zone 1, 19.3% in Zone 2, and 13.5% in Zone 3.
COP_{EFF}	= Coefficient of Performance of AWHP (COP @ A5W110), provided by customer/contractor. The minimum qualification criteria for an air to water heat pump is to generate 110°F supply water at an outdoor temperature of 5°F with a COP of 1.7 or greater (COP @ A5W110). To account for varying COP at different outdoor air temperatures instead of only the COP@A5W110, use

Appendix G calculator. Deemed savings are built on Appendix G calculation with varying COP.

EFF_{BASE} = Coefficient of Performance (COP) of baseline electric system, or AFUE of baseline fossil fuel system, provided by customer/contractor. See Table 2 for assumptions if unknown.

EFF_{BACK} = Coefficient of Performance (COP) of backup electric system, or AFUE of backup fossil fuel system, provided by customer/contractor. See Table 2 for assumptions if unknown. Backup system can either be the existing baseline system left in place to serve backup at low OSA, or can be new system using the same or different fuel as the baseline system.

Example:

A southern Minnesota (Zone 3) single family home with hydronic in-floor heat served by an 17 kW electric boiler is removed and replaced with a 3 ton AWHP (actually 40,000 Btu/hr rated at 47 degrees OSA) from the qualified products list. The AWHP is sized for heating and includes a new 8 kW auxiliary electric boiler for backup heat, sequenced to switch over at 5 degrees OSA temperature. The COP @ A5W110 is 2.25. The system is designed to circulate 110 degree leaving water temperature.

Baseline kWh Consumption per Year = 17 kW x 1,046 x (1 / 1.0) = 17,782 kWh

Efficient kWh Consumption per Year = (40,000 / 3,412) x 2,069 x (1 / 2.25) x (1-13.5%)

+ 8 kW x 1,046 x (1/1.0) x 13.5% = 10,455 kWh

Unit kWh Savings per Year = 17,782 kWh – 10,455 kWh = 7,327 kWh

Note that the above example utilizes the algorithm with a fixed COP. The resulting savings differ from the deemed savings illustrated in Table 5 (baseline case 2) because Table 5 deemed savings were derived from Appendix G which replaces the capacity and EFLH with total heating load determined by binned OSA hours. Appendix G also varies the COP of the AWHP against OSA bins.

Deemed Input Tables

Table 1. Equivalent Full Load Heating Hours ($EFLH_{HEAT}$) by Climate Zone (Ref. 5, 13)

Zone	Furnace, Boiler, Electric Resistance, and other Systems ($EFLH_{HEAT\ BASE}$)	HP Systems ($EFLH_{HEAT\ HP}$)
Zone 1 (Northern MN)	1145	2576
Zone 2 (Central MN)	1046	2383
Zone 3 (Southern MN/Twin Cities)	1046	2069

Table 2. Baseline COP and AFUE Values (Ref. 6)

Product Type	COP_{BASE}	$AFUE_{BASE}$
Boiler (natural gas, propane, oil)	-	82%
Boiler or baseboard (Electric Resistance)	1.0	-

Table 3. AWHP Incremental cost (Ref. 2,3,8)

Baseline (cost)	AWHP Incremental Cost
Electric boiler ($6,000)	$4,000 + $1,880 per ton
Gas, propane, oil boiler ($7,000)	$3,000 + $1,880 per ton

Table 4. Deemed Inputs to Appendix G to Derive Deemed Savings Values

Input	Zone 1	Zone 2	Zone 3
Total Heat Load (Btu)	62,581,725	57,517,444	49,857,968
Percent Load Served by Backup (%BACKUP)	21.4%	19.3%	13.5%
AWHP COP @ A5 W110 (5°F, Leaving temp 110°F)	2.25	2.25	2.25
AWHP COP @ A17 W110	2.59	2.59	2.59
AWHP COP @ A47 W110	3.23	3.23	3.23
AWHP Capacity @ A5 W110 (Btu/Hr)	32,000	32,000	32,000
AWHP Capacity @ A17 W110 (Btu/Hr)	36,000	36,000	36,000
AWHP Capacity @ A47 W110 (Btu/Hr)	40,000	40,000	40,000

Deemed Savings Tables

To determine a set of deemed values for this measure, several variables have been held to constant, the inputs and assumptions are shown in Table 4. Baseline system efficiency constants have been derived from those shown in Table 3. Baseline and backup capacities become irrelevant to the calculation which is driven by the total heat load and the AWHP capacity. The resulting savings from the fixed variables are shown below.

Table 5. Deemed Heating Energy Savings for AWHP, Partial Replacement

Baseline Case	Efficient Case	Savings Type	Zone 1	Zone 2	Zone 3
Fossil Fuel boiler Hydronic System	New AWHP serves primary, existing FF boiler serves backup	Dth Saved	60	57	53
		kWh Saved (Added)	(5,552)	(5,243)	(4,863)
		Net MMBtu Saved	41	39	36
Electric Resistance boiler Hydronic System	New AWHP serves primary, smaller electric resistance serves backup	Dth Saved	0	0	0
		kWh Saved (Added)	8,861	8,364	7,780
		Net MMBtu Saved	30	29	27
Fossil Fuel boiler Hydronic System	New AWHP serves primary, smaller electric resistance serves backup	Dth Saved	76	70	61
		kWh Saved (Added)	(9,481)	(8,493)	(6,833)
		Net MMBtu Saved	44	41	37

Methodology and Assumptions

Building heating and cooling loads shall be calculated and systems shall be sized in accordance with applicable federal, state, local and municipal codes and standards. This measure is not intended to provide direction in appropriately sizing a heat pump, but it does assume that the heat pump is sized as close to the heating load as possible.

The algorithm calculates heating savings only because data quantifying cooling savings from hydronic distribution remains limited. The algorithm calculates baseline case consumption and performance case

consumption separately so that baseline system and fuel type can be quantified independently. See Appendix G for a full list of the model inputs, assumptions, model permutations and outputs. As an alternative to using Appendix G calculator to calculate this measure, custom approaches supported by customer collected data can be proposed.

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13. Engineering assumption to increase the Climate Zone 2 EFLH Heat value to be equal to Zone 3. The original study value determined this value to be 1020 hours, which is lower than Zone 3 at 1046 hours.

Revision History

Version	Description	Author	Date
5.0	Measure Created	Cadmus	9/1/2025

Residential HVAC – Ground Source Heat Pump Systems (GSHP)

Measure Detail	Measure Value
Measure ID	1.02.05
Target Market Segments	Residential
Target End Uses	HVAC
Applicable To	Residential customers in single-family homes and multifamily homes consisting of 2 units or more where ground source heat pump equipment can be installed
Actions	Replace on Failure, Early Replacement, New Construction
Required from Customer/Contractor	Existing HVAC system type, efficiency, and system size. Proposed system size, heating COP and cooling EER
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	25 years (Ref. 1)
Unit Participant Incremental Cost	Actuals preferred when known, see Measure Costs section

Measure Description

This measure includes replacement of non-working and working ground source heat pump (GSHP) equipment and replacement of non-working and working heating and cooling equipment with ground source heat pump systems (GSHP). Qualified GSHPs must meet ENERGY STAR energy efficiency performance requirements for geothermal ground source heat pumps, outlined in Table 4 (Ref. 15), but need not be qualified through the EPA ENERGY STAR program. GSHP systems could be considered normal replacement for baseline systems including ASHP (heating and cooling, existing or NC), electric resistance heating (with or without AC, existing only), fossil fuel furnace/boiler (with or without AC, existing only, EFS), or an existing GSHP at end of life (existing only). This measure assumes there is no or negligible backup heating needed when efficient GSHP is operating.

GSHP systems can reduce domestic hot water (DHW) energy consumption when a desuperheater is installed with the GSHP system. Waste heat from the compressor of the GSHP system is transferred through a heat exchanger, preheating the water within the storage tank style heater (electric or gas fired). The preheating energy benefit only occurs when the GSHP is operating (potentially in both heating and cooling mode) and the compressor is running. The DHW energy savings from the desuperheater is not included in this measure, and is included in a separate measure – MN TRM Residential Hot Water – Desuperheater.

The Minnesota Energy Conservation and Optimization Act (Ref. 14 and 15) allows for efficient fuel switching (EFS) improvements where electricity or natural gas replaces another fuel used by the customer (i.e. natural gas, fuel oil, propane, etc) provided that the following criteria are met for each measure pursued:

1. The proposed efficient fuel switching measure results in a net reduction in the amount of source energy consumed for a particular use, measured on a fuel-neutral basis, using the utility's annual system average efficiency, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.
2. The proposed efficient fuel switching measure results in a net reduction of statewide greenhouse gas emissions (Ref 16), over the lifetime of the improvement. For an efficient fuel-switching improvement installed by an electric utility, the reduction in emissions must be measured using the utility's annual average emissions factor, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.
3. The proposed efficient fuel switching measure is cost-effective, considering the costs and benefits from the perspective of the utility, participants, and society.
4. The proposed efficient fuel switching measure should produce a similar or higher level of quality, service, or output as the technical assumptions identified in the baseline technology to be eligible (Ref. 17).

Utilities can pursue efficient fuel switching energy savings as part of their ECO programs if an applicable incentive/program/rate is offered to customers and has measured participation. Annual participation within the applicable measure should be tracked to claim savings for any efficient fuel switching savings claimed.

This measure potentially includes the efficient fuel switching energy savings resulting from conversion of some or all of the non-electric heating energy of the baseline equipment to electric heating energy in the proposed equipment.

Algorithms

Heating and Cooling Savings:

Unit kWh Savings per Year = (Unit Heating kWh Baseline per Year + Unit Cooling kWh Baseline per Year) - (Unit Heating Proposed kWh per Year + Unit Cooling Proposed kWh per Year)

Unit Peak kW Savings = (Unit Cooling kWh Baseline per Year - Unit Cooling Proposed kWh per Year) / EFLHCOOL x CF

For EFS Baseline Only:

Unit MMBtu Savings per Year (net) = Unit Heating Dth Baseline per Year + (Unit kWh Savings per Year / 293.07)

Proposed Case, Non EFS and EFS:

Unit Heating Proposed kWh per Year = $Capacity_{GSHP}$ x (3.52 / COP_EFF) x COP_Adjust x $EFLH_{HEAT}$

Unit Cooling Proposed kWh per Year = $Capacity_{GSHP}$ x (12 / EER_EFF) x EER_Adjust x $EFLH_{COOL}$

ASHP Baseline, Non EFS:

Unit Heating kWh Baseline per Year = $Capacity_{BASE}$ x (3.52 / COP_Base) x COP_Adjust x $EFLH_{HEAT\ PUMP}$

Unit Cooling kWh Baseline per Year = $Capacity_{BASE}$ x (12 / SEER_Base) x $EFLH_{COOL}$

Existing GSHP Baseline, Non EFS:

Unit Heating kWh Baseline per Year = $Capacity_{BASE}$ x (3.52 / COP_Base) x COP_Adjust x $EFLH_{HEAT}$

Unit Cooling kWh Baseline per Year = $Capacity_{BASE}$ x (12 / EER_Base) x EER_Adjust x $EFLH_{COOL}$

Electric Heat with A/C Baseline, Non EFS:

Unit Heating kWh Baseline per Year = kWBASE x EFLHHEAT

Unit Cooling kWh Baseline per Year = CapacityBASE x (12 / SEER_Base) x EFLHCOOL

Fossil Fuel Heat with A/C Baseline, EFS:

Unit Heating Dth Baseline per Year = CapacityBASE x (0.12 / EFF BASE) x EFLHHEAT

Unit Cooling kWh Baseline per Year = CapacityBASE x (12 / SEER_Base) x EFLHCOOL

Where:

$Capacity_{GSHP}$	= Output capacity in tons (1 ton = 12,000 btu/h). GSHP is installed proposed efficient system.
$Capacity_{BASE}$	= Output capacity in tons (1 ton = 12,000 btu/h). Baseline system is ASHP, GSHP, AC or Fossil Fuel heating system, also in tons. If baseline capacity is unknown, match output capacity of installed GSHP system.
kW_{BASE}	= Output capacity in kW for electric resistance heating systems.
3.52	= Unit conversion, 1 ton per 3.52 kW
12	= Unit conversion tons to btu. 0.012 MMBtu per 1 ton also used.
293.07	= Conversion from Dth to kWh
$EFLH_{HEAT}$	= Equivalent Full Load Hours, Heating. Align the EFLH metric with the system in place. Performance EFLH will be the heat pump values. Baseline EFLH will either be the heat pump values or the other heating system values depending on the existing system in place. See Table 1.
$EFLH_{COOL}$	= Equivalent Full Load Hours, Cooling. Align the EFLH metric with the system in place. Performance EFLH will be the heat pump values. Baseline EFLH will either be the heat pump values or the A/C system values depending on the existing system in place. See Table 1.
COP_Base	= Rated COP in heating mode for the baseline system. For existing systems, actuals can be used if verified by contractor. For new construction and replace on fail, use defaults provided. For GSHP default baseline, see Table 2 (Ref. 5). For electric boilers and electric resistance heat, use default 1.0 COP. For ASHP, use default 8.2 HSPF (Ref 6). HSPF x 0.29 = COP, or HSPF2 x 0.34 = COP
EFF Base	= Rated AFUE efficiency of baseline fossil fuel system. See Table 3 for default baseline efficiencies by equipment type.

COP_EFF = actual rated COP in heating mode for the proposed ground source heat pump, See Table 4 (Ref 11). COP value rated at entering water temperature 32°F for closed loop systems, and 50°F for open loop systems.

EER_Base = Rated EER in cooling mode for the system. For early replacement, actuals can be used if verified by contractor. See Table 2 for GSHP (Ref. 5), for ASHP or AC baseline assume 12 EER for package system and 12.5 EER for split systems (Ref 6)

EER_EE = actual rated EER in cooling mode for the proposed ground source heat pump, See Table 3 (Ref 9). EER value rated at entering water temperature 77°F for closed loop systems, and 59°F for open loop systems.

SEER_Base = 15.0, baseline split system A/C or ASHP SEER (Ref. 5)

COP_Adjust = 81.6%, adjustment factor from HP rated COP to average COP (Ref. 3)

EER_Adjust = 89.1%, adjustment factor from HP rated EER to average EER (Ref. 3)

CF = Coincidence factor = 0.90 (Ref. 8)

Table 1. Equivalent Full Load Hours (EFLH) by Climate Zone (Ref. 11, 18)

Zone	$EFLH_{HEAT}$ Heat Pump Systems	$EFLH_{HEAT}$ All Other Heating Systems	$EFLH_{COOL}$ Heat Pump Systems	$EFLH_{COOL}$ AC Systems
Zone 1 (Northern MN)	2576	1145	456	312
Zone 2 (Central MN)	2383	1046	512	565
Zone 3 (Southern MN/Twin Cities)	2069	1046	678	567

Note: EFLH values have been derived such that load factor and oversizing factor has been included in the values outlined above. See methodology assumptions and notes on EFLH derivation below.

Table 2. Baseline Case Minimum Energy Efficiency Requirements (Ref. 5)

System Type	Single Stage		Multistage	
	EER	COP	EER	COP
Closed Loop Water-to-Air	14.1	3.2	EER= (highest rated capacity EER + lowest rated capacity EER) / 2	COP= (highest rated capacity COP + lowest rated capacity COP) / 2
Open Loop Water-to-Air	18.0	3.7		
Closed Loop Water-to-Water	12.1	2.5		
Open Loop Water-to-Water	16.3	3.1		
Direct Geoexchange DGX-to-Air	14.1	3.2		
Direct Geoexchange DGX-to-Water	12.1	2.5		

Table 3. Baseline Efficiency (Ref. 5,6, 7, 8, 9, 10 and the Methodology and Assumptions Section within Measure ID 1.02.14)

Building Type	Single-family	Multifamily	
Equipment Type/Action	New Construction, Replace on Fail, Early Replacement	New Construction	Replace on Fail, Early Replacement
Furnace	90%[A]	90%	80%
Boiler	84%	84%	84%

[A] The default baseline efficiency for furnaces for single-family homes in this table is set higher than the current Federal minimum standard for Replace on Fail and Early Replacement actions (Ref. 7). If utilities can verify that the actual efficiency of the customer's existing furnace equipment is less than 90%, the Federal minimum standard of 80% AFUE for furnaces can be used (Ref. 8, 9, 10, and Methodology and Assumptions Section within Measure ID 1.02.14).

Table 4. Performance Case Energy Efficiency Requirements (Ref. 13)

System Type	Single Stage		Multistage	
	EER*	COP**	EER	COP
Closed Loop Water-to-Air	17.1	3.6	Meet req of single stage. EER= (highest rated capacity EER + lowest rated capacity EER) / 2	Meet req of single stage. COP= (highest rated capacity COP + lowest rated capacity COP) / 2
Open Loop Water-to-Air	21.1	4.1		
Closed Loop Water-to-Water	16.1	3.1		
Open Loop Water-to-Water	20.1	3.5		
Direct Geoexchange DGX-to-Air	16.0	3.6		
Direct Geoexchange DGX-to-Water	15.0	3.1		

*EER values rated at entering water temperature of 77°F for closed loop systems, and 59°F for open loop systems.
**COP values rated at entering water temperature of 32°F for closed loop systems, and 50°F for open loop systems.

Non EFS Example 1:

A low-efficiency ground source heat pump is being replaced by a high-efficiency single stage 2.5 ton open loop water to water model with COP of 4.2 and EER of 21 in a single-family residential home in zone 3:

Unit Heating Proposed kWh per Year =2.5 tons x (3.52 / 4.2 COP) x 81.6% x 2,069 hrs = 3,537 kWh
Unit Cooling Proposed kWh per Year = 2.5 tons x (12 / 21 EER) x 89.1% x 678 hrs = 863 kWh
Unit Heating kWh Baseline per Year = 2.5 tons x (3.52 / 3.1 COP) x 81.6% x 2,069 hrs = 4,793 kWh
Unit Cooling kWh Baseline per Year = 2.5 tons x (12 / 16.3 EER) x 89.1% x 678 hrs = 1,112 kWh

Unit kWh Savings per Year = (4,793 + 1,112) - (3,537 + 863) = 1,504 kWh
Unit Peak kW Savings = (1,112 - 863) / 678 hrs x 0.9 = 0.33 kW

EFS Example 2:

An existing gas fired furnace and central AC are replaced with a single stage GSHP, 2.5 ton open loop water to water model, rated efficiency of 21 EER and 4.2 COP, in a single family home in zone 3. The

efficiency of the existing systems are unknown, defaults are used. AC default 12 EER, Gas furnace default 0.9 AFUE.

Unit Heating Proposed kWh per Year =2.5 tons x (3.52 / 4.2 COP) x 81.6% x 2,069 hrs = 3,537 kWh
Unit Cooling Proposed kWh per Year = 2.5 tons x (12 / 21 EER) x 89.1% x 678 hrs = 863 kWh
Unit Heating Dth Baseline per Year = 2.5 tons x (0.12 / 0.9 AFUE) x 2,069 hrs = 68.97 Dth
Unit Cooling kWh Baseline per Year = 2.5 tons x (12 / 16.3 EER) x 678 hrs = 1,248 kWh

Unit kWh Savings per Year = (0 + 1,248) - (3,537 + 863) + (0) = -3,153 kWh (penalty)
Unit Peak kW Savings = (1,248 - 863) / 678 hrs x 0.9 = 0 kW (penalty)
Unit MMBtu Savings per Year (net) = 77.59 Dth + (-3,287 kWh / 293.07) = 79.72 MMBtu

Notes

$EFLH_{COOL}$ and $EFLH_{HEAT}$ values were determined from a 2022 MN CARD study using PRISM utility billing data analysis method collected from Minnesota utility customers, and NOAA 2005 - 2020 MN weather data. The EFLH heating calculation uses total heating energy use and equipment input capacity. The total heating energy use was determined from customer billing data and the input capacity was determined through customer interview and utility provided data on installations. In this method, the load factor and oversizing factor are already included in the resulting value derived and are therefore not additionally included as a separate metric in the algorithm. Deviating from the results from the 2022 CARD study, the $EFLH_{HEAT}$ value for Climate Zone 2 (Central MN) matches the $EFLH_{HEAT}$ value for Climate Zone 3 (Southern MN/Twin Cities) to reflect concerns with unexplored variables influencing the initial results that did not trend as expected due to climate.

Effective January 1, 2023, HVAC products will be subject to regional minimum efficiencies, according to Seasonal Energy Efficiency Ratio 2 (SEER2). The nomenclature of SEER2, EER2 and HSPF2 will be used to denote the new M1 ratings. Conversion between the new M1 ratings and original M ratings should be done using an AHRI approved method, using the multipliers in the Tables below.

Table 5. M to M1 Forward Conversion (Ref. 4)

System Type	Multiplier to convert to SEER2*	Multiplier to convert to EER2	Multiplier to convert to HSPF2
Ducted	0.95	0.95	0.85
Ductless	1.00	1.00	0.90
Packaged	0.95	0.95	0.84

Table 6. M1 to M Backward Conversion (Ref. 4)

System Type	Multiplier to convert to SEER*	Multiplier to convert to EER	Multiplier to convert to HSPF2
Split System Air Conditioner	1.05	1.04	N/A

Split System Heat Pump	1.05	1.04	1.18
Packaged Air Conditioner	1.04	1.04	N/A
Packaged Heat Pump	1.04	1.04	1.18
Ductless Heat Pump	1.00	1.00	1.12
Space Constrained System	1.01	1.00	1.17
Small Duct High Velocity System	1.00	1.00	1.18

Measure Costs

For Time of Sale and new construction, the actual installed cost should be used minus the assumed installation cost of the baseline equipment. Default are $3,957 per ton for new GSHP, $6,562 + $500 per ton for ASHP, $4,053 for fossil fuel heating system, $40 per input MBH for electric boiler and $952 per ton for new central AC system (Ref. 2). Add $500 to the incremental cost when a desuperheater is installed as part of the GSHP upgrade.

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18. Engineering assumption to increase the Climate Zone 2 EFLH Heat value to be equal to Zone 3. The original study value determined this value to be 1020 hours, which is lower than zone 3 at 1046 hours.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	7/31/2015
3.1	Removed gas heating baseline, clarified electric heat with split A/C baseline, updated incremental costs	Cadmus	10/2018
4.0	EFLH modifications based on recent CARD study.	Cadmus	11/1/2022
4.1	Clarification to SEER2, EER2 and HSPF2 conversions	Cadmus	11/1/2023
5.0	Clarification to inputs definitions and values, updates to incremental costs, updates to resources referenced, EFS baseline added to measure.	Cadmus	9/1/2025
5.0	Updated the $EFLH_{HEAT}$ value for Climate Zone 2 (Central MN) to match the $EFLH_{HEAT}$ value for Climate Zone 3 (Southern MN/Twin Cities) Updated the baseline efficiency for Furnaces in single-family homes to 90% in some applications with a caveat.	MN Department of Commerce	2025

Residential HVAC – AC/ASHP Quality Install Additional Savings

Measure Detail	Measure Value
Measure ID	1.02.06
Target Market Segments	Residential
Target End Uses	HVAC
Applicable To	Residential customers in single-family homes, duplexes, multifamily homes (including 3- and 4-family homes), and townhomes
Actions	O&M
Required from Customer/Contractor	Equipment size (tons), SEER or EER of new equipment, HSPF of new equipment (ASHP only), existing or new construction, building type (single family or multifamily*), project location (county)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	18 years (Ref. 1)
Unit Participant Incremental Cost	$250/unit (Ref. 2)
* Multifamily includes duplexes, townhomes, and buildings with three or more units.	

Measure Description

This measure represents additional savings from installation of high-efficiency AC systems or ASHP in existing or new homes through a "Quality Installation" program.

Intended for use with the Residential Efficient Air conditioning (A/C-ASHP) measure which represents the estimated savings that would be achieved without a Quality Installation program.

Algorithms

Unit kWh Savings per Year for AC system =

$$Size \times EFLH_{COOL} \times (12 / SEER_{EFF}) \times [1 / (1 - Loss_{NoQI,e}) - 1]$$

Unit kWh Savings per Year for ASHP =

$$Size \times EFLH_{COOL} \times (12 / SEER_{EFF}) \times [1 / (1 - Loss_{NoQI,e}) - 1] +$$
$$Size \times EFLH_{HEAT} \times (12 / (HSPF_{EFF} \times C_{IV-V})) \times [1 / (1 - Loss_{NoQI,e}) - 1]$$

Unit Peak kW Savings = $Size \times CF \times (12 / EER_{EFF}) \times [1 / (1 - Loss_{NoQI,d}) - 1]$

Where:

Size	= Unit capacity in tons (1 ton = 12,000 btu/h)
$EFLH_{COOL}$	= Effective Full Load Cooling Hours. See Table 1 (Ref. 3)
$SEER_{EFF}$	= SEER of new high-efficiency unit provided by customer/contractor.
EER_{EFF}	= EER of new high-efficiency unit provided by customer/contractor. Actuals strongly preferred, particularly for variable speed systems. If unavailable, for single speed systems use EER = 1.12 x SEER – 0.02 x $SEER^2$ if SEER is provided

(Ref. 4). Note that if EER2 is given, either convert to EER or use EER2 in both baseline and efficient when making a direct comparison.

$Loss_{NoQI,e}$ = Efficiency loss of average unit due to improper installation for energy = 10%. (See Notes)

$Loss_{NoQI,d}$ = Efficiency loss of average unit due to improper installation for demand = 8%. (See Notes)

CF = Coincidence factor = 0.75 for standard single-speed compressor equipment, 0.9 for variable-speed compressor equipment (see Notes)

$EFLH_{HEAT}$ = Effective Full Load Heating Hours. See Table 2 (Ref. 7)

$HSPF_{EFF}$ = Heating system performance factor of efficient ASHP, provided by customer/contractor.

C_{IV-V} = Conversion from rated HSPF to HSPF appropriate for AHRI climate zone V = 0.85 (Ref. 8, Ref. 9)

Examples:

Retrofit AC System installed in single-family home, 3-ton with SEER rating 14.5 (EER 12), Climate Zone 3 following quality installation procedures.

Additional kWh Savings per Year = 3 x 567 x (12 / 14.5) x [1 / (1 - 0.10) - 1] = 156.4

Additional Peak kW Savings = 3 x 0.75 x (12 / 12) x [1 / (1 – 0.08) - 1] = 0.2

Retrofit ASHP in single-family home, 3-ton with SEER rating 15 (EER 12.3), HSPF rating 9, Climate Zone 2.

Additional kWh Savings per Year = 3 x 512 x (12 / 15) x [1 / (1 - 0.10) - 1] +
3 x 2383 x (12 / (9 x 0.85)) x [1 / (1 - 0.10) - 1] = 1,382.5

Additional Peak kW Savings = 3 x 0.75 x (12 / 12.3) x [1 / (1 - 0.08) - 1] = 0.19

Deemed Input Tables

Table 1. Effective Full Load Heating and Cooling Hours (EFLH) by Climate Zone (Ref. 7, 11)

Zone	$EFLH_{HEAT}$ Heat Pump Systems	$EFLH_{HEAT}$ All Other Heating Systems	$EFLH_{COOL}$ Heat Pump Systems	$EFLH_{COOL}$ AC Systems
Zone 1 (Northern MN)	2576	1145	456	312
Zone 2 (Central MN)	2383	1046	512	565
Zone 3 (Southern MN/Twin Cities)	2069	1046	678	567

Note: EFLH values have been derived such that load factor and oversizing factor has been included in the values outlined above. See methodology assumptions and notes on EFLH derivation below.

Methodology and Assumptions

Savings with QI consist of four measures: equipment sizing, air flow, refrigerant charge, and duct leakage. The savings for each measure are not additive as stated in (6), (7). Our review of the studies' shows the reasonable estimated savings would be 25%, approximately 75% of max savings in studies.

To claim Quality Installation savings, a certified technician must sign off on the installation indicating that he or she has inspected the installation and reviewed the submitted data, and verifies that the installation meets proper refrigerant charging and indoor airflow specifications, is sized appropriately according to Manual J calculations, and that ducts have been sealed to the extent practical. In addition, the technician must verify that the indoor and outdoor units are part of a matched system according to the AHRI Certification Directory (www.ahridirectory.org) or other recognized source.

Certification implies that the technician has passed an HVAC certification test by NATE, HVACReducation.net, or a similar organization.

$EFLH_{COOL}$ and $EFLH_{HEAT}$ values were determined from a 2022 MN CARD study using PRISM utility billing data analysis method collected from Minnesota utility customers, and NOAA 2005 - 2020 MN weather data. The EFLH heating calculation uses total heating energy use and equipment input capacity. The total heating energy use was determined from customer billing data and the input capacity was determined through customer interview and utility provided data on installations. In this method, the load factor and oversizing factor are already included in the resulting value derived and are therefore not additionally included as a separate metric in the algorithm. Deviating from the results from the 2022 CARD study, the $EFLH_{HEAT}$ value for Climate Zone 2 (Central MN) matches the $EFLH_{HEAT}$ value for Climate Zone 3 (Southern MN/Twin Cities) to reflect concerns with unexplored variables influencing the initial results that did not trend as expected due to climate.

Effective January 1, 2023, HVAC products will be subject to regional minimum efficiencies, according to Seasonal Energy Efficiency Ratio 2 (SEER2). The nomenclature of SEER2, EER2 and HSPF2 will be used to denote the new M1 ratings. Conversion between the new M1 ratings and original M ratings should be done using an AHRI approved method, using the multipliers in Table 2 and Table 3 below.

Table 2. M to M1 Forward Conversion (Ref. 10)

System Type	Multiplier to convert to SEER2*	Multiplier to convert to EER2	Multiplier to convert to HSPF2
Ducted	0.95	0.95	0.85
Ductless	1.00	1.00	0.90
Packaged	0.95	0.95	0.84

Table 3. M1 to M Backward Conversion (Ref. 10)

System Type	Multiplier to convert to SEER*	Multiplier to convert to EER	Multiplier to convert to HSPF2
Split System Air Conditioner	1.05	1.04	N/A
Split System Heat Pump	1.05	1.04	1.18
Packaged Air Conditioner	1.04	1.04	N/A
Packaged Heat Pump	1.04	1.04	1.18
Ductless Heat Pump	1.00	1.00	1.12
Space Constrained System	1.01	1.00	1.17
Small Duct High Velocity System	1.00	1.00	1.18

The value for coincidence factor is derived from a 2016 CARD study (Ref. 5) that examined quality install and maintenance practices for residential furnaces, air conditioners and heat pumps, in part by metering the behavior and performance of 58 cooling systems and 55 furnaces. A follow-on memo was produced (Ref. 6) that recommended coincidence factor be reduced from 90% to 75%. Because the previous 90% value was simply deemed as a typical value worth updating when primary data was available, that update is applied here. However, because the metered systems had single-speed compressors, 90% may still be used for equipment with variable-speed compressors.

The memo (Ref. 6) also recommends updating $Loss_{NoQI,e}$ to 10%, rather than the previous value of 25%. It also recommends using a separate demand loss factor, $Loss_{NoQI,d}$ of 8%, and eliminating assumed losses for units with a quality install.

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11. Engineering assumption to increase the Climate Zone 2 EFLH Heat value to be equal to Zone 3. The original study value determined this value to be 1020 hours, which is lower than Zone 3 at 1046 hours.

Revision History

Version	Description	Author	Date
2.9	Federal standard grace period note added	Franklin Energy Services	07/31/2014
3.0	Changed heating savings approach and changed from HDD to EFLH	Franklin Energy Services	1/13/2016
3.1	Updated CF and $Loss_{NoQI}$, set $Loss_{QI}$ to zero, adjusted HSPF for AHRI climate zone V	Cadmus	10/2019
4.0	EFLH modifications based on recent CARD study.	Cadmus	11/1/2022
4.1	Clarification to SEER2, EER2 and HSPF2 conversions.	Cadmus	11/1/2023
5.0	Updated the $EFLH_{HEAT}$ value for Climate Zone 2 (Central MN) to match the $EFLH_{HEAT}$ value for Climate Zone 3 (Southern MN/Twin Cities). Modified gas furnace baseline default to 90% (from 80%)	MN Department of Commerce	2025

Residential HVAC – AC or ASHP Tune-Up

Measure Detail	Measure Value
Measure ID	1.02.07
Target Market Segments	Residential
Target End Uses	HVAC
Applicable To	This measure assumes that the existing unit has not been serviced for at least 1 year for residential customers in single-family homes, duplexes, multifamily homes*, and townhomes
Actions	O&M
Required from Customer/Contractor	Project location (county), tons, SEER, actual cost of tune-up, procedures performed during tune-up, building type (single family or multifamily*)
Measure Energy Savings	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	Coil cleaning and filter change: 1 year (Ref. 4) Refrigerant charge and airflow adjustment: 3 years (Ref. 7)
Unit Participant Incremental Cost	$175 (default/planning figure; Use actual cost of tune-up) (Ref. 4)

* Multifamily includes duplexes, townhomes, and buildings with three or more units.

Measure Description

This measure is for the maintenance and tune up of a residential style air conditioning or ASHP unit (either ducted or unducted). The baseline condition models the existing unit prior to efficiency gains achieved by tune up actions. The efficient condition models the existing unit with a savings factor applied.

A residential air conditioning or air source heat pump tune-up can incorporate one or more of several actions:

- General maintenance activities including:
  - Condenser coil cleaning
  - Air filter change
  - Check line loads
  - Measure temperature drop
  - Maintain condenser fan and motor
  - Verify thermostat operation in in accordance with manufacturer recommendations
- Refrigerant charge measurement and correction
- Air flow measurement and correction

General maintenance actions such as coil cleaning and an air filter change are frequently needed and provide a modest boost to system performance. Actions such as refrigerant charge and airflow correction (RCA), generally produce a larger boost in performance but are typically only conducted

periodically as operational issues are exhibited rather than preventatively. For this reason, tune up activities have been tiered with different savings factors and EULs applied.

Algorithms

AC Unit kWh Savings per Year = $(Cap \times 12) \times EFLH_{COOL} / [SEER \times (1 - SF_E)] \times SF_E$

ASHP Unit kWh Savings per Year = $(Cap \times 12) \times EFLH_{COOL} / [SEER \times (1 - SF_E)] \times SF_E$

$+ (Cap \times 12) \times EFLH_{HEAT} / [HSPF \times (1 - SF_E)] \times SF_E$

Unit Peak kW Savings = $(Cap \times 12) \times CF / [EER \times (1 - SF_D)] \times SF_D$

Where:

Cap	= Cooling capacity of AC system or ASHP, in tons. Note 1 ton=12,000 Btu/h. For units with unknown capacity use 2.5 tons
12	= Conversion from tons to MBtu
$EFLH_{COOL}$	= Full load cooling hours (varies by location, see Table 1)
$EFLH_{HEAT}$	= Full load heating hours (varies by location, see Table 1)
SEER	= Nameplate SEER of equipment (kWh / MBtu). For units with unknown SEER use 11.5 (Ref. 2)
EER	= Nameplate EER of equipment (kWh / MBtu). Actuals strongly preferred, particularly for variable speed systems. If unavailable, for single speed systems use EER = 1.12 x SEER – 0.02 x $SEER^2$ = 10.2 (Ref. 5, Ref. 2)
HSPF	= Nameplate heating efficiency of equipment. For units with unknown HSPF use 7.3 (Ref 9)
CF	= Coincidence factor = 0.75 for standard single-speed compressor equipment, 0.9 for variable-speed compressor equipment (see Notes)
SF_E	= Energy savings factor, see Table 2. Savings factors should be summed for each action taken. Note different EULs for Actions, See example 2.
SF_D	= Demand savings factor, see Table 2

Example 1:

Annual tune-up of a central 11.5 SEER (EER 10.24) AC unit sized 2.5 tons in a single-family house in Zone 3, consisting of coil cleaning and filter change only:

Unit kWh Savings per Year = (2.5 x 12) x 567 / [11.5 x (1 – 0.05)] x 0.05 = 77.85 kWh

Unit Peak kW Savings = (2.5 x 12) x 0.75 / [10.24 x (1 – 0.02)] x 0.02 = 0.045 kW

Example 2:

Enhanced tune-up of a 2.5 ton ASHP with unknown efficiency and speed (assume 11.5 SEER, 10.24 EER) in a single family house in Zone 3, consisting of coil cleaning, filter change and refrigerant recharge. Air

flow correction was not conducted during the tune up. Different EULs are applied to the different activities taken, the example has been broken out in detail to demonstrate the steps of calculation:

SF_E = 5% Maintenance Activities + 7% Enhanced Activities: Refrigerant Recharge

SF_D = 2% Maintenance Activities + 3% Enhanced Activities: Refrigerant Recharge

Cumulative Unit kWh Savings = kWh Savings for Maintenance Activities + kWh Savings for Enhanced Activities = 1,313.7 kWh

Cooling kWh Savings for Maintenance Activities = (2.5 x 12) x 678 / [11.5 x (1 – 0.05)] x 0.05 = 93.1 kWh

Heating kWh Savings for Maintenance Activities = (2.5 x 12) x 2,069 / [7.3 x (1 – 0.05)] x 0.05 = 447.5 kWh

Cooling kWh Savings for Enhanced Activities = (2.5 x 12) x 678 / [11.5 x (1 – 0.07)] x 0.05 = 133.1 kWh

Heating kWh Savings for Enhanced Activities = (2.5 x 12) x 2,069 / [7.3 x (1 – 0.07)] x 0.05 = 640 kWh

Cumulative Unit Peak kW Savings = Peak kW Savings for Maintenance Activities + Peak kW Savings for Enhanced Activities = 0.113 kW

Peak kW Savings for Maintenance Activities = (2.5 x 12) x 0.75 / [10.24 x (1 – 0.02)] x 0.02 = 0.045 kW

Peak kW Savings for Enhanced Activities = (2.5 x 12) x 0.75 / [10.24 x (1 – 0.03)] x 0.03 = 0.068 kW

Deemed Input Tables

Table 1. Equivalent Full Load Hours ($EFLH_{HEAT}$ and $EFLH_{COOL}$) by Climate Zone (Ref. 3)

Zone	$EFLH_{HEAT}$ Heat Pump Systems	$EFLH_{COOL}$ Heat Pump Systems	$EFLH_{COOL}$ AC Systems
Zone 1 (Northern MN)	2,576	456	312
Zone 2 (Central MN)	2,383	512	565
Zone 3 (Southern MN/Twin Cities)	2,069	678	567

Note: EFLH values have been derived such that load factor and oversizing factor has been included in the values outlined above. See methodology assumptions and notes on EFLH derivation below.

Table 2: Savings Factors for Tune-Up Actions

Actions	Energy Savings Factor (SF_E)	Demand Savings Factor (SF_D)	SF Reference	EUL
Maintenance activities including: Condenser coil cleaning, filter change, etc	5%	2%	Ref. 2, Ref. 6,	1 Year
Refrigerant charge correction	7%	3%	Ref. 2, Ref. 6	3 Years
Air flow correction	6%	3%	Ref. 2, Ref. 6	3 Years

Methodology and Assumptions

Measurements and corrections must be performed with standard industry tools and practices, and the results tracked by the efficiency program.

The references for the savings factors used in Table 2 (Ref 2 and Ref 6) have similar savings findings for each individual action taken as part of a tune up. The studies both summarize a cumulative savings factor, taking the average number of actions into the weighting of the savings factor. Instead of using the summarized savings factor from either study, this measure has been developed with tiered action options and their own savings factors. The Energy Savings Factors (SFe) of each action, represented in Table 2, are the rounded average of the findings of the two studies. Action one, general preventative maintenance activities has been bundled with an EUL of 1 year given these activities are generally performed annually, according to manufacturer maintenance recommendations, and the study findings demonstrated the savings factors achieved rapidly diminished after they were performed.

Effective January 1, 2023, HVAC products will be subject to regional minimum efficiencies, according to Seasonal Energy Efficiency Ratio 2 (SEER2). The nomenclature of SEER2, EER2, and HSPF2 will be used to denote the new M1 ratings. Conversion between the new M1 ratings and original M ratings should be done using an AHRI approved method, using the multipliers in Table 2 and Table 3 below.

Table 3. M to M1 Forward Conversion (Ref. 8)

System Type	Multiplier to convert to SEER2*	Multiplier to convert to EER2	Multiplier to convert to HSPF2
Ducted	0.95	0.95	0.85
Ductless	1.00	1.00	0.90
Packaged	0.95	0.95	0.84

Table 4. M1 to M Backward Conversion (Ref. 8)

System Type	Multiplier to convert to SEER*	Multiplier to convert to EER	Multiplier to convert to HSPF2
Split System Air Conditioner	1.05	1.04	N/A
Split System Heat Pump	1.05	1.04	1.18
Packaged Air Conditioner	1.04	1.04	N/A
Packaged Heat Pump	1.04	1.04	1.18
Ductless Heat Pump	1.00	1.00	1.12
Space Constrained System	1.01	1.00	1.17
Small Duct High Velocity System	1.00	1.00	1.18

$EFLH_{COOL}$ and $EFLH_{HEAT}$ values were determined from a 2022 MN CARD study using PRISM utility billing data analysis method collected from Minnesota utility customers, and NOAA 2005–2020 MN weather data. The EFLH heating calculation uses total heating energy use and equipment input capacity. The total heating energy use was determined from customer billing data and the input capacity was determined through customer interview and utility provided data on installations. In this method, the

load factor and oversizing factor are already included in the resulting value derived and are therefore not additionally included as a separate metric in the algorithm.

The value for coincidence factor is derived from a 2016 CARD study (Ref. 7) that examined quality install and maintenance practices for residential furnaces, air conditioners and heat pumps, in part by metering the behavior and performance of 58 cooling systems and 55 furnaces. A follow-on memo was produced (Ref. 6) that recommended that the coincidence factor be reduced from 90% to 75%. Because the previous 90% value was simply deemed as a typical value worth updating when primary data was available, that update is applied here. However, because the metered systems had single-speed compressors, 90% may still be used for equipment with variable-speed compressors.

References

1. Based on Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Master's Thesis, University of Colorado at Boulder. Note this is appropriate for single-speed units only.
2. Energy Center of Wisconsin. *Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research*. May 2008. https://focusonenergy.com/sites/default/files/centralairconditioning_report.pdf
3. Cadmus and Minnesota Department of Commerce. "*MN CARD Study: Residential Thermostat Savings and HVAC Equipment Equivalent Full Load Hours*" Accessed July 2022. https://www.cards.commerce.state.mn.us/security/search.do?documentId=%7B3D4A3D02-73F6-480A-B365-D582C35C44CC%7D
4. DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com)
5. ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment
6. Seventhwave. *TRM Implications from the CARD "Improving Installation and Maintenance Practices for Minnesota Residential Furnaces, Air Conditioners, and Heat Pumps" study*. Memo from Seventhwave to MN DER. June 8, 2016. https://mn.gov/commerce-stat/pdfs/card-improving-insullation.pdf
7. Illinois Stakeholder Advisory Group. *2023 Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 11.0, Volume 3: Residential Measures.* September 22, 2023. https://www.ilsag.info/technical-reference-manual/
8. Consortium for Energy Efficiency. CEE Residential Electric HVAC Specification. Published October 18, 2023. https://cee1.my.site.com/s/resources?id=a0V2R00000sUQbyUAG
9. Based average of split system efficiencies meeting the Minimum Federal Standards for 1994 & 2008.

Revision History

Version	Description	Author	Date
1.0	Initial version based on Nexant's original specification	Joe Plummer	
1.1	Increased default tune-up cost to $200	Joe Plummer	
2.1	Changed energy savings equations arrangement	Franklin Energy Services	7/25/2012
2.2	Changed measure life	Franklin Energy Services	7/25/2012
2.3	Changed incremental cost	Franklin Energy Services	7/25/2012
2.4	Changed references	Franklin Energy Services	7/25/2012
2.5	Changed assumption that unit has not been serviced for at least three years to two years to be consistent with measure life of two years	Joe Plummer	3/25/2013
2.6	Added explanation of multifamily buildings	Joe Plummer	3/12/14
3.0	Made EFLH terminology consistent with other measures, added to description of source	Franklin Energy Services	11/12/15
3.1	Adjusted equations, split measure into two tiers	Cadmus	10/2018
3.2	Updated CF	Cadmus	10/2019
4.0	EFLH modifications based on recent CARD study.	Cadmus	11/1/2022
4.1	Clarification to SEER2, EER2, and HSPF2 conversions. Heating savings added for ASHP equipment.	Cadmus	11/1/2023
5.0	Split actions and savings factors for the more enhanced actions. Reduced EUL for general maintenance actions to 1 year (from 2 years). Clarified algorithm operation for the Savings Factor metrics and ASHP portion of savings.	Cadmus	8/1/2025

Residential HVAC – Duct Sealing

Measure Detail	Measure Value
Measure ID	1.02.08
Target Market Segments	Residential
Target End Uses	HVAC
Applicable To	Residential customers in single-family homes, duplexes, townhomes, and multifamily homes (including 3- and 4-family homes) with residential type ducted heating or cooling systems
Actions	O&M
Required from Customer/Contractor	ΔCFM25 as measured in pressurized duct test, Cooling System SEER, Heating System HSPF, Duct Location, project location (county)
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	20 (Ref. 1)
Unit Participant Incremental Cost	$5 per CFM reduction (ΔCFM25DL) (Ref. 2)

Measure Description

Duct Sealing reduces the exfiltration of supply air and infiltration of return air. Sealing of duct work can be accomplished through application of mastic sealant or metal tape to or injection of fog sealant into the distribution system of homes with either central air conditioning or a ducted heating system. For application of mastic or tape the following minimum requirements should be completed.

- Plenum, main ducts, takeoffs and boots must be sealed.
- Post-project carbon monoxide tests must be taken and adjustments made to heating system, until test results are within standard industry acceptable limits.
- In areas where mastic is the main source of sealing, thickness of mastic must be a minimum of 1/16th inch and a good faith effort must be made to remove existing duct tape and cover with mastic.

Algorithms

Unit kWh Savings per Year = ΔkWh_cooling + ΔkWh_heating

Unit Peak kW Savings = ΔCFM25DL/ (Size x 400) x Size x 12,000 x TRF_{cool} / 1000 / (ηDuct x EER) x CF

Unit Dth Savings per Year = ΔCFM25DL / (Btuh_in x 0.017) x EFLH_heat x Btuh_in / ηDuct x TRF_{Heat} / 1,000,000

Where:

ΔkWh_cooling = ΔCFM25DL/ (Size x 400) x $EFLH_{COOL}$ x Size x 12,000 x TRF_{Cool} / (ηDuct x SEER) / 1000

ΔkWh_heating = For electrically heated homes: ΔkWh_heating = ΔCFM25DL/(Size x 400) x $EFLH_{HEAT}$ x Size x 12000 x TRF_{Heat} / (ηDuct x (HSPF x C_{IV-V})) / 1000
For gas heated homes: ΔkWh_heating = (Unit Dth Savings per Year) x Fe x Conversion_Factor

ΔCFM25DL = Reduction in CFM25 as measured through blower testing of pressurized duct work.

12,000 = Conversion factor for Btu/h to tons of refrigeration

400 = nominal cfm per ton of refrigeration (Ref. 3)

$EFLH_{COOL}$ = Equivalent Full Load Cooling Hours. See Table 1.

TRF_{Cool} = Thermal Regain Factor for Cooling depending upon duct location. See Table 2.

SEER = Cooling efficiency of equipment. Assume 11.5 unless provided with other input from customer. (Ref. 6)

EER = Actuals strongly preferred, particularly for variable speed systems. If unavailable, for single speed systems use EER = 1.12* SEER – 0.02 x $SEER^2$ if SEER given. (Ref. 9)

Size = Capacity of AC, heat pump or electric resistance system in tons provided by the customer (1 ton = 12,000 Btu/h)

Btuh_in = rated input capacity of gas furnace in Btu/h provided by the customer

HSPF = the efficiency of the electric heating system provided by customer. See Table 3 for default values depending upon heating system type. (Ref. 7)

C_{IV-V} = Conversion from rated HSPF to HSPF appropriate for AHRI climate zone V = 0.85 (Ref. 15, Ref. 16)

Fe = ratio of furnace electric usage to gas usage = 2.97% (Ref. 8)

Conversion_Factor = 293 kWh/Dth

0.017 = Conversion of Heating Capacity to CFM (0.017 CFM / (Btu/hr)) (Ref. 10)

$EFLH_{HEAT}$ = Equivalent Full Load Heating Hours. See Table 1

TRF_{Heat} = Thermal Regain Factor for Heating depending upon duct location, see Table 2 (Ref. 5)

ηDuct = pre–duct sealing system distribution efficiency. Assume 89% if unknown. (Ref. 12)

CF = electric peak coincidence factor = 0.75 for cooling equipment with standard single-speed compressor, 0.9 for cooling equipment with variable-speed compressor (see Notes). If unknown use 0.75.

Example:

Duct sealing in single-family home Climate Zone 3 crawl space with 2.5 ton SEER 14 (EER 11.8) AC and 60,000 btu/h input gas furnace with a reduction of 300 CFM25.

Unit kWH Savings per Year = 300 / (2.5 x 400) x 567 x 2.5 x 12,000 x 1.0 / (0.89 x 14) / 1000 + 38.3 x 0.0297 x 293 = 742.9 kWh

Unit kW Peak Savings = 300 / (2.5 x 400) x 2.5 x 12,000 x 1.0 / 1000 / (0.89 x 11.8) x 0.75 = 0.64 kW

Unit Dth Savings per Year = 300 / (60,000 x 0.017) x 1046 x 60,000 / 0.89 x 1.0 / 1,000,000 = 20.7 Dth

Deemed Input Tables

Table 1. Equivalent Full Load Cooling and Heating Hours ($EFLH_{COOL}$ and $EFLH_{HEAT}$) by Climate Zone (Ref. 4, 18)

Zone	$EFLH_{HEAT}$ Heat Pump Systems	$EFLH_{HEAT}$ All Other Heating Systems	$EFLH_{COOL}$ Heat Pump Systems	$EFLH_{COOL}$ AC Systems
Zone 1 (Northern MN)	2576	1145	456	312
Zone 2 (Central MN)	2383	1046	512	565
Zone 3 (Southern MN/Twin Cities)	2069	1046	678	567

Note: EFLH values have been derived such that load factor and oversizing factor has been included in the values outlined above. See methodology assumptions and notes on EFLH derivation below.

Table 2. Thermal Regain Factor (TRF) by Duct Location (Ref. 5)

Duct Location	TRF	
	Cooling, TRF_{cool}	Heating, TRF_{Heat}
Unfinished Basement (semi-conditioned)	0.0	0.40
Attic, Crawl Space, Outdoors (unconditioned)	1.0	1.0

Table 3. Electrical Heat System Efficiencies (Ref. 7)

Heat System Type	System HPSF
Heat Pump	7.3
Electric Resistance	1.0

Methodology and Assumptions

$EFLH_{COOL}$ and $EFLH_{HEAT}$ values were determined from a 2022 MN CARD study using PRISM utility billing data analysis, with billing data collected from Minnesota utility customers, and NOAA 2005 - 2020 MN weather data. The EFLH heating calculation uses total heating energy use and equipment input capacity. The total heating energy use was determined from customer billing data, and the input capacity was determined through customer interviews and utility provided data on installations. With this method, the load factor and oversizing factor are already included in the resulting value and are therefore not included as a separate metric in the algorithm. Deviating from the results from the 2022 CARD study, the $EFLH_{HEAT}$ value for Climate Zone 2 (Central MN) matches the $EFLH_{HEAT}$ value for Climate Zone 3 (Southern

MN/Twin Cities) to reflect concerns with unexplored variables influencing the initial results that did not trend as expected due to climate.

Unknown efficiency determination for cooling is based upon the market dominant efficiency values over the measure life of the equipment.

Unknown efficiency determination for heating equipment is based upon recent federal standards and available equipment.

The percentage of fan energy consumption was determined using values for the North Region were applicable from: Table 5.5.1 Characteristics of Representative Residential Furnaces, Table 7.3.2 – Range of Adjusted Heating Loads for Each Furnace Product Class by Region, MMBtu/y; Table 7.3.3 – Range of Baseline Furnace Heating Hours Annual Burner Operating Hours for Each Furnace Product Class, hours; Table 7B.3.1 Furnace Fan Motor Power Consumption by Product Type and Furnace Fan Size, watts from the reference noted.

Pre-sealing duct efficiency assumes greater than 90% of duct work is contained within the building envelop and some observable leaks are present.

Effective January 1, 2023, HVAC products will be subject to regional minimum efficiencies, according to Seasonal Energy Efficiency Ratio 2 (SEER2). The nomenclature of SEER2, EER2, and HSPF2 will be used to denote the new M1 ratings. Conversion between the new M1 ratings and original M ratings should be done using an AHRI approved method, using the multipliers in Table 2 and Table 3 below.

Table 4. M to M1 Forward Conversion (Ref. 17)

System Type	Multiplier to convert to SEER2*	Multiplier to convert to EER2	Multiplier to convert to HSPF2
Ducted	0.95	0.95	0.85
Ductless	1.00	1.00	0.90
Packaged	0.95	0.95	0.84

Table 5. M1 to M Backward Conversion (Ref. 17)

System Type	Multiplier to convert to SEER*	Multiplier to convert to EER	Multiplier to convert to HSPF2
Split System Air Conditioner	1.05	1.04	N/A
Split System Heat Pump	1.05	1.04	1.18
Packaged Air Conditioner	1.04	1.04	N/A
Packaged Heat Pump	1.04	1.04	1.18
Ductless Heat Pump	1.00	1.00	1.12
Space Constrained System	1.01	1.00	1.17
Small Duct High Velocity System	1.00	1.00	1.18

Duct sealing cost may vary depending on contractor's procedure.

The value for coincidence factor is derived from a 2016 CARD study (Ref. 13) that examined quality install and maintenance practices for residential furnaces, air conditioners and heat pumps, in part by metering the behavior and performance of 58 cooling systems and 55 furnaces. A follow-on memo was produced (Ref. 14) that recommended coincidence factor be reduced from 90% to 75%. Because the previous 90% value was simply deemed as a typical value worth updating when primary data was available, that update is applied here. However, because the metered systems had single-speed compressors, 90% may still be used for equipment with variable-speed compressors.

References

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
2. FES calculated from nominal leakage rate of 30% ("New duct-sealing law could save homeowners big bucks this fall", News Release, California Energy Commission), average cost $1250 ("Duct Sealing", Maryland Home Performance with Energy Star) and nominal central air conditioning size of 2.5 tons ("Central Air Conditioning in Wisconsin", Scott Pigg, Focus on Energy & Energy Center of Wisconsin).
3. Rule of Thumb: http://www.hvacsalesandsupply.com/Linked%20Documents/Tech%20Tips/61-Why%20400%20CFM%20per%20ton.pdf
4. Cadmus and Minnesota Department of Commerce. "*MN CARD Study: Residential Thermostat Savings and HVAC Equipment Equivalent Full Load Hours*" Accessed July 2022. https://www.cards.commerce.state.mn.us/security/search.do?documentId=%7B3D4A3D02-73F6-480A-B365-D582C35C44CC%7D
5. Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.
6. Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."
7. Based average of split system efficiencies meeting the Minimum Federal Standards for 1994 & 2008.
8. Table 7.3.14, Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces, 2/10/2015, DOE. Ratio of electrical energy (converted to MMBtu) to gas energy in MMBtu, averaged across all efficiency levels, for North region.
9. ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment. This value is given as a SEER and is modified as EER = 1.12* SEER – 0.02 x $SEER^2$ if only SEER given.
10. Determined from values in Table 5.5.1 Characteristics of Representative Residential Furnaces, Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces, 2/10/2015, DOE.

11. FES scaled annual heating loads from those provided in the Illinois Technical Reference Manual based on Minnesota weather data.
12. Building Performance Institute, Inc., 11/20/2007, Distribution Efficiency look- Up Table, Building Performance Institute Technical Standards for the Heating Professional.
13. Seventhwave. *Improving Installation and Maintenance Practices for Minnesota Residential Furnaces, Air Conditioners and Heat Pumps*. September 30, 2016. https://www.cards.commerce.state.mn.us/CARDS/security/search.do?documentId=%7B881DD1B7-1FE4-495A-9FC0-F74A54B99CB6%7D
14. Seventhwave. *TRM Implications from the CARD "Improving Installation and Maintenance Practices for Minnesota Residential Furnaces, Air Conditioners, and Heat Pumps" study*. Memo from Seventhwave to MN DER. June 8, 2016.
15. P. Francisco et al. *Understanding Heating Seasonal Performance Factor for Heat Pumps*. 2004. https://aceee.org/files/proceedings/2004/data/papers/SS04_Panel1_Paper08.pdf. Comparing adjusted HSPF values in climate zone IV to zone V in Figures 3, 5, and 7 reveals a ratio of 85%.
16. C.K. Rice et al. *An Analysis of Representative Heating Load Lines for Residential HSPF Ratings*. July 2015. https://info.ornl.gov/sites/publications/files/Pub56184.pdf. Fig. B.4 shows an actual HSPF approximately 15% less than rated HSPF for zone V, using the standard AHRI 210/240 load line.
17. Consortium for Energy Efficiency. CEE Residential Electric HVAC Specification. Published October 18, 2023. https://cee1.my.site.com/s/resources?id=a0V2R00000sUQbyUAG
18. Engineering assumption to increase the Climate Zone 2 EFLH Heat value to be equal to Zone 3. The original study value determined this value to be 1020 hours, which is lower than Zone 3 at 1046 hours.

Revision History

Version	Description	Author	Date
1.0	New measure	Franklin Energy Services	11/12/2015
3.1	Updated CF, adjusted HSPF for AHRI climate zone V	Cadmus	10/2019
4.0	EFLH modifications based on recent CARD study.	Cadmus	11/1/2022
4.1	Clarification to SEER2, EER2 and HSPF2 conversions	Cadmus	11/1/2023
5.0	Updated the $EFLH_{HEAT}$ value for Climate Zone 2 (Central MN) to match the $EFLH_{HEAT}$ value for Climate Zone 3 (Southern MN/Twin Cities)	MN Department of Commerce	2025

Residential HVAC – Dehumidifiers

Measure Detail	Measure Value
Measure ID	1.02.09
Target Market Segments	Residential
Target End Uses	HVAC
Applicable To	Residential customers
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Unit capacity (pints per day)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	12 (Ref. 1)
Unit Participant Incremental Cost	$50 for units < 75 pints/day, $35 for units 75-185 pints/day (Ref. 1)

Measure Description

This measure includes installation of a new dehumidifier or replacement of an old dehumidifier with a new unit. The new unit must meet current ENERGY STAR performance criteria specified within this measure, but need not be ENERGY STAR qualified through the EPA program.

Algorithms

Unit kWh Savings per Year = CAP x 0.473 / 24 x HOU x (1 / EF_{BASE} - 1 / EF_{EFF})

Unit Peak kW Savings = Unit kWh Savings per Year / HOU x CF

Where:

CAP	= Capacity of the unit in pints/day. CAP = 50 pints/day if unknown
0.473	= Liters/pint conversion factor
HOU	= 1,933 hours/year, run hours per year (Ref. 2, see Notes)
EF_{BASE}	= Energy factor (liters of water removed per kWh) of baseline standard efficiency unit, as provided in Table 1 below
EF_{EFF}	= Energy factor (liters of water removed per kWh) of new ENERGY STAR unit, as provided in Table 1 below
CF	= 0.6, Coincidence Factor (Ref. 2, see Notes)

Example:

Install an ENERGY STAR dehumidifier with a capacity of 50 pints/day.

Unit kWh Savings per Year = 50 x 0.473 / 24 x 1,933 x (1 / 1.6 - 1 / 1.8) = 132.3

Unit Peak kW Savings = 132.3 / 1,933 x 0.6 = 0.041

Deemed Input Tables

Table 1. Federal Standard and ENERGY STAR Criteria (Ref. 3, Ref. 4)

Capacity (Pints/Day)	Federal Standard Criteria (L/kWh) EF Base	ENERGY STAR Criteria (L/kWh) EF EFF
≤ 25	≥ 1.30	≥ 1.57
> 25 to ≤50	≥ 1.60	≥ 1.80
> 50	≥ 2.80	≥ 3.30

Notes

Qualifying units shall be equipped with an adjustable humidistat control or shall require a remote humidistat control to operate.

For its study of dehumidifier use in Minnesota (Ref. 2), Center for Energy and Environment metered energy use, run time, and condensate production of 23 dehumidifiers at 20 sites. These sites were selected based on criteria developed from a statewide phone survey, including HVAC system characteristics, dehumidifier equipment details, and behavioral and operational details specified by occupants. Though not called out in the study text, the metering showed average HOU of 1,933 hours across the sites. The metering also showed coincidence factors varying by month, measured as the average hourly power divided by the sum of maximum power across the fleet of dehumidifiers. These coincidence factors were 0.29, 0.54, 0.66, 0.59, and 0.42 for May, June, July, August, and September respectively. A value of 0.6 is used here. While the metering also showed considerably poorer performance than ratings would indicate, this poorer performance translated largely to lower condensate production and not to increased total energy use.

References

1. Savings Calculator for ENERGY STAR Qualified Appliances. https://www.energystar.gov/ia/partners/promotions/cool_change/downloads/CalculatorConsumerDehumidifier.xls. Accessed 09/20/16.
2. Center for Energy and Environment. *Portable Dehumidification in Minnesota Single-Family Homes*. September 23, 2020. https://mn.gov/commerce-stat/pdfs/20210421_cee_dehumidification.pdf
3. Electronic Code of Federal Regulations. Title 10, Part 430, Subpart C, §430.32. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32
4. ENERGY STAR Program Requirements for Dehumidifiers. Version 5.0. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Dehumidifiers%20Version%205.0%20Program%20Requirements.pdf

Revision History

Version	Description	Author	Date
3.0	Removed old federal efficiency criteria tables.	Franklin Energy Services	1/16/2016
3.1	Updated ES values, notes, and example. Updated incremental cost. Added future energy standard information.	Franklin Energy Services	8/19/2016
4.0	Updated federal and ENERGY STAR criteria, and HOU and CF	Cadmus	9/2021

Residential HVAC – ECM Blower Motors

Measure Detail	Measure Value
Measure ID	1.02.10
Target Market Segments	Residential
Target End Uses	HVAC
Applicable To	Residential customers in single-family/ multifamily homes, duplexes, and townhomes
Actions	Early Replacement, Modify existing
Required from Customer/Contractor	Central AC present (yes/no), AFUE of existing furnace
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	9 years (Ref. 6)
Unit Participant Incremental Cost	$475 (Ref. 3)

Measure Description

This measure is the retrofit of a less efficient (PCS) motor to a two-stage BPM or ECM motor in an existing functional furnace. The target age range for existing furnaces is 10-12 years. This measure characterizes only the electric savings associated with the fan.

Savings improve when the blower is used for cooling as well and when it is used for continuous ventilation, but only if the non-ECM motor would have also been used for continuous ventilation.

New standards for residential furnace blower motor fans (Ref. 8) require the incorporation of ECMs, thereby making ECMs the baseline. Accordingly, this measure does not apply to new construction or replace on fail actions. See Definitions section for definition and application of baselines.

Algorithms

Unit kWh Savings per Year = Heating Savings + Cooling Savings + Shoulder Season Savings

Unit Peak kW Savings = Cooling Watts Savings x CF/1000

Unit Dth Savings per Year = -Heating Savings x 0.003412 / AFUE

Where:

Heating Savings = 126 kWh (Ref. 4)

Cooling Savings = 68 kWh if AC is present (Ref. 5) , = 0 if no AC is present

Shoulder Season Savings = 54 kWh (Ref. 7)

Cooling Watts Savings = Cooling Watts Saved = 220 if retrofit of single-speed PSC motor and AC is present (Ref. 3) , = 0 if no AC is present

CF	= Coincidence factor = 0.75 for cooling equipment with standard single-speed compressor, 0.9 for cooling equipment with variable-speed compressor (see Notes). If unknown use 0.75.
0.003412	= Converts kWh to Dth
AFUE	= Efficiency (%) or AFUE of existing furnace heating system.

Example:

An ECM blower is installed in place of an existing single-speed PSC motor in a home where central AC is present and AFUE of furnace is unknown.

Unit kWh Savings per Year = 126 + 68 + 54 = 248 kWh

Unit Peak kW Savings = 220 x 0.75/1000 = 0.20 kW

Unit Dth Savings = -126 x 0.003412 / 0.9 = -0.48 Dth

Methodology and Assumptions

All the assumptions were made based on furnaces analysis in Wisconsin described in study "PA Consulting Group/Patrick Engineering Residential Deemed Savings Review for Focus on Energy, 2009" (Ref. 1) and the values were adapted for Minnesota.

The value for coincidence factor is derived from a 2016 CARD study (Ref. 2) that examined quality install and maintenance practices for residential furnaces, air conditioners and heat pumps, in part by metering the behavior and performance of 58 cooling systems and 55 furnaces. A follow-on memo was produced (Ref. 9) that recommended coincidence factor be reduced from 90% to 75%. Because the previous 90% value was simply deemed as a typical value worth updating when primary data was available, that update is applied here. However, because the metered systems had single-speed compressors, 90% may still be used for equipment with variable-speed compressors.

References

1. PA Consulting Group/Patrick Engineering Residential Deemed Savings Review for Focus on Energy, 2009
2. Seventhwave. *Improving Installation and Maintenance Practices for Minnesota Residential Furnaces, Air Conditioners and Heat Pumps*. September 30, 2016. https://www.cards.commerce.state.mn.us/CARDS/security/search.do?documentId=%7B881DD1B7-1FE4-495A-9FC0-F74A54B99CB6%7D
3. "Evaluation of Retrofit Variable-Speed Furnace Fan Motors", R. Aldrich and J. Williamson, Consortium for Advanced Residential Buildings, January 2014
4. Ibid. The Evaluation referenced noted a difference of 126 Watts. Over the course of 1000 hour heating system, "Electricity Savings from Variable-Speed Furnaces in Cold Climates", Scott Pigg, Energy Center of Wisconsin and Tom Talerico, Glacier Consulting Group, the kWH savings = 126 Watts x 1000 hrs / 1000 W/KW = 126 kWh.

5. Ibid. The Evaluation referenced noted a difference of 220 Watts. Over the course of 310 hour cooling system, "State of Wisconsin Public Service Commission, Focus on Energy Evaluation, Residential Programs: CY09 Deemed Savings Review", March 26, 2010, the kWH savings = 220 Watts x 310 hrs / 1000 W/KW = 68 kWh.
6. Massachusetts Common Assumption: The early replacement measure life of 9 years was determined by subtracting the estimated target age range of existing equipment between 10 and 12 years old from the 20 year measure life for new equipment.
7. Modified by the ratio of Watt savings 422 watts (Ref. 4) / 400 watts (Ref. 1) x 51 kWh = 54 kWh.
8. Electronic Code of Federal Regulations. Title 10, Chapter II, Subchapter D, Part 430, Subpart C, §430.32. https://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
9. Seventhwave. *TRM Implications from the CARD "Improving Installation and Maintenance Practices for Minnesota Residential Furnaces, Air Conditioners, and Heat Pumps" study*. Memo from Seventhwave to MN DER. June 8, 2016.

Revision History

Version	Description	Author	Date
1.0	New measure. Added additional output to Cooling Savings input that cooling savings = 0 if central AC installed as part of project.	Franklin Energy Services	7/31/2012
1.2	Removed project location and AFUE from required inputs from customer/contractor, removed Table 1 (EFLH by zone- not needed)	Joe Plummer	3/2/2014
1.3	Added retrofit option. Corrected cooling watt savings and calculations.	Franklin Energy Services	12/23/2014
1.4	Moved seasonal savings into a deemed input table, updated example description Included interactive effect of negative Dth gas savings and aligned % of homes with CAC with lighting measure assumptions	Joe Plummer	2/2/2015
2.1	Removed replace on fail and new construction actions consistent with new federal standards	Cadmus	10/2018
2.2	Updated CF	Cadmus	10/2019
5.0	Updated the information required from Customer/Contractor to include the "AFUE of the existing furnace." No default value can be assumed if this information is not provided.	MN Department of Commerce	2025

Residential HVAC – ECM Circulators

Measure Detail	Measure Value
Measure ID	1.02.11
Target Market Segments	Residential and multifamily
Target End Uses	Pumps
Applicable To	Residential and multifamily customers
Actions	Replace Working, Replace on Fail, New Construction
Required from Customer/Contractor	Motor wattage, motor application
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	$6 per ECM Watt (Ref. 2)

Measure Description

Electronically commutated (EC) circulators (pumps) are high-efficiency brushless DC motors. They are typically fractional horsepower motors that have several benefits over the more common permanent split capacitor (PSC) fractional horsepower motor. This measure outlines savings resulting from ECM motor replacement for domestic hot water circulation, cooling water circulation or hot water circulation. For applications where the motor serves both heating water and cooling water circulation (heat pump), total hours of operation should be the sum of heating water and cooling water hours of operation in Table 1.

Algorithms

Unit kWh Savings per Year = $(W_{BASE} \times HOU_{BASE} - W_{ECM} \times HOU_{EFF}) / 1{,}000$

Unit Peak kW Savings = $(W_{BASE} - W_{ECM}) / 1{,}000 \times CF$

Where:

W_{BASE}	= W_{ECM} / 18% (Ref. 3), or actual existing motor wattage (if given in HP, = HP x 745.7 watts)
W_{ECM}	= Actual motor wattage (or if given in HP, = HP x 745.7 Watts). If unknown, use 15 watts(Ref. 4)
HOU_{BASE}	= Hours of motor use by equipment type, See Table 1
HOU_{EFF}	= Hours of motor use by equipment type, See Table 1
1,000	= Conversion from watts to kW
CF_{DHW}	= Coincidence factor for domestic hot water circulation motor, = 1.0 (Ref. 5)
CF_{CW}	= Coincidence factor for cooling water circulation motor, = 0.7 (Ref. 6)
CF_{HW}	= Coincidence factor for heating water circulation motor, = 0

Example:

A customer installed a new 15 watt ECM pump on their radiant floor heating water loop.

Unit kWh Savings per Year = (15 W / 18% x 2,582 hours - 15 W 2,582 hours) / 1,000 = 176 kWh

Unit Peak kW Savings = (15 W / 18% - 15 W) / 1,000 x 0= 0 kW

Deemed Input Tables

Table 1. Annual Hours of Operation

HOU	DHW Circulator (Ref. 7, 8)	Heating Water Circulator (Ref. 9)	Cooling Water Circulator (Ref. 10)
Baseline	4,000	2,582	1,191
Proposed	2,190	2,582	1,191

Table 2. Deemed Peak Demand Savings (kW) by Motor Size

ECM Motor Size	DHW Circulator	Heating Water Circulator	Cooling Water Circulator
15 watts (1/50 HP)	0.07	0	0.05
30 watts (1/25 HP)	0.14	0	0.10

Table 3. Deemed Energy Savings (kWh) by Motor Size **ECM Motor Size**	DHW Circulator	Heating Water Circulator	Cooling Water Circulator
15 watts (	300	0	81
30 watts (1/25 HP)	601	0	163

Methodology and Assumptions

- Pump motor must be EC, DC brushless, or permanent magnet style.
- Pump motor must be capable of variable speed operation.
- Motor must include integrated “smart” controls that will modulate flow based on demand.
- Motor must be < 1 hp

References

1. Pump Life Cycle Costs: A Guide to LCC Analysis for Pumping Systems. January 2001. Page 4. Accessed 6/11/14. https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/pumplcc_1001.pdf.
2. These values are based on $29/gpm for ECM pumps and $12/gpm for PSC pumps. Costs are found in Wilo's Price Book – Pumps and systems for Building Services and Groundwater. Accessed 6/10/2014. http://www.wilo-usa.com/fileadmin/us/Price_Pages/2014_Wilo_Price_Book_BS.GW_20-44-004-0614.pdf.

3. The Cadmus Group, Inc. Impact Evaluation of the 2011–2012 ECM Circulator Pump Pilot Program. October 18, 2012. Table 2. Pump Spot Measurements.
4. Guidehouse. ECM Circulator Deemed Savings Update Memorandum. September 30, 2021. https://api-plus.anbetrack.com/etrm-gateway/etrm/api/v1/etrm/documents/616996543b0e447ee97cdfc3/view?authToken=3187157a6f71c346a7939268d347299b779ee6c0fdf54d249d3c74e73bed931ba193655c0e8b1b43ca44711bc12abf51385a268946a3962d2de54fe59af21cc90bd55b333d0b0a
5. Assumes baseline pump would be operating during the peak period. Franklin Energy Services.
6. Cadmus. Cadmus and Focus on Energy Coincidence Factor Load Profile Memorandum, September 3, 2024.
7. Estimate based on EPRI Report Assessment of New Energy Efficient Circulator Pump Technology (40% x 8,760 hr = 3,504 hr) and recommendation by Grundfos representatives (60% x 8,760 hr = 5,256 hr).
8. Hours of use for pumps with an aqua-stat control in multifamily applications (6 hr/d x 365 d = 2,190 hr). DHW Recirculation System Control Strategies, Final Report 99-1. NYSERDA, January 1999. Page 3-30. http://www.emra.com/NYSERDA%20DHW%20Report%2099-1%20(Recirc%20Control)%20(a5-0).pdf.
9. Estimated based on an average of HDD65. Hours = HDD65 x 24/(70°F-Design Temps).
10. Estimated based on an average of CDD65. Hours = CDD65 x 24/(Design Temps-70°F).

Revision History

Version	Description	Author	Date
1.0	Measure created	Franklin Energy Services	11/10/2015
5.0	Updated several references to more current sources of data. Modified algorithm layout and variables for clarity. Modified deemed savings based on smaller motor more applicable to residential application.	Cadmus	8/1/2025
5.0	Updated Algorithm formatting.	MN Department of Commerce	2025

Residential HVAC – Energy Recovery Ventilator (ERV)

Measure Detail	Measure Value
Measure ID	1.02.12
Target Market Segments	Residential
Target End Uses	HVAC
Applicable To	Residential customers in single-family homes, duplexes, townhomes, and multifamily homes with residential type heating systems.
Actions	Replace on Fail, Replace Working, Modify, new installation in existing buildings, new construction (where not required by building code)
Required from Customer/Contractor	ERV type, outside air cfm, project location (county), cooling system type (if applicable), heating system type
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm (Ref. 11)
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	See Table 4 (Ref. 2)

Measure Description

This measure includes the optional addition of energy recovery on existing air side equipment, and also on new equipment where energy recovery is not required by current building codes. Where ERVs are required by current building codes, a modeled performance path should be pursued to demonstrate savings achieved over code baseline. This measure analyzes the heating savings potential of an energy recovery ventilator on air side equipment. This measure is applicable to all gas-fired heated air systems (Dth and kW demand savings), and all electric ASHP heated air systems (kWh and kW demand savings).

Algorithms

ASHP electrical heating system:

Unit kWh Savings per Year = ((4.5 x CFM x Δh_heating) / η_ASHP x ((HDD65 x 24) / (T_indoor – T_design)) x (Hours / 24)) / 3,412 x ERV_E x 0.75

Unit Peak kW Savings = ((4.5 x CFM x Δh_cooling) x (1 / EER x ERV_E)/1000 – (CFM x PD / 6346 / Eff_Motor / Eff_Fan x 0.75) x CF

Gas Fired heating system:

Unit Dth Savings per Year = ((4.5 x CFM x Δh_heating) / η_Furnace x ((HDD65 x 24) / (T_indoor – T_design)) x (Hours / 24)) / 1,000,000 x ERV_E x 0.75

Unit Peak kW Savings = ((4.5 x CFM x Δh_cooling) x (1 / EER x ERV_E)/1000 – (CFM x PD / 6346 / Eff_Motor / Eff_Fan x 0.75) x CF

Where:

CF	=	Coincidence Factor = 0.9 (Ref. 8)
CFM	=	Outside Air Flow in cubic feet per minute, provided by customer. If unknown, default values are 114 CFM for single family residences, 64 CFM for multifamily residences.
EER	=	Provided by customer. If SEER provided use EER = 1.12 x SEER – 0.02 x $SEER^2$ (Ref. 10). If value not provided use default value of 10.2 EER (from default of 11.5 SEER). (Ref. 6).
Eff_Fan	=	Efficiency of Fan. Provided by customer. If value not provided assume 0.705 (Ref. 13)
Eff_Motor	=	Efficiency of Motor. Provided by customer. If value not provided assume 0.855 (Ref. 14)
ERV_E	=	Total Energy Effectiveness of ERV. Provided by manufacturer/customer If values are not provided use default values in Table 3. (Ref. 7)
Hours	=	Hours of ventilation per day. Average annual daily ERV run time during which heat/cooling is being recovered, based on the assumption that ERV is selected to provide adequate ventilation rate when operated continuously on the coldest day of the year, when the defrost cycle interrupts heat recovery for a period of time depending on outdoor air temperature. On the coldest day, the fan would operate 100% of the time. When not in defrost, it is assumed the homeowner would reduce fan operation to 80% runtime to avoid over ventilating the residence. This assumed behavior results in an average annual runtime per day of 18 hours/day. (Ref. 15)
HDD65	=	Heating Degree Days See Table 1. (Ref. 3)
PD	=	Additional Pressure Drop through heat exchanger, inches of Water Column per CFM. Provided by customer. If value is not provided see values in Table 4. (Ref. 7)
T_indoor	=	Customer provided indoor heating conditioned space temperature in °F. See Table 1 for default values if not provided.
T_design	=	the equipment design heating temperature of the climate zone. See Table 1. (Ref. 4)
η_ASHP	=	Efficiency of electric ASHP heating equipment. Assume 7.7 HSPF (Ref. 6) unless different efficiency is provided by customer.
η_Furnace	=	Efficiency of gas fired heating equipment (furnace, boiler). Assume 0.8 (Ref. 9) unless different efficiency is provided by customer.

Δh_cooling	=	Difference in enthalpies (btu/lb) between the design day cooling enthalpy and exhaust air heat exchanger inlet enthalpy. See Table 2 for default values if not provided.
Δh_heating	=	Difference in enthalpies (btu/lb) between the exhaust air heat exchanger inlet enthalpy and design day heating enthalpy. See Table 1 for default values if not provided.
4.5	=	Conversion factor for flow rate and specific volume of air at standard room conditions and minutes to hours (0.075 lb/cubic foot at 1 atm and 68 degrees F x 60 min/hr = 4.5)
6,346	=	Conversion factor for ft-lb/min to horsepower, and psi to inches of water (33,013 ft-lb/min divided by 5.202 inches of water per pound/square foot = 6,346)
1,000	=	Conversion factor of watts per kWh
1,000,000	=	Conversion factor for BTU to Dth
3,412	=	Conversion factor for BTU to kWh
0.75	=	factor to account for prevention of freezing of condensate. Control strategies incorporate full air flow by-pass or other strategies that reduce the number of hours of operation at lower temperatures, multiply ERV_E by 0.75 if not adjusted by manufacturer or customer. (Ref. 15). 24 = Conversion factor, 24 hours per day

Example:

Install a rotary heat recovery wheel in an existing single family residence Climate Zone 3. The outside air existing supply rate is 114 cfm, and the ventilation is estimated to run an approximate deemed 18 hours per day. The heating system is a gas fired furnace, unknown efficiency. The cooling system utilizes a 10.2 EER air cooled packaged AC unit.

Unit peak kW Savings = (((4.5 x 114 x (36.55– 28.36)) x1 / 15 x 0.730)/1000 – (114 x 0.00012 / 6346 / 0.855 / 0.705 x 0.75)) x 0.9 = 0.30 kW

Unit Dth Savings per Year = ((4.5 x 114 x (25.34 – (-3.29)) / 0.8) x (7,651 x 24) / (70.0 – (-14.5)) x 18 / 24) / 1,000,000 x 0.730 x 0.75 = 16.4 Dth

Deemed Input Tables

Table 1. Heating design temperatures, heating enthalpies and heating degree days base 65

Climate Zone	Design Day Heating Outside Air Conditions		Return Air Conditions - Heating		ΔT_heating	Δh_heating	HDD65 (Ref. 9)
	T_Design Heating (°F) (Ref. 4)	Enthalpy (Btu/lb) (Ref. 12)	T_Indoor Temp.(°F) (Ref. 5)	Enthalpy (Btu/lb) (Ref. 12)	Temp.(°F)	Enthalpy (Btu/lb)	
Zone 1 (Northern)	-22.0	-5.16	70.0	25.34	92.0	30.5	9,833
Zone 2 (Central)	-16.5	-3.79	70.0	25.34	86.5	29.1	8,512
Zone 3 (Southern/ Twin Cities)	-14.5	-3.29	70.0	25.34	84.5	28.6	7,651

Table 2. Cooling design temperatures and enthalpies

Climate Zone	Design Day Cooling Outside Air Properties	Return Air Conditions - Cooling		Δh_cooling
	Enthalpy (Btu/lb) (Ref. 12)	T_Indoor Temp.(°F) (Ref. 5)	Enthalpy (Btu/lb) (Ref. 12)	Enthalpy (Btu/lb)
Zone 1 (Northern)	32.40	76.0*	28.36	4.04
Zone 2 (Central)	35.55	76.0*	28.36	7.19
Zone 3 (Southern/ Twin Cities)	36.55	76.0*	28.36	8.19

* Assuming 74F air at 50% RH with an additional 2F duct temperature rise

Table 3. Energy Recovery Effectiveness Factor, Pressure Drop and Incremental Cost

Energy Recover Type	ERV_E Total Heating Effectiveness	PD Pressure Drop /CFM Inches WC/CFM	Incremental Cost** /CFM
	(Ref.7, 18)	(Ref. 7)	(Ref. 2)
Fixed Plate – (Sensible Heat Only)	0.355	0.00035	$6
Fixed Plate – (Sensible and Latent Heat)	0.640	0.00074	$6
Fixed Plate – Unknown	0.498	0.00055	$6
Membrane Plate	0.660	0.00055	$6
Rotary Wheel	0.730	0.00012	$6
Heat Pipe	0.310	0.00011	$6

** Cost includes cabinet and controls incorporated into packaged and built up air handler units.

Methodology and Assumptions

Default efficiencies assume 1-to-1 ratio of fresh vs. exhaust/relief air. Savings do not include any savings from reduced energy for humidification.

Studies have shown that potential cooling savings (9-23% of load) are frequently offset by the increased fan energy in all Minnesota climate zones but could reduce peak demand load by up to 50% when operated in cooling season (Ref 18). For this reason, kWh cooling savings are not quantified in this measure, but peak kW demand savings have been quantified. Customers are encouraged to operate installed ERVs in both mechanical heating and mechanical cooling conditions, but particularly when OSA temperatures are between 0 – 45 degrees F (when 60-80% of potential savings can be realized, Ref 18).

Effective January 1, 2023, HVAC products will be subject to regional minimum efficiencies, according to Seasonal Energy Efficiency Ratio 2 (SEER2). The nomenclature of SEER2, EER2 and HSPF2 will be used to denote the new M1 ratings. Conversion between the new M1 ratings and original M ratings should be done using an AHRI approved method, using the multipliers in Table 2 and Table 3 below.

Table 6. M to M1 Forward Conversion (Ref. 17)

System Type	Multiplier to convert to SEER2	Multiplier to convert to EER2	Multiplier to convert to HSPF2
Ducted	0.95	0.95	0.85
Ductless	1.00	1.00	0.90
Packaged	0.95	0.95	0.84

Table 7. M1 to M Backward Conversion (Ref. 17)

System Type	Multiplier to convert to SEER	Multiplier to convert to EER	Multiplier to convert to HSPF2
Split System Air Conditioner	1.05	1.04	N/A
Split System Heat Pump	1.05	1.04	1.18
Packaged Air Conditioner	1.04	1.04	N/A
Packaged Heat Pump	1.04	1.04	1.18
Ductless Heat Pump	1.00	1.00	1.12
Space Constrained System	1.01	1.00	1.17
Small Duct High Velocity System	1.00	1.00	1.18

References

1. Assumed service life limited by controls –" Demand Control Ventilation Using CO2 Sensors", pg. 19, by US Department of Energy Efficiency and Renewable Energy.
2. "Map to HVAC Solutions", by Michigan Air, Issue 3, 2006.
3. National Climate Data Center – National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.

4. 1997 ASHRAE Handbook HVAC Fundamentals.
5. Assumed heating set point of 70°F and cooling set point of 72° F with a 2F temperature rise in the return ducting and 50% relative humidity
6. 2024 Minnesota Energy Code with ANSI/ASHRAE/IES Standard 90.1-2019. Section 6.8.1 Minimum Efficiency Requirement Listed Equipment—Standard Rating and Operating Conditions Effective January 5, 2024. https://codes.iccsafe.org/content/MNEC2024P1/6-heating-ventilating-and-air-conditioning#MNEC2024P1_Ch06_Sec6.8
7. Analysis of AHRI listed devices available 1/1/2016.
8. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to with most being very close to 0.9, primary data has not been identified.
9. Title 10, Code of Federal Regulations, Part 431 – Energy Efficiency Program for Certain Commercial and Industrial Equipment. November 2023. https://www.energy.gov/femp/incorporate-minimum-efficiency-requirements-heating-and-cooling-products-federal-acquisition
10. ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment. This value is given as a SEER and is modified as EER = 1.12 x SEER – 0.02 x $SEER^2$ for single stage equipment.
11. It is assumed cooling savings are equal to the increased fan energy usage.
12. Psychometric Calculator, by kW Engineering and from ASHRAE 2009 Cooling DB/MCWB @ 1.0% for each TRM weather zone
13. Average Fan efficiency for centrifugal fans from the Energy Efficiency Guide Book (2004), Chapter 5, Bureau of Energy Efficiency, Government of India.
14. Assumed average 5 HP Nema EPAct Open Frame motor efficiency.
15. Illinois Stakeholder Advisory Group. Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 13.0, Volume 3. Measure 5.3.20. September 20, 2024. https://www.ilsag.info/technical-reference-manual/illinois-statewide-technical-reference-manual-version-13-0/
16. Values calculated using psychrometric conditions at 1000ft and 50% relative humidity.
17. Consortium for Energy Efficiency. CEE Residential Electric HVAC Specification. Published October 18, 2023. https://cee1.my.site.com/s/resources?id=a0V2R00000sUQbyUAG
18. Center for Energy and Environment. MN CARD Final Report: *Energy Recovery in Minnesota Commercial and Institutional Buildings: Expectations and Performance*. April 28, 2017. https://mn.gov/commerce-stat/pdfs/card-report-cee-erv.pdf

Revision History

Version	Description	Author	Date
5.0	New measure development	Cadmus	9/1/2025

Residential HVAC – Electronic Ignition Hearth

Measure Detail	Measure Value
Measure ID	1.02.13
Target Market Segments	Residential
Target End Uses	HVAC
Applicable To	Residential customers in single-family homes, duplexes, townhomes, and multifamily homes (including 3- and 4-family homes) with residential type heating equipment
Actions	Replace on Failure, Replace Working
Required from Customer/Contractor	None
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	$193 (Ref. 1)

Measure Description

This measure includes replacement of existing hearth/artificial fireplace using a standing pilot with a unit using electronic ignition.

Algorithms

Unit Dth Savings per Year = P/CF x t

Where:

P = Pilot rate in Btu/h, assumed to be 1,000 Btu/h (Ref. 2, 3)

CF = Conversion factor, CF=1,000,000 Btu/Dth

t = Unit usage, in hrs/year, assumed to be 24 hours x 182.5 days/year = 4,380

Example:

An electronic ignition for fireplace installation. Fireplace is used 24 hrs/day, 182.5 days/year.

Unit Dth Savings per Year = 1,000 / 1,000,000 x 24 x 182.5 = 4.38

Notes

Electronic ignition is difficult to install on existing systems and should be undertaken only by someone who is very experienced in this type of work.

References

1. Online survey and discussion with suppliers and manufacturers
2. Pilot lights add small increase to gas bill, Clark County Public Utilities, March 26, 2006
3. Canadian study Home Energy Magazine, January/February 1997

Revision History

Version	Description	Author	Date
1.0	New measure	Franklin Energy Services	8/14/2012
1.1	Changed name to Electronic Ignition Hearth	Joe Plummer	4/3/2013
1.2	Made P and t deemed values	Joe Plummer	4/3/2013

Residential HVAC – Furnaces and Boilers

Measure Detail	Measure Value
Measure ID	1.02.14
Target Market Segments	Residential
Target End Uses	HVAC
Applicable To	Residential customers in single-family homes, duplexes, townhomes, and multifamily homes (including 3- and 4-family homes) with residential type heating equipment
Actions	Replace on Failure, Early Replacement, New Construction
Required from Customer/Contractor	Equipment type (furnace w/o ECM or boiler), Input Btu/h of new unit, project location (county), AFUE of the existing furnaces (only applicable to Furnaces in single-family homes with action types Replace on Fail or Replace Working), AFUE of the new equipment, Action Type (Replace on Fail, Early Replacement, or New Construction), building type (single-family or duplex, multifamily*or townhome)
Measure Energy Type	Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	20 (Ref. 1)
Unit Participant Incremental Cost	See Table 3 of installed costs. Derive incremental cost from difference in installed and baseline equipment by efficiency rating, from Table 3 or from actuals if known.

* Multifamily includes buildings with three or more units.

Measure Description

This measure includes replacement of failed or working furnaces and boilers in existing homes with high-efficiency units, as well as installation of high-efficiency furnaces and boilers in new residences. Electric kWh and kW savings are included only for furnaces with ECM blowers replacing a working unit—i.e. no electric savings for replace on failure or new construction (Ref. 2).

Algorithms

Unit kWh Savings per Year

= Heating Savings + Cooling Savings + Shoulder Season Savings (for replaced working furnaces incorporating a Blower ECM motor)
= 0 (for boilers, furnaces not incorporating a Blower ECM motor, or for replace on failure or new construction furnaces)

Unit Peak kW Savings

= Cooling Watts Savings x CF/1000 (for furnaces incorporating a Blower ECM motor)
= 0 (for boilers, furnaces not incorporating a Blower ECM motor, or for replace on failure or new construction furnaces)

Unit Dth Savings per Year

= Btuh_in x $EFLH_{HEAT}$ x Eff_High x (1/Eff_Base - 1/Eff_high) / 1,000,000 - Heating Savings x 0.003412 / Eff_High

Where:

Heating Savings = Blower ECM motor savings during heating season = 418 kWh (Ref 3)

Cooling Savings = Blower ECM motor savings during cooling season. If central AC = 263 kWh. If no central AC = 175 kWh. If unknown = 251 kWh (Ref 4.) If new central AC installed as part of the project, cooling savings equal 0 (Ref. 5).

Shoulder Season Savings = Blower ECM motor savings during shoulder season = 51 kWh (Ref 3)

Cooling Watts Savings = ECM motor Cooling Watts Saved = 73 (Ref. 3)

CF	= Coincidence factor = 0.75 for cooling equipment with standard single-speed compressor, 0.9 for cooling equipment with variable-speed compressor (see Notes). If unknown use 0.75.
1,000	= 1,000 watts/kW conversion factor
Btuh_in	= the nominal rating of the input capacity of the new furnace or boiler in Btu/h
$EFLH_{HEAT}$	= Effective Full Load Hours of Heating, See Table 1 (Ref. 6, 7)
Eff_base	= Efficiency (%) or AFUE of baseline heating system. See Table 2 for default baseline efficiencies by equipment type.
Eff_high	= Efficiency (AFUE) of the new furnace or boiler, supplied by customer/contractor.
1,000,000	= 1,000,000 Btu/Dth conversion factor
0.003412	= 0.003412 Dth/kWh conversion factor

Example:

Retrofit replacing a working furnace installed in single-family home, 97% AFUE furnace with a Blower ECM motor, 60,000 btu/h input, Climate Zone 3. The home has an existing central AC unit remaining in place.

Unit kWh Savings per Year = 418 + 263 + 51 = 720

Unit Peak kW Savings = 73 x 0.75 / 1000 = 0.056

Unit Dth Savings per Year = 60,000 x 1046 x 0.97 x (1 / 0.90 – 1 / 0.97) / 1,000,000 - 418 kWh x 0.003412 / 0.97 = 3.4 Dth

Deemed Input Tables

Table 1. Equivalent Full Load Heating Hours ($EFLH_{HEAT}$) by Climate Zone (Ref. 6, 7)

Zone	$EFLH_{HEAT}$ Heat Pump Systems	$EFLH_{HEAT}$ All Other Heating Systems
Zone 1 (Northern MN)	2576	1145
Zone 2 (Central MN)	2383	1046
Zone 3 (Southern MN/Twin Cities)	2069	1046

Note: EFLH values have been derived such that load factor and oversizing factor has been included in the values outlined above. See methodology assumptions and notes on EFLH derivation below.

Table 2. Baseline Efficiency (Ref. 8, 9, 10, 11, 12, 13 and the Methodology and Assumptions Section)

Building Type	Single-family		Duplexes, Townhomes, and Multifamily	
Equipment Type/Action	New Construction	Replace on Fail, Early Replacement	New Construction	Replace on Fail, Early Replacement
Furnace	90%	90%[A]	90%	80%
Boiler	84%	84%	84%	84%

[A] The default baseline efficiency for furnaces for single-family homes in this table is set higher than the current Federal minimum standard for Replace on Fail and Early Replacement actions (Ref. 9). If utilities can verify that the actual efficiency of the customer's existing furnace equipment is less than 90%, the Federal minimum standard of 80% AFUE for furnaces can be used (Ref. 10, 11, 12, and Methodology and Assumptions Section).

Table 3. Installed Costs (Ref. 13, 14 and see Methodology)

Equipment Type	Installed Cost ($/unit) *(Includes Equipment cost and assumed $600 Installation cost)*
Furnace AFUE = 80%	$1,693
Furnace AFUE = 90%	$2,200
Furnace AFUE > 90% < 96%	$2,374
Furnace AFUE = 96%	$2,720
Furnace AFUE ≥ 97%	$3,750
Boiler AFUE = 84%	$5,001
Boiler AFUE ≥ 90% and < 95%	$5,750
Boiler AFUE ≥ 95%	$6,073

Methodology and Assumptions

Assumes dedicated exhaust installation for furnaces and chimney liner for water heaters.

A baseline AFUE of 90% is assumed for new construction furnaces. This follows from air tightness requirements forcing furnaces in new homes to have direct venting capability and a survey of builders indicating that new homes and townhomes would have 90% AFUE furnaces installed without an incentive (Ref. 9).

On May 1, 2013, federal standards prohibiting the sale or import of non-weatherized furnaces with AFUEs of less than 90% were set to take effect in the Northern Region (including MN). This federal standard was postponed. In 2023, the US DOE issued amended standards to equipment manufactured or imported into the US with 95% AFUE baseline to take effect December 18, 2028 (Ref. 16). Analysis of a WI HVAC contractor survey issued in 2023 by WI Focus On Energy and published in the WI TRM v2024 (Ref. 11) supported an increased efficiency baseline to 90% for non-income qualified single-family residential customers (applicable to all baseline scenarios including early replacement). In 2025, Center for Energy and Environment shared aggregated data on existing furnaces collected during CenterPoint Energy and Xcel Energy's residential energy audits completed in MN between 2020 and 2025 (Ref. 12 and 13). Most of these audits were completed within Hennepin and Ramsey counties. Both the WI HVAC contractor survey and the supplemental research completed by Center for Energy and Environment signal upward movement in residential furnace code baseline in the coming years. With this in mind, the baseline efficiency for residential furnaces was modified in single-family homes to 90% with the caveat that if a utility can verify the actual efficiency of the existing furnace and the AFUE of that existing furnace is lower than 90%, the utility can use the federal minimum standard of 80% AFUE as the measure baseline.

AFUE does not include any electrical power savings.

$EFLH_{COOL}$ and $EFLH_{HEAT}$ values were determined from a 2022 MN CARD study (Ref 6) using PRISM utility billing data analysis method collected from Minnesota utility customers, and NOAA 2005 - 2020 MN weather data. The EFLH heating calculation uses total heating energy use and equipment input capacity. The total heating energy use was determined from customer billing data and the input capacity was determined through customer interview and utility provided data on installations. In this method, the load factor and oversizing factor are already included in the resulting value derived and are therefore not additionally included as a separate metric in the algorithm. Deviating from the results from the 2022 CARD study, the $EFLH_{HEAT}$ value for Climate Zone 2 (Central MN) matches the $EFLH_{HEAT}$ value for Climate Zone 3 (Southern MN/Twin Cities) to reflect concerns with unexplored variables influencing the initial results that did not trend as expected due to climate.

Incremental costs are periodically updated to reflect data from MN utility installations and market available product costs.

The coincidence factor value is derived from a 2016 CARD study (Ref. 17) that examined quality install and maintenance practices for residential furnaces, air conditioners and heat pumps, in part by metering the behavior and performance of 58 cooling systems and 55 furnaces. A follow-on memo was produced (Ref. 18) that recommended that the coincidence factor be reduced from 90% to 75%. Because the previous 90% value was simply deemed as a typical value worth updating when primary data was available, that update is applied here. However, because the metered systems had single-speed compressors, 90% may still be used for equipment with variable-speed compressors.

References

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc. June 2007. http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf
2. US Department of Energy standard for residential furnace fans https://www.regulations.gov/document?D=EERE-2010-BT-STD-0011-0117
3. PA Consulting Group/Patrick Engineering Residential Deemed Savings Review for Focus on Energy, 2009
4. The weighted average value is based on assumption that 75% of homes installing BPM furnace blower motors have central AC.
5. Energy use of blower motor during cooling season is reflected in the SEER of the new central AC.
6. Cadmus and Minnesota Department of Commerce. "*MN CARD Study: Residential Thermostat Savings and HVAC Equipment Equivalent Full Load Hours*" Accessed July 2022. https://mn.gov/commerce/energy/industry-government/cip/card-grant-search/
7. Engineering assumption to increase the Climate Zone 2 EFLH Heat value to be equal to Zone 3. The original study value determined this value to be 1020 hours, which is lower than Zone 3 at 1046 hours.
8. 2024 Minnesota Energy Code with ANSI/ASHRAE/IES Standard 90.1-2019. Section 6.8.1 Minimum Efficiency Requirement Listed Equipment—Standard Rating and Operating Conditions Effective January 5, 2024. https://codes.iccsafe.org/content/MNEC2024P1/6-heating-ventilating-and-air-conditioning#MNEC2024P1_Ch06_Sec6.8
9. Minnesota Office of Energy Security. *Analysis, Recommendations, and Proposed Decision of the Staff of the Office of Energy Security*. Docket G008/CIP 09-644. https://www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?method=showPoup&documentId={13E7C0EF-4534-449F-AD49-8DAB9AFF01DF}&documentTi
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12. Center for Energy and Environment. *Center for Energy and Environment's Comments In the Matter of the Minnesota Technical Reference Manual Version 5.0.* November 20, 2025. https://efiling.web.commerce.state.mn.us/documents/%7B008BA79A-0000-CB1C-ADD2-937BCC4CD817%7D/download?contentSequence=0&rowIndex=9
13. Center for Energy and Environment. *Center for Energy and Environment's Reply Comments In the Matter of the Minnesota Technical Reference Manual Version 5.0.* December 15, 2025. https://efiling.web.commerce.state.mn.us/documents/%7B900B249B-0000-C911-9B13-8862D199F8FA%7D/download?contentSequence=0&rowIndex=1

14. CenterPoint Energy. *In the Matter of CenterPoint Energy's 2024-2026 Natural Gas Energy Conservation and Optimization Program Triennial Plan Program Modification Request Exhibit A*. October 1, 2024. https://efiling.web.commerce.state.mn.us/documents/%7B70594992-0000-C232-A4DE-CBFA6A6AF8DE%7D/download?contentSequence=0&rowIndex=38
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17. Seventhwave. *Improving Installation and Maintenance Practices for Minnesota Residential Furnaces, Air Conditioners and Heat Pumps*. September 30, 2016. https://www.cards.commerce.state.mn.us/CARDS/security/search.do?documentId=%7B881DD1B7-1FE4-495A-9FC0-F74A54B99CB6%7D

Revision History

Version	Description	Author	Date
1.0	Replaces ResidentialFurnaceMeasures_v01, moved furnace tune-ups to a separate measure, updated baseline efficiencies to reflect decisions in 2010-2012 gas utility triennials. Added specifications for actions and needed from customer/vendor. Added missing incremental cost categories	Joe Plummer, DER	1/1/2011
2.0	Changed savings equation. Added multifamily buildings to the measure. Added efficiency standards. Added references	Franklin Energy Services	7/25/2012
2.1	Updated equipment costs. Updated baselines and Federal standard comments due to the postponing of the furnace efficiency standard. Updated baselines from 78% to 80%	Franklin Energy Services	8/1/2013
2.2	Added Action Type as Required Input from Customer/Contractor (determines existing or new construction which is needed to determine baseline efficiency.) Added equipment type to required inputs from customer/contractor.	JP	1/13/14

Version	Description	Author	Date
3.0	Changed to $EFLH_{HEAT}$ algorithm and added kWh and kW savings and heating penalty factors.	Franklin Energy Services	11/12/2015
3.1	Indicated fan savings are for furnaces with ECM motors only.	Franklin Energy Services	1/15/2016
3.2	Updated incremental costs. Removed ECM savings for replace on failure and new construction	Cadmus	10/2018
3.3	Updated CF	Cadmus	10/2019
3.4	Noted upcoming boiler baseline AFUE change	Cadmus	10/2020
4.0	EFLH modifications based on recent CARD study. Removed loading factor % (originally meant to decrease EFLH, which is now already accomplished by modified EFLH)	Cadmus	11/2022
4.1	Modified boiler baseline efficiency to 84% to match the reference for gas fired hot water boiler, likely to be defined as most typical average boiler equipment.	Cadmus	11/2023
5.0	Updated Incremental Cost Methodology and Installed Cost Data.	Cadmus	2025
5.0	Updated the $EFLH_{HEAT}$ value for Climate Zone 2 (Central MN) to match the $EFLH_{HEAT}$ value for Climate Zone 3 (Southern MN/Twin Cities). Updated the baseline efficiency for Furnaces in single-family homes to 90% in Replace on Fail and Replace Early applications with a caveat.	MN Department of Commerce	2025

Residential HVAC – Furnace Quality Installation/Maintenance

Measure Detail	Measure Value
Measure ID	1.02.15
Target Market Segments	Residential
Target End Uses	HVAC
Applicable To	Residential customers in single-family homes, duplexes, townhomes, and multifamily homes (including 3- and 4-family homes) with residential type furnaces
Actions	O&M, Early Replacement, Replace on Fail, New Construction
Required from Customer/Contractor	Input Btu/h for existing and new furnace, nameplate AFUE of existing and new furnaces, test-in conversion efficiency, test-out conversion efficiency, project location (county), building type (single-family or duplex, multifamily*or townhome)
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	20 years if Early Replacement, Replace on Fail, New Construction (Ref. 1); 10 years if O&M (Ref. 2)
Unit Participant Incremental Cost	Field Testing/Verification Labor + Incremental Equipment/Installation Cost if new furnace installed. See Table 2a and Table 2b. (Ref. 2)

*Multifamily includes buildings with three or more units.

Measure Description

This measure characterizes the impact of quality maintenance (QM) and quality installation (QI) practices performed by a qualified HVAC professional on gas forced-air furnace energy consumption. The measure is based on the HVAC SAVE® program (System Adjustment and Verified Efficiency).

For each tune-up or new installation, a contractor must perform the following actions in addition to a standard "clean and check":

1. Determine manufacturer's expected capacity based on current conditions. This includes determining the gas flow rate by clocking the gas meter.
2. With equipment running, measure the temperature difference across the heat exchanger. Adjust airflow to manufacturer's rated temperature range.
3. Measure dry bulb temperature at the equipment.
4. Measure dry bulb temperature at three grilles and registers.
5. Enter measurements in steps 2, 3, and 4, plus outdoor temperature and elevation into M&V software to determine score (conversion efficiency).

Electrical energy impacts may result from airflow adjustments or duct sealing but are not included in this characterization.

Algorithms

Unit Dth Savings per Year = Btuh_EE x EFLH x AFUE_EE x (1/(AFUE_base x CE_base) - 1/(AFUE_EE x CE_EE)) / C

Where:

Btuh_EE	= the nominal rating of the input capacity of the proposed furnace in Btu/h. If equipment is not being replaced, then use input capacity of the existing equipment.
EFLH	= Effective full load heating hours. See Table 1. (Ref. 3 and 4)
AFUE_base	= Efficiency (%) or AFUE of baseline furnace. See Table 2. (Ref. 6, 7, 8 and 9)
AFUE_EE	= Nameplate efficiency of the efficient furnace. If furnace is not being replaced, then AFUE_EE = AFUE_base.
CE_base	= Test-in conversion efficiency of existing furnace. A formula for conversion efficiency is provided in Methodology and Assumptions.
CE_EE	= Test-out conversion efficiency of proposed furnace. A formula for conversion efficiency is provided in Methodology and Assumptions.
C	= conversion factor from Btu to Dth, 1,000,000 Btu/Dth.

Examples:

Example 1: Quality maintenance is performed on a 60,000 Btu/h, 80% AFUE existing furnace in single-family home located in Climate Zone 3. The actual efficiency of the existing furnace was verified by the contractor. The test-in conversion efficiency is calculated as 70%. The test-out conversion efficiency is calculated as 90%.

Unit Dth Savings per Year = (60,000 x 0.77 x 1046 x 0.80 x (1 / (0.80 x 0.70) – 1 / (0.80 x 0.90))) / 1,000,000

= 19.2 Dth

Example 2: Install a 60,000 Btu/h, 95% AFUE furnace in a single-family home located in Climate Zone 1. The existing furnace is a working 80,000 Btu/h, 80% AFUE furnace, actual efficiency verified by the contractor. The test-in conversion efficiency of the existing furnace is calculated as 75%. The test-out conversion efficiency is calculated as 88%.

Unit Dth Savings per Year = 60,000 x 0.77 x 1145 x 0.95 x (1 / (0.80 x 0.75) – 1 / (0.95 x 0.88)) / 1,000,000

= 24.8 Dth

Deemed Input Tables

Table 1. Effective Full Load Heating Hours by Climate Zone (Ref. 4, 5)

Zone	$EFLH_{HEAT}$ Heat Pump Systems	$EFLH_{HEAT}$ All Other Heating Systems
Zone 1 (Northern MN)	2576	1145
Zone 2 (Central MN)	2383	1046
Zone 3 (Southern MN/Twin Cities)	2069	1046

Note: EFLH values have been derived such that load factor and oversizing factor has been included in the values outlined above

Table 2. Baseline Efficiency (Ref. 6, 7, 8, 9, 10 and the Methodology and Assumptions Section within Measure ID 1.02.14)

Building Type	O&M	New Construction	Replace on Fail	Early Replacement
Single-family	Nameplate efficiency of the existing furnace	90%	90%[A]	90%[A]
Duplexes, Townhomes, and Multifamily	Nameplate efficiency of the existing furnace	90%	80%	80%

[A.] The default baseline efficiency for furnaces for single-family homes in this table is set higher than the current Federal minimum standard for Replace on Fail and Early Replacement actions (Ref. 6). If utilities can verify that the actual efficiency of the customer's existing furnace equipment is less than 90%, the Federal minimum standard of 80% AFUE for furnaces can be used (Ref. 8, 9, 10 and the Methodology and Assumptions Section within Measure ID 1.02.14)

Table 3. Incremental Costs (Ref. 11)

AFUE_EE	Early Replacement	New Construction, Replace on Fail
AFUE < 92%	$630	$0
AFUE ≥ 92% and < 94%	$802	$172
AFUE ≥ 94%	$1,438	$636

Methodology and Assumptions

The savings algorithm is based on measurement of conversion efficiency at "test in" and "test out." Conversion efficiency is defined as:

Actual Btuh output / Theoretical Btuh output = (1.08 x CFM x ΔT) / (Installed Input Btu/h x AFUE)

Where:

CFM	= airflow across the heat exchanger in cubic feet per minute
ΔT	= temperature rise across the heat exchanger in ˚F
Installed Btu/h	= Btu/h measured by clocking the gas flow rate
AFUE	= nameplate annual fuel utilization efficiency, see variable definition above.

Baseline or "test in" conversion efficiency (CE_base) is a measured parameter using the formula above for early replacements (Replace Working) or tune-ups of existing equipment (O&M) where the AFUE of the existing equipment is known. In the case of replacement of failed equipment (Replace on Fail) or New Construction, a deemed value for CE_base is provided under Algorithms. This value is based on a field testing results for over 500 homes in Iowa (see Ref. 1). For early replacements where existing furnace AFUE is unknown, use the deemed value for CE_base.

An assumed value for proposed or "test out" conversion efficiency (CE_prop) is provided based on a different sample of Iowa HVAC SAVE homes (see Ref. 1) for planning purposes. However, it is strongly recommended that a measured CE_prop be used for each installation for calculating actual savings.

Table 4. Field Time Estimates (Replace on Fail, New Construction)

	Required By Program	Required by OEM	Required SAVE Verification
Complete Rebate Form	Required		Required
M&V Software			15
Equipment Pressures (2)		5	5
Other Pressures (2)			5
Equipment Temps (2)		5	5
Duct Temperatures (7)			10
Clock Gas Meter		10	10
Verify CFM		5	5
Time Required (minutes)		25	55
Contractor Billable Rate		**$85.00**	**$85.00**
Measure Cost		**$35.42**	**$77.92**

Table 5. Field Time Estimates (Early Replacement, O&M)

	Required By Program	Required SAVE Verification
Complete Rebate Form	Required	Required
M&V Software		25
Test-In (no room temps)		30
Reset Furnace by setting optimum air flow and tuning combustion		25
Test-Out (with room temps)		40
Contractor Billable Rate		**$85.00**
Measure Cost		**$170.00**

Table 6. Estimated field testing and verification labor costs

Action	Labor
O&M	$170
New Construction	$78
Replace on Fail	$78
Early Replacement	$170

References

1. A measure life of 20 years for Replace on Fail, Replace Working, and New Construction is based on: Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc. June 2007
2. A measure life of 10 years for O&M assumes that on average, tune-ups are performed at the midpoint of the equipment's lifespan (20 years).
3. Engineering assumption that residential furnaces in MN are oversized by 30% on average.
4. Cadmus and Minnesota Department of Commerce. "*MN CARD Study: Residential Thermostat Savings and HVAC Equipment Equivalent Full Load Hours*" Accessed July 2022. https://www.cards.commerce.state.mn.us/security/search.do?documentId=%7B3D4A3D02-73F6-480A-B365-D582C35C44CC%7D
5. Engineering assumption to increase the Climate Zone 2 EFLH Heat value to be equal to Zone 3. The original study value determined this value to be 1020 hours, which is lower than Zone 3 at 1046 hours.
6. United States of America Department of Energy. *§430.32 Energy and water conservation standards and their compliance dates*. Code of Federal Regulations. January 1, 2026. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32
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11. Incremental labor costs for QI/QM were derived from the labor estimates in Tables 4, 5, and 6.

Revision History

Version	Description	Author	Date
1.0	New measure	Franklin Energy Services	9/14/2015
2.0	Modified lifetime methodology	Franklin Energy Services	10/30/2015
2.1	EFLH modifications based on recent CARD study.	Cadmus	11/1/2022
5.0	Updated the $EFLH_{HEAT}$ value for Climate Zone 2 (Central MN) to match the $EFLH_{HEAT}$ value for Climate Zone 3 (Southern MN/Twin Cities). Updated the baseline efficiency for Furnaces in single-family homes to 90% in some applications with a caveat.	MN Department of Commerce	2025

Residential HVAC – Furnaces & Boiler Tune-Up

Measure Detail	Measure Value
Measure ID	1.02.16
Target Market Segments	Residential
Target End Uses	HVAC
Applicable To	Residential customers in single-family homes, duplexes, townhomes, and multifamily homes (including 3- and 4-family homes) with residential type furnace
Actions	O&M
Required from Customer/Contractor	Input Btu/h, project location (county), heating equipment type, building type
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	2 (Ref. 1)
Unit Participant Incremental Cost	Unit Participant Incremental Cost = $175 (default/planning figure; OK to use actual cost of tune-up)

Measure Description

This measure is applicable to residential furnaces and boilers that provide space heating. The tune up activities listed by equipment below will improve heating system performance by ensuring correct and efficient operation.

A furnace tune-up includes inspection/adjustment of the following components as performed by a qualified service technician:

- Burner(s) – clean per manufacturer's recommendations
- Pilot and Pilot Tube – clean per manufacturer's recommendations
- Flame Baffle – clean and adjust per manufacturer's recommendations
- Gas Pressure – adjust per manufacturer's recommendations
- Burner Air – adjust and set per manufacturer's recommendations
- Fan Control – verify operation is per manufacturer's recommendations (furnace only)
- Heat Exchanger – clean and verify condition is per manufacturer's recommendations
- Gas piping and valves – verify configuration and condition are per manufacturer's recommendations
- Ignition System – verify operation is per manufacturer's recommendations
- Combustion Chamber – verify condition is per manufacturer's recommendations
- Temperature Rise – verify operation is per manufacturer's recommendations
- Blower system – verify condition and operation are per manufacturer's recommendations

- Wiring – replace/repair loose connections and verify conditions are per manufacturer's recommendations
- Air filtration system – clean per manufacturer's recommendations
- Flue & Venting – verify configurations and conditions are per manufacturer's recommendations
- Thermostat – verify operation is per manufacturer's recommendations
- Safety Locks – verify operation is per manufacturer's recommendations
- Final Operation – verify operation is per manufacturer's recommendations

A boiler tune-up includes inspection/adjustment of the following components as performed by a qualified service technician:

- Burner(s) – clean per manufacturer's recommendations
- Pilot and Pilot Tube – clean per manufacturer's recommendations
- Flame Baffle – clean and adjust per manufacturer's recommendations
- Gas Pressure – adjust per manufacturer's recommendations
- Burner Air – adjust and set per manufacturer's recommendations
- Heat Exchanger – clean and verify condition is per manufacturer's recommendations
- Gas piping and valves – verify configuration and condition are per manufacturer's recommendations
- Ignition System – verify operation is per manufacturer's recommendations
- Combustion Chamber – verify condition is per manufacturer's recommendations
- Temperature Rise – verify operation is per manufacturer's recommendations
- Blower system – verify condition and operation are per manufacturer's recommendations (if applicable)
- Wiring – replace/repair loose connections and verify conditions are per manufacturer's recommendations
- Pumping system – verify correct operation
- Flue & Venting – verify configurations and conditions are per manufacturer's recommendations
- Thermostat – verify operation is per manufacturer's recommendations
- Safety Locks – verify operation is per manufacturer's recommendations
- Final Operation – verify operation is per manufacturer's recommendations

Algorithms

Unit Dth Savings per Year = Btuh_input x Load_Factor x $EFLH_{HEAT}$ / Conversion_Factor x MF

Where:

Btuh_in	=	The nominal rating of the input capacity of the furnace in Btu/h
Load_Factor	=	The load factor, assumed to be 0.77 (implies 30% oversizing) (Ref. 2)
$EFLH_{HEAT}$	=	Equivalent Full Load Hours of Heating. (Ref. 3)
Conversion_Factor = 1,000,000 Btu/Dth		
MF	=	Maintenance saving factor. MF=2%. (Ref. 4)

Example:

Furnace Tune-up in single-family home, 60,000 btu/h input, Climate Zone 3.

Unit Dth Savings per Year = 60,000 x 0.77 x 1046 / 1,000,000 x 0.02 = 0.97 Dth

Deemed Input Tables

Table 1. Equivalent Full Load Heating Hours ($EFLH_{HEAT}$) by Climate Zone (Ref. 4, 5)

Zone	$EFLH_{HEAT}$ Heat Pump Systems	$EFLH_{HEAT}$ All Other Heating Systems
Zone 1 (Northern MN)	2576	1145
Zone 2 (Central MN)	2383	1046
Zone 3 (Southern MN/Twin Cities)	2069	1046

Note: EFLH values have been derived such that load factor and oversizing factor has been included in the values outlined above. See methodology assumptions and notes on EFLH derivation below.

Methodology and Assumptions

Measurements and corrections must be performed with standard industry tools and practices; it is recommended that the results be tracked by the efficiency program.

$EFLH_{COOL}$ and $EFLH_{HEAT}$ values were determined from a 2022 MN CARD study using PRISM utility billing data analysis method collected from Minnesota utility customers, and NOAA 2005 - 2020 MN weather data. The EFLH heating calculation uses total heating energy use and equipment input capacity. The total heating energy use was determined from customer billing data and the input capacity was determined through customer interview and utility provided data on installations. In this method, the load factor and oversizing factor are already included in the resulting value derived and are therefore not additionally included as a separate metric in the algorithm.

Deviating from the results from the 2022 CARD study, the $EFLH_{HEAT}$ value for Climate Zone 2 (Central MN) matches the $EFLH_{HEAT}$ value for Climate Zone 3 (Southern MN/Twin Cities) to reflect concerns with unexplored variables influencing the initial results that did not trend as expected due to climate.

Actual tune-up cost may vary depending on contractor's tune-up procedure.

References

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc. June 2007 http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf
2. PA Consulting, KEMA, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010. This factor implies that boilers are 30% oversized on average.
3. Cadmus and Minnesota Department of Commerce. "*MN CARD Study: Residential Thermostat Savings and HVAC Equipment Equivalent Full Load Hours*" Accessed July 2022. https://www.cards.commerce.state.mn.us/security/search.do?documentId=%7B3D4A3D02-73F6-480A-B365-D582C35C44CC%7D
4. FES determined by collection of results from over 125 projects completed through a Midwest energy project.
5. Engineering assumption to increase the Climate Zone 2 EFLH Heat value to be equal to Zone 3. The original study value determined this value to be 1020 hours, which is lower than Zone 3 at 1046 hours.

Revision History

Version	Description	Author	Date
1.0	Replaces furnace tune-up measure in ResidentialFurnaceMeasures_v01; changed algorithm to match commercial boiler tune-up	Joe Plummer	
1.1	Specified action, removed modification type from list of inputs from customer/vendor	Joe Plummer	
1.2	Corrected error so that cost of tune-up is an optional input, increased cost of tune-up to $200	Joe Plummer	
2.1	Changed savings equation	Franklin Energy Services	8/14/2012
2.2	Added multifamily buildings to the measure	Franklin Energy Services	8/14/2012
2.3	Added efficiency standards	Franklin Energy Services	8/14/2012
2.4	Added references	Franklin Energy Services	8/14/2012
2.5	Changed wording of Btuh_input description	Joe Plummer	4/3/2013
3.0	Added Service Recommendations and changed algorithm format to EFLH and Boilers	Franklin Energy Services	11/12/2015
4.0	EFLH modifications based on recent CARD study.	Cadmus	11/1/2022
5.0	Updated the $EFLH_{HEAT}$ value for Climate Zone 2 (Central MN) to match the $EFLH_{HEAT}$ value for Climate Zone 3 (Southern MN/Twin Cities)	MN Department of Commerce	2025

Residential HVAC – Thermostats

Measure Detail	Measure Value
Measure ID	1.02.17
Target Market Segments	Residential
Target End Uses	HVAC
Applicable To	Residential customers in single-family homes, duplexes, townhomes, and multifamily homes (including 3- and 4-family homes)
Actions	Replace on Failure, Replace Working, New Construction
Required from Customer/Contractor	Confirmation of heating type, existing or new home
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0 unless Tier III device with demand response program. See Notes.
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	10 (Ref. 1, Ref. 2)
Unit Participant Incremental Cost	Unit Participant Cost = See Table 2 or use actual device costs plus installation cost if available

Measure Description

This measure includes installation of a programmable (Tier I), communicating (Tier II), analytics capable (Tier III), or ENERGY STAR thermostat in existing or new homes. Note: There is a great deal of model overlap between Tier III and ENERGY STAR Certified Smart Thermostats, and this savings algorithm assumes no difference in measured savings performance. Furthermore, the 2022 Minnesota billing analysis results (Ref. 12) indicated identical percentage savings for Tier II (communicating) and Tier III (analytics capable) thermostats.

Each tier is defined by the following characteristics:

Tier I: Programmable

- Customer programmed set points schedule

Tier II: Communicating

- Customer access to set points and schedule from anywhere using a smart device (phone, tablet or computer)

Tier III: Analytics Capable

- Additional energy savings features, including coaching, HVAC diagnostics, geofencing, comparative information, etc.
- Demand response capabilities
- Customer engagement features including customer-specific data and recommendations

ENERGY STAR Certified Smart Thermostat (Ref. 10)

- Static temperature accuracy ≤ 2.0 °F, average network standby power ≤ 3.0 W, ≤ 5 minutes to enter standby
- Customer engagement features
- Open access demand response capabilities
- Capable of collecting data including thermostat ID, HVAC equipment type (if possible), cooling and heating run time, auxiliary heat run time, space temperature, setpoints
- Demonstrated field savings calculated via collected usage data used with ENERGY STAR software

The thermostat savings presented in this TRM have been updated to reflect specific billing analysis results for Minnesota customers (Ref. 12). The MN Residential Energy Code requires new homes with gas furnace heating have at least Tier I programmable thermostats installed. For this reason, Tier 1 programmable thermostats have no associated savings for new construction installations.

Advanced programmable thermostats allow residential customers to save energy by automatically adjusting the temperature of the home based on a set schedule of use and personal preferences. To achieve maximum energy savings, residential customers should consider setting the thermostat preferences to setback 7°F – 10°F from 70°F, or the occupied temperature setting, for at least 8 hours per day (Ref. 13). Consider the following best practice settings when programming a thermostat (Ref. 14):

- 68°F (or lower to preference) in the winter season when occupants are present and awake
- 62°F (or lower to preference) in the winter season when occupants are asleep or absent
- 78°F (or higher to preference, or off) in the summer season when occupants are present
- 82°F (or higher to preference, or off) when occupants are away. Temperature settings during sleeping hours will be highly dependent on personal preference.
- Consider setting the setback timing 30 minutes prior to expected departure or sleep, the temperature will coast within a comfortable range while still occupied.

Communicating and smart thermostats have the potential to incorporate automated early/late initiation of setpoint changes to achieve the desired setpoint depending on the current temperature in the home and the forecasted weather conditions. Communicating and smart thermostats might also incorporate occupancy sensing technology and geofencing to anticipate and automatically adjust the occupancy state to meet the occupant's set preferences.

Residential customers can realize increased savings in mechanical conditioning by monitoring the solar gain through windows. In general, customers should attempt to limit solar gain on hot, sunny summer days, by adjusting window shades on southern and western exposures to block direct sunlight infiltration. Conversely, customers can positively utilize solar gain in the winter to provide passive heating to the home. This strategy is most efficiently achieved by utilizing shading mechanisms external to the home, such as planting trees to shade the southern exterior, or installing external overhangs on south facing windows.

Algorithms

Unit kWh Savings per Year = (CSF x Cooling kWh) + (HSF x Heating kWh) x Install Rate

Unit Dth Savings per Year = (HSF x Heating Dth) x Install Rate

Where:

CSF	= Cooling savings factor, assumed fraction of cooling energy saved by thermostat, see Table 1
Cooling kWh =	Baseline cooling energy for residences in pilot area (Default = 1,146 kWh/yr.) (Ref. 12)
HSF	= Heating savings factor, assumed fraction of heating energy saved by thermostat, see Table 1
Heating kWh =	Baseline heating energy for primary electric-heated homes. (Default = 16,200 kWh/yr for electric resistance, 7,200 kWh for air source heat pump, 4,900 kWh for ground source heat pump, and 0 for gas heat) (Ref. 9)
Heating Dth =	Baseline heating energy for natural gas-heated residences in pilot area. Default = 75 Dth/yr (Ref. 12) for homes with gas heat, = 0 for homes with electric heat
Install Rate =	The percentage of rebated equipment that is assumed to be installed

Example:

150 Tier III thermostats are directly installed in 148 natural gas-heated homes with air-conditioning as part of a pilot program. The pilot does not include demand response.

kWh Savings per Year = 148 x (1146 x 0.132) x 100% = 22,422 kWh (151.5 kWh per home)

Dth Savings = 148 x (75 x 0.051) x 100% = 562.4 Dth (3.8 Dth per home)

Deemed Input Tables

Table 1. Heating and Cooling Savings Factors (Ref, 12)

Thermostat Type	Baseline Thermostat	Heating (HSF)	Cooling (CSF)
		Value	Value
Tier I	Manual Operation[2]	4.2% / 0%[1]	0.0%
Tier II	Unknown	5.1%	13.2%
Tier III / ENERGY STAR	(Manual Operation or Tier I)[2]	5.1%	13.2%

[1]No savings may be claimed for Tier I thermostats in new homes with gas furnaces because they are required by MN Residential Energy Code.

[2]The assumed baseline for installation of a Tier I thermostat is a manually operated thermostat (not programmable). The assumed baseline for the installation of a Tier II or Tier III thermostat is not defined, the assumed baseline is likely either a manual operated thermostat or a tier I thermostat and have not been differentiated within the percentage savings data.

Table 2. Incremental costs

Thermostat Type	Baseline Thermostat	Baseline Cost	Efficient Cost	Incremental Cost	Source
Tier I	Manual	$24	$54	$30	Ref. 8 for efficient cost. Assumed $24 baseline cost.
Tier II	Unknown	$39	$130	$91	Ref. 4 for efficient cost. $39 base cost reflects 50/50 average of manual and programmable.
Tier III / ENERGY STAR			$213	$174	

Table 3. Install Rate based on Delivery Method (Ref. 15)

Delivery Method	Install Rate
Retail	56%
Direct Install	100%
Virtual Assessment + Unverified Self-Install	56%
Distributed School Efficiency Kit	56%

Methodology and Assumptions

Programmable thermostats are required by the 2015 Minnesota Residential Energy Code for new homes with gas furnaces.

As savings is dependent on household consumption, households with multiple thermostats shall not attain savings beyond that of the installation of one thermostat.

The reference used to derive savings factors was a large billing analysis, conducted in 2022 using monthly billing data from 2016 to 2020 for 2017 to 2019 Minnesota thermostat program participants (Ref. 12).

There are few studies available examining electric heat (resistance and heat pump) savings for thermostats. In the 2022 billing analysis the electric heating sample size was too small to obtain a reliable savings fraction estimate. Sites with electric heat are assumed to have the same heating savings fractions as those with gas heat.

Notes

The ENERGY STAR qualification tests assume baseline setpoints that may not reflect actual practice, and do not necessarily reflect actual HVAC savings fractions—using secondary billing analysis is used instead here.

There is little information on demand response impacts from smart thermostat programs at this time. kW demand savings could be updated as more pilot programs are completed.

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Revision History

Version	Description	Author	Date
1.0	Measure Created	Franklin Energy Services	2/28/2014
1.1	Added duplex to multifamily category	Joe Plummer	3/11/2014
1.2	Added IECC 2012 note	Franklin Energy Services	7/31/2014
1.3	In Methodology and Assumption, changed "solely" to "primarily" regarding gas heating for consistency with Description	Joe Plummer	7/31/2014
2.0	Expanded measure to three Tiers of Thermostats	Franklin Energy Services	11/12/2015
2.1	Expanded measures to include ENERGY STAR Thermostats	Franklin Energy Services	09/01/2017
2.2	Adjusted savings factors and costs, merged measures for gas and electric heating	Cadmus	10/2019
2.3	Adjusted savings factors using MN Card Thermostat billing analysis savings factors	Cadmus	11/01/2022
5.0	Included Install Rates	MN Department of Commerce	2025

Residential HVAC – Line Voltage Thermostats

Measure Detail	Measure Value
Measure ID	1.02.18
Target Market Segments	Residential
Target End Uses	HVAC
Applicable To	Residential customers in single-family homes, duplexes, townhomes, and multifamily homes (including 3- and 4-family homes)
Actions	Replace on Failure, Replace Working, New Construction
Required from Customer/Contractor	Confirmation of heating type, existing or new home
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	0
Measure Lifetime (years)	10 (Ref. 1)
Unit Participant Incremental Cost	$115 per smart thermostat (Ref. 2) $37 per programmable thermostat (Ref. 2)

Measure Description

Thermostats for typical central HVAC systems get power and send signals via low voltage wires running to the furnace, boiler, AC, or heat pump control panel. But the controls for baseboard electric heaters are installed as part of the full-voltage circuit powering the heater, typically 120 or 240 volts. Therefore these are often referred to as line voltage thermostats. These are often bimetallic-controlled manual thermostats, although electronic-controlled manual and programmable varieties have been widely available for some time.

Recently, line voltage smart thermostats have become available which offer features similar to standard smart thermostats, including:

- Easier use and programming
- Occupancy sensing, via sensors on the thermostat or location tracking via a smartphone app
- Learning capability and / or automatic schedule generation or modification
- Encouraging the use of more energy-efficient set temperatures by users

This measure represents the installation of a line voltage thermostat in place of a manual or programmable thermostat.

Caution is advised in using this measure as few large-scale pilots have been completed to date and results have varied significantly. One or more large-scale whole-home consumption analyses are recommended in order to refine savings for these measures in Minnesota.

Algorithms

Unit kWh Savings per Year per thermostat = Heating kWh x SizeFactor x HSF / N

Where:

Heating kWh = Estimated average annual heating kilowatt-hours consumed by whole homes with baseboard electric heat, see Table 1.

SizeFactor = Adjustment factor for heated area of residence, = 1 if heated square footage is unknown, = home heated square footage divided by 1,889 for single family or 834 for multifamily (see Notes)

HSF = Heating savings factor, = 10% for smart thermostats, = 7% for programmable thermostats, see Savings Fraction section.

N = Deemed number of thermostats per home, = 6 for single-family homes, = 4 for multifamily homes (Ref. 3)***Example:***

A single-family home heated completely by baseboard heat, of unknown size and unknown base thermostat is outfitted with two line voltage smart thermostats, MN climate zone 3.

kWh Savings per Year = 2 x 1 x 11,527 x 0.08 / 6 = 307 kWh

Cost = $115 x 2 = $230

Deemed Input Tables

Table 1. Baseline Heating kWh for baseboard heaters (Ref. 4, Ref. 5, Ref. 6, see Notes)

Zone	Baseline Baseboard Heater Household kWh	
	Single family	Multifamily
Zone 1 (Northern MN)	14,184	3,357
Zone 2 (Central MN)	12,824	2,906
Zone 3 (Southern MN/Twin Cities)	11,527	2,612

Table 2. Savings Fractions

Baseline Thermostat	New Thermostat	Heating Savings Fraction	Formula (see Notes)
Manual	Programmable	6.0%	3.6% x (1 - 30%) + 3.5%
Manual	Smart	11.1%	10.9% x (1 - 30%) + 3.5%
Unknown	Smart	8.0%	5.5% x (1 - 30% + 30%) + 3.5% x (1 - 30%)
Programmable	Smart	5.1%	11.1% - 6.0%

Notes

Savings Fraction

Baseboard heaters are often controlled by bimetallic manual thermostats. Such thermostats for line voltage use may be less efficient than manual thermostats are for central systems because of droop and increased deadband (Ref. 3), and upgrading to electronic control relying on thermistors may produce

savings, even if these thermostats are not programmable or smart. However there is mixed evidence for this, as seen in the studies in Table 2. The Regional Technical Forum (Ref. 7) currently uses a 5% savings factor for electronic manual line voltage thermostats, a value based on Ref. 8 and other earlier small studies. Here, a conservative estimate of 3.5% is used for this part of the upgrade.

Table 2. Line voltage thermostat studies

State	Ref	Equipment	Participant Count	Baseline	Efficient	Findings
OR	8	Baseboard	98	Bimetallic manual	Electronic programmable	1,475 kWh (Table 6) vs. 380 kWh for comparison group, vs. 11,548 kWh baseline so 9.4%
			65		Electronic manual	250 vs. 380 kWh for comparison group, no observed savings
CT, MA, NH	9	Baseboard	56	Bimetallic manual	Electronic manual	7.1% of heating load

Line voltage programmable and smart thermostats have electronic control and also likely provide additional savings from programmable and smart functionality. A study in Table 2 measured line voltage programmable thermostat savings, but it was relatively small, and in a climate different from Minnesota. Additionally, no studies have been completed examining line voltage smart thermostat performance, and very few recent studies have been conducted examining low-voltage smart thermostat performance with electric heat (heat pump, baseboard, or resistance heat with forced air). Those and other recent studies examining gas savings are presented in Table 2 below. It should also be noted that the Regional Technical Forum only adds 1% to its 5% electronic manual savings fraction if the line voltage thermostat is smart (Ref. 7).

Table 3. Recent low-voltage smart thermostat studies

State	Ref	Equipment	Participant Count	Baseline	Efficient	Findings
FL	10	Mixed heat pump and resistance	30	Mixed	Smart	9.6% of heating load
OR	11	Heat pumps	176			12% of HVAC load
OR	12		113 treatment 211 control			12% of heating load
MI	13	Gas heating	6,479	Mixed	Smart	28 therms savings
WI	14		2,427			4.8% of heating load
IL	15		2,118 treatment 2,058 control			6.7% of heating load
				Manual	Smart	8.8% of heating load
IN	16		381 treatment, 3,845 control			12.5% of heating load
IN	17		455 treatment, 469 control			13.4% of heating load
IL	18		76	Programmable	Smart	3% of heating load

To sum these measured findings:

- Mixed to smart, electric, coastal: 10% to 12% savings
- Mixed to smart, gas, upper Midwest: 5% to 7% savings
- Manual to smart, gas, upper Midwest: 9% to 13% savings
- Programmable to smart, gas, upper Midwest: 3% savings (1 study)
- Manual to programmable, baseboard, coastal: 9.4% (1 study, includes bimetallic to electronic sensor upgrade)

For sites with an unknown baseline thermostat, the thermostat mix is likely a majority of bimetallic manual, some electronic manual, and a minority of electronic programmable. Upgrading from this baseline to a smart thermostat should produce savings that are a combination of savings from a bimetallic to electronic upgrade (deemed 3.5% above) and a manual or mixed to programmable or smart upgrade (Table 3). But the correct value to use for each of those is uncertain, and this combination may not be a linear one.

Reflecting the above notes, the savings estimates employ the savings fractions from the standard thermostat measure writeup, which are largely based on references cited here, and modify them:

- Standard thermostat savings fractions are 3.6% for manual to programmable, 10.9% for manual to smart, and 5.5% for unknown to smart.
- These savings fractions are each reduced by 30% as a conservative measure because they reflect gas central heating values but are being applied to electric space heating here.
- However for an unknown baseline, the 5.5% standard value reflects a low-voltage thermostat mix of manual and programmable. Because baseboard heaters likely have a higher proportion of manual baselines, 30% is added back.
- Then a full 3.5% is added for manual baselines, reflecting an upgrade from bimetallic to electronic sensing.
- For an unknown baseline, that additional 3.5% is reduced by 30% because some of this baseline likely already has electronic sensing.
- Programmable to smart upgrades reflect the difference between manual to programmable and manual to smart.

Base Consumption

To estimate base consumption for homes with baseboard heat, data from the 2015 Residential Energy Consumption Survey (RECS, Ref. 4) was used. The following filters were applied and a weighted average was obtained:

- Census division 4 (IA, KA, MN, MO, NE, ND, SD)
- Type of housing = single-family detached and attached for single family, = apartment in a building 2 to 4 units, and with more than 5 units, for multifamily
- Equipment type = built-in electric units installed in walls, ceilings, basements, or floors
- Heating fuel = electricity

This produced values of 10,220 kWh for single family and 2,316 kWh for multifamily. This value was then adjusted to represent Minnesota specifically. Population-average heating degree days (HDDs) were obtained for the seven states in RECS census division 4 (Ref. 6). These were then used with the state populations (Ref. 5) to calculate an average HDD value for RECS census division 4 of 6,784. This is then combined with Minnesota climate zone heating degree days to produce normalized SF and MF consumption for each MN climate zone. For instance, Zone 3 has 7,651 heating degree days, so it has a single family consumption of 10,220 x 7,651 / 6,784 = 11,527.

The average heated square footage observed by RECS for these residences are 1,889 square feet for single family and 834 square feet for multifamily. Base consumption may be adjusted based on this, if heated square footage is known.

General Notes

Few large-scale pilot programs have been completed as of the drafting of this measure and results vary significantly. As a result, the savings factors may require adjustment as more pilot programs are completed. One or more large-scale whole-home consumption analyses are recommended in order to refine savings for these measures in Minnesota.

There is little information on demand response impacts from smart thermostat programs at this time. kW savings could be updated as more pilot programs are completed.

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Revision History

Version	Description	Author	Date
1.0	Measure Created	Cadmus	9/2020

Envelope

Residential Envelope – Insulation and Air Sealing

Measure Detail	Measure Value
Measure ID	1.03.01
Target Market Segments	Residential, Commercial
Target End Uses	Envelope
Applicable To	Residential and small commercial customers. For existing buildings only
Actions	Modify
Required from Customer/Contractor	Pre- and post-insulation R-values of attic insulation (if applicable); pre- and post-insulation R-values of wall insulation (if applicable); confirmation of gas, electric resistance, or heat pump heating; confirmation of air conditioning, relative exposure of building (well-shielded, normal, or exposed, if air sealing), no. of stories project location (county), Efficiency of heating and cooling systems, Infiltration before and after sealing as measured by blower door testing at 50 Pascals (if applicable).
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	35 (Ref. 2)
Unit Participant Incremental Cost	See Table 4

Measure Description

This measure characterizes increased attic and/or wall insulation and air sealing for reduction of thermal losses through the building envelope.

The Minnesota Residential Energy Code requires that accessible attic bypasses be sealed prior to installing attic insulation (Ref. 8). Neglecting to seal bypasses can drastically reduce the effectiveness of insulation and lead to ice dams on the roof of the building during the winter. Ice dams can damage the roof and lead to water infiltration.

It is recommended that programs include pre- and post-blower door testing to measure the effectiveness of air sealing. Over-sealing a building can reduce natural ventilation to unsafe levels. The Minnesota Residential Energy Code specifies requirements for natural and mechanical ventilation to maintain acceptable air quality (Ref. 9). Programs should also include worst case draft testing of atmospherically-vented gas heating equipment following comprehensive air sealing and recommend installation of carbon monoxide detectors if not present.

Algorithms

For homes with gas heat

Unit Dth Savings per Year = $Savings_{WALL,DTH}$ + $Savings_{ATTIC,DTH}$ + $Savings_{AIRSEALING,DTH}$

$Savings_{WALL,DTH}$ (Dth) = [1/($R1_{INS,WALL}$ + R_{WALL}) - 1/($R2_{INS,WALL}$ + R_{WALL})] x A_{WALL} x (1 - FF) x 24 x HDD65 x CorrF / (AFUE x 1,000,000)

$Savings_{ATTIC,DTH}$ (Dth) = [1/($R1_{INS,ATT}$ + R_{ATT}) – 1/($R2_{INS,ATT}$ + R_{ATT})] x A_{ATT} x (1 - FF/2) x 24 x HDD65 x CorrF / (AFUE x 1,000,000)

$Savings_{AIRSEALING,DTH}$ (Dth) = 1.08 x 24 x HDD65 x CorrF x (CFM50 / N_{HEAT}) / (AFUE x 1,000,000)

Where:

$R1_{INS,WALL}$	= Initial R-value of wall insulation
$R2_{INS,WALL}$	= Final R-value of wall insulation
R_{WALL}	= R-value of uninsulated wall assembly including air films = 2.73. See Methodology and Assumptions for derivation.
$R1_{INS,ATT}$	= Initial R-value of attic insulation
$R2_{INS,ATT}$	= Final R-value of attic insulation
R_{ATT}	= R-value of uninsulated attic assembly including air films = 2.37. See Methodology and Assumptions for derivation.
A_{WALL}	= Total area of insulated wall (square feet)
A_{ATT}	= Total area of insulated ceiling/attic (square feet)
FF	= Adjustment factor to account for the area of framing materials = 15%
HDD65	= the heating degree days of the climate zone with a 65 degree base. See Table 1.
AFUE	= Efficiency or AFUE of gas heating system. If the gas heating system is known, AFUE = nameplate efficiency of the existing furnace if the efficiency of the gas heating system is unknown, see Table 9.
CFM50	= Total reduction in Infiltration at 50 Pascals as measured by blower door.
CorrF	= Correction factor. Assumed to be 0.7 (Ref. 7)
N_{HEAT}	= Conversion factor from leakage at 50 Pascal to leakage at natural conditions, based on climate, building height and exposure level, see Table 2
1,000,000	= Conversion factor from Btu to Dth

For homes with gas heat and air conditioning

Unit Dth Savings per Year = see above

Unit kWh Savings per Year = $Savings_{WALL,kWh,COOL}$ + $Savings_{ATTIC,kWh,COOL}$ + $Savings_{AIRSEALING,kWh,COOL}$

$Savings_{WALL,kWH,COOL}$ (kWh) = $[1/(R1_{INS,WALL} + R_{WALL}) – 1/(R2_{INS,WALL} + R_{WALL})] \times A_{WALL} \times (1 – FF) \times 24 \times CDD65 \times DUA / (SEER \times 1,000)$

$Savings_{ATTIC,kWH,COOL}$ (kWh) = $[1/(R1_{INS,ATT} + R_{ATT}) – 1/(R2_{INS,ATT} + R_{ATT})] \times A_{ATT} \times (1 – FF/2) \times 24 \times CDD65 \times DUA / (SEER \times 1,000)$

$Savings_{AIRSEALING,kWH,COOL}$ (kWh) = $1.08 \times 24 \times CDD65 \times DUA \times (CFM50 / N_{COOL}) / (SEER \times 1,000) \times LM$

Unit Peak kW Savings = $kWh_{COOL} / EFLH_{COOL} \times CF$

Where:

CDD65	= The heating degree days of the climate zone with a 65 degree base. See Table 1.
DUA	= Discretionary Use Adjustment to account for the fact that people do not always operate their air conditioning system when the outside temperature is greater than 75°F = 0.75 (Ref. 15)
N_{COOL}	= Conversion factor from leakage at 50 Pascal to leakage at natural conditions, based on climate, building height and exposure level, see Table 2
LM	= Latent multiplier to convert the calculated sensible cooling savings to a value representing sensible and latent cooling loads = 6.2 (Ref. 12)
SEER	= Nameplate efficiency of equipment, default = 11.5 (for units with unknown efficiency) (Ref. 14)
$EFLH_{COOL}$	= Equivalent Full Load Cooling Hours. See Table 3
CF	= Coincidence factor = 0.75 for cooling equipment with standard single-speed compressor, 0.9 for cooling equipment with variable-speed compressor (see Notes). If unknown use 0.75.
1000	= Conversion factor from kW to kWh

For homes with electric resistance heat or heat pumps

Unit Dth Savings per Year = 0

Unit kWh Savings per Year = $Savings_{WALL,kWh,COOL} + Savings_{WALL,kWh,HEAT} + Savings_{ATTIC,kWh,COOL} + Savings_{ATTIC,kWh,HEAT} + Savings_{AIRSEALING,kWh,COOL} + Savings_{AIRSEALING,kWh,HEAT}$

$Savings_{WALL,kWh,COOL}$ = see above

$Savings_{ATTIC,kWh,COOL}$ = see above

$Savings_{AIRSEALING,kWh,COOL}$ = see above

$Savings_{WALL,kWH,HEAT}$ (kWh) = $[1/(R1_{INS,WALL} + R_{WALL}) – 1/(R2_{INS,WALL} + R_{WALL})] \times A_{WALL} \times (1 – FF) \times 24 \times HDD65 \times CorrF / (HSPF \times 1,000)$

$Savings_{ATTIC,kWH,HEAT}$ (kWh) = [1/($R1_{INS,ATT}$ + R_{ATT}) – 1/($R2_{INS,ATT}$ + R_{ATT})] x A_{ATT} x (1 – FF/2) x 24 x HDD65 x CorrF / (HSPF x 1,000)

$Savings_{AIRSEALING,kWH,HEAT}$ (kWh) = 1.08 x 24 x HDD65 x CorrF x (CFM50 / N_{HEAT}) / (HSPF x 1,000)

Unit Peak kW Savings = see above

Where:

HSPF = Electric heating system efficiency = 3.412 for electric resistance heat, the number of Btu in a watt-hour; = 7.7 x 0.85 = 6.55 for air source heat pump (Ref. 10, Ref. 18, Ref. 19)

Example:

A two-story single-family house with gas heat, air conditioning, and normal exposure in Zone 1 receives attic insulation and air sealing. The existing insulation had an R-value of R-11. Cellulose insulation is blown into the 1,000 square foot attic to increase the R-value from 11 to 50. Pre– and post–blower door testing shows a decrease in CFM50 of 500. No wall insulation work is performed.

$Savings_{WALL,DTH}$ = 0

$Savings_{ATTIC,DTH}$ = [(1 / (11 + 2.37) - 1/(50 + 2.37)] x 1,000 x (1 - 0.15 / 2) x 24 x 9,833 x 0.7 / (0.80 x 1,000,000) = 10.6 Dth

$Savings_{AIRSEALING,DTH}$ = 1.08 x 24 x 9,833 x 0.7 x (500 / 15.5) / (0.9 x 1,000,000) = 6.4 Dth

Unit Dth Savings per Year = 0 + 10.6 + 9.0 = 17.8 Dth

$Savings_{WALL,kWH,COOL}$ (kWh) = 0

$Savings_{ATTIC,kWH,COOL}$ (kWh) = [1 / (11 + 2.37) – 1 / (50 + 2.37)] x 1000 x (1 - 0.15 / 2) x 24 x 140 x 0.75 / (11.5 x 1,000) = 43.6 kWh

$Savings_{AIRSEALING,kWH,COOL}$ (kWh) = 1.08 x 24 x 140 x 0.75 x (500 / 12.4) / (11.5 x 1,000) x 6.2 = 59.2 kWh

Unit kWh Savings per Year = 0 + 43.6 + 59.2 = 96.7 kWh

Unit Peak kW Savings = 96.7 /312 x 0.75 = 0.23 kW

Deemed Input Tables

Table 1. Heating and Cooling Degrees Days (HDD / CDD) per zone in Minnesota

	Zone 1 (Northern MN)	Zone 2 (Central MN)	Zone 3 (Southern MN / Twin Cities)
HDD65 (Ref. 5)	9,833	8,512	7,651
CDD65 (Ref. 11)	140	414	634

Table 2. N_{HEAT} (Ref. 3) and N_{COOL} (see Notes) for Minnesota

Variable	Relative Exposure	Building Height (Stories)		
		1	2	3
N_{HEAT}	Well Shielded	18.6	14.9	13.0
	Normal	15.5	12.4	10.9
	Exposed	14.0	11.2	9.8
N_{COOL}	Well Shielded	29.8	23.8	20.8
	Normal	24.8	19.8	17.4
	Exposed	22.4	17.9	15.7

Well shielded: urban areas with buildings or sheltered areas. Buildings surrounded by trees, bermed earth, or higher terrain.
Normal: buildings in a residential neighborhood or subdivision setting, with yard space between buildings.
Exposed: buildings in an open setting with few buildings or trees around; buildings on top of a high hill, exposed to winds.

Table 3. Equivalent Full Load Cooling Hours ($EFLH_{COOL}$) by Climate Zone (Ref. 16)

Zone	$EFLH_{COOL}$ Heat Pump Systems	$EFLH_{COOL}$ AC Systems
Zone 1 (Northern MN)	456	312
Zone 2 (Central MN)	512	565
Zone 3 (Southern MN/Twin Cities)	678	567

Note: EFLH values have been derived such that load factor and oversizing factor has been included in the values outlined above. See methodology assumptions and notes on EFLH derivation below.

Table 4. Incremental Costs of Insulation (Ref. 6)

Insulation Type	Incremental Cost ($ / Square Foot)	
	Attic Insulation	Wall Insulation
R-12	$0.62	$1.77
R-19	$0.81	$1.96
R-22	$0.96	$2.11
R-26	$1.16	$2.31
R-30	$1.29	$2.44
R-38	$1.61	$2.76
R-49	$2.05	$3.20

Methodology and Assumptions

The assumed R-value of an uninsulated wall assembly was derived from the following inputs:

Table 5. Component R-values for typical wall assembly

Component	R-value
Wall - Outside Air Film	0.17
Siding - Wood Bevel	0.8
Plywood Sheathing - 1/2"	0.63
Insulation	0
1/2" Drywall	0.45
Inside Air Film	0.68
Total Wall Component R-Values	2.73

The assumed R-value of an uninsulated attic assembly was derived from the following inputs:

Table 6. Component R-values for typical attic assembly

Component	R-value
Roof - Outside Air Film	0.17
Asphalt Shingles	0.44
Plywood Sheathing - 1/2"	0.63
Insulation	0
1/2" Drywall	0.45
Inside Air Film	0.68
Total Attic Component R-Values	2.37

Notes

Values for N_{COOL} were derived by examining the Illinois and Iowa TRMs (Ref. 1, Ref. 4). Their air sealing measures calculate various values for N_{HEAT} and N_{COOL}, for various cities in these regions. The ratio of N_{COOL} / N_{HEAT} is consistently between 1.5 and 1.7, with an average value of 1.6. That ratio is applied to the previously-derived values for N_{HEAT} in Minnesota to produce values for N_{COOL}.

There are statewide energy codes related to minimum insulation values of newly constructed and renovated commercial and residential buildings. There may also be local building codes in place. Energy codes pertaining to insulation, air sealing, and ventilation should be verified for each utility or location.

$EFLH_{COOL}$ and $EFLH_{HEAT}$ values were determined from a 2022 MN CARD study using PRISM utility billing data analysis method collected from Minnesota utility customers, and NOAA 2005 - 2020 MN weather data. The EFLH heating calculation uses total heating energy use and equipment input capacity. The total heating energy use was determined from customer billing data and the input capacity was determined through customer interview and utility provided data on installations. In this method, the load factor and oversizing factor are already included in the resulting value derived and are therefore not additionally included as a separate metric in the algorithm.

The value for coincidence factor is derived from a 2016 CARD study (Ref. 13) that examined quality install and maintenance practices for residential furnaces, air conditioners and heat pumps, in part by metering the behavior and performance of 58 cooling systems and 55 furnaces. A follow-on memo was

produced (Ref. 17) that recommended coincidence factor be reduced from 90% to 75%. Because the previous 90% value was simply deemed as a typical value worth updating when primary data was available, that update is applied here. However, because the metered systems had single-speed compressors, 90% may still be used for equipment with variable-speed compressors.

Effective January 1, 2023, HVAC products will be subject to regional minimum efficiencies, according to Seasonal Energy Efficiency Ratio 2 (SEER2). The nomenclature of SEER2, EER2 and HSPF2 will be used to denote the new M1 ratings. Conversion between the new M1 ratings and original M ratings should be done using an AHRI approved method, using the multipliers in Table 2 and Table 3 below.

Table 7. M to M1 Forward Conversion (Ref. 20)

System Type	Multiplier to convert to SEER2*	Multiplier to convert to EER2	Multiplier to convert to HSPF2
Ducted	0.95	0.95	0.85
Ductless	1.00	1.00	0.90
Packaged	0.95	0.95	0.84

Table 8. M1 to M Backward Conversion (Ref. 20)

System Type	Multiplier to convert to SEER*	Multiplier to convert to EER	Multiplier to convert to HSPF2
Split System Air Conditioner	1.05	1.04	N/A
Split System Heat Pump	1.05	1.04	1.18
Packaged Air Conditioner	1.04	1.04	N/A
Packaged Heat Pump	1.04	1.04	1.18
Ductless Heat Pump	1.00	1.00	1.12
Space Constrained System	1.01	1.00	1.17
Small Duct High Velocity System	1.00	1.00	1.18

Table 9. Baseline Efficiency (Ref. 21, 22, 23, 24, and the Methodology and Assumptions Section within Measure ID 1.02.14)

Equipment Type/Building Type	Single-family	Multifamily
Furnace	90%[A]	80%
Boiler	84%	84%

[A] The default baseline efficiency for furnaces for single-family homes in this table is set higher than the current Federal minimum standard for Replace on Fail and Early Replacement actions (Ref. 21). If utilities can verify that the actual efficiency of the customer's existing furnace equipment is less than 90%, the Federal minimum standard of 80% AFUE for furnaces can be used (Ref. 22, 23, 24, and Methodology and Assumptions Section within Measure ID 1.02.14).

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Revision History

Version	Description	Author	Date
1.0	Original Document	Franklin Energy Services	7/31/2012
1.1	Changed Action to Modify. Added "confirmation of gas heating system" to Required Inputs. Added Commercial to market segment since also applicable to small commercial customers. Added definitions of shielding categories from FES.	Joe Plummer	11/24/13
1.4	Changed algorithm to accept R-value of insulation as inputs rather than R-value of assembly for useability; added correction factor to ceiling and wall insulation	Franklin Energy Services	12/18/15
3.1	Added algorithms for cooling and electric heat	Cadmus	11/2018
3.2	Updated CF, adjusted HSPF for AHRI climate zone V	Cadmus	10/2019
4.0	EFLH modifications based on recent CARD study.	Cadmus	11/1/2022
4.1	Clarification to SEER2, EER2 and HSPF2 conversions	Cadmus	11/1/2023
5.0	Updated the baseline efficiency for Furnaces in single-family homes to 90% in some applications with a caveat.	MN Department of Commerce	2025

Residential Envelope – Multifamily Aerosol Air Sealing

Measure Detail	Measure Value
Measure ID	1.03.02
Target Market Segments	Multifamily
Target End Uses	Envelope
Applicable To	Residential customers in multifamily homes (including 3- and 4-family homes)
Actions	Modify, New Construction
Required from Customer/Contractor	Building type (existing or new construction), building ventilation type (exhaust only, exhaust and half supply, balanced, no ventilation)
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	20 (Ref. 1)
Unit Participant Incremental Cost	$0.50 / SqFt of home size (Ref. 1)

Measure Description

This measure is the application of an aerosol sealant to a new or existing multifamily building (Ref. 1). The aerosol envelope sealing technology developed by the Western Cooling Efficiency Center at UC Davis uses an automated approach to produce extremely tight envelopes. Air is blown into a unit while an aerosol sealant "fog" is released in the interior. As air escapes the building through leaks in the envelope, the sealant particles are carried to the leaks where they impact and stick to the edges of the leaks, eventually sealing them. A standard house or duct air leakage test fan is used to pressurize the building and provide real-time feedback and a permanent record of the sealing. A recent CARD study, *Demonstrating the Effectiveness of an Aerosol Sealant to Reduce Multi-Unit Dwelling Envelope Air Leakage,* (Ref. 1) measured and modeled savings for new and existing multifamily buildings receiving this treatment.

When possible, custom modeling is recommended to address site specific characteristics. The CARD makes several recommendations to apply to custom modeling approaches.

Algorithms

Unit Dth Savings per Year = varies, see Table 1 and Table 2

Unit kWh Savings per Year = varies, see Table 1 and Table 2

Unit Peak kW Savings = (Unit kWh Savings per Year) / $EFLH_{COOL}$ x CF

Where:

$EFLH_{COOL}$ = Full load cooling hours, in hr (Table 3)

CF = 0.9; coincidence factor (Ref. 2)

Deemed Input Tables

Table 1. Dth and kWh Savings per Unit, New Construction

Ventilation Type	Space Heating Savings (Dth / unit)	Space Cooling Savings (kWh / unit)
Exhaust only	1.2	4
Exhaust and half supply	1.7	-5
Balanced	2.7	-19
No ventilation	2.6	-29

Table 2. Dth and kWh Savings per Unit, Existing

Ventilation Type	Space Heating Savings (Dth / unit)	Space Cooling Savings (kWh / unit)
Exhaust only	4.1	-8
Exhaust and half supply	5.6	-26
Balanced	6.7	-38
No ventilation	6.8	-47

Table 3. Effective Full Load Cooling Hours (EFLH) by Climate Zone (Ref. 3)

Zone	$EFLH_{COOL}$ Heat Pump Systems	$EFLH_{COOL}$ AC Systems
Zone 1 (Northern MN)	456	312
Zone 2 (Central MN)	512	565
Zone 3 (Southern MN/Twin Cities)	678	567

Note: EFLH values have been derived such that load factor and oversizing factor has been included in the values outlined above. See methodology assumptions and notes on EFLH derivation below.

Methodology and Assumptions

The CARD study (Ref. 1) examined 18 units receiving aerosol envelope sealing in three new construction multifamily buildings, and nine units in three existing multifamily buildings. The study measured envelope leakage reductions from 67% to 94% for new construction buildings, and 39% to 89% for existing buildings. EnergyPlus models for four different ventilation strategies in new buildings used these reductions as inputs, and showed space heating energy savings of 4% to 25%, and similar models for existing buildings showed greater reductions. These savings are reflected in Table 1 and Table 2 above.

The study also showed that there is a small impact on the cooling energy required. This is due to the increased cooling energy needed after sealing (less infiltration to offset internal loads) The Card study concluded this is a relatively small impact and is not considered to be significant. Deemed savings here reflect this, with space cooling kWh penalties ranging from 0.7% to 3.8% of Dth savings (in absolute energy terms).

In 2015, Minnesota adopted the 2012 Residential International Energy Conservation Code with state amendments that requires multifamily buildings with one, two and three stories should meet envelope

tightness of 3.0 ACH50. Whereas multifamily buildings with four stories and above, are required to meet the 2012 Commercial International Energy Conservation Code with state amendments by using continuous air barriers, tight materials, tight assemblies, or an envelope air leakage test.

$EFLH_{COOL}$ and $EFLH_{HEAT}$ values were determined from a 2022 MN CARD study using PRISM utility billing data analysis method collected from Minnesota utility customers, and NOAA 2005 - 2020 MN weather data. The EFLH heating calculation uses total heating energy use and equipment input capacity. The total heating energy use was determined from customer billing data and the input capacity was determined through customer interview and utility provided data on installations. In this method, the load factor and oversizing factor are already included in the resulting value derived and are therefore not additionally included as a separate metric in the algorithm.

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Revision History

Version	Description	Author	Date
1.0	Original document	Cadmus	11/2018
4.0	EFLH modifications based on recent CARD study.	Cadmus	11/1/2022

Residential Envelope – Low-E storm windows

Measure Detail	Measure Value
Measure ID	1.03.03
Target Market Segments	Residential, Multifamily
Target End Uses	Envelope
Applicable To	Residential and small commercial customers. For existing buildings only
Actions	Modify
Required from Customer/Contractor	Single family: Number of low-E windows sold, site HVAC system type, climate zone Multifamily: Square footage of low-E windows installed, number of windows installed, existing window type (single or double pane), site HVAC system type, climate zone
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	20 (Ref. 1)
Unit Participant Incremental Cost	Single family = $126 per window (see Notes) Multifamily = $160 per window (see Notes)

Measure Description

Modern low emissivity (low-E) storm windows are a glazing attachment added to single-pane or double-pane windows. Low-E metal oxide coating (low-E storm windows/panels) decreases the winter heat loss and summer heat gain of an existing window by reducing thermal transmission. A low-E storm window may be installed on the interior or exterior of the existing window assembly. They are typically permanently mounted and operable. The products reduce thermal transmission in three ways:

- The low-E metal oxide coating acts as a selective heat mirror that reflects infrared light back into the home during the winter and back outside during the summer.
- The marine-quality glazing and caulked or compression-sealed interface reduces air leakage and infiltration.
- The dead air space created between the existing window and new storm window frame further reduces thermal transmission during both the winter and summer.

Algorithms

Unit Dth Savings per Year = $SF_{GASHEAT}$ x Area / 1,000

Unit kWh Savings per Year = kWh_{COOL} + kWh_{HEAT}

kWh_{COOL} = SF_{COOL} x Area

kWh_{HEAT} = $SF_{ELECHEAT}$ x Area

Unit Peak kW Savings = kWh_{COOL} / $EFLH_{COOL}$ x CF

Where:

$SF_{GASHEAT}$	=	See table 1; Average thousand Btu (kBtu) gas heating savings per square foot (= 0 for homes without a gas furnace)
Area	=	10.7 sq ft; size of average low-E storm window (Ref. 8)
1,000	=	Conversion from kBtu to Dth
SF_{COOL}	=	See table 2; Average kWh cooling savings per square foot (= 0 for homes without an air conditioner or heat pump)
$SF_{ELECHEAT}$	=	See table 3; Average kWh electric heating savings per square foot (= 0 for homes without a heat pump or electric resistance heat)
$EFLH_{COOL}$	=	Equivalent full load cooling hours. See Table 2 (Ref. 2)
CF	=	Coincidence factor = 0.75 for cooling equipment with standard single-speed compressor, 0.9 for cooling equipment with variable-speed compressor (see Notes). If unknown use 0.75.

Deemed Input Tables

Table 1. Gas Heating Savings kBtu/Sqft by climate zone (see Notes)

Zone	Single Pane Baseline	Double Pane Baseline	Weighted Baseline
Zone 1 (Northern MN)	103	45	59.5
Zone 2 (Central MN)	82	37	48.3
Zone 3 (Southern MN/Twin Cities)	80	35	46.3

Table 2. Cooling Savings kWh/Sqft by climate zone (see Notes)

Zone	Single Pane Baseline	Double Pane Baseline	Weighted Baseline
Zone 1 (Northern MN)	0.182	0.178	0.179
Zone 2 (Central MN)	0.325	0.318	0.320
Zone 3 (Southern MN/Twin Cities)	0.483	0.451	0.459

Table 3. Electric Heating Savings kWh/Sqft by climate zone (see Notes)

Zone	Electric Resistance Heat			Air Source Heat Pump		
	Single Pane Baseline	Double Pane Baseline	Weighted Baseline	Single Pane Baseline	Double Pane Baseline	Weighted Baseline
Zone 1 (Northern MN)	25.42	11.09	14.67	11.26	4.91	6.5
Zone 2 (Central MN)	20.28	9.05	11.86	8.99	4.01	5.26
Zone 3 (Southern MN/Twin Cities)	19.73	8.68	11.44	8.74	3.85	5.07

Table 4. Effective Full Load Cooling Hours ($EFLH_{COOL}$) by Climate Zone (Ref. 2)

Zone	$EFLH_{COOL}$ Heat Pump Systems	$EFLH_{COOL}$ AC Systems
Zone 1 (Northern MN)	456	312
Zone 2 (Central MN)	512	565
Zone 3 (Southern MN/Twin Cities)	678	567

Note: EFLH values have been derived such that load factor and oversizing factor has been included in the values outlined above. See methodology assumptions and notes on EFLH derivation below.

Methodology and Assumptions

Savings per square foot are based on RESFEN 5 models produced by D+R in October of 2018. These models closely mimic those used for ENERGY STAR Low-E window savings calculations (Ref. 4, Ref. 5), but were conducted specifically for the three Minnesota TRM climate zones, and additionally model savings for a double pane window baseline.

Window Characteristics

The EPA analysis shows U-factor and solar heat gain coefficient (SHGC) values for a variety of low-E storm window assemblies, as compared to single-pane wood frame primary windows. The properties of the low-E storm window used in the building models are shown in the table below. This measure assumes equal weighting between the three low-E storm window glass options.

Table 5. Properties of Modeled Window Glasses

Window Type	Glass Options (3 mm)	Emissivity	Solar Transmission	U-factor	SHGC
Standard	Clear	0.84	0.86	0.466	0.537
Low-E	AGC Comfort Select 73	0.15	0.69	0.356	0.458
	Guardian IS20	0.20	0.77	0.364	0.502
	PPG Sungate 500	0.22	0.69	0.367	0.468

Building Characteristics

The savings calculations are based on modeling two types of prototypical residential homes: one-story (1,700 sq ft) existing construction and two-story (2,800 sq ft) new construction. Both modeled homes have a 15% window-to-floor-area ratio. This workpaper assumes equal weighting between the two building types. The model building assumptions are shown in the table below.

Table 6. RESFEN Model Assumptions

Characteristic	Existing Construction	New Construction
Area	1,700 sq ft	2,800 sq ft
Window Area	255 sq ft (15 % of floor area)	420 sq ft (15 % of floor area)
Foundation	Basement	Basement
Insulation	RESFEN 5	2006 IECC
HVAC System	Natural gas furnace and A/C	Natural gas furnace and A/C
HVAC Efficiency	Natural gas furnace AFUE = 0.78 Air conditioner SEER = 10	Natural gas furnace AFUE = 0.90 Air conditioner SEER = 13

Conversion to Electric Heat

As noted, the RESFEN models simulated homes with a gas furnace and air conditioner. Heating kWh savings are calculated for homes with electric resistance and heat pump heat via a two-step process. First, the MBtu/Sqft savings for furnaces (Table 1) are converted to actual heat loss prevention by multiplying them by an AFUE of 84%, which reflects the average AFUE of the two modeled homes. Then, for electric resistance heat, this number is divided by 3.412 MBh per kWh. For heat pump heat, this number is divided by an assumed HSPF of 7.7 Btu/(watt-hour).

Window Baseline

Data obtained for the 2020–2029 Minnesota Energy Efficiency Study show that 25% of single-family homes have single-pane windows and 75% have double pane windows. This weighting is used to produce the weighted savings per square foot in Table 1, Table 2, and Table 3.

Incremental Cost

The incremental cost for a low-E storm window includes the product cost and the installation cost. Because the baseline condition is an existing single-pane or double-pane window assembly, the incremental product cost is the full cost of the low-E storm window and its installation. A low-E window is assumed to cost $115, which is the average of the $80 to $150 range provided in a recent paper (Ref. 6). The installation cost of a self-install is assumed to be $2, while the cost of a professional installation is $45. It is assumed that single-family residence low-E storm windows are installed by homeowners 80% of the time, and that multifamily residence low-E storm windows are always installed by contractors (Ref. 7). Therefore the average installation cost for single-family sites is $2 x 80% + $45 x 20% = $11, the average total cost per window for single-family sites is $115 + $11 = $126, and the total cost for multifamily sites is assumed to be $115 + $45 = $160.

Notes

The value for coincidence factor is derived from a 2016 CARD study (Ref. 3) that examined quality install and maintenance practices for residential furnaces, air conditioners and heat pumps, in part by metering the behavior and performance of 58 cooling systems and 55 furnaces. A follow-on memo was produced (Ref. 9) that recommended coincidence factor be reduced from 90% to 75%. Because the previous 90% value was simply deemed as a typical value worth updating when primary data was available, that update is applied here. However, because the metered systems had single-speed compressors, 90% may still be used for equipment with variable-speed compressors.

$EFLH_{COOL}$ and $EFLH_{HEAT}$ values were determined from a 2022 MN CARD study using PRISM utility billing data analysis method collected from Minnesota utility customers, and NOAA 2005 - 2020 MN weather data. The EFLH heating calculation uses total heating energy use and equipment input capacity. The total heating energy use was determined from customer billing data and the input capacity was determined through customer interview and utility provided data on installations. In this method, the load factor and oversizing factor are already included in the resulting value derived and are therefore not additionally included as a separate metric in the algorithm.

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Revision History

Version	Description	Author	Date
1.0	New workpaper	Cadmus	10/2018
3.1	Updated CF	Cadmus	10/2019
4.0	EFLH modifications based on recent CARD study.	Cadmus	11/1/2022

Residential Envelope – Cellular Shade Window Coverings

Measure Detail	Measure Value
Measure ID	1.03.04
Target Market Segments	Residential
Target End Uses	Envelope
Applicable To	Residential customers, with gas heating and/or air conditioning.
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Quantity of windows modified with cellular shades, Confirmation of AERC listing and specification threshold met for all cellular shade products installed, home heating system type (confirmation of gas fuel), home cooling system type (to determine if cooling savings are applicable)
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	None
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	13 (Ref. 1)
Incremental Cost	See Table 1

Measure Description

This measure characterizes installation of cellular window coverings to provide greater window insulation for reduction of thermal losses through the building envelope, and optimizing solar gains added to the space. High-efficiency window coverings can be considered part of a package of potential retrofits to cost-effectively improve thermal performance of the building envelope. Cellular shades are designed to trap air inside pockets, acting as insulators which can decrease the U-factor of the window covering and reduce thermal heat transfer through window (Ref. 4). Solar gain adds to the heat load within a home. Solar gain can be advantageous in the winter to offset heating needs from the mechanical heating system. Mitigating solar gain in the summer can result in reduced cooling loads and increased occupant comfort. Installing window coverings, particularly in southern-facing and west-facing windows, can have a significant impact on reducing the amount of heat entering a home (Ref. 8).

Eligible cellular shade products must be listed with the Attachments Energy Rating Council (AERC) and certified with the following:

- Warm Climate rating (Cooling Energy, EPc) of at least 36
- Cool Climate rating (Heating Energy EPh) of at least 9

If automated cellular shades are installed, the shades must meet the requirements above in addition to being programmable to operate according to a set schedule automatically. The schedule of operation the customer programs does not need to be verified, however the customer should be provided with guidance as to an optimal schedule to achieve energy savings, like that illustrated in Table 2.

Savings have been determined by energy modeling a single-family home with gas heating and air conditioning (Ref. 2-6). Electrically heated homes (resistance and heat pumps) have not been modeled and are therefore not eligible to claim savings for the heating portion of this measure. Savings have been modeled with a home assuming 16 total windows, therefore any offered incentives should not exceed 16 windows per home or customer.

Algorithms

Heating Savings (For homes with gas heat)

Dth Savings per Year = WindowQty x ((Manual Factor x $HeatSavings_{MANUAL}$) + (Automated Factor x $HeatSavings_{AUTO}$))

Cooling Savings (For homes with air conditioning)

kWh Savings per Year = WindowQty x ((Manual Factor x CoolSavingsMANUAL) + (Automated Factor x CoolSavingsAUTO))

Where:

Window Qty	= Number of windows with cellular shades installed
Manual Factor	= 1 for manually operated shades, 0 for automatically operated shades
$HeatSavings_{MANUAL}$	= Deemed savings value per window based on manually operated window shades = 0.32 Dth. See Deemed Input Tables, and Methodology and Assumptions for derivation.
Automated Factor	= 0 for manually operated shades, 1 for automatically operated shades
$HeatSavings_{AUTO}$	= Deemed savings value per window based on automatically operated window shades = 0.76 Dth. See Deemed Input Tables, and Methodology and Assumptions for derivation.
$CoolSavings_{MANUAL}$	= Deemed Savings value per window based on manually operated window shades = 16.04 kWh. See Deemed Input Tables, and Methodology and Assumptions for derivation.
$CoolSavings_{AUTO}$	= Deemed Savings value per window based on automatically operated window shades = 40.83 kWh. See Deemed Input Tables, and Methodology and Assumptions for derivation.

Example:

A single-family house with gas heat and air conditioning replaced four window shades with qualifying cellular shades. The cellular shades are manually operated.

Heating Dth Savings	= 4 windows x ((1 x 0.32 Dth) + (0 x 0.76 Dth))	= 1.28 Dth
Cooling kWh Savings	= 4 windows x ((1 x 16.04 kWh) + (0 x 40.83 kWh))	= 64.16 kWh

Table 1. Heating and Cooling Savings (Ref. 2-6), and Incremental Costs (Ref. 7) by Product Type

	Heating Savings Dth / Window	Cooling Savings kWh / Window	Incremental Costs $ / Window
Manual Operation	0.32	16.04	$12.50
Automated Operation (Programmed)	0.76	40.83	$435.75

Methodology and Assumptions

Energy performance indices, EPC and EPH of window attachments are developed on the basis of ISO 18292 standard (ISO 2011), which gives methodology for calculating heating and cooling energy performance of windows. This methodology is based on the results of energy simulation of a typical single-family residential building (house) utilizing a gas furnace and electric air conditioning in the Minneapolis Minnesota cooling and heating climate, using sub hourly energy analysis program EnergyPlus (DOE 2016) using TMY3 weather data (Ref. 2-6). The model residential home assumed:

- 2,400 SF, 2 story (each 8.5' high), square structure (34.64' x 34.64'), cardinal direction orientation, equal square footage of each exterior exposure
- 16 equal windows, four on each exposure, 39" high x 30" wide. Double clear wood frame U = 0.472 Btu/hr x ft^2 x °F
- Insulation ceiling R49, walls R-21. Air Infiltration ACH50 = 7
- Gas furnace efficiency: AFUE = 0.78. A/C efficiency: SEER 10
- Thermostat settings 70°F in heating season, 75°F in cooling season

The model was run with four different cases simulated:

1. Typical house with no window covering (Serving as control scenario, not baseline)
2. Typical house with Aluminum horizontal blinds, manual operation (Baseline). Assumes off-white 1" aluminum product. Assumes blinds have EPc of 25 and EPh of -11. Operated manually, which is defined as operating according to a deployment schedule for operable window attachments, developed from the results of a behavioral study. Based on the results of the survey of 2,467 households in 12 markets, a deployment schedule was developed for 3 periods during the day, two periods during the week, and for two seasons (Ref. 2).
3. Typical house with AERC cellular shades, manual operation (Performance, Manual). Assumes a light colored single cell product with an EPc of 36 and EPh of 9. Operated manually, identical to the baseline case operation.
4. Typical house with AERC cellular shades, automatic operation (Performance, Auto). Assumes a light colored single cell product with an EPc of 36 and EPh of 9. Operated automatically, which is defined as a reasonably optimal programmed schedule, illustrated in Table 2.

Table 2. Automated Schedule Modeled (Ref. 2)

Program Season	Northern Exposure	Southern Exposure	Eastern Exposure	Western Exposure
June 1 – August 31	Closed all day	Closed all day	Closed all day	Closed all day
Sept 1 – May 31	Closed all day	Open 8am – 4pm	Open 8am – 12pm	Open 12pm – 4pm

The output of the model displays the whole home energy consumption in each scenario. The difference between the heating and cooling consumption in the baseline case versus the performance cases determines the deemed savings for the whole home. The saving per window has been determined by the whole home savings divided by 16 total windows. Actual savings are skewed higher for southern and western windows given higher solar gain on those exposures. However, this measure does not distinguish between exposures and assumes that installations will on average be evenly distributed amongst all four exposures.

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Revision History

Version	Description	Author	Date
1.0	Original Document	Cadmus	11/01/2022

Residential Envelope – High-Performance Windows

Measure Detail	Measure Value
Measure ID	1.03.05
Target Market Segments	Residential, multifamily
Target End Uses	Envelope
Applicable To	Residential customers
Actions	Replace failed or working existing windows
Required from Customer/Contractor	Site HVAC system type, climate zone, existing window type (single, double pane), replaced window area
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	None
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	36 Years
Unit Participant Incremental Cost	$54 / window

Measure Description

This measure includes replacement of failed or working standard (single or double pane) residential windows with ENERGY STAR certified high performance windows (HPW). HPWs significantly reduce heat transfer and air infiltration into the home, resulting in lower HVAC loads. HPWs are defined as residential windows that meet ENERGY STAR v7.0 performance specifications with a U-factor of ≤ 0.22 and SHGC ≥0.17 (Ref. 3) for the Northern Climate Zone. HPWs can achieve these performance specifications in a number of ways. Some examples of HPWs include:

• Thin Triple Windows (TTW) – the insulating glass unit (IGU) contains three panes of glass. A thin pane of center glass allows the IGU to fit within a standard window frame, eliminating the need to redesign the window. The inclusion of a thin pane of center glass allows for an additional surface for low-E coating, reducing the window's emissivity of thermal radiation and the rate of heat transfer by improving the Uvalue of the IGU and overall assembly. TTWs have two equal width panes of glass on the exterior and interior of the IGU and a thin center piece of glass that allows the IGU to fit within an existing double-pane window frame.

• Triple Pane Windows – conventional triple pane windows that contain three panes of standard thickness glass. These windows provide an additional surface for a low-e coating and provide improved thermal performance by decreasing a window's emissivity and improving the window's resistance to heat loss. These windows are typically heavier than double-panes or TTWs and require a redesign of the window to allow the heavier, wider IGU to fit within the window frame.

• Double-pane windows that have low-e coatings on the two surfaces that face the cavity between the two panes of glass as well as on the interior-facing interior pane of glass, warm edge spacers, and improved frame thermal properties (e.g., adding foam or other insulation to the frame cavities).

There are two baselines for this measure. For new construction, the baseline is a code compliant window defined as a U-factor, SHGC and VT of 0.32, 0.28 and 0.81 respectively. For existing building

retrofits, the baseline is a market average window defined as a U-factor, Solar Heat Gain Coefficient (SHGC) and Visible Transmittance (VT) of 0.44, 0.57 and 0.90 respectively. The high-performance window in both models assumed a U-factor, SHGC and VT of 0.22, 0.28 and 0.73 respectively. The model assumptions are discussed in more detail in the Methodology section.

Algorithms

Unit kWh Savings per Year = $kWh_{SAVINGS}$ / 15 x $Area_{WINDOW}$

Unit Dth Savings per Year = Dth_{HEAT} / 15 x $Area_{WINDOW}$

Algorithm Inputs:

Variable	Definition	Units	Ref	Table Ref
$kWh_{SAVINGS}$	Deemed cooling and heating savings per 15 SF of window area by climate zone and equipment type, see table 1 for new construction application, and table 2 for existing building application.	kWh/SF	4	1
$Area_{WINDOW}$	Total area of installed high performance windows, provided by customer/contractor. If unknown, assume each window is 3'x5' = 15 SF x number of windows installed	SF		
Dth_{HEAT}	Deemed heating savings per 15 SF of window area by climate zone and equipment type, see table 1 for new construction application, and Table 2 for existing building retrofit application	Dth/SF	4	1

New Construction Example:

A new construction residential single family home located in Minneapolis (Zone 3) installs all new windows (qty 20), each 15 SF, with high performance windows meeting the performance specifications outlined in ENERGY STAR v7.0 for HPW for northern climate zones. The home is heated and cooled by an ASHP, supplemented by electric resistance backup.

Unit kWh Savings per Year = 69.3 / 15 x (15 x 20) = 1,386 kWh

Unit Dth Savings per Year = 0 / 15 x (15 x 20) = 0 Dth

Existing Building Example:

An existing single family residential home located in Duluth (Zone 1) replaces 4 windows, each 15 SF with high performance windows meeting the performance specifications outlined in ENERGY STAR v7.0 for HPW for northern climate zones. The home is heated by a gas furnace and has an air conditioning unit providing cooling.

Unit kWh Savings per Year = 63 / 15 x (15 x 4) = 252 kWh

Unit Dth Savings per Year = 1.26 / 15 x (15 x 4) = 5.04 Dth

Deemed Input Tables

Table 1: New Construction - Summary kWh and Dth Energy Savings per 3'x5' (15 SF) HPW over current MN Energy Code, by equipment type and Heating/Cooling (Ref 4)

	Electric Heating (furnace or resistance) and Electric Cooling (AC)		Gas Heating (furnace or boiler) and Elec Cooling (AC)		Gas Heating (furnace or boiler) and no mechanical cooling		Electric Heating and Cooling (ASHP primary, elec resist at approx 30 F switchover)	
Climate Zone	**kWh Savings**	**Dth Savings**	**kWh Savings**	**Dth Savings**	**kWh Savings**	**Dth Savings**	**kWh Savings**	**Dth Savings**
Zone 1	85.8	0	0.0	0.43	0.0	0.43	86.7	0.00
Zone 2	84.4	0	0.0	0.40	0.0	0.40	78.0	0.00
Zone 3	82.9	0	0.0	0.36	0.0	0.36	69.3	0.00

Table 2: Existing Building - Summary kWh and Dth Energy Savings per 3'x5' (15 SF) HPW over market, by equipment type and Heating/Cooling (Ref 4)

	Electric Heating (furnace or resistance) and Electric Cooling (AC)		Gas Heating (furnace or boiler) and Elec Cooling (AC)		Gas Heating (furnace or boiler) and no mechanical cooling		Electric Heating and Cooling (ASHP primary, elec resist at approx 30 F switchover)	
Climate Zone	**kWh Savings**	**Dth Savings**	**kWh Savings**	**Dth Savings**	**kWh Savings**	**Dth Savings**	**kWh Savings**	**Dth Savings**
Zone 1	319.2	0	63.0	1.26	0.0	1.26	332.6	0.00
Zone 2	291.7	0	66.6	1.00	0.0	1.00	306.0	0.00
Zone 3	264.1	0	70.1	0.73	0.0	0.73	279.3	0.00

Methodology and Assumptions

The modeling analysis used in this measure was completed by Lawrence Berkeley National Laboratory (LBNL) in partnership with Partnership for Advanced Window Solutions (PAWS) using EnergyPlus modeling software. This modeling estimated the energy use of a model home with two window replacement scenarios that were utilized in this savings calculation. The model included permutations for four different HVAC scenarios across several Minnesota locations. Three window models were used; a home with market baseline windows, a home with code minimum windows and a home with high-performance windows. Table 1 represents the difference between the high performance window model and the code minimum model, to be used for new construction applications only. The code minimum window model assumed a U-factor, SHGC and VT of 0.32, 0.28 and 0.81 respectively. Table 2 represents the difference between the high performance window model and the existing market model, to be used for existing building retrofits. The market baseline window model assumed a U-factor, Solar Heat Gain Coefficient (SHGC) and Visible Transmittance (VT) of 0.44, 0.57 and 0.90 respectively. The high-performance window in both models assumed a U-factor, SHGC and VT of 0.22, 0.28 and 0.73 respectively. These values were determined with LBNL to represent a market baseline window that is

equivalent to a double-pane clear glass window, a code minimum window that aligns with Minnesota's current code requirements (U=0.32), and a high performance window that aligns with the prescriptive path for ENERGY STAR windows in the northern region. The SHGC and VT were determined from LBNL's experience with how these U-values are achieved and the windows that are available on the market. Each model calculated whole home energy use so that they could be compared to analyze energy savings of a high-performance replacement scenario over a code and market baseline.

$EFLH_{COOL}$ and $EFLH_{HEAT}$ values were determined from a 2022 MN CARD study using PRISM utility billing data analysis, with billing data collected from Minnesota utility customers, and NOAA 2005 - 2020 MN weather data. The EFLH heating calculation uses total heating energy use and equipment input capacity. The total heating energy use was determined from customer billing data, and the input capacity was determined through customer interviews and utility provided data on installations. With this method, the load factor and oversizing factor are already included in the resulting value and are therefore not included as a separate metric in the algorithm.

The value for coincidence factor is derived from a 2016 CARD study (Ref. 5) that examined quality install and maintenance practices for residential furnaces, air conditioners and heat pumps, in part by metering the behavior and performance of 58 cooling systems and 55 furnaces. A follow-on memo was produced (Ref. 8) that recommended coincidence factor be reduced from 90% to 75%. Because the previous 90% value was simply deemed as a typical value worth updating when primary data was available, that update is applied here. However, because the metered systems had single-speed compressors, 90% may still be used for equipment with variable-speed compressors.

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Revision History

Version	Description	Author	Date
4.2	New measure developed	Cadmus	8/1/2024

Hot Water

Residential Hot Water – Drainpipe Heat Exchanger with Electric Water Heater

Measure Detail	Measure Value
Measure ID	1.04.01
Target Market Segments	Residential
Target End Uses	DHW
Applicable To	Residential customers in single-family homes and multifamily homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size electric water heaters
Actions	Modify
Required from Customer/Contractor	Confirmation of electric water heater, building type (single family or multifamily*), project location (county). * Includes buildings with 2+ units and townhomes
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	20 (Ref. 1)
Unit Participant Incremental Cost	$742 (Ref. 1)

Measure Description

This measure includes installing a drainpipe heat exchanger to a residential or multifamily building to recover heat from heated water going down the building's drain. The savings for this measure is "per living unit affected."

Algorithms

Unit kWh Savings per Year = EnergyToHeatWater / Eff x SavingsFactor / ConversionFactor

Unit Peak kW Savings = Unit kWh Savings per Year / 8,760

Where:

EnergyToHeatWater = SpecificHeat x Density x Gal/Day x 365 Days/Year x (Tset - Tcold)

SpecificHeat = 1.0 Btu/(lb x °F)

Density = 8.34 lbs/gal

Gal/Day = See Table 2; Average gallons per day of hot water usage (gal/day)

Tset = 120 °F (Ref. 4)

Tcold = Average groundwater temperature per Table 1 (Ref. 3). Default to average statewide MN groundwater temperature.

Eff = Recovery efficiency of electric water heater, 0.98.

SavingsFactor = 0.25 (Ref. 2)

ConversionFactor = 3,412 Btu/kWh

Example:

A single-family customer in Zone 1 has installed a drain pipe heat exchanger to recover wasted energy from the house's drain line.

EnergyToHeatWater = (1 Btu/lb°F) x (8.34 lbs/gal) x (52.7 gal/day) x (365 days/yr) x (120°F - 46.5°F) = 11,799,245 Btu/yr

Unit kWh Savings per Year = (11,799,245 Btu/yr) / (0.98) x (25%) / (3,412 Btu/kWh) = 882 kWh

Unit Peak kW Savings = 882 kWh / 8,760 h = 0.101 kW

Deemed Input Tables

Table 1. Average groundwater temperatures (Ref. 3)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3
MN statewide average, or if location unknown	**49.0**

Table 2. Daily Hot Water Usage by Building Type

Building Type	Daily Gal/person (Ref. 5)	Num_People (Ref. 6)	Total Daily Hot Water Use (gal/day)
Single-family	20.4	2.59	52.7
Multifamily	18.7	2.17	40.5

Notes

There are no current efficiency standards for this technology.

References

1. State of Ohio Energy Efficiency Technical Reference Manual, 2010. Prepared by Vermont Energy Investment Corporation. Page 78.
2. Drain pipe heat exchange savings estimates are based on study findings reported in a communication from J. J. Tomlinson, Oak Ridge Buildings Technology Center, to Marc LaFrance, DOE Appliance and Emerging Technology Center, DOE, August 24, 2000, suggesting 25 to 30% of water heating consumption savings potential. The lower end of the savings scale was chosen for this report, assuming ideal installation for the study.
3. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules* http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

4. "Lower Water Heating Temperature for Energy Savings," Department of Energy website, http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13090. Accessed 7/26/12. The webpage referenced by the link has since changed and is no longer relevant.
5. Interpolated values from Table 38, Ohio Technical Reference Manual. October 15, 2009. Page 52.
6. U.S. Census Bureau, *Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates)* for the state of MN. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=tabl

Revision History

Version	Description	Author	Date
1.0	Derived from ResidentialElectricDHW_v03.2 and ResidentialGasDHW_v03.2 which were based on Nexant's original spec.	Joe Plummer	
2.0	Updated the groundwater temperatures, see "Water Temps" tab. Updated the measure cost	Franklin Energy Services	7/23/2012
2.3	Changed action to Modify, changed “electric or gas water heater” to “confirmation of electric water heater” under required inputs, changed annual hours from 8,760 to 8,760, updated example for electric instead of gas	Joe Plummer	11/24/2013
2.4	Added building type to required inputs, added definition of multifamily	Joe Plummer	3/18/2014
2.5	Added unknown location and removed gas information.	Franklin Energy Services	12/18/2015

Residential Hot Water – Drainpipe Heat Exchanger with Gas Water Heater

Measure Detail	Measure Value
Measure ID	1.04.02
Target Market Segments	Residential
Target End Uses	DHW
Applicable To	Residential customers in single- and multifamily homes consisting of two units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size gas water heaters
Actions	Modify
Required from Customer/Contractor	Confirmation of gas water heater, building type (single family or multifamily*), project location (county) * Includes buildings with 2+ units and townhomes
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	20 (Ref. 1)
Unit Participant Incremental Cost	$742 (Ref. 1)

Measure Description

This measure includes installing a drainpipe heat exchanger to a residential or multifamily building to recover heat from heated water going down the building's drain.

Algorithms

Unit Dth Savings per Year = EnergyToHeatWater / Eff x SavingsFactor / ConversionFactor

Where:

EnergyToHeatWater = SpecificHeat x Density x Gal/Day x 365 Days/Year x (Tset - Tcold)

SpecificHeat = 1.0 Btu/(lb x °F)

Density = 8.34 lbs/gal

Gal/Day = See Table 2; Average gallons per day of hot water usage (gal/day)

Tset = 120 °F (Ref. 4)

Tcold = Average groundwater temperature per Table 1 (Ref. 3). Default to average statewide MN groundwater temperature.

Eff = Recover efficiency of gas water heater, 0.75.

SavingsFactor = 0.25 (Ref. 2)

ConversionFactor = 1,000,000 Btu/Dth

Example:

A single-family customer in Zone 1 has installed a drain pipe heat exchanger to recover wasted energy from the house's drain line.

EnergyToHeatWater = (1 Btu/lb°F) x (8.34 lbs/gal) x (52.7 gal/day) x (365 days/yr) x (120°F - 46.5°F) = 11,791,169 Btu/yr

Unit Dth Savings per Year = (11,791,169 Btu/yr) / (0.75) x (25%) / (1,000,000 Btu/Dth) = 3.9 Dth

Deemed Input Tables

Table 1. Average groundwater temperatures (Ref. 3)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3
MN statewide average, or if location unknown	**49.0**

Table 2. Daily Hot Water Usage by Building Type

Building Type	Daily Gal/person (Ref. 5)	Num_People (Ref. 6)	Total Daily Hot Water Use (gal/day)
Single-family	20.4	2.59	52.7
Multifamily*	18.7	2.17	40.5

* Includes buildings with 2+ units and townhomes

Notes

There are no current efficiency standards for this technology.

References

1. State of Ohio Energy Efficiency Technical Reference Manual, 2010. Prepared by Vermont Energy Investment Corporation. Page 78.
2. Drain pipe heat exchange savings estimates are based on study findings reported in a communication from J. J. Tomlinson, Oak Ridge Buildings Technology Center, to Marc LaFrance, DOE Appliance and Emerging Technology Center, DOE, August 24, 2000, suggesting 25 to 30% of water heating consumption savings potential. The lower end of the savings scale was chosen for this report, assuming ideal installation for the study.
3. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules* http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html
4. "Lower Water Heating Temperature for Energy Savings," Department of Energy website, http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13090. Accessed 7/26/12. The webpage referenced by the link has since changed and is no longer relevant.

5. Interpolated values from Table 38, Ohio Technical Reference Manual. October 15, 2009. Page 52.
6. U.S. Census Bureau, *Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates)* for the state of MN. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=tabl

Revision History

Version	Description	Author	Date
1.0	Derived from ResidentialElectricDHW_v03.2 and ResidentialGasDHW_v03.2 which were based on Nexant's original spec.	Joe Plummer	
2.0	Updated the groundwater temperatures, see "Water Temps" tab	Franklin Energy Services	7/23/2012
2.1	Added example	Franklin Energy Services	7/23/2012
2.2	Updated the measure cost	Franklin Energy Services	7/23/2012
2.3	Changed action type to Modify, changed "electric or gas water heater" to "confirmation of gas water heater" in Required Inputs	Joe Plummer	11/25/2013
2.4	Added building type to required inputs, added footnotes clarifying multifamily definition	Joe Plummer	3/18/2014
2.5	Added unknown location and removed electric information	Franklin Energy Services	12/18/2015

Residential Hot Water – Heat Pump Water Heater

Measure Detail	Measure Value
Measure ID	1.04.03
Target Market Segments	Residential
Target End Uses	Water Heating
Applicable To	Residential customers in single- and multifamily homes consisting of two units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size electric water heaters
Actions	Replace on Failure, Replace Working, New Construction
Required from Customer/Contractor	Tank size in gallons, new water heater uniform energy factor (UEF), UEF draw pattern (High, Medium, Low, or Very Small), single- or multifamily*, project location (county)
Measure Energy Type	Gas, Electric, EFS
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	13 years (Ref. 2)
Unit Participant Incremental Cost	$784 (Ref. 2)

Measure Description

This measure includes replacement of failed or working storage-type electric resistance storage, gas storage, electric or gas instantaneous and residential oil storage water heaters in residential and multifamily buildings with more efficient storage-type electric heat pump water heaters. Qualifying efficient equipment must meet the performance criteria outlined in ENERGY STAR v5 (Ref 7) for residential water heaters, but does not need to be ENERGY STAR certified to be eligible. See Table 3 for the current ENERGY STAR performance criteria.

Projects involving GSHP desuperheaters providing preheating to the DHW tank should reference *MN TRM Res HVAC – GSHP* measure for savings algorithm.

The Minnesota Energy Conservation and Optimization Act (Ref. 10, 11) allows for efficient fuel switching (EFS) improvements where electricity or natural gas replaces the use of another fuel used by the customer (i.e. natural gas, fuel oil, propane, etc) provided that the following criteria are met for each measure pursued:

1. The proposed efficient fuel switching measure results in a net reduction in the amount of source energy consumed for a particular use, measured on a fuel-neutral basis, using the utility's annual system average efficiency, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.
2. The proposed efficient fuel switching measure results in a net reduction of statewide greenhouse gas emissions (Ref 12), over the lifetime of the improvement. For an efficient fuel-switching improvement installed by an electric utility, the reduction in emissions must be measured using the utility's annual average emissions factor, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.

3. The proposed efficient fuel switching measure is cost-effective, considering the costs and benefits from the perspective of the utility, participants, and society;
4. The proposed efficient fuel switching measure should produce a similar or higher level of quality, level of service or output as the technical assumptions identified in the baseline technology to be eligible (Ref. 13).

This measure potentially includes the efficient fuel switching energy savings resulting conversion of non-electric heating energy of the baseline equipment to electric heating energy in the proposed HPWH equipment. Baseline equipment for this measure is assumed to include residential sized storage and instant hot water heaters driven by electric resistance, gas or oil. The proposed efficient technology is a heat pump hot water heater. To meet the same quality of service the baseline provides, the HPWH should be sized to meet the demand served by the baseline equipment.

Algorithms

Electric Water Heater Replacement

Unit kWh Savings per Year = $Energy_{HEATWATER}$ x $(1/UEF_{BASE} – 1/UEF_{EFF}) / CF_1$

Unit Peak kW Savings = (Unit kWh Savings per Year) / 8,760

Gas or Oil Water Heater Replacement

Unit Dth Savings per Year = $Energy_{HEATWATER}$ x $(1/UEF_{BASE}) / CF_3$

Unit kWh Added per Year = $Energy_{HEATWATER}$ x $(1/UEF_{EFF}) / CF_1$

Net MMBtu savings = Unit Dth Savings – (Unit kWh Added x CF_2)

Where:

$Energy_{HEATWATER}$	= SpecificHeat × Density × Gallons per Day × 365 Days / Yr × ($T_{SET} – T_{COLD}$). Given deemed inputs to this calculation below, resulting deemed value for this variable is 11,109,139 Btu for single family and 9,401,703 for Multifamily
SpecificHeat	= 1.0 btu / (lb·°F)
Density	= 8.34 lbs / gal
GPD	= Gallons of hot water use per day, see Table 1
T_{SET}	= 120˚F (Ref. 7)
T_{COLD}	= See Table 1; average groundwater temperature. Average of 49.0 used in deemed values (Ref 4).
UEF_{BASE}	= See Table 2; base water heater efficiency based on tank size. If draw pattern is unknown, assume medium. V = rated volume of DHW tank in gallons
UEF_{EFF}	= Uniform Energy Factor (UEF) of new water heater. V = rated volume of DHW tank in gallons. See Table 3 for minimum criteria.

CF_1 = 3,412 Btu / kWh

CF_2 = 0.003412 Dth/kWh

CF_3 = 1,000,000 Btu / Dth

Example 1:

A single-family customer has installed a new 120-volt, 50-gallon heat pump water heater with an UEF of 3.0 to replace an electric resistance water heater, with unknown UEF. The average MN ground water temperature and a medium draw pattern will be used in the calculations.

UEF_min = 0.9307 – (0.0002 × 50) = 0.9207

$Energy_{HeatWater}$ = 1 × 8.34 × 51.4 GPD × 365 × (120 - 49.0) = 11,109,139 Btu/yr

Unit kWh Savings per Year = 11,109,139 x (1/0.9207 – 1/3.0) / 3,412 = 2,451 kWh

Unit Peak kW Savings per Year = 2,451 / 8,760 = 0.28 kW

Example 2:

A single family customer has installed a new 120-volt, 50 gallon heat pump water heater with an UEF of 3.0 to replace a gas storage hot water heater, with unknown UEF. The average MN ground water temperature and a medium draw pattern will be used in the calculations.

UEF_min =0.6483 – (0.0017 × 50) = 0.5633

$Energy_{HeatWater}$ = 1 × 8.34 × 51.4 GPD × 365 × (120 - 49.0) = 11,109,139 Btu/yr

Unit Dth Savings per Year = 11,109,139 x (1/0.5633) / 1,000,000 = 19.7 Dth

Unit kWh Added per Year = 11,109,139 x (1/3.0) / 1,000,000 / 0.003412 = 1,085.3 kWh

Net MMBtu Saved = Unit Dth Savings – (Unit kWh Added x 0.003412) = 16.55 – (3.64) = 16.0 MMBtu

Deemed Input Tables

Table 1. Average groundwater temperatures by zone (Ref. 4) , and daily hot water usage in gallons by zone and residential type (Ref. 6, 9, see Assumptions)

Location	T_{IN} (°F)	Single-Family	Multifamily
		GPD	GPD
Zone 1 (Northern MN)	46.5	52	44
Zone 2 (Central MN)	49.1	51.4	43.5
Zone 3 (Twin Cities/Southern MN)	51.3	50.8	43
MN statewide average, or if location unknown	**49.0**	**51.4**	**43.5**

Table 2. Baseline efficiency based federal minimum efficiency standards (UEF) (Ref. 3)

Product Class	Rated Storage Volume	Draw Patten	Uniform Energy Factor (V = rated volume of DHW tank in gallons)
Electric Storage Water Heaters	≥ 20 gallons and ≤ 55 gallons	Very Small	0.8808 – (0.0008 × V)
		Low	0.9254 – (0.0003 × V)
		Medium	0.9307 – (0.0002 × V)
		High	0.9349 – (0.0001 × V)
	> 55 gallons and ≤ 100 gallons	Very Small	1.9236 – (0.0011 × V)
		Low	2.0440 – (0.0011 × V)
		Medium	2.1171 – (0.0011 × V)
		High	2.2418 – (0.0011 × V)
Electric Instantaneous Water Heaters	≤12kW and ≤2 gal	All other	UEF = 0.91
		High	UEF = 0.92
Gas Storage Water Heaters	≥20 gal and ≤55 gal	Very Small	0.3456 − (0.0020 x V)
		Low	0.5982 − (0.0019 x V)
		Medium	0.6483 − (0.0017 x V)
		High	0.6920 − (0.0013 x V)
	>55 gal and ≤100 gal	Very Small	0.6470 − (0.0006 x V)
		Low	0.7689 − (0.0005 x V)
		Medium	0.7897 − (0.0004 x V)
		High	0.8072 − (0.0003 x V)
Gas Instantaneous Water Heaters	All	Very Small	0.80
		Low	0.81
		Medium	0.81
		High	0.81
Residential Oil Storage Water Heater	≤50 gallon tanks	Very small	UEF = 0.2509 − (0.0012 x V)
		Low	UEF = 0.5330 − (0.0016 x V)
		Medium	UEF = 0.6087 − (0.0016 x V)
		High	UEF = 0.6815 − (0.0014 x V)

Table 3. ENERGY STAR Equipment Standards (Ref. 7)

	Type of Equipment	Energy Factor
Heat Pump Electric Storage Water Heaters	Integrated Heat Pump Water Heater, 240 Volt / 30 Amp Circuit	UEF ≥ 3.30
	Heat Pump Water Heater, 120 Volt / 15 Amp Circuit	UEF ≥ 2.20
	Split System Heat Pump Water Heater	UEF ≥ 2.20

Methodology and Assumptions

Gallons per day (GPD) values were determined based on the following assumptions and resources:

1. This measure adopts a method outlined in the Wisconsin Technical Reference Manual to determine gallons of hot water used per day given residential occupant count (Ref. 9). An equation for gallons per day of hot water usage found in a Florida Solar Energy Study (Ref. 9) forms the basis of the figure, adapted with Minnesota data.

   HWgpd = 22 x (Occupancy x Fmix) + CW + DW

   - Where Occupancy represents the average occupants per household. A Minnesota state average value of 2.59 occupants per home was used for a single-family home, and 2.17 occupants per home was used for a multifamily home (Ref. 6).
   - Where Fmix = 1 – (Tset – Tmix) / (Tset – Tmains) = 1 – (120-105) / (120 – 49) = 0.79. Where Tmains has been defined as the ground temperature of the climate zone (see Table 1, The average of all zones has been used = 49.0). Tset in this example represents the efficient case setting. Hot water use consists of two components: unmixed and mixed use. Unmixed use, primarily for clothes washers and dishwashers, is direct draw from the water heater and does not vary with stored hot water temperature. Mixed use, for showers and sinks, is delivered to the fixture at 105°F, so the total draw from the water heater varies with stored water temperature.
   - Where CW is clothes washer gallons of hot water per day. CW gallons per cycle is defined as 12.7 gallons per cycle for an average sized ENERGY STAR rated appliance (Ref. 11), half of which is hot water. Gallons per day = (gallons per cycle x 50%) x (123+61 x occupancy)/365 = 4.9 gallons single family, 4.4 gallons multifamily.
   - Where DW is dishwasher gallons of hot water per day (defined as 100% of rated gallons per cycle = 3.2 gallons per cycle). Gallons per cycle determined by ENERGY STAR criteria v7 for a standard residential unit.
   - When the above metrics are applied to the equation using zone 3 metrics for example, the GPD by residence type results in the following equation, shown in Table 1.

     Single-Family GPD = 22 x (2.59 x 0.79) +4.9 + 3.2 = 51.4 GPD in zone 3 efficient case

     Multifamily GPD = 22 x (2.17 x 0.79) + 2.1 + 4.4 = 43.5 GPD in zone 3 efficient case

References

1. US DOE Building America Program. Building America Analysis Spreadsheet, Standard Benchmark DHW Schedules http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html.
2. NOTICE OF PROPOSED RULEMAKING TECHNICAL SUPPORT DOCUMENT ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters. Chapter 8. US Department of Energy. November 23, 2009.

3. Code of Federal Regulations Section 430 Part 32. Energy and water conservation standards and their compliance dates. https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8, accessed 9/28/17.
4. Interpolated values from Table 38, Ohio Technical Reference Manual. October 15, 2009. Page 52.
5. U.S. Census Bureau, Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates) for the state of MN. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=table.
6. This factor accounts for a mix of water heater locations (assumes 64% are in conditioned space, Ref. 9) and that no electric savings will occur in the heating season (50% of the year) if the space heat is electric. 0.68 = 1 - (64% x 50%).
7. This factor accounts for the increase in gas usage that results from the water heater being located in conditioned space. 1.3 = 6.6/5.0 x 50%, where 6.6 kWh represents the increase in daily space heating usage and 5.0 kWh represents the daily DHW usage and 50% accounts for the heating season being approximately half of the year. *The Impact of Heat Pump Water Heaters on Whole-House Energy Consumption*, Canadian Mortgage and Housing Corporation.
8. ENERGY STAR® Water Heater Product Criteria, version 5. Published July 18, 2022.https://www.energystar.gov/products/water_heaters/residential_water_heaters_key_product_criteria, and https://www.energystar.gov/products/spec/residential_water_heaters_specification_version_5_0_pd
9. Florida Solar Energy Center. Estimating Daily Domestic Hot-Water Use in North American Homes. June 30, 2015. http://www.fsec.ucf.edu/en/publications/pdf/FSEC-PF-464-15.pdf
10. Minn. Stat. § 216B.2402, subd. 4(2023). https://www.revisor.mn.gov/statutes/cite/216B.2402
11. Laws of Minn. 2024, art. 6, sec. 14. https://www.revisor.mn.gov/laws/2024/0/Session+Law/Chapter/126/
12. Minn. Stat. § 216H.01 subd. 2 (2016). https://www.revisor.mn.gov/statutes/cite/216H/full#stat.216H.01
13. Minnesota Department of Commerce Division of Energy Resources, Decision In the Matter of Technical Guidance for the Inclusion of Efficient Fuel-Switching, Load Management, and Pre-Weatherization Measures in CIP, (March 15, 2022). Docket No. E,G999/CIP-21-837. (eDocket No. 20223-183807-01). At 13. https://efiling.web.commerce.state.mn.us/edockets/searchDocuments.do?method=showPoup&documentId=%7B90098F7F-0000-C11B-B04F-C063DF81A5F9%7D&documentTitle=20223-183807-01

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	11/10/13
1.1	Added ENERGY STAR criteria, updated Table 4	Franklin Energy Services	9/27/16
1.2	Updated EF efficiency value to UEF value	Franklin Energy Services	9/28/17
3.0	Updated ENERGY STAR UEF value	Cadmus	10/2018
4.0	Updated UEF efficient case values to meet ENERGY STAR v5.0 criteria. Updated reference links and listing.	Cadmus	11/1/2022
4.1	EFS measure, added gas baseline to algorithm	Cadmus	11/1/2023
4.2	Simplified GPD calculation to be derived from a MN average ground water temperature, aligning with other DHW measures.	Cadmus	8/1/2024
5.0	GPD values in Table 1 and examples corrected to align with Res Hot Water Gas Water Heater measure	Cadmus	7/1/2025

Residential Hot Water – Electric Water Heater Setback

Measure Detail	Measure Value
Measure ID	1.04.04
Target Market Segments	Residential
Target End Uses	DHW
Applicable To	Residential customers in single-family homes and multifamily homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size electric water heaters
Actions	Operations and Maintenance
Required from Customer/Contractor	Confirmation of electric water heater, project location (county), single-family or multifamily (2+ units)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	2 (Ref. 2)
Unit Participant Incremental Cost	$0

Measure Description

This measure involves turning the water heater set point temperature to 120°F on residential storage-type electric water heaters. There is a separate measure for gas residential storage-type water heaters. The action must be performed by a utility representative on site during a home energy audit or other home visit. The existing temperature set point is assumed to be 130°F.

Algorithms

$$\text{Unit kWh Savings per Year} = (\text{WH}_{\text{BASE}} - \text{WH}_{\text{EFF}}) * 365 * \left(\frac{1}{3412}\right) * \text{Install Rate}$$

$$\text{WH}_{\text{BASE}} = \left(\frac{\text{Cp} * \rho * \text{GPD} * (\text{T}_{\text{SET BASE}} - \text{T}_{\text{IN}})}{\text{RE}}\right) * \left[1 - \left(\frac{\text{UA} * (\text{T}_{\text{SET BASE}} - \text{T}_{\text{AMB}})}{\text{Input}}\right)\right] + \left(\text{UA} * 24 * (\text{T}_{\text{SET BASE}} - \text{T}_{\text{AMB}})\right)$$

$$\text{WH}_{\text{EFF}} = \left(\frac{\text{Cp} * \rho * \text{GPD} * (\text{T}_{\text{SET EFF}} - \text{T}_{\text{IN}})}{\text{RE}}\right) * \left[1 - \left(\frac{\text{UA} * (\text{T}_{\text{SET EFF}} - \text{T}_{\text{AMB}})}{\text{Input}}\right)\right] + \left(\text{UA} * 24 * (\text{T}_{\text{SET EFF}} - \text{T}_{\text{AMB}})\right)$$

$$\text{UA} = \left(\frac{1}{\text{EF}} - \frac{1}{\text{RE}}\right) / \left[\text{T}_{\text{DIFF}} * \left(\frac{24}{\text{Q}_{\text{OUT}}} - \frac{1}{\text{RE} * \text{Input}}\right)\right] = 2.2$$

$$\text{Unit Peak kW Savings} = \left(\frac{\text{Unit kWh Savings per Year}}{8{,}760\ Hours}\right) * \text{CF}$$

Where:

WH_{BASE}	= Baseline daily water heater energy use, consisting of water heating energy consumption and standby energy losses (Btu/day)
WH_{EFF}	= Efficient daily water heater energy use, consisting of water heating energy consumption and standby energy losses (Btu/day))
365	= Number of days per year
3,412	= Conversion factor from Btu to kilowatt-hours
C_P	= Specific heat of water, 1.0 btu⁄(lb·°F)
ρ	= Density of water, 8.34 lbs⁄gal
GPD	= Gallons of hot water use per day, see Table 1
$T_{SET\ BASE}$	= Set water temperature in tank (Baseline=130°F) (Ref. 8)
$T_{SET\ EFF}$	= Set water temperature in tank (Efficient=120°F)
T_{IN}	= Average groundwater temperature, see Table 1, Average MN statewide value of 49°F used in deemed values (Ref. 2)
T_{AMB}	= Ambient temperature in space surrounding tank (= 67.5°F; see Assumptions) (Ref. 4)
RE	= Water heater recovery efficiency (= 0.98) (Ref. 3)
Input	= Rated input power of water heater (= 15,354 Btu/hr) (Ref. 4, see Assumptions)
UA	= Electric water heater equivalent heat loss factor (2.2 Btu/hr-°F) Deemed value from the inputs below, algorithm represented above.
EF	= 0.917 Energy Factor (2004 Federal minimum Energy Factor for 40-gal tank = 0.97 - 0.00132 x rated storage volume gallons)
24	= hours per day
T_{DIFF}	= Average temperature difference between baseline tank temperature and ambient room temperature (130 – 67.5 = 62.5°F) (Ref. 4)
Q_{OUT}	= Energy content of water drawn from water heater during 24-hour test (= 41,094 Btu/day; see Assumptions) (Ref. 4)
8,760	= Number of hours per year
CF	= Coincidence Factor (=1) (Ref. 6)
Install Rate	= The percentage of rebated equipment that is assumed to be installed, See Table 3 (Ref. 13)

Example:

A direct install team reduces the set point of an electric water heater in a single-family home from 130°F to 120°F.

UA = ((1/0.917) – (1/0.98)) / ((62.5 °F x (24 / 41,094 Btu/day)) - (1 / (0.98 x 15,354 Btu/hr))

= 2.2 Btu/hr-°F

WH_{BASE} = [((1 Btu/lb°F) x 8.34 lb/gal x 45.7 gal/day x (130°F – 51.3°F)) / 0.98]

x[1 – (2.2 Btu/hr-°F x (130°F – 67.5°F) / 15,354 Btu/hr)]

+ (2.2 Btu/hr-°F x 24 hrs/day x (130°F – 67.5°F))

= 34,531 Btu/day

WH_{EFF} = [((1 Btu/lb°F) x 8.34 lb/gal x 51.4 gal/day x (120°F – 51.3°F)) / 0.98]

x [1 – (2.2 Btu/hr-°F x (120°F – 67.5°F) / 15,354 Btu/hr)]

+ (2.2 Btu/hr-°F x 24 hrs/day x (120°F – 67.5°F))

= 33,604 Btu/day

kWh_{SAVED} = [(34,531 Btu/day) – (33,604 Btu/day)] x 365 day/yr x (1 / 3,412 Btu/kWh) x 100%

= 99.2 kWh/yr

kW_{SAVED} = 99.2 kWh/yr / 8,760 hrs x 1.0 CF = 0.011 kW

Deemed Input Tables

Table 1. Average Groundwater Temperatures by Zone (Ref. 3), and Daily Hot Water Usage in Gallons by Zone and Residential Type (see Assumptions)

Location	T_{IN} (°F)	Single-Family		Multifamily	
		GPD_{BASE}	GPD_{EFF}	GPD_{BASE}	GPD_{EFF}
Zone 1 (Northern MN)	46.5	46.3	52.0	39.2	44.0
Zone 2 (Central MN)	49.1	45.7	51.4	38.7	43.5
Zone 3 (Twin Cities/Southern MN)	51.3	45.1	50.8	38.3	43.0
MN statewide average, or if location unknown	**49.0**	**45.7**	**51.4**	**38.7**	**43.5**

Table 2. Annual Deemed Savings per Unit if Directly Installed

Residential Type	Zone	Annual Savings (kWh)	Demand Reduction (kW)
Single-Family	Avg	99.2	0.011
Multifamily	Avg	96.2	0.011

Table 3. Install Rate based on Delivery Method (Ref. 13)

Delivery Method	Install Rate
Retail	NA
Direct Install	100%
Virtual Assessment + Unverified Self-Install	10%
Requested Efficiency Kit	10%
Distributed Efficiency Kit	10%
Distributed School Efficiency Kit	20%

Methodology and Assumptions

The existing temperature is assumed to be 130°F (Ref. 8).

The derivation of the heat loss factor (UA) comes from the U.S. Department of Energy test procedures for consumer and commercial water heaters.

Some algorithm inputs were derived from the Home Energy Saver engineering documentation from the Lawrence Berkeley National Laboratory website:

- Input is from the "User Inputs to the Water Heater Model" heading. This resource demonstrates that the average rated input for residential electric water heaters is 4.5 kW, which is the equivalent of 15,354 Btu/hr (Ref. 4).
- Q_{OUT} can be found under the "Standby Heat Loss Coefficient" heading, which shows that 41,093.7 Btu/day is drawn during the standard test (Ref. 4).

Gallons per day (GPD) values were determined based on the following assumptions and resources:

1. This measure adopts a method outlined in the Wisconsin Technical Reference Manual to determine gallons of hot water used per day given residential occupant count (Ref. 7). An equation for gallons per day of hot water usage found in a Florida Solar Energy Study (Ref. 10) forms the basis of the figure, adapted with Minnesota data.
   HWgpd = 22 x (Occupancy x Fmix) + CW + DW
   - Where Occupancy represents the average occupants per household. A Minnesota state average value of 2.59 occupants per home was used for a single-family home, and 2.17 occupants per home was used for a multifamily home (Ref. 9).
   - Where Fmix = 1 – (Tset – Tmix) / (Tset – Tmains) = 1 – (120-105) / (120 – 49) = 0.79. Where Tmains has been defined as the ground temperature of the climate zone (see Table 1, the average of all zones has been used = 49.0). Tset in this example represents the efficient case setting. Hot water use consists of two components: unmixed and mixed use. Unmixed use, primarily for clothes washers and dishwashers, is direct draw from the water heater and does not vary with stored hot water temperature. Mixed use, for showers and sinks, is delivered to the fixture at 105°F, so the total draw from the water heater varies with stored water temperature.

- Where CW is clothes washer gallons of hot water per day. CW gallons per cycle is defined as 12.7 gallons per cycle for an average sized ENERGY STAR rated appliance (Ref. 11), half of which is hot water. Gallons per day = (gallons per cycle x 50%) x [(123+61 x occupancy)/365] = 4.9 gallons single family, 4.4 gallons multifamily.
- Where DW is dishwasher gallons of hot water per day (defined as 100% of rated gallons per cycle = 3.2 gallons per cycle). Gallons per cycle determined by ENERGY STAR criteria v7 for a standard residential unit (Ref. 12). Gallons per day = gallons per cycle x [(91+30 x occupancy)/365] = 1.5 gallons single family, 1.4 gallons multifamily.
- When the above metrics are applied to the equation using zone 3 metrics for example, the GPD by residence type results in the following, shown in Table 1.

  Single-Family GPD = 22 x (2.59 x 0.79) + 4.9 + 1.5 = 51.4 GPD in efficient case

  Multifamily GPD = 22 x (2.17 x 0.79) + 4.4 + 1.4 = 43.5 GPD in efficient case

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13. Illinois Statewide Technical Reference Manual v12.0 Vol. 3 – Residential Measures, 5.4.6 Water Heater Temperature Setback. September 22, 2023.

Revision History

Version	Description	Author	Date
1.0	Originally part of ResidentialGasDHW_v03.2 which was derived from Nexant spec; changed algorithm to assume an average starting and final temperature rather than using an unsupported savings factor. Updated algorithm to use Savings_Factor of 4%. Updated measure lifetime per Ref. 2	Joe Plummer	7/1/2012
2.0	Updated algorithm to use Savings_Factor of 4%. Updated measure lifetime per Ref. 2. Updated the hot water usage to be consistent with the hot water heater measure algorithm	Franklin Energy Services	7/26/2012
2.3	Changed “electric or gas water heater” to “confirmation of electric water heater” under required inputs, changed annual hours from 8,760 to 8,766	Joe Plummer	11/25/2013
2.4	Added footnotes clarifying multifamily definition. In kWh algorithm, replaced Gal/Day with Gal_Person x People. Corrected example calculation.	Joe Plummer	3/18/2014
4.0	Revised and updated savings algorithm, updated assumptions, updated references.	Cadmus	11/1/2022
4.2	Simplified GPD to a single average MN climate zone (ground water incoming temperature) to produce a single set of SF and MF deemed savings values.	Cadmus	8/1/2024
5.0	Included Install Rates	MN Department of Commerce	2025

Residential Hot Water – Gas Water Heater

Measure Detail	Measure Value
Measure ID	1.04.05
Target Market Segments	Residential
Target End Uses	Water Heating
Applicable To	Residential customers in single- and multifamily homes consisting of two units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size gas water heaters
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Confirmation of gas water heater, tank size in gallons, new water heater uniform energy factor (UEF), UEF Usage Bin (High or Medium), single-family or multifamily*, project location (county)
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	15 years for storage models, 20 years for tankless models (Ref. 2)
Unit Participant Incremental Cost	See Table 2

* Multifamily is defined as buildings with two or more units or townhomes.

Measure Description

This measure includes replacement of failed or working storage-type, domestic gas-fired storage and instantaneous water heaters in residential and multifamily buildings, as well as installation of gas-fired storage or instantaneous water heaters in new construction.

The baseline is assumed to be a natural gas-fired residential storage water heater, including for new instantaneous gas-fired water heater installations. Qualifying efficient equipment must meet the performance criteria outlined in ENERGY STAR v5 (Ref 7) for water heaters, but does not need to be ENERGY STAR certified to be eligible. See Table 4 for the current v5 ENERGY STAR performance criteria.

Projects involving GSHP desuperheaters providing preheating to the DHW tank should reference *MN TRM Res HVAC – GSHP* measure for savings algorithm.

Algorithms

Unit Dth Savings per Year = $Energy_{HEATWATER}$ x (1 / UEF_{BASE} - 1 / UEF_{EFF}) / 1,000,000

$Energy_{HEATWATER} = C_P \times \rho \times GPD \times 365 / Yr \times (T_{SET} - T_{COLD})$

Where:

C_P = Specific heat of water, 1.0 btu/(lb·°F)

ρ = Density of water, 8.34 lbs/gal

GPD	= Gallons of hot water use per day, see Table 1. Deemed savings calculations derived from average MN values of 51.4 GPD single family and 43.5 GPD multifamily.
365	= Days per year
T_{SET}	= 120˚F (Ref. 4)
T_{COLD}	= Average groundwater temperature, see Table 1, Average of 49.0 used in deemed values (Ref 1)
UEF_{BASE}	= Base water heater uniform energy factor, 0.603 (see Notes) or use actual based on tank size, type and draw pattern, see Table 3. V = rated volume of DHW tank in gallons
UEF_{EFF}	= New water heater uniform energy factor, if draw pattern unknown, assume medium draw, see Table 4. V = rated volume of DHW tank in gallons
1,000,000	= Conversion from Btu to Dth

Example:

A single-family customer has installed a new 50-gallon gas-fired water heater (UEF = 0.81, Medium Usage Bin) to replace their previous gas-fired storage water heater, UEF unknown. The average MN ground water temperature will be used in the calculations.

UEF_{BASE}=0.6483 – (0.0017 x 50) = 0.5633

$Energy_{HEATWATER}$ = 1.0 btu / lb·˚F × 8.34 lbs / gal × 51.4 GPD × 365 Days / Yr × (120°F -49.0°F) = 11,109,139 Btu

Unit Dth Savings per Year = 11,109,139 x (1/0.5633 – 1/0.81) / 1,000,000 = 6.0 Dth

Deemed Input Tables

Table 1. Average groundwater temperatures by zone (Ref. 1) and daily hot water usage in gallons by zone and residential type (Ref. 6, 9, see Assumptions)

Location	T_{IN} (°F)	Single-Family GPD	Multi-family GPD
Zone 1 (Northern MN)	46.5	52.0	44.0
Zone 2 (Central MN)	49.1	51.4	43.5
Zone 3 (Twin Cities/Southern MN)	51.3	50.8	43.0
MN statewide average, or if location unknown	**49.0**	**51.4**	**43.5**

Table 2. Incremental Cost by Type (Ref. 2)

Type of Water Heater	Incremental Cost
Gas storage	$400
Condensing gas storage	$685
Instantaneous Gas	$605

Table 3. Baseline Efficiency (Ref. 8)

Tank Size	Draw Pattern	UEF Formula (V = rated volume of DHW tank in gallons)	Calculated UEF Value for Tank Size (Gallons)				
			30	40	50	55	75
≥20 gal and ≤55 gal	Very Small	0.3456 – (0.0020 x V)	0.2856	0.2656	0.2456	0.2356	n/a
	Low	0.5982 – (0.0019 x V)	0.5412	0.5222	0.5032	0.4937	
	Medium	0.6483 – (0.0017 x V)	0.5973	0.5803	0.5633	0.5548	
	High	0.6920 – (0.0013 x V)	0.6530	0.6400	0.6270	0.6205	
>55 gal and ≤100 gal	Very Small	0.6470 – (0.0006 x V)	n/a				0.6020
	Low	0.7689 – (0.0005 x V)					0.7314
	Medium	0.7897 – (0.0004 x V)					0.7597
	High	0.8072 – (0.0003 x V)					0.7847
Instant	Very Small	0.80	n/a				
	Low	0.81					
	Medium	0.81					
	High	0.81					

If the tank volume and draw pattern of the storage water heater are known, UEF_{BASE} should be calculated from the above table. For instant water heaters, a storage baseline with a 50 gallon tank can be assumed. If tank volume or draw pattern are unknown, a UEF_{BASE} of 0.5633 can be assumed for storage or instant water heaters, calculated from a 50 gallon unit at medium draw pattern. Deemed values shown in Table 5 are calculated using a medium draw pattern at the specified size and type.

Table 4. ENERGY STAR Equipment Standards, effective 4/18/2023 (Ref. 7)

Criteria		ENERGY STAR Requirements
Gas Storage Water Heaters	≤ 55 gallons	Medium Draw Pattern UEF ≥ 0.81
		High Draw Pattern UEF ≥ 0.86
	>55 gallons	Medium Draw Pattern UEF ≥ 0.86
		High Draw Pattern UEF ≥ 0.86
Gas Instantaneous Water Heaters		UEF ≥ 0.95

Table 5. Deemed Annual Savings by Tank Size and Residential Type

Base Type and Size of Water Heater		Dth Savings per Year			
		Storage type Efficient Case		Instant type Efficient Case	
		Single Family	Multifamily	Single Family	Multifamily
Storage	30 gallons	4.88	4.13	6.91	5.84
	40 gallons	5.43	4.59	7.45	6.30
	50 gallons	6.01	5.08	8.03	6.79
	55 gallons	6.31	5.34	8.33	7.05
	75 gallons	1.71	1.44	2.93	2.48
Instant	N/A	N/A	N/A	2.02	1.71

Methodology and Assumptions

Gallons per day (GPD) values were determined based on the following assumptions and resources:

1. This measure adopts a method outlined in the Wisconsin Technical Reference Manual to determine gallons of hot water used per day given residential occupant count (Ref. 9). An equation for gallons per day of hot water usage found in a Florida Solar Energy Study (Ref. 10) forms the basis of the figure, adapted with Minnesota data.
   HWgpd = 22 x (Occupancy x Fmix) + CW + DW

- Where Occupancy represents the average occupants per household. A Minnesota state average value of 2.59 occupants per home was used for a single-family home, and 2.17 occupants per home was used for a multifamily home (Ref. 6).
- Where Fmix = 1 – (Tset – Tmix) / (Tset – Tmains) = 1 – (120-105) / (120 – 49) = 0.79. Where Tmains has been defined as the ground temperature of the climate zone (see Table 1, the average of all zones has been used = 49.0). Tset in this example represents the efficient case setting. Hot water use consists of two components: unmixed and mixed use. Unmixed use, primarily for clothes washers and dishwashers, is direct draw from the water heater and does not vary with stored hot water temperature. Mixed use, for showers and sinks, is delivered to the fixture at 105°F, so the total draw from the water heater varies with stored water temperature.
- Where CW is clothes washer gallons of hot water per day. CW gallons per cycle is defined as 12.7 gallons per cycle for an average sized ENERGY STAR rated appliance (Ref. 11), half of which is hot water. Gallons per day = (gallons per cycle x 50%) x (123+61 x occupancy)/365 = 4.9 gallons single family, 4.4 gallons multifamily.
- Where DW is dishwasher gallons of hot water per day (defined as 100% of rated gallons per cycle = 3.2 gallons per cycle). Gallons per cycle determined by ENERGY STAR criteria v7 for a standard residential unit (Ref. 12). Gallons per day = gallons per cycle x (91+30 x occupancy)/365 = 1.5 gallons single family, 1.4 gallons multifamily.
- When the above metrics are applied to the equation using zone 3 metrics for example, the GPD by residence type results in the following, shown in Table 1.

  Single-Family GPD = 22 x (2.59 x 0.79) + 4.9 + 1.5 = 51.4 GPD in efficient case

  Multifamily GPD = 22 x (2.17 x0.79) + 4.4 + 1.4 = 43.5 GPD in efficient case

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Revision History

Version	Description	Author	Date
1.0	Created standalone spec from ResidentialElectricDHW_v03.2. Updated the groundwater temperatures. Amended description, measure requirements and EF_Efficient. Updated the incremental costs. Updated the hot water usage	Joe Plummer	7/23/2012
1.6	Updated measure lifetimes for tankless water heaters	Franklin Energy Services	3/20/13
1.7	Added footnotes clarifying multifamily definition, changed “tankless” to “instantaneous” since some instantaneous water heaters have small buffer tanks	Joe Plummer	3/12/2014
1.8	Added unknown input values	Franklin Energy Services	11/11/15
1.9	Updated EF efficiency value to UEF value	Franklin Energy Services	9/28/17
3.3	Allowed storage baselines for instant water heaters, added deemed UEF_{BASE} for when volume and draw are unknown	Cadmus	9/2021
4.0	Updated UEF efficient case values to meet ENERGY STAR v5.0 criteria, modified gallons per day calculation.	Cadmus	11/1/2022
4.2	Simplified GPD calculation to be derived from a MN average ground water temperature, aligning with other DHW measures. Added deemed table of savings given simplification made to GPD value	Cadmus	8/1/2024

Residential Hot Water – Gas Water Heater Setback

Measure Detail	Measure Value
Measure ID	1.04.06
Target Market Segments	Residential
Target End Uses	DHW
Applicable To	Residential customers in single and multifamily homes consisting of two units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size gas water heaters
Actions	Operations and Maintenance
Required from Customer/Contractor	Confirmation of gas water heater, project location (county), building type (single family or multifamily*)
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	2 (Ref. 1)
Unit Participant Incremental Cost	$0

* Multifamily includes buildings with two or more units or townhomes.

Measure Description

This measure involves turning the water heater set point temperature to 120°F on residential storage-type gas water heaters. There is a separate measure for electric residential storage-type water heaters. The action must be performed by a utility representative on site during a home energy audit or other home visit.

The existing temperature set point is assumed to be 130°F.

Algorithms

Unit Dth Savings per Year = = $(\mathrm{WH_{BASE}} - \mathrm{WH_{EFF}}) * 365 * \left(\frac{1}{1{,}000{,}000}\right) * \text{Install Rate}$

$$\mathrm{WH_{BASE}} = \left(\frac{\mathrm{Cp} * \rho * \mathrm{GPD} * (\mathrm{T_{SET\ BASE}} - \mathrm{T_{IN}})}{\mathrm{RE}}\right) * \left[1 - \left(\frac{\mathrm{UA} * (\mathrm{T_{SET\ BASE}} - \mathrm{T_{AMB}})}{\mathrm{Input}}\right)\right] + \left(\mathrm{UA} * 24 * (\mathrm{T_{SET\ BASE}} - \mathrm{T_{AMB}})\right)$$

$$\mathrm{WH_{EFF}} = \left(\frac{\mathrm{Cp} * \rho * \mathrm{GPD} * (\mathrm{T_{SET\ EFF}} - \mathrm{T_{IN}})}{\mathrm{RE}}\right) * \left[1 - \left(\frac{\mathrm{UA} * (\mathrm{T_{SET\ EFF}} - \mathrm{T_{AMB}})}{\mathrm{Input}}\right)\right] + \left(\mathrm{UA} * 24 * (\mathrm{T_{SET\ EFF}} - \mathrm{T_{AMB}})\right)$$

$$\mathrm{UA} = \left(\frac{1}{\mathrm{EF}} - \frac{1}{\mathrm{RE}}\right) / \left[\mathrm{T_{DIFF}} * \left(\frac{24}{\mathrm{Q_{OUT}}} - \frac{1}{\mathrm{RE} * \mathrm{Input}}\right)\right] = 9.4$$

Where:

WH_{BASE}	= Baseline daily water heater energy use, consisting of water heating energy consumption and standby energy losses (Btu/day)
WH_{EFF}	= Efficient daily water heater energy use, consisting of water heating energy consumption and standby energy losses (Btu/day))
365	= Number of days per year
1,000,000	= Conversion factor from Btu to Dth
C_P	= Specific heat of water, 1.0 btu⁄(lb·°F)
ρ	= Density of water, 8.34 lbs⁄gal
GPD	= Gallons of hot water use per day, see Table 1
$T_{SET\ BASE}$	= Set water temperature in tank (Baseline=130°F) (Ref. 8)
$T_{SET\ EFF}$	= Set water temperature in tank (Efficient=120°F)
T_{IN}	= Average groundwater temperature, see Table 1, Average of 49 used in deemed values (Ref. 2) (Ref. 2)
T_{AMB}	= Ambient temperature in space surrounding tank (= 67.5°F; see Assumptions) (Ref. 3)
RE	= Water heater recovery efficiency (= 0.76) (Ref. 3)
Input	= Rated input power of water heater (= 38,000 Btu/hr) (Ref. 4, see Assumptions)
UA	= Water heater equivalent heat loss factor (9.4 Btu/hr-°F) Deemed value from the inputs below, algorithm represented above. EF = 0.61 Energy Factor (Ref. 5)
24	= hours per day
T_{DIFF}	= Average temperature difference between baseline tank temperature and ambient room temperature (130 – 67.5 = 62.5°F) (Ref. 4)
Q_{OUT}	= Energy content of water drawn from water heater during 24-hour test (= 41,094 Btu/day; see Assumptions) (Ref. 4)
Install Rate	= The percentage of rebated equipment that is assumed to be installed, See Table 3 (Ref. 13)

Example:

A direct install team reduces the set point of a gas water heater in a single-family home from 130°F to 120°F.

UA = ((1/0.61) – (1/0.76)) / ((62.5 °F x (24 / 41,094 Btu/day)) - (1 / (0.76 x 38,000 Btu/hr))

= 9.4 Btu/hr-°F

WH_{BASE} = [((1 Btu/lb°F) x 8.34 lb/gal x 45.7 gal/day x (130°F – 51.3°F)) / 0.76]

x [1 – (9.4 Btu/hr-°F x (130°F – 67.5°F) / 38,000 Btu/hr)]

+ (9.4 Btu/hr-°F x 24 hrs/day x (130°F – 67.5°F))

= 54,107 Btu/day

WH_{EFF} = [((1 Btu/lb°F) x 8.34 lb/gal x 51.4 gal/day x (120°F – 51.3°F)) / 0.76]

x [1 – (9.4 Btu/hr-°F x (120°F – 67.5°F) / 38,000 Btu/hr)]

+ (9.4 Btu/hr-°F x 24 hrs/day x (120°F – 67.5°F))

= 51,382 Btu/day

Dth_{SAVED} = [(54,107 Btu/day) – (51,382 Btu/day)] x 365 day/yr x (1 / 1,000,000 Btu/Dth) x 100%

= 0.99 Dth/yr

Deemed Input Tables

Table 1. Average groundwater temperatures by zone (Ref. 4), and daily hot water usage in gallons by zone and residential type (Ref. 9, 10, see Assumptions)

Location	T_{IN} (°F)	Single-Family		Multifamily	
		GPD_{BASE}	GPD_{EFF}	GPD_{BASE}	GPD_{EFF}
Zone 1 (Northern MN)	46.5	46.3	52.0	39.2	44.0
Zone 2 (Central MN)	49.1	45.7	51.4	38.7	43.5
Zone 3 (Twin Cities/Southern MN)	51.3	45.1	50.8	38.3	43.0
MN statewide average, or if location unknown	**49.0**	**45.7**	**51.4**	**38.7**	**43.5**

Table 2. Annual Deemed Savings per unit if Directly Installed

Residential Type	Zone	Annual Savings (Dth)
Single-Family	Avg	0.99
Multifamily	Avg	0.98

Table 3. Install Rate based on Delivery Method (Ref. 13)

Delivery Method	Install Rate
Retail	NA
Direct Install	100%
Virtual Assessment + Unverified Self-Install	10%
Requested Efficiency Kit	10%
Distributed Efficiency Kit	10%
Distributed School Efficiency Kit	20%

Methodology and Assumptions

The existing temperature is assumed to be 130°F (Ref. 8)

The derivation of the heat loss factor (UA) comes from the U.S. Department of Energy test procedures for consumer and commercial water heaters.

Some algorithm inputs were derived from the Home Energy Saver engineering documentation from the Lawrence Berkeley National Laboratory website:

- Input is from the "User Inputs to the Water Heater Model" heading. This resource demonstrates that the average rated input for residential electric water heaters is 4.5 kW, which is the equivalent of 15,354 Btu/hr (Ref. 4).
- Q_{OUT} can be found under the "Standby Heat Loss Coefficient" heading, which shows that 41,093.7 Btu/day is drawn during the standard test (Ref. 4).

Gallons per day (GPD) values were determined based on the following assumptions and resources:

1. This measure adopts a method outlined in the Wisconsin Technical Reference Manual to determine gallons of hot water used per day given residential occupant count (Ref. 7). An equation for gallons per day of hot water usage found in a Florida Solar Energy Study (Ref. 10) forms the basis of the figure, adapted with Minnesota data.
   HWgpd = 22 x (Occupancy x Fmix) + CW + DW
   - Where Occupancy represents the average occupants per household. A Minnesota state average value of 2.59 occupants per home was used for a single-family home, and 2.17 occupants per home was used for a multifamily home (Ref. 9).
   - Where Fmix = 1 – (Tset – Tmix) / (Tset – Tmains) = 1 – (120-105) / (120 – 49) = 0.79. Where Tmains has been defined as the ground temperature of the climate zone (see Table 1,the average of all zones has been used = 49.0). Tset in this example represents the efficient case setting. Hot water use consists of two components: unmixed and mixed use. Unmixed use, primarily for clothes washers and dishwashers, is direct draw from the water heater and does not vary with stored hot water temperature. Mixed use, for showers and sinks, is delivered to the fixture at 105°F, so the total draw from the water heater varies with stored water temperature.

- Where CW is clothes washer gallons of hot water per day. CW gallons per cycle is defined as 12.7 gallons per cycle for an average sized ENERGY STAR rated appliance (Ref. 11), half of which is hot water. Gallons per day = (gallons per cycle x 50%) x (123+61 x occupancy)/365 = 4.9 gallons single family, 4.4 gallons multifamily.
- Where DW is dishwasher gallons of hot water per day (defined as 100% of rated gallons per cycle = 3.2 gallons per cycle). Gallons per cycle determined by ENERGY STAR criteria v7 for a standard residential unit (Ref. 12). Gallons per day = gallons per cycle x (91+30 x occupancy)/365 = 1.5 gallons single family, 1.4 gallons multifamily.
- When the above metrics are applied to the equation using zone 3 metrics for example, the GPD by residence type results in the following, shown in Table 1.

  Single-Family GPD = 22 x (2.59 x 0.79) + 4.9 + 1.5 = 51.4 GPD in efficient case

  Multifamily GPD = 22 x (2.17 x 0.79) + 4.4 + 1.4 = 43.5 GPD in efficient case

Notes

There are no current energy standards for this measure.

References

1. Efficiency Vermont Technical Reference User Manual (TRM), 2/19/2010. Page 409. This value is supported by the Illinois Technical Reference User Manual, 2012.
2. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules.* https://www.energy.gov/eere/buildings/building-america-analysis-spreadsheets
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4. Lawrence Berkley National Laboratory. Home Energy Saver and Score: Engineering Documentation. http://hes-documentation.lbl.gov/calculation-methodology/calculation-of-energy-consumption/water-heater-energy-consumption
5. Cadmus. 2016 Potential Study for Focus on Energy. Data maintained by Cadmus and Wisconsin PSC.
6. Illinois Energy Efficiency Stakeholder Advisory Group. *2021 Illinois Statewide Technical Reference Manual for Energy Efficiency Version 9.0*. September 25, 2020. https://ilsag.s3.amazonaws.com/IL-TRM_Effective_010121_v9.0_Vol_3_Res_09252020_Final.pdf
7. Public Service Commission of Wisconsin. Wisconsin Focus on Energy 2021 Technical Reference Manual. Spring 2022. Page 891.
8. Franklin Energy Services internal value.
9. U.S. Census Bureau, *Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates)* for the state of MN. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=table

10. Florida Solar Energy Center. Estimating Daily Domestic Hot-Water Use in North American Homes. June 30, 2015. http://www.fsec.ucf.edu/en/publications/pdf/FSEC-PF-464-15.pdf
11. ENERGY STAR Residential Clothes Washer Product Criteria, version 8.1. Published April 22, 2021. https://www.energystar.gov/products/clothes_washers/partners
12. ENERGY STAR Residential Dishwasher Product Criteria, version 7.0. Effective July 19, 2022. https://www.energystar.gov/products/dishwashers/partners
13. Illinois Statewide Technical Reference Manual v12.0 Vol. 3 – Residential Measures, 5.4.6 Water Heater Temperature Setback. September 22, 2023.

Revision History

Version	Description	Author	Date
1.0	Originally part of ResidentialGasDHW_v03.2 which was derived from Nexant spec; changed algorithm to assume an average starting and final temperature rather than using an unsupported savings factor	Joe Plummer	7/1/2012
2.0	Updated algorithm to use Savings_Factor of 4%. Updated measure lifetime per Ref. 2. Updated the hot water usage to be consistent with the hot water heater measure algorithm.	Franklin Energy Services	8/1/2012
3.1	Changed action type to Modify, changed "electric or gas water heater" to "confirmation of gas water heater" in Required Inputs, changed example to compute gas savings instead of electric	Joe Plummer	11/25/2013
3.2	Added footnotes clarifying multifamily definition. In Dth algorithm, replaced Gal/Day with Gal_Person x People.	Joe Plummer	3/18/2014
4.0	Revised and updated savings algorithm, updated assumptions, updated references.	Cadmus	11/1/2022
4.2	Simplified GPD to a single average MN climate zone (ground water incoming temperature) to produce a single set of SF and MF deemed savings values.	Cadmus	8/1/2024
5.0	Included Install Rates	MN Department of Commerce	2025

Residential Hot Water – Faucet Aerator with Electric Water Heater

Measure Detail	Measure Value
Measure ID	1.04.07
Target Market Segments	Residential
Target End Uses	DHW
Applicable To	Residential customers in single-family homes and multifamily homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size electric water heaters
Actions	Replace Working
Required from Customer/Contractor	Confirmation of electric water heater, building type (single family or multifamily*), project location (county) * Includes buildings with 2+ units and townhomes
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	10 (Ref. 1)
Unit Participant Incremental Cost	$6.70 (Ref. 6)

Measure Description

This measure includes replacing an existing faucet aerator with low-flow aerator.

Algorithms

Unit kWh Savings per Year = $(GPM_{BASE} \times TF_{BASE} - GPM_{LOW} \times TF_{LOW}) \times (PH \times FLU / FH) \times DF \times 365 \times Density \times C_P \times (T_{OUT} - T_{IN}) / (ReEff \times 3{,}412) \times$ Install Rate

Unit Peak kW Savings = Unit kWh Savings per Year x CF / Hours

Where:

GPM_{BASE} = Actual or 2.2 gallons per minute (Ref. 5)

TF_{BASE} = Throttling factor for base use, 0.83 (Ref. 8)

GPM_{LOW} = Actual

TF_{LOW} = Throttling factor for installed use, 0.95 (Ref. 8)

PH = Number of people per household, per Table 1 (Ref. 3)

FLU = Fixture length of use in minutes / person per day, per Table 2 (Ref. 2)

FH = Fixtures per home per Table 2 (Ref. 2)

DF = Drain factor per Table 2 (Ref. 7). Drain factor accounts for the fact that a portion of faucet use is dictated by volume, not time (generally filling vessels, as opposed to washing items).

365 = Days per year

Density = 8.34 lb / gal

C_P	= 1.0 Btu / (lb x °F)
T_{OUT}	= Temperature of faucet usage per Table 2 (Ref. 2)
T_{IN}	= Average groundwater temperature per Table 3 (Ref. 4). Default to the average MN statewide temperature.
ReEff	= Recovery Efficiency = 98% (electric water heater) (Ref. 7)
3,412	= Conversion from Btu to kWh
CF	= Coincidence factor per Table 2 (Ref. 9)
Hours	= Hours of use per year = (PH x FLU / FH) x 365 / 60
Install Rate	= The % of rebated equipment that is assumed to be installed (Ref. 10)

Example:

Direct install of a 1.5 GPM faucet aerator in an apartment with electric water heat, located in Zone 1, room type unknown.

Unit kWh Savings per Year = (2.2 x 0.83 – 1.5 x 0.95) x (2.17 x 3.1 / 1.22) x 0.83 x 365 x 8.34 x 1 x (90 – 46.5) / (0.98 x 3,412) x 100% = 72.7 kWh

Hours = (2.17 x 3.1 / 1.22) x 365 / 60 = 33.5 hours

Unit Peak kW Savings = 72.7 x 0.0023 / 33.5 = 0.005 kW

Deemed Input Tables

Table 1. People per Household (Ref. 3)

Application	PH
Single-Family	2.59
Multifamily	2.17
If unknown	2.38

Table 2. Fixture Length of Use and T_{OUT} (Ref. 2), Drain Factor (Ref. 7), and Coincidence Factor (Ref. 9)

Location	FLU	T_{OUT}	DF	CF
Kitchen	4.5	93°F	0.75	0.0033
Bathroom	1.6	86°F	0.90	0.0012
Unknown	3.1	90°F	0.83	0.0023

Table 3. Fixtures Per Home (Ref. 2)

Application	Location	FH
Single-Family	Kitchen	1
	Bathroom	2.04
	Unknown	1.52
Multifamily*	Kitchen	1
	Bathroom	1.43
	Unknown	1.22
Unknown	Unknown	1.37

Table 4. Average groundwater temperatures (Ref. 4)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3
MN statewide average, or if location unknown	**49.0**

Table 5. Install Rate based on Delivery Method (Ref. 10)

Delivery Method	Install Rate
Retail	-
Direct Install	93%
Virtual Assessment + Unverified Self-Install	77%
Requested Efficiency Kit	60%
Distributed Efficiency Kit	46%
Distributed School Efficiency Kit	51%

References

1. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values. http://www.deeresources.com/deer2008exante/downloads/DEER%200607%20Measure%20Update%20Report.pdf. Accessed on 7/31/12.
2. Cadmus and Opinion Dynamics. Showerhead and Faucet Aerator Meter Study. Memo to Michigan Evaluation Working Group. June 2013.
3. U.S. Census Bureau, *Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates)* for the state of MN. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=table
4. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules* http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html
5. Title 10, Code of Federal Regulations, Part 430 – Energy Conservation Program for Consumer Products, Subpart C – Energy and Water Conservation Standards. https://www.ecfr.gov/cgi-bin/text-

idx?SID=45151ba12ebfbba8afbf95d31bcd2ace&mc=true&node=pt10.3.430&rgn=div5#sp10.3.430.c

6. 2008 Database for Energy-Efficient Resources, Cost Values and Summary Documentation http://www.deeresources.com/deer2008exante/downloads/DEER%200607%20Measure%20Update%20Report.pdf
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9. Public Service Commission of Wisconsin. Wisconsin Focus on Energy 2017 Technical Reference Manual. Spring 2017. Page 642. https://focusonenergy.com/sites/default/files/Focus%20TRM-%20Spring%202017-%20Final%20for%20Posting%20May%202017_0.pdf
10. Illinois Statewide Technical Reference Manual v12.0 Vol. 3 – Residential Measures, 5.4.4 Low Flow Faucet Aerators. September 22, 2023.

Revision History

Version	Description	Author	Date
1.0	Created standalone spec from ResidentialElectricDHW_v03.2. Revised formatting and algorithms. Update the measure life and measure cost. Corrected Energy Factor equations	Joe Plummer	
3.1	Changed action from Direct Install to Replace Working. Removed extra multiplication sign following Eff in savings algorithms. Changed “electric or gas water heater” to “confirmation of electric water heater” under required inputs, changed efficiency (0.92) to recovery efficiency (0.98) and updated example accordingly, changed annual hours from 8,760 to 8,760	Joe Plummer	4/5/2013
3.4	Added residence type (single family or multifamily) to required inputs. Removed “owner-occupied” from single-family and “renter-occupied” from multifamily categories in Tables 2 and 3, added footnotes clarifying multifamily definition. Added in average values and a deemed value for applications where the inputs are unknown	Joe Plummer	1/3/14
4.1	All hours of use changed to 365.25 and commercial usage	Franklin Energy Services	1/13/2016
5.0	Updated algorithm for kWh and kW savings, splitting out savings for kitchen and bathroom aerators, and using actual installed GPM and drain and throttling factors	Cadmus	10/2018
5.0	Included Install Rates	MN Dept of Commerce	2025

Residential Hot Water – Faucet Aerator with Gas Water Heater

Measure Detail	Measure Value
Measure ID	1.04.08
Target Market Segments	Residential
Target End Uses	DHW
Applicable To	Residential customers in single- and multifamily homes consisting of two units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size gas water heaters
Actions	Replace Working
Required from Customer/Contractor	Confirmation of gas water heater, building type (single family or multifamily*), project location (county) * Includes buildings with 2+ units and townhomes
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	10 (Ref. 1)
Unit Participant Incremental Cost	$6.70 (Ref. 6)

Measure Description

This measure includes replacing an existing faucet aerator with low-flow aerator.

Algorithms

Unit Dth Savings per Year = $(GPM_{BASE} \times TF_{BASE} - GPM_{LOW} \times TF_{LOW}) \times (PH \times FLU / FH) \times DF \times 365 \times Density \times C_P \times (T_{OUT} - T_{IN}) / (ReEff \times 1{,}000{,}000) \times Install\ Rate$

Where:

GPM_{BASE} = Actual or 2.2 gallons per minute (Ref. 5)

TF_{BASE} = Throttling factor for base use, 0.83 (Ref. 8)

GPM_{LOW} = Actual

TF_{LOW} = Throttling factor for installed use, 0.95 (Ref. 8)

PH = Number of people per household, per Table 1 (Ref. 3)

FLU = Fixture length of use in minutes / person per day, per Table 2 (Ref. 2)

FH = Fixtures per home per Table 2 (Ref. 2)

DF = Drain factor per Table 2 (Ref. 7). Drain factor accounts for the fact that a portion of faucet use is dictated by volume, not time (generally filling vessels, as opposed to washing items).

365 = Days per year

Density = 8.34 lb / gal

C_P = 1.0 Btu / (lb x °F)

T_{OUT}	= Temperature of faucet usage per Table 2 (Ref. 2)
T_{IN}	= Average groundwater temperature per Table 4 (Ref. 4). Default to average MN statewide temperature.
ReEff	= Recovery efficiency gas water heater per Table 1 (Ref. 7)
1,000,000	= Conversion from Btu to Dth
Install Rate	= The percentage of rebated equipment that is assumed to be installed (Ref. 9)

Example:

Direct installation of a 1.5 GPM faucet aerator in an apartment with gas water heat located in Zone 1, room type unknown.

Unit Dth Savings per Year = (2.2 x 0.83 – 1.5 x 0.95) x (2.17 x 3.1 / 1.22) x 0.83 x 365 x 8.34 x 1 x (90 – 46.5) / (0.67 x 1,000,000) x 100% = 0.36 Dth

Deemed Input Tables

Table 1. People per Household (Ref. 3) and ReEff (Ref. 7)

Application	PH	ReEff
Single-Family	2.59	0.78
Multifamily*	2.17	0.67
If unknown	2.38	0.73

* Includes buildings with 2+ units and townhomes

Table 2. Fixture Length of Use and T_{OUT} (Ref. 2), and Drain Factor (Ref. 7)

Location	FLU	T_{OUT}	DF
Kitchen	4.5	93°F	0.75
Bathroom	1.6	86°F	0.90
Unknown	3.1	90°F	0.83

Table 3. Fixtures Per Home (Ref. 2)

Application	Location	FH
Single-Family	Kitchen	1
	Bathroom	2.04
	Unknown	1.52
Multifamily*	Kitchen	1
	Bathroom	1.43
	Unknown	1.22
Unknown	Unknown	1.37

Table 4. Average groundwater temperatures (Ref. 4)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3
MN statewide average, or if location unknown	**49.0**

Table 5. Install Rate based on Delivery Method (Ref. 9)

Delivery Method	Install Rate
Retail	-
Direct Install	93%
Virtual Assessment + Unverified Self-Install	77%
Requested Efficiency Kit	60%
Distributed Efficiency Kit	46%
Distributed School Efficiency Kit	51%

References

1. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values. http://www.deeresources.com/deer2008exante/downloads/DEER%200607%20Measure%20Update%20Report.pdf. Accessed on 7/31/12.
2. Cadmus and Opinion Dynamics. Showerhead and Faucet Aerator Meter Study. Memo to Michigan Evaluation Working Group. June 2013.
3. U.S. Census Bureau, *Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates)* for the state of MN. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=table
4. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules* http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html
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7. Illinois Stakeholder Advisory Group. State of Illinois Energy Efficiency Technical Reference Manual, Version 6.0, Volume 3: Residential Measures. February 8th, 2017. Page 179.

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9. Illinois Statewide Technical Reference Manual v12.0 Vol. 3 – Residential Measures, 5.4.4 Low Flow Faucet Aerators. September 22, 2023.

Revision History

Version	Description	Author	Date
1.0	Created standalone spec from ResidentialElectricDHW_v03.2	Joe Plummer	
2.0	Revised formatting and algorithms	Franklin Energy Services	7/27/2012
2.1	Update the measure life and measure cost	Franklin Energy Services	7/27/2012
3.0	Corrected Energy Factor equations	Franklin Energy Services	3/20/2013
3.1	Changed action from Direct Install to Replace Working	Joe Plummer	4/5/2013
3.2	Removed extra multiplication sign following Eff in savings algorithms	Joe Plummer	8/28/2013
3.3	Changed "electric or gas water heater" to "confirmation of gas water heater" in Required Inputs, changed efficiency to recovery efficiency of 0.75 and updated example accordingly	Joe Plummer	11/25/13
3.4	Added residence type (single family or multifamily) to required inputs	Joe Plummer	1/3/14
3.5	Removed “owner-occupied” from single-family and “renter-occupied” from multifamily in Table 1, added footnotes clarifying multifamily definition.	Joe Plummer	3/11/14
4.0	Added average input values and a deemed value for applications where the inputs are unknown.	Franklin Energy Services	10/20/15
5.0	Updated algorithm for kWh and kW savings, splitting out savings for kitchen and bathroom aerators, and using actual installed GPM and drain and throttling factors	Cadmus	10/2018
5.0	Included Install Rates	MN Department of Commerce	2025

Residential Hot Water – Low Flow Showerheads with Electric Water Heater

Measure Detail	Measure Value
Measure ID	1.04.09
Target Market Segments	Residential: Single-family and Multifamily
Target End Uses	DHW
Applicable To	Residential customers in single- and multifamily homes consisting of two units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size electric water heaters
Actions	Replace Working
Required from Customer/Contractor	Confirmation of electric water heater, building type (single-family or multifamily*), project location (county) * Includes buildings with 2+ units and townhomes
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	10 (Ref. 4)
Unit Participant Incremental Cost	$12 (Ref. 5)

Measure Description

This measure involves replacing a standard showerhead with a low flow showerhead.

Algorithms

Unit kWh Savings per Year = $(GPM_{BASE} – GPM_{LOW})$ x (PH x SPD x SL / SPH) x 365 x Density x C_P x $(T_{OUT} – T_{IN})$ / (ReEff x 3,412) x Install Rate

Unit Peak kW Savings = Unit kWh Savings per Year x CF / Hours

Where:

GPM_{BASE}	= Actual or 2.5 gallons per minute (Ref. 3)
GPM_{LOW}	= Actual
PH	= Number of people per household per Table 2
SPD	= Showers per person per day = 0.6 (Ref. 6)
SL	= Shower length in minutes / shower = 7.8 (Ref. 6)
SPH	= Showerheads per Household per Table 3
365	= Days per year
Density	= 8.34 lbs/gal
C_P	= 1.0 Btu/(lb°F)
T_{OUT}	= Temperature of typical shower usage = 101°F (Ref. 6)

T_{IN}	= Average groundwater temperature per Table 1. Default to average MN statewide temperature.
ReEff	= Recovery efficiency = 98% (electric water heater) (Ref. 6)
3,412	= Conversion from Btu to kWh
CF	= Coincidence factor = 0.0023 (Ref. 7)
Hours	= Hours of use per year = (PH x SPD x SLU / SPH) x 365 / 60
Install Rate	= The percentage of rebated equipment that is assumed to be installed (Ref. 8)

Example:

Direct installation of a 1.5 GPM low-flow showerhead in an apartment with electric water heat located in Zone 3.

Unit kWh Savings per Year = (2.5 – 1.5) x (2.17 x 0.6 x 7.8 / 1.3) x 365 x 8.34 x 1 x (101 – 51.3) / (0.98 x 3,412) x 100% = 353 kWh

Hours = (2.17 x 0.6 x 7.8 / 1.3) x 365 / 60 = 47.5 hours

Unit Peak kW Savings = 353 x 0.0023 / 47.5 = 0.017 kW

Deemed Input Tables

Table 1. Average groundwater temperatures (Ref. 2)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3
MN statewide average, or if location unknown	**49.0**

Table 2. People per Household (Ref. 1)

Application	PH
Single-Family	2.59
Multifamily*	2.17
If unknown	2.38

* Includes buildings with 2+ units and townhomes

Table 3. Showerheads per Household (Ref. 7)

Application	SPH
Single-Family	1.50
Multifamily*	1.11
If unknown	1.31

* Includes buildings with 2+ units and townhomes

Table 4. Install Rate based on Delivery Method (Ref. 8)

Delivery Method	Install Rate
Retail	NA
Direct Install	96%
Virtual Assessment + Unverified Self-Install	80%
Requested Efficiency Kit	65%
Distributed Efficiency Kit	48%
Distributed School Efficiency Kit	57%

References

1. U.S. Census Bureau, Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates) for the state of MN. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=table
2. US DOE Building America Program. Building America Analysis Spreadsheet, Standard Benchmark DHW Schedules. http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html
3. Title 10, Code of Federal Regulations, Part 430 – Energy Conservation Program for Consumer Products, Subpart C – Energy and Water Conservation Standards and Their Effective Dates. https://www.ecfr.gov/cgi-bin/text-idx?SID=45151ba12ebfbba8afbf95d31bcd2ace&mc=true&node=pt10.3.430&rgn=div5#sp10.3.430.c
4. Table C-6, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. Evaluations indicate that consumer dissatisfaction may lead to reductions in persistence, particularly in multifamily, http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf
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6. Cadmus and Opinion Dynamics. Showerhead and Faucet Aerator Meter Study. Memo to Michigan Evaluation Working Group. June 2013.
7. Public Service Commission of Wisconsin. Wisconsin Focus on Energy 2017 Technical Reference Manual. Spring 2017. Page 642. https://focusonenergy.com/sites/default/files/Focus%20TRM-%20Spring%202017-%20Final%20for%20Posting%20May%202017_0.pdf
8. Illinois Statewide Technical Reference Manual v12.0 Vol. 3 – Residential Measures, 5.4.5 Low Flow Showerheads. September 22, 2023.

Revision History

Version	Description	Author	Date
1.0	Created standalone spec from ResidentialElectricDHW_v03.2	Joe Plummer	
2.0	Changed algorithm per IL TRM and modified the HW usage estimates. Changed Measure Lifetime from 7 to 10	Franklin Energy Services	7/31/2012
3.0	Updated ShowerWater description to read "shower water…" instead of "hot water…" Changed action from Direct Install to Replace Working; Added residence type to list of required inputs from customer/vendor; Changed description of Tshower from "typical faucet usage" to "typical shower usage"; Changed "Required Inputs from Direct Installer" to "Required Inputs from Customer/Contractor." Changed “electric or gas water heater” to “confirmation of electric water heater” under required inputs, changed efficiency to recovery efficiency of 0.98 and updated example accordingly, changed annual hours to 8,766	Franklin Energy Services	1/4/2013
4.0	Added average input values and a deemed value for applications where the inputs are unknown	Franklin Energy Services	10/15/2015
4.1	All hours of use changed to 365.25	Franklin Energy Services	1/13/2016
5.0	Updated algorithm for kWh and kW savings, using measured values for shower duration and temperature and actual installed GPM	Cadmus	10/2018
5.0	Included Install Rates	MN Department of Commerce	2025

Residential Hot Water – Low Flow Showerheads with Gas Water Heater

Measure Detail	Measure Value
Measure ID	1.04.10
Target Market Segments	Residential
Target End Uses	DHW
Applicable To	Residential customers in single- and multifamily homes consisting of two units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size gas water heaters
Actions	Replace Working
Required from Customer/Contractor	Electric or gas water heater, residence type (single-family or multifamily*), project location (county) * Includes buildings with 2+ units and townhomes
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	10 (Ref. 4)
Unit Participant Incremental Cost	$12 (Ref. 5)

Measure Description

This measure involves replacing a standard showerhead with a low flow showerhead.

Algorithms

Unit Dth Savings per Year = $(GPM_{BASE} – GPM_{LOW})$ x (PH x SPD x SL / SPH) x 365 x Density x C_P x $(T_{OUT} – T_{IN})$ / (ReEff x 1,000,000) x Install Rate

Where:

GPM_{BASE} = Actual or 2.5 gallons per minute (Ref. 3)

GPM_{LOW} = Actual

PH = Number of people per household per Table 2

SPD = Showers per person per day = 0.6 (Ref. 6)

SL = Shower length in minutes / shower = 7.8 (Ref. 6)

SPH = Showerheads per Household per Table 3

Density = 8.34 lbs / gal

C_P = 1.0 Btu/(lb°F)

T_{OUT} = Temperature of typical shower usage = 101°F (Ref. 6)

T_{IN} = Average groundwater temperature per Table 1. Default to average MN statewide temperature.

ReEff = Recovery efficiency (gas water heater) per Table 2 (Ref. 5)

1,000,000 = Conversion from Btu to Dth

Install Rate = The percentage of rebated equipment that is assumed to be installed (Ref. 7)

Example:

Direct installation of a 1.5 GPM low-flow showerhead in an apartment with gas water heat located in Zone 3.

Unit Dth Savings per Year = (2.5 – 1.5) x (2.17 x 0.6 x 7.8 / 1.3) x 365 x 8.34 x 1 x (101 – 51.3) / (0.67 x 1,000,000) x 100% = 1.76 Dth

Deemed Input Tables

Table 1. Average groundwater temperatures (Ref. 2).

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3
MN statewide average, or if location unknown	**49.0**

Table 2. People per Household (Ref. 1) and ReEff (Ref. 5)

Application	PH	ReEff
Single-Family	2.59	0.78
Multifamily*	2.17	0.67
If unknown	2.38	0.73

* Includes buildings with 2+ units and townhomes

Table 3. Showerheads per Household (Ref. 6)

Application	SPH
Single-Family	1.50
Multifamily*	1.11
If unknown	1.31

* Includes buildings with 2+ units and townhomes

Table 4. Install Rate based on Delivery Method (Ref. 7)

Delivery Method	Install Rate
Retail	NA
Direct Install	96%
Virtual Assessment + Unverified Self-Install	80%
Requested Efficiency Kit	65%
Distributed Efficiency Kit	48%
Distributed School Efficiency Kit	57%

References

1. U.S. Census Bureau, *Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates)* for the state of MN. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=table
2. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules.* http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html
3. Title 10, Code of Federal Regulations, Part 430 – Energy Conservation Program for Consumer Products, Subpart C – Energy and Water Conservation Standards and Their Effective Dates. https://www.ecfr.gov/cgi-bin/text-idx?SID=45151ba12ebfbba8afbf95d31bcd2ace&mc=true&node=pt10.3.430&rgn=div5#sp10.3.430.c
4. Table C-6, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. Evaluations indicate that consumer dissatisfaction may lead to reductions in persistence, particularly in multifamily, http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf
5. Illinois Stakeholder Advisory Group. State of Illinois Energy Efficiency Technical Reference Manual, Version 6.0, Volume 3: Residential Measures. February 8th, 2017. Page 179. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_3_Res_020817_Final.pdf
6. Cadmus and Opinion Dynamics. Showerhead and Faucet Aerator Meter Study. Memo to Michigan Evaluation Working Group. June 2013.
7. Illinois Statewide Technical Reference Manual v12.0 Vol. 3 – Residential Measures, 5.4.5 Low Flow Showerheads. September 22, 2023.

Revision History

Version	Description	Author	Date
1.0	Created standalone spec from ResidentialElectricDHW_v03.2	Joe Plummer	
2.0	Changed algorithm per IL TRM and modified the HW usage estimates; Changed Measure Lifetime from 7 to 10	Franklin Energy Services	7/31/2012
3.0	Updated ShowerWater description to read "shower water…" instead of "hot water…"	Franklin Energy Services	1/4/2013
3.1	Changed Action type from Direct Install to Replace Working; Added residence type to list of required inputs from customer/vendor; Changed description of Tshower from "typical faucet usage" to "typical shower usage"; Changed "Required Inputs from Direct Installer" to "Required Inputs from Customer/Contractor"	Joe Plummer	4/8/2013
3.2	Changed action type to Modify, changed "electric or gas water heater" to "confirmation of gas water heater" in Required Inputs, changed efficiency to recovery efficiency of 0.75 and updated example accordingly	Joe Plummer	11/25/2013
3.3	Added footnotes clarifying multifamily definition	Joe Plummer	3/18/2014
4.0	Added average input values and a deemed value for applications where the inputs are unknown.	Franklin Energy Services	10/20/2015
5.0	Updated algorithm for Dth savings, using measured values for shower duration and temperature and actual installed GPM	Cadmus	10/2018
5.0	Included Install Rates	MN Department of Commerce	2025

Residential Hot Water – Water Heater Jacket Insulation

Measure Detail	Measure Value
Measure ID	1.04.11
Target Market Segments	Residential
Target End Uses	DHW
Applicable To	Residential customers in single-family, duplexes and townhomes with storage water heaters
Actions	Retrofit
Required from Customer/Contractor	Project location (county), water heater size in gal, water heater fuel type
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	7 (Ref. 4)
Unit Participant Incremental Cost	$30 (Ref. 5)

Measure Description

This measure includes installing a water heater blanket on an electric or gas water storage water heater.

Algorithms

Unit kWh Savings per Year = (A_base / R_base - A_insul / R_insul) x (T_hot - T_ambient) x Hours / (ElecEff x 3,412)
Electric-fueled storage water heater only

Unit Peak kW Savings = Unit kWh Savings per Year / Hours
Electric-fueled storage water heater only

Unit Dth Savings per Year = (A_base / R_base - A_insul / R_insul) x (T_hot - T_ambient) x Hours / (GasEff x 1,000,000)
Gas-fueled storage water heater only

Where:

R_base = R-value of existing water heater tank insulation = Actual or if unknown assume R-12 (Ref. 1)

R_insul = R-value of total water heater insulation after insulation addition = Actual or if unknown assume R-18 (Ref. 5)

A_base = Surface area of uninsulated water heater (Table 1)

A_insul = Surface area of insulated water heater (Table 1)

T_hot = 120°F (Ref. 3)

T_ambient = 60°F (Ref. 6)

ElecEff = Recovery efficiency of electric water heater = 98% (Ref. 2)

GasEff	=	Recovery efficiency of gas water heater = 78% (Ref. 2)
Hours	=	8,760 hours
3,412	=	Conversion from Btu to kWh
1,000,000	=	Conversion from Btu to Dth

Example:

A customer in Zone 2 installed an insulation jacket on their 50-gallon water heater.

Unit kWh Savings per Year = (24.99 / 12 - 27.06 / 18) x (120 - 60) x 8,760 / (0.98 x 3,412) = 91.0 kWh

Unit Peak kW Savings = 91.0 kWh / 8,760 hours = 0.010 kW

Dth Savings per Year = 0

Deemed Input Tables

Table 1. Surface Areas, ft^2 (Ref. 1)

Water Heater Size	A_base	A_insul
30-gallon tank	19.16	20.94
40-gallon tank	23.18	25.31
50-gallon tank	24.99	27.06
80-gallon tank	31.84	34.14

Notes

If assuming 46 gal/day hot water usage, the savings in the example comes out to about 4% of the overall DHW energy.

There is no current standard for level of insulation necessary for new or existing water heaters.

References

1. Pennsylvania Public Utility Commission. *Technical Reference Manual. Volume 2: Residential Measures*. August 2019. http://www.puc.pa.gov/pcdocs/1630968.docx
2. Electric water heaters generally have recovery efficiency of 98%, and gas water heaters generally have a recovery efficiency of 78%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx
3. Recommended value on DOE website, http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13090. Consistent with other DHW measures.
4. California Energy Commission and California Public Utilities Commission. Database for Energy Efficient Resources. EUL Table. 2014. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx

5. Online research at Amazon, Lowes, and Home Depot conducted by Cadmus, September 2020. Costs for 15 models ranged from $22 to $44, no trends observed with respect to area or R-value. Average $31. Average R-value of 7; 6 is a conservative default.
6. The ambient temperature is based on the water heaters being located in the basement.

Revision History

Version	Description	Author	Date
1.0	Based on original from Nexant, cleaned up and reformatted	Joe Plummer	
2.0	Added algorithms based on IL TRM	Franklin Energy Services	7/31/2012
3.0	Updated hours from 8,760 to 8,766.	Franklin Energy Services	1/11/2016
4.0	Updated recovery efficiency, added gas measure, reverted hours to 8,760 to be consistent with other measures.	Cadmus	9/2020

Residential Hot Water – Pipe Insulation with Electric Water Heater

Measure Detail	Measure Value
Measure ID	1.04.12
Target Market Segments	Residential
Target End Uses	DHW
Applicable To	Residential customers in single-family, duplexes and townhomes with electric water heaters.
Actions	Modify
Required from Customer/Contractor	Length of pipe insulation (linear feet), confirmation of electric water heater
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	13 (Ref. 3)
Unit Participant Incremental Cost	$3.63 per foot (Ref. 4)

Measure Description

This measure includes installing pipe insulation on un-insulated piping of an electric water heating system.

Algorithms

Unit kWh Savings per Year = (Qloss_base - Qloss_insul) x Hours x Length / ConversionFactor / Eff x Install Rate

Unit Peak kW Savings = Unit kWh Savings per Year / 8,760 hours

Where:

Qloss_base = See Table 1 for values. Heat loss (Btu/ft) from bare piping.

Qloss_insul = See Table 1 for values. Heat loss (Btu/ft) from insulated piping.

Length = Length of pipe insulation in linear feet (provided by customer)

Eff = 0.92

Hours = 4,823 hours; Hours when outside air temperature is above building balance point. Heat loss from pipe is wasted. (Ref. 5)

ConversionFactor = 3,412 Btu/kWh

Install Rate = The percentage of rebated equipment that is assumed to be installed (Ref. 6, 7)

Example:

A direct install team installed R-2 insulation on one foot of un-insulated hot water piping.

Unit kWh Savings per Year = (36.9 Btu/ft - 6.9 Btu/ft) x 4,823 hours x 1 ft. / 3,412 Btu/kWh / 0.92 x 100%
= 46.1 kWh

Unit Peak kW Savings= 46.1 kWh / 8,760 hours = 0.0053 kW

Deemed Input Tables

Table 1. Average Heat Loss Figures (Ref. 5)

Location	Avg. Heat Loss of Bare Pipe (Btu/ft)	Avg. Heat Loss of Insulated Pipe (Btu/ft)
Zone 1, 2, and 3	36.9	6.9

Table 2. Install Rate based on Delivery Method

Delivery Method	Install Rate	Reference
Retail	100%	6
Direct Install	100%	6
Virtual Assessment + Unverified Self-Install	75%	7
Requested Efficiency Kit	50%	6
Distributed Efficiency Kit	50%	6
Distributed School Efficiency Kit	50%	6

Methodology and Assumptions

Pipes are assumed to be an equal mix of 1/2", 3/4" and 1" sizes. Insulation is assumed to be R-2 pipe insulation. T_hot = 120°F; (Ref. 2; to be consistent with other DHW measures). T_ambient = 60°F (Ref. 1)

Notes

Section N1103.3 of the 2006 International Residential Code requires mechanical system piping that is capable of carrying fluids above 105 degrees F or below 55 degrees F to be insulated to a minimum of R-2.

References

1. The ambient temperature is assumed to be 60°F, based on the estimated temperature of a basement where the water heater is assumed to be located.
2. "Lower Water Heating Temperature for Energy Savings," Department of Energy, Accessed 7/26/12. http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13090.
3. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values. http://www.deeresources.com/deer2008exante/downloads/DEER%200607%20Measure%20Update%20Report.pdf. Accessed on 7/31/12.

4. 2008 Database for Energy-Efficient Resources, Cost Values and Summary Documentation (updated 6/2/2008 - NR linear fluorescent labor costs typo) http://www.deeresources.com/deer2008exante/downloads/DEER%200607%20Measure%20Update%20Report.pdf. Accessed on 7/31/12.
5. Xcel Energy 2010-2012 CIP Triennial (Docket No. E, G002/CIP-09-198), Pages 470-477.
6. Illinois Statewide Technical Reference Manual v12.0 Vol. 3 – Residential Measures, 5.4.1 Domestic Hot Water Pipe Insulation. September 22, 2023.
7. Minnesota Power 2024-2026 Triennial Filing. Measure "Energy Analysis with Unverified Self-Install, Version No. 1.0."

Revision History

Version	Description	Author	Date
1.0	Based on original from Nexant, cleaned up and reformatted	Joe Plummer	
2.0	Reformatted	Franklin Energy Services	7/26/2012
2.1	Updated the measure cost value/source	Franklin Energy Services	7/31/2012
2.2	Updated the measure lifetime from 15 to 13	Franklin Energy Services	7/31/2012
2.3	Changed Action to Modify, changed Table1 so that same heat loss figures apply to all zones, delete zip code from required inputs, added confirmation of electric water heater to required inputs, changed annual hours to 8,766	Joe Plummer	11/24/13
3.0	Updated measure cost to "per foot", moved T_hot and T_ambient to the Notes section, corrected sample calculation and removed some erroneous text.	Franklin Energy Services	1/6/16
5.0	Included Install Rates	MN Department of Commerce	2025

Residential Hot Water – Pipe Insulation with Gas Water Heater

Measure Detail	Measure Value
Measure ID	1.04.13
Target Market Segments	Residential
Target End Uses	DHW
Applicable To	Residential customers in single-family, duplexes and townhomes with gas water heaters
Actions	Modify
Required from Customer/Contractor	Length of pipe insulation (linear feet), confirmation of gas water heater
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	13 (Ref. 3)
Unit Participant Incremental Cost	$3.63 (Ref. 4)

Measure Description

This measure includes installing pipe insulation on un-insulated piping of a gas water heating system.

Algorithms

Unit Dth Savings per Year = (Qloss_base - Qloss_insul) x Hours x Length / ConversionFactor / Eff x Install Rate

Where:

Qloss_base = See Table 1 for values. Heat loss (Btu/ft) from bare piping; See "Btu per Foot" tab for explanation.

Qloss_insul = See Table 1 for values. Heat loss (Btu/ft) from insulated piping; See "Btu per Foot" tab for explanation.

Eff = 0.59

Hours = 4,823 hours; Hours when outside air temperature is above building balance point. Heat loss from pipe is wasted. (Ref. 5)

ConversionFactor = 1,000,000 Btu/Dth

Install Rate = The percentage of rebated equipment that is assumed to be installed (Ref. 6, 7)

Example:

A direct install team in Zone 1 installed R-2 insulation on one foot of un-insulated hot water piping

Unit Dth Savings per Year = (36.9 Btu/ft - 6.9 Btu/ft) x 4,823 hours x 1 ft. / 1,000,000 Btu/Dth / 0.59 x 100% = 0.245 Dth

Deemed Input Tables

Table 1. Average Heat Loss Figures (Ref. 5)

Location	Avg. Heat Loss of Bare Pipe (Btu/ft)	Avg. Heat Loss of Insulated Pipe (Btu/ft)
Zone 1, 2, and 3	36.9	6.9

Table 2. Install Rate based on Delivery Method

Delivery Method	Install Rate	Reference
Retail	100%	6
Direct Install	100%	6
Virtual Assessment + Unverified Self-Install	75%	7
Requested Efficiency Kit	50%	6
Distributed Efficiency Kit	50%	6
Distributed School Efficiency Kit	50%	6

Methodology and Assumptions

Pipes are assumed to be an equal mix of 1/2", 3/4" and 1" sizes. Insulation is assumed to be R-2 pipe insulation. T_hot = 120°F; (Ref. 2). T_ambient = 60°F (Ref. 1).

Notes

Section N1103.3 of the 2006 International Residential Code requires mechanical system piping capable of carrying fluids above 105 degrees F or below 55 degrees F to be insulated to a minimum of R-2.

References

1. The ambient temperature is assumed to be 60°F, based on the estimated temperature of a basement where the water heater is assumed to be located.
2. "Lower Water Heating Temperature for Energy Savings," Department of Energy website, http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13090. Accessed 7/26/12.
3. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values. http://www.deeresources.com/deer2008exante/downloads/DEER%200607%20Measure%20Update%20Report.pdf. Accessed on 7/31/12.
4. 2008 Database for Energy-Efficient Resources, Cost Values and Summary Documentation (updated 6/2/2008 - NR linear fluorescent labor costs typo). Accessed on 7/31/12. http://www.deeresources.com/deer2008exante/downloads/DEER%200607%20Measure%20Update%20Report.pdf
5. Xcel Energy 2010-2012 CIP Triennial (Docket No. E, G002/CIP-09-198), Pages 470-477.
6. Illinois Statewide Technical Reference Manual v12.0 Vol. 3 – Residential Measures, 5.4.1 Domestic Hot Water Pipe Insulation. September 22, 2023.
7. Minnesota Power 2024-2026 Triennial Filing. Measure “Energy Analysis with Unverified Self-Install, Version No. 1.0.”

Revision History

Version	Description	Author	Date
1.0	Based on original from Nexant, cleaned up and reformatted	Joe Plummer	
2.0	Reformatted	Franklin Energy Services	7/26/2012
2.1	Updated the measure cost value/source	Franklin Energy Services	7/31/2012
2.2	Updated the measure lifetime from 15 to 13	Franklin Energy Services	7/31/2012
2.3	Changed Action to Modify, changed Table1 to use heat loss figures for all zones, delete zip code from required inputs, added confirmation of gas water heater to required inputs	Joe Plummer	11/24/13
5.0	Included Install Rates	MN Department of Commerce	2025

Residential Hot Water – Thermostatic Restriction Valve with Electric Water Heater

Measure Detail	Measure Value
Measure ID	1.04.14
Target Market Segments	Residential: Single-family and Multifamily
Target End Uses	DHW
Applicable To	Residential customers in single- and multifamily homes consisting of two units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size electric water heaters
Actions	Replace on Failure, Replace Working, New Construction
Required from Customer/Contractor	Showerhead flow rate, zip code
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	10 (Ref. 1)
Unit Participant Incremental Cost	$30 (Ref. 2)

Measure Description

This measure involves installing a thermostatically restricting shower valve that reduces the amount of excess hot shower water during warm-up periods.

Algorithms

Unit kWh Savings per Year = GPM_base x t_valve x Num_People x SPCD x 365 / SPH x EPG

Unit Peak kW Savings = Unit kWh Savings per Year / 8,760 hours

Where:

GPM_base = 1.5 gal/min, if unknown; Flow rate of showerhead.

T_valve = 0.94 minutes; Time that valve is restricted. (Ref. 3)

Num_People = Number of people per household per Table 1 (Ref. 4)

SPCD = 0.75; Showers per capita per day (Ref. 5)

SPH = Showerheads per Household per Table 2 (Ref. 5)

EPG = Energy to heat water in kWh/gal; = Density_H2O x Cp_H2O x (T_shower - T_cold) / (ReEff x C1)

Density_H2O = 8.33 lbs/gal

Cp_H2O = 1.0 Btu/lb-F

T_cold = See Table 3; Temperature of incoming water (Ref. 7). Default to average MN statewide temperature.

T_shower = 105 F; Temperature of shower water. (Ref. 5)

ReEff_electric = 0.98; Recovery efficiency of electric water heater (Ref. 6)

C1 = 3,412 Btu/kWh

Example:

Direct installation of a thermostatic restriction valve showerhead in an apartment with electric water heat located in Zone 3.

EPG (kWh/gal) = 8.33 lb/gal x 1.0 Btu/lb-°F x (105°F - 51.3°F) / (0.98 x 3,412 Btu/kWh) = 0.13378 kWh/gal

Unit kWh Savings per Year (kWh/yr) = 1.5 gal/min x 0.94 min x 2.21 x 0.75 x 365 days/yr / 1.3 x 0.13378 kWh/gal = 87.8 kWh

Peak kW Saved (kW) = 87.8 kWh / 8,760 hours = 0.010 kW

Deemed Input Tables

Table 1. People per Household (Ref. 4)

Application	Num_People
Single-Family (owner-occupied)	2.59
Multifamily (renter-occupied)	2.17
If unknown	2.38

Table 2. Showerheads per Household (Ref. 5)

Application	SPH
Single-Family (owner-occupied)	1.79
Multifamily (renter-occupied)	1.30
If unknown	1.55

Table 3. Average groundwater temperatures (Ref. 7)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3
MN statewide average, or if location unknown	**49.0**

References

1. Pacific Gas and Electric Company Work Paper PGECODHW125. Accessed 07/20/15. http://www.water.ca.gov/waterenergygrant/2014Applications/Rising%20Sun%20Energy%20Center%20%20(201418760035)/Attachment%202%20-%20Att2_WE14_RisingSun_WEGHG_3ofTotal4.pdf.
2. Based on actual cost of the SS-1002CP-SB Ladybug Water-Saving Shower-Head adapter from Evolve showerheads. $29.95. Accessed 07/20/15. http://www.amazon.com/Evolve-Showerheads-SS-1002CP-SB-Water-Saving-Shower-Head/dp/B0017YXIKC.

3. This is a calculated value, based on information provided by the source in footnote 1 (shower length = 7.8 minutes) and Water and Energy Wasted During Residential Shower Events: Findings from a Pilot Field Study of Hot Water Distribution Systems by Jim Lutz, which concluded that 30% of shower water wasted and about 40% of energy used in the shower is wasted. 7.8 minutes x 30% x 40% = 0.94.
4. U.S. Census Bureau, Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates) for the state of MN. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=table.
5. Illinois Technical Reference Manual, 6/1/12. Pages 419-426. Accessed 07/20/15. http://ilsagfiles.org/SAG_files/Meeting_Materials/2012/June%2026,%202012%20Meeting/Illinois_Statewide_TRM_Final_Review.pdf.
6. Showerhead and Faucet Aerator Metering Study, Cadmus and Opinion Dynamics. June 2013.
7. US DOE Building America Program. Building America Analysis Spreadsheet, Standard Benchmark DHW Schedules http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html.

Revision History

Version	Description	Author	Date
1.0	Measure created	Franklin Energy Services	11/10/2015
1.1	Added conversion factor for gas	Franklin Energy Services	12/16/2015

Residential Hot Water – Thermostatic Restriction Valve with Gas Water Heater

Measure Detail	Measure Value
Measure ID	1.04.15
Target Market Segments	Residential: Single-family and Multifamily
Target End Uses	DHW
Applicable To	Residential customers in single- and multifamily homes consisting of two units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size electric water heaters
Actions	Replace Working, Replace on Fail, New Construction
Required from Customer/Contractor	Showerhead flow rate, zip code
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	10 (Ref. 1)
Unit Participant Incremental Cost	$30 (Ref. 2)

Measure Description

This measure involves installing a thermostatically restricting shower valve that reduces the amount of excess hot shower water during warm-up periods.

Algorithms

Unit Dth Savings per Year = GPM_base x t_valve x Num_People x SPCD x 365 / SPH x EPG

Where:

GPM_base = 1.5 gal/min, if unknown; Flow rate of showerhead.

T_valve = 0.94 minutes; Time that valve is restricted. (Ref. 3)

Num_People = Number of people per household per Table 1 (Ref. 4)

SPCD = 0.75; Showers per capita per day (Ref. 5)

SPH = Showerheads per Household per Table 2 (Ref. 5)

EPG = Energy to heat water in Dth/gal; = Density_H2O x Cp_H2O x (T_shower - T_cold) / (ReEff x C1)

Density_H2O = 8.33 lbs/gal

Cp_H2O = 1.0 Btu/lb-F

T_cold = See Table 3; Temperature of incoming water (Ref. 7). Default to average MN statewide temperature.

T_shower = 105 F; Temperature of shower water. (Ref. 5)

ReEff_gas = 0.76; Recovery efficiency of gas water heater (Ref. 6)

C1 = 1,000,000 Btu/Dth

Example:

Direct installation of a thermostatic restriction valve showerhead in an apartment with gas water heat located in Zone 3.

EPG (kWh/gal) = 8.33 lb/gal x 1.0 Btu/lb-°F x (105°F - 51.3°F) / (0.76 x 1,000,000 Btu/Dth) = 0.000589 Dth/gal

Unit Dth Savings per Year (Dth/yr) = 1.5 gal/min x 0.89 min x 2.21 x 0.75 x 365 days/yr / 1.3 x 0.000589 Dth/gal = 0.366 Dth

Deemed Input Tables

Table 1. People per Household (Ref. 4)

Application	Num_People
Single-Family	2.59
Multifamily*	2.17
Avg MN Statewide, or if unknown	2.38

* Includes buildings with 2+ units and townhomes

Table 2. Showerheads per Household (Ref. 5)

Application	SPH
Single-Family	1.79
Multifamily*	1.30
If unknown	1.55

* Includes buildings with 2+ units and townhomes

Table 3. Average groundwater temperatures (Ref. 7)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3
MN statewide average, or if location unknown	**49.0**

References

1. Pacific Gas and Electric Company Work Paper PGECODHW125. Accessed 07/20/15. http://www.water.ca.gov/waterenergygrant/2014Applications/Rising%20Sun%20Energy%20Center%20%20(201418760035)/Attachment%202%20-%20Att2_WE14_RisingSun_WEGHG_3ofTotal4.pdf.
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3. This is a calculated value, based on information provided by the source in footnote 1 (shower length = 7.8 minutes) and Water and Energy Wasted During Residential Shower Events: Findings from a Pilot Field Study of Hot Water Distribution Systems by Jim Lutz, which concluded that 30% of shower water wasted and about 40% of energy used in the shower is wasted. 7.8 minutes x 30% x 40% = 0.94.
4. U.S. Census Bureau, Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates) for the state of MN. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=table.
5. Illinois Technical Reference Manual, 6/1/12. Pages 419-426. Accessed 07/20/15. http://ilsagfiles.org/SAG_files/Meeting_Materials/2012/June%2026,%202012%20Meeting/Illinois_Statewide_TRM_Final_Review.pdf.
6. Showerhead and Faucet Aerator Metering Study, Cadmus and Opinion Dynamics. June 2013.
7. US DOE Building America Program. Building America Analysis Spreadsheet, Standard Benchmark DHW Schedules http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html.

Revision History

Version	Description	Author	Date
1.0	Measure created	Franklin Energy Services	11/10/2015

Residential Hot Water – Indirect Water Heaters

Measure Detail	Measure Value
Measure ID	1.04.16
Target Market Segments	Residential
Target End Uses	Water Heating
Applicable To	Residential customers in single- and multifamily homes consisting of two units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size gas water heaters
Actions	Replace Working, Replace on Fail, New Construction
Required from Customer/Contractor	Confirmation of gas water heater, tank size in gallons, single-family or multifamily*, project location (county) * Includes buildings with two or more units and townhomes
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	15 (Ref. 4)
Unit Participant Incremental Cost	$988.50 (Ref. 5)

Measure Description

Indirect water heaters are applicable to any indirectly fueled water heater, and must be paired with a high-efficiency boiler. In addition, qualifying indirect water heaters must be whole-house units or used for domestic water heating.

Unlike other water heaters, indirect water heaters use a boiler as the heat source. The water heater may also have a direct energy source for non-heating seasons when the boiler is shut off and thus not able to meet the water heating demands

Algorithms

Unit Dth Savings per Year = $[Energy_{HEATWATER} \times (1/RE_{BASE} - 1/E_{C,EE}) + (UA_{BASE} / RE_{BASE} - UA_{EE}/E_{C,EE}) \times (T_{SET} - T_{ROOM}) \times 8{,}760] / 1{,}000{,}000$

Where:

$Energy_{HEAWATER}$ = SpecificHeat × Density × Gallons / Person × People × 365 Days / Yr × (T_{SET} – T_{COLD})

SpecificHeat = 1.0 btu/(lb·°F)

Density = 8.34 lbs/gal

Gallons/Person = See Table 2; daily hot water usage per person.

People = See Table 3; number of people per household.

T_{SET} = 120˚F (Ref. 7)

T_{COLD}	= See Table 1; average groundwater temperature. Default to average MN statewide temperature.
RE_{BASE}	= base water heater recovery efficiency, Default = 0.77 (if efficiency is unknown) (Ref. 7)
$E_{C,EE}$	= Combustion efficiency of energy-efficient boiler used to heat indirect water heater, Default = 0.95 (if efficiency is unknown)
UA_{BASE}	= See Table 4; Overall heat loss coefficient of base tank type water heater (Btu/hr-°F)
UA_{EE}	= See Table 4; Overall heat loss coefficient of indirect water heater storage tank (Btu/hr-°F)
T_{ROOM}	= 60˚F (Ref. 8)
1,000,000	= Conversion from Btu to Dth

Example:

A single-family customer in Zone 2 has installed a 45 Gal. indirect water heater connected to a high-efficiency boiler (EC = 0.95) to replace their previous gas-fired storage water heater.

$Energy_{HeatWater}$ = 1.0 btu / lb·°F × 8.34 lbs / gal × 20.4 gal / person × 2.59 People × 365 Days / Yr × (120°F - 49.1°F) = 11,403,419 Btu / yr

Unit Dth Savings per Year = [11,403,419 Btu / yr x (1/0.77 – 1/0.95) + (7.57 Btu/hr-°F /0.77 – 6.18 Btu/hr-°F /0.95 x (120°F – 60°F) x 8,760] / 1,000,000 = 4.6 Dth

Deemed Input Tables

Table 1. Average groundwater temperatures (Ref. 2)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3
MN statewide average, or if location unknown	**49.0**

Table 2. Daily Hot Water Usage per Person (Ref. 1)

Application	(Gal/day)/person
Single-Family	20.4
Multifamily*	18.7
If unknown	19.6

Table 3. People per Household (Ref. 3)

Application	Num_People
Single-Family	2.59
Multifamily*	2.17
If unknown	2.38

Table 4. Typical Values for UA based on size (Ref. 6)

Rated Storage Volume	UA, Baseline (gas storage water heater) (Btu/hr-°F)	UA, efficient (boiler) (Btu/hr-°F)
<40	6.88	4.79
40-79	7.57	6.18
80-120	13.80	7.43

Notes

This measure produces savings through both upgrading from the water heater recovery efficiency (RE) to the boiler combustion efficiency (Ec), and from the reduction in standby losses (represented by UA values for water heaters and boilers). Recommend using actual baseline water heater RE and boiler Ec. If the baseline RE is unknown, an average RE is provided by examining current AHRI data.

References

1. Daily hot water usage is based on CEE's tankless water heater field study in Minneapolis/St. Paul (2008-2010); Supported by Focus on Energy's Residential Deemed Savings Review, page 4.
2. US DOE Building America Program. Building America Analysis Spreadsheet, Standard Benchmark DHW Schedules. http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html.
3. U.S Census Bureau, Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates) for the state of MN. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=table.
4. Natural Gas Energy Efficiency Potential in Massachusetts. April 22, 2009. http://ma-eeac.org/wordpress/wp-content/uploads/5_Natural-Gas-EE-Potenial-in-MA.pdf
5. Average of Mean and Median costs using both approaches in table 1-4 from New York Statewide Residential Gas High-Efficiency Heating Equipment Programs. August 5, 2014 https://www.nationalfuelforthought.com/wp-content/uploads/2018/03/August-2014-New-York-Statewide-Residential-Gas-High-Efficiency-Heating-Equipment-and-National-Fuel-Gas-Distribution-Corporations-Residential-Rebate-Program-Impact-Evaluation.pdf
6. Based on average value from AHRI data for indirect water heaters. https://www.ahridirectory.org/Search/QuickSearch?category=8&searchTypeId=3&producttype=19
7. Based on average value from AHRI data for gas storage water heaters. https://www.ahridirectory.org/Search/QuickSearch?category=8&searchTypeId=3&producttype=15
8. The ambient temperature is assumed to be 60°F, based on the estimated temperature of a basement where the water heater is assumed to be located.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Cadmus	10/2018

Residential Hot Water – Desuperheater

Measure Detail	Measure Value
Measure ID	1.04.17
Target Market Segments	Residential
Target End Uses	Water Heating
Applicable To	Residential customers in single- and multifamily homes consisting of two units or more (this includes 2-, 3-, and 4-plexes and townhomes)
Actions	Replace Working, Replace on Fail, New Construction
Required from Customer/Contractor	Existing DHW tank volume (gallons), fuel type, and UEF.
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	13 Years, see Measure Description for further detail
Unit Participant Incremental Cost	Actuals if available, default of $500

Measure Description

This measure includes the savings resulting in the installation of a desuperheater on new or existing storage-type electric resistance, gas, oil or electric heat pump water heaters in residential and multifamily buildings. The existing or new water heater does not need to meet any qualifying UEF threshold. Ideally the actual UEF is known but default values are given in this measure if unknown. Desuperheaters are typically installed as part of a ground source heat pump installation, where the desuperheater provides preheating to the DHW tank, effectively meeting a portion of the DHW load from waste heat from the GSHP system. Desuperheaters installed as part of other HVAC systems are allowable (Air to Water HPs, or other applicable systems). While typically installed as part of a GSHP installation (EUL 25 years), the Desuperheater supports energy savings from the DHW unit, therefore the EUL of this measure is aligned with the EUL of the DHW unit. The savings outlined within this measure could be claimed for a second EUL interval during the incentivized replacement of the DHW unit if the desuperheater is in good functional order.

Algorithms

Desuperheater Installed on Electric Water Heater

$$\text{Unit kWh Savings per Year} = \%\text{DHWDisplaced} \times \text{Energy}_{\text{HEATWATER}} \times (1/\text{UEF}) / 3{,}412$$

$$\text{Unit Peak kW Savings} = (\text{Unit kWh Savings per Year}) / 8{,}760$$

Desuperheater Installed on Gas or Oil Water Heater

$$\text{Unit Dth Savings per Year} = \%\text{DHWDisplaced} \times \text{Energy}_{\text{HEATWATER}} \times (1/\text{UEF}) / 1{,}000{,}000$$

Where:

$Energy_{HEATWATER}$ = SpecificHeat × Density × Gallons per Day × 365 Days / Yr × (T_{SET} – T_{COLD}). Given deemed inputs to this calculation below, resulting deemed value for this variable is 11,109,139 Btu for single family and 9,401,703 for Multifamily

SpecificHeat = 1.0 btu / (lb·°F)

Density = 8.34 lbs / gal

GPD = Gallons of hot water use per day, see Table 1

T_{SET} = 120˚F (Ref. 7)

T_{COLD} = See Table 1; average groundwater temperature. Average of 49.0 used in deemed values (Ref 4).

UEF See Table 2 and 3; existing or new water heater efficiency based on type, tank size and draw pattern. Actual UEF if known. If draw pattern is unknown, assume medium. V = rated volume of DHW tank in gallons. If volume is unknown, assume 50 gallons.

3,412 = 3,412 Btu / kWh

1,000,000 = 1,000,000 Btu / Dth

%DHWDisplaced = Percentage of total DHW load that the HVAC system will provide through Desuperheater. Actuals if known, or assume 30% for both single family and multifamily (Ref 10).

Example

A desuperheater is installed as part of a GSHP installation project, connected to an existing electric 50 gallon DHW storage water heater with unknown UEF. The UEF will be calculated by electric storage type, 50 gallon volume and medium draw pattern via Table 2 defaults. The average MN ground water temperature given in Table 1 will be used in the calculations.

UEF_min = 0.9307 - (0.0002* 50 gallons) = 0.93

$Energy_{HeatWater}$ = 1 × 8.34 × 51.4 × 365 × (120 - 49.0) = 11,109,139 Btu/yr

Unit kWh Savings per Year = (30% x 11,109,139 x (1/0.93)) / 3,412 = 1,050 kWh

Unit Peak kW Savings per Year = 1,050 / 8,760 = 0.12 kW

Deemed Input Tables

Table 1. Average groundwater temperatures by zone (Ref. 4) , and daily hot water usage in gallons by zone and residential type (Ref. 6, 9, see Assumptions)

Location	T_{IN} (°F)	Single-Family	Multifamily
		GPD	GPD
Zone 1 (Northern MN)	46.5	52	44
Zone 2 (Central MN)	49.1	51.4	43.5
Zone 3 (Twin Cities/Southern MN)	51.3	50.8	43
MN statewide average, or if location unknown	**49.0**	**51.4**	**43.5**

Table 2. Default Electric Resistance and Gas DHW UEFs (Ref. 3)

Product Class	Rated Storage Volume	Draw Patten	Uniform Energy Factor (V = rated volume of DHW tank in gallons)
Electric Storage Water Heaters	≥ 20 gallons and ≤ 55 gallons	Very Small	0.8808 – (0.0008 × V)
		Low	0.9254 – (0.0003 × V)
		Medium	0.9307 – (0.0002 × V)
		High	0.9349 – (0.0001 × V)
	> 55 gallons and ≤ 100 gallons	Very Small	1.9236 – (0.0011 × V)
		Low	2.0440 – (0.0011 × V)
		Medium	2.1171 – (0.0011 × V)
		High	2.2418 – (0.0011 × V)
Electric Instantaneous Water Heaters	≤12kW and ≤2 gal	All other	UEF = 0.91
		High	UEF = 0.92
Gas Storage Water Heaters	≥20 gal and ≤55 gal	Very Small	0.3456 – (0.0020 x V)
		Low	0.5982 – (0.0019 x V)
		Medium	0.6483 – (0.0017 x V)
		High	0.6920 – (0.0013 x V)
	>55 gal and ≤100 gal	Very Small	0.6470 – (0.0006 x V)
		Low	0.7689 – (0.0005 x V)
		Medium	0.7897 – (0.0004 x V)
		High	0.8072 – (0.0003 x V)
Gas Instantaneous Water Heaters	All	Very Small	0.80
		Low	0.81
		Medium	0.81
		High	0.81
Residential Oil Storage Water Heater	≤50 gallon tanks	Very small	UEF = 0.2509 – (0.0012 x V)
		Low	UEF = 0.5330 – (0.0016 x V)
		Medium	UEF = 0.6087 – (0.0016 x V)
		High	UEF = 0.6815 – (0.0014 x V)

Table 3. Default Heat Pump Water Heater UEFs (Ref. 7)

	Type of Equipment	Energy Factor
Heat Pump Electric Storage Water Heaters	Integrated Heat Pump Water Heater, 240 Volt / 30 Amp Circuit	UEF 3.30
	Heat Pump Water Heater, 120 Volt / 15 Amp Circuit	UEF 2.20
	Split System Heat Pump Water Heater	UEF 2.20

Methodology and Assumptions

Gallons per day (GPD) values were determined based on the following assumptions and resources:

1. This measure adopts a method outlined in the Wisconsin Technical Reference Manual to determine gallons of hot water used per day given residential occupant count (Ref. 9). An equation for gallons per day of hot water usage found in a Florida Solar Energy Study (Ref. 9) forms the basis of the figure, adapted with Minnesota data.

   HWgpd = 22 x (Occupancy x Fmix) + CW + DW

- Where Occupancy represents the average occupants per household. A Minnesota state average value of 2.59 occupants per home was used for a single-family home, and 2.17 occupants per home was used for a multifamily home (Ref. 6).
- Where Fmix = 1 – (Tset – Tmix) / (Tset – Tmains) = 1 – (120-105) / (120 – 49) = 0.79. Where Tmains has been defined as the ground temperature of the climate zone (see Table 1, The average of all zones has been used = 49.0). Tset in this example represents the efficient case setting. Hot water use consists of two components: unmixed and mixed use. Unmixed use, primarily for clothes washers and dishwashers, is direct draw from the water heater and does not vary with stored hot water temperature. Mixed use, for showers and sinks, is delivered to the fixture at 105°F, so the total draw from the water heater varies with stored water temperature.
- Where CW is clothes washer gallons of hot water per day. CW gallons per cycle is defined as 12.7 gallons per cycle for an average sized ENERGY STAR rated appliance (Ref. 11), half of which is hot water. Gallons per day = (gallons per cycle x 50%) x (123+61 x occupancy)/365 = 4.9 gallons single family, 4.4 gallons multifamily.
- Where DW is dishwasher gallons of hot water per day (defined as 100% of rated gallons per cycle = 3.2 gallons per cycle). Gallons per cycle determined by ENERGY STAR criteria v7 for a standard residential unit.
- When the above metrics are applied to the equation using zone 3 metrics for example, the GPD by residence type results in the following equation, shown in Table 1.

  Single-Family GPD = 22 x (2.59 x 0.79) +4.9 + 3.2 = 51.4 GPD in zone 3 efficient case

  Multifamily GPD = 22 x (2.17 x 0.79) + 2.1 + 4.4 = 43.5 GPD in zone 3 efficient case

References

1. US DOE Building America Program. Building America Analysis Spreadsheet, Standard Benchmark DHW Schedules http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html.

2. NOTICE OF PROPOSED RULEMAKING TECHNICAL SUPPORT DOCUMENT ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters. Chapter 8. US Department of Energy. November 23, 2009.
3. Code of Federal Regulations Section 430 Part 32. Energy and water conservation standards and their compliance dates. https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8, accessed 9/28/17.
4. Interpolated values from Table 38, Ohio Technical Reference Manual. October 15, 2009. Page 52.
5. U.S. Census Bureau, Selected Housing Characteristics 2010 American Community Survey 1-Year Estimates) for the state of MN. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_1YR_DP04&prodType=table.
6. This factor accounts for a mix of water heater locations (assumes 64% are in conditioned space, Ref. 9) and that no electric savings will occur in the heating season (50% of the year) if the space heat is electric. 0.68 = 1 - (64% x 50%).
7. This factor accounts for the increase in gas usage that results from the water heater being located in conditioned space. 1.3 = 6.6/5.0 x 50%, where 6.6 kWh represents the increase in daily space heating usage and 5.0 kWh represents the daily DHW usage and 50% accounts for the heating season being approximately half of the year. *The Impact of Heat Pump Water Heaters on Whole-House Energy Consumption*, Canadian Mortgage and Housing Corporation.
8. ENERGY STAR® Water Heater Product Criteria, version 5. Published July 18, 2022.https://www.energystar.gov/products/water_heaters/residential_water_heaters_key_product_criteria, and https://www.energystar.gov/products/spec/residential_water_heaters_specification_version_5_0_pd
9. Florida Solar Energy Center. Estimating Daily Domestic Hot-Water Use in North American Homes. June 30, 2015. http://www.fsec.ucf.edu/en/publications/pdf/FSEC-PF-464-15.pdf
10. Henderson, Frontier Energy. Prepared for NYSERDA. White Paper: Savings Calculations for Residential Air Source Heat Pumps. June 16, 2020. https://dps.ny.gov/system/files/documents/2025/05/white-paper_savings-calculations-for-residential-ashp.-eflh-and-seasonal-efficiency.pdf

Revision History

Version	Description	Author	Date
5.0	New measure developed in coordination with updates to Res HVAC GSHP measure.	Cadmus	10/1/2025

Plug Load and Demand Management

Residential Plug Load – Load Management Technologies

Measure Detail	Measure Value
Measure ID	1.08.01
Target Market Segments	Residential
Target End Uses	HVAC, DHW
Applicable To	Residential customers in single-family homes
Actions	Modify, Replace Working, Replace on Fail, New Construction
Required from Customer/Contractor	Load control technology installed (A/C cycling, electric heat cycling, electric water heater curtailment, electric thermal storage for space heating), installation location (zone 1, 2 or 3), average quantity events per year.
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	See Table 4
Unit Participant Incremental Cost	See Table 4

Measure Description

This measure includes the following residential load management technologies: A/C cycling, electric heat cycling, electric water heater curtailment, and electric thermal storage for space heating. Load management programs are primarily intended to reduce peak electrical demand and/or shift energy use to off-peak hours. Therefore, the primary impact is peak kW savings, though secondary kWh savings also result except from electric thermal storage.

Algorithms

Unit kWh Savings per Year = (Average Qty of Event per Year) x (kWh Savings per Event)

Unit Peak kW Savings = Peak kW Savings per Event

Unit Dth Savings per Year = 0

Where:

Average Qty of Events per Year = average number of load control events during a typical year, provided by utility

kWh Savings per Event = Modeled net kWh savings per load control event per installation, including snapback (refer to Tables 1-3.). (Ref. 1,5)

Peak kW Savings per Event = Modeled peak kW savings per load control event per installation (refer to Tables 1-3). (Ref. 1,5)

Example:

An A/C cycling device is installed at a single-family home in Zone 3. Based on historical experience and load growth projections, the utility expects that on average, two load control events will occur in a typical year. From Table 3.

Unit kWh Savings per Year = 2 x 0.71 = 1.42 kWh

Unit Peak kW Savings = 0.30 kW

Deemed Input Tables

Table 1. Modeled kWh and kW savings per Load Control Event per Unit, Zone 1 (Ref. 1)

Technology	kWh Savings	Summer kW Savings	Winter kW Savings
A/C Cycling	0.01	0.07	0.00
Electric Heat Cycling	2.54	0.00	2.00
DHW Curtailment	0.58	0.54	0.76
Electric Thermal Storage	0.00	0.00	26.90
Smart Thermostat Load Management	2.00	1.11	0.00

Table 2. Modeled kWh and kW savings per Load Control Event per Unit, Zone 2 (Ref. 1)

Technology	kWh Savings	Summer kW Savings	Winter kW Savings
A/C Cycling	0.65	0.23	0.00
Electric Heat Cycling	1.62	0.00	1.27
DHW Curtailment	0.43	0.49	0.76
Electric Thermal Storage	0.00	0.00	24.00
Smart Thermostat Load Management	2.00	1.11	0.00

Table 3. Modeled kWh and kW savings per Load Control Event per Unit, Zone 3 (Ref. 1)

Technology	kWh Savings	Summer kW Savings	Winter kW Savings
A/C Cycling	0.71	0.30	0.00
Electric Heat Cycling	3.11	0.00	1.42
DHW Curtailment	0.40	0.60	0.84
Electric Thermal Storage	0.00	0.00	22.43
Smart Thermostat Load Management	2.00	1.11	0.00

Table 4. Default Incremental Cost (Equipment plus Installation) by Technology

Technology	Measure Lifetime (Ref 2,5)	Incremental Cost (Ref 2,3,5)
A/C Cycling	15	$200
Electric Heat Cycling	15	$200
DHW Curtailment Summer	15	$200
DHW Curtailment Winter	15	$200
Electric Thermal Storage	15	$11,700
Smart Thermostat Load Management	5	$0

Methodology and Assumptions

Default incremental costs include equipment and installation only. If the program includes meter installation, some portion of these costs should be included in a cost-effectiveness analysis.

Energy and demand impacts are based on simulation results by Michaels Energy using BEopt and EnergyPlus for a median residential home as defined in Ref. 1 in Zones 1, 2, and 3.

- A demand response event was simulated on July 15 and the air conditioning was cycled every 15 minutes during the event, which lasted for 7 hours, from 1 pm to 8 pm. A domestic water heater demand response event was also simulated on these homes on both winter (January 28) and summer peak days. The winter demand event occurred from 4 pm to 7 pm. TMY3 (typical meteorological year, third collection) weather data was used in all of the simulations using the designated cities for each climate zone (Minneapolis, Saint Cloud, Duluth). The summer event schedule was selected based on the data provided by the two utilities in this study, which showed that 1 pm to 8 pm was the most common control period. The winter event schedule was selected based on the fact that the IOU triggers events on winter afternoons and the G&T Co-op's website shows that their winter loads peak in the late afternoon and early evening hours. Although there are a variety of control methods, 50% cycling of air conditioners was used in this model because it is the most commonly used scheme in Minnesota. Load curtailment during the event was used for domestic water heaters, since that is the most common form of control for those systems, according to the websites of both of the utilities. July 15 was selected as the summer peak day because the TMY3 weather data showed that the outdoor air temperature was near the annual peak and the following day had a nearly identical temperature profile in order to properly evaluate snapback effects that may linger into the next day after a demand response event. (Ref. 1)
- January 28th was selected for the winter event (except in Minneapolis; see footnote) because it was a typical winter day in the TMY3 weather data and the following day's temperature profile was very similar.
- TMY3 data were used for all simulations. Duluth was selected for Zone 1; St. Cloud was selected for Zone 2; and Minneapolis was selected for Zone 3.
- A/C cycling
  - A load control event was simulated on July 15 between 1 pm and 8pm. The A/C was cycled every 15 minutes during the event.
- Domestic hot water (DHW) curtailment
  - Load control events were simulated on both winter (January 28 except for Zone 3) and summer (July 15) peak days. The winter demand event occurred from 4 pm to 7 pm. The summer demand event occurred from 1 pm to 8 pm.
  - The weather file data for Minneapolis on January 28 contained temperatures well below the design temperature for Minneapolis, while the other two climates had temperatures above their design temperatures on that data. Therefore, January 7 was selected for Minneapolis

as a suitable replacement since it had a similar daily load profile at more typical temperatures with the following day (January 8) having a similar load profile.

- Electric heat cycling
  - Winter demand events occurred from 1 pm to 8 pm on January 28 except for Zone 3.
- Electric thermal storage
  - Days were selected to match the heating design temperatures in the TRM: Zone 1: -22F, Zone 2: -16.5F, Zone 3: -14.5F. In each case, the following day had a similar load profile.

References

1. Michaels Energy. *Demand Response and Snapback Impact Study.* August 2013. Prepared for Minnesota Department of Commerce, Division of Energy Resources under a grant through the Conservation Applied Research and Development (CARD) program. https://www.cards.commerce.state.mn.us/CARDS/security/search.do?method=showPoup&documentId={0E17848D-92FB-4522-B02B-EABAE9D71BE9}&documentTitle=85669&documentType=6
2. Average of pricing data from two Minnesota utilities. Includes equipment and installation costs. Does not include metering costs.
3. Efficiency Maine. *Energy Efficient Heating Options: Pilot Projects and Relevant Studies.* April 8, 2013. http://www.efficiencymaine.com/docs/EMT_Energy-Efficient-Heating-Options-Report_2013_4_8.pdf, accessed February 11, 2014. Average cost of electric thermal storage furnace = $13,000.
4. Web research on 2.11.14 and 2.12.14. Average price of 25 kW electric forced-air furnace = $1,300. Models: WMA60-25 (sold under names of Hamilton Home Products and Winchester 81,912 BTU 5 TON Multi-Position Electric Furnace); 21D25 (Nortron D-series 25 kW). Retailers: Northern Tool, Ecco Supply, Home Depot, Lowes.

Revision History

Version	Description	Author	Date
1.0	New measure	Joe Plummer	2/11/14
4.2	Updated Measure to review assumptions and methodology around A/C Cycling and added a Smart Thermostat Load Management Measure	MN Department of Commerce	9/1/2024

Residential Plug Load – Tier 1 Advanced Power Strips

Measure Detail	Measure Value
Measure ID	1.08.02
Target Market Segments	Residential
Target End Uses	Misc. Electric Loads
Applicable To	Residential customers in single-family homes, duplexes, townhomes, and multifamily homes (including 3- and 4-family homes) with audio-visual home entertainment systems
Actions	Modify
Required from Customer/Contractor	n/a
Measure Energy Type	Electric
Unit kWh Savings per Year	67.6 kWh
Unit Peak kW Savings	0.009 kW
Unit Dth Savings per Year	0
Measure Lifetime (years)	7 years (Ref. 2)
Unit Participant Incremental Cost	$20 (Ref. 6)

Measure Description

This measure relates to tier 1 advanced power strips, which are multi-plug surge protector power strips with the ability to automatically disconnect specific connected loads depending upon the power draw of a control load, also plugged into the strip. Power is disconnected from the switched (controlled) outlets when the control load power draw is reduced below a certain adjustable threshold, thus turning off the appliances plugged into the switched outlets. By disconnecting, the standby load of the controlled devices, the overall load of a centralized group of equipment (i.e. entertainment centers and home office) can be reduced. Uncontrolled outlets are also provided that are not affected by the control device and so are always providing power to any device plugged into it.

Algorithms

Unit kWh Savings per Year = kWh_{BASE} x SF x Install Rate

Unit Peak kW Savings = (Unit kWh Savings per Year) x CF / HOU

Where:

kWh_{BASE} = 356 kWh; yearly average consumption of baseline power strip (Ref. 3)

SF = 0.19; savings factor (Ref. 4)

CF = 0.83; coincidence factor (Ref. 5)

HOU = 6,588; hours of use (Ref. 4)

Install Rate = The percentage of rebated equipment that is assumed to be installed

Example:

Directly installing a tier 1 advanced power strip in a single-family home.

Unit kWh Savings = 356 kWh x 0.19 x 100% = 67.6 kWh

Unit kW Savings = 67.6 kWh x 0.83 / 6,588 = 0.009 kW

Deemed Input Tables

Table 1. Install Rate based on Delivery Method

Delivery Method	Install Rate	Reference
Retail	71%	7
Direct Install	100%	-
Virtual Assessment + Unverified Self-Install	75%	8
Requested Efficiency Kit	NA	-
Distributed Efficiency Kit	91%	7
Distributed School Efficiency Kit	NA	-

Methodology and Assumptions

The estimated electric energy savings for this measure represent average savings per advanced power strip installed. The baseline consumption comes from a recent study measuring pre- and post-install consumption in Wisconsin homes receiving tier 2 advanced power strips (Ref. 3). The savings factor comes from a separate study of tier 1 power strips, showing baseline consumption of 391.5 kWh and savings of 75 kWh, or a savings factor of 19%.

References

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Revision History

Version	Description	Author	Date
1.0	Document Created	Franklin Energy Services	9/7/17
2.0	Updated savings based on more recent data	Cadmus	10/2018
5.0	Included Install Rates	MN Department of Commerce	2025

Residential Plug Load – Tier 2 Advanced Power Strips

Measure Detail	Measure Value
Measure ID	1.08.03
Target Market Segments	Residential
Target End Uses	Misc. Electric Loads
Applicable To	Residential customers in single-family homes, duplexes, townhomes, and multifamily homes (including 3- and 4-family homes) with audio-visual home entertainment systems
Actions	Modify
Required from Customer/Contractor	n/a
Measure Energy Type	Electric
Unit kWh Savings per Year	117.5 kWh
Unit Peak kW Savings	0.015 kW
Unit Dth Savings per Year	0
Measure Lifetime (years)	8 years (Ref. 1)
Unit Participant Incremental Cost	$70 (Ref. 1)

Measure Description

Tier 2 advanced power strips (APS) use an external sensor paired with a configurable countdown timer to manage both active and standby power loads for controlled devices in a complete system. Tier 2 APS may operate either with or without a master control socket. Those without a master control socket sense power of all devices connected to the controlled sockets; those with a master control socket sense power for the device connected to the control socket. The external sensor of a Tier 2 APS may utilize an infrared-only sensor, or it may utilize a "multi-sensor" which detects both infrared (IR) remote control signals and motion to determine device inactivity and deliver additional savings as compared to a Tier 1 APS device. Both versions of external sensor use IR filtering to prevent inappropriate switching events which may have otherwise resulted from natural interference such as sunlight or light bulbs.

Algorithms

Unit kWh Savings per Year = kWh_{BASE} x SF x Install Rate

Unit kW Savings per Year = (Unit kWh Savings per Year) x CF / HOU

Where:

kWh_{BASE}	= 356 kWh; yearly average consumption of baseline power strip (Ref. 2)
SF	= 0.33; savings factor (Ref. 2)
CF	= 0.83; coincidence factor (Ref. 5)
HOU	= 6,588; hours of use (Ref. 4)
Install Rate	= The percentage of rebated equipment that is assumed to be installed

Example:

Directly installing a tier 2 advanced power strip in a single-family home.

Unit kWh Savings per Year = 356 kWh x 0.33 x 100% = 117.5 kWh

Unit kW Peak Savings = 117.5 kWh x 0.83 / 6,588 = 0.015 kW

Deemed Input Tables

Table 1. Install Rate based on Delivery Method

Delivery Method	Install Rate	Reference
Retail	71%	5
Direct Install	100%	-
Virtual Assessment + Unverified Self-Install	75%	6
Requested Efficiency Kit	NA	-
Distributed Efficiency Kit	91%	5
Distributed School Efficiency Kit	NA	-

The estimated electric energy savings for this measure represent average savings per advanced power strip installed. The baseline consumption and savings factor come from a recent study measuring pre- and post-install consumption in Wisconsin homes receiving tier 2 advanced power strips (Ref. 3).

References

1. "Electricity Savings Opportunities for Home Electronics and Other Plug-In Devices in Minnesota Homes", Energy Center of Wisconsin, May 2010.
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5. Illinois Statewide Technical Reference Manual v12.0 Vol. 3 – Residential Measures, 5.2.2 Tier 2 Advanced Power Strips (APS) – Residential Audio Visual. September 22, 2023.
6. Minnesota Power 2024-2026 Triennial Filing. Measure "Energy Analysis with Unverified Self-Install, Version No. 1.0."

Revision History

Version	Description	Author	Date
1.0	Document Created	Franklin Energy Services	10/15/15
2.0	Updated savings based on more recent data	Cadmus	10/2018
5.0	Included Install Rates	MN Department of Commerce	2025

Appliances

Residential Appliances – Clothes Washers

Measure Detail	Measure Value
Measure ID	1.09.01
Target Market Segments	Residential
Target End Uses	Plug Loads
Applicable To	Residential customers in single-family homes and multifamily housing of 2 or more units (including 3- and 4-family homes, duplexes, townhomes and apartment complexes)
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Washer capacity in ft3, electric or gas water heating, electric or gas drying, confirmation of ENERGY STAR performance criteria met
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	11 (Ref. 1)
Unit Participant Incremental Cost	$28.79 for top loading $210.12 for front loading $163.49 for unknown (Ref. 11)

Measure Description

This measure includes replacement of failed or working clothes washer in existing homes and multifamily common areas with clothes washers that meet current ENERGY STAR performance criteria, or installation of a clothes washer that meets current ENERGY STAR performance criteria in a new home or multifamily common area. Compliant efficient appliances do not need to be ENERGY STAR qualified through the EPA program but would need to meet the ENERGY STAR performance criteria specified within this measure.

Algorithms

$$\text{Unit kWh Savings per Year} = [(Cap/IMEF_{BASE} \times N) \times (CW_{BASE} + (DHW_{BASE} \times \%Elec_{DHW}) + (Dry_{BASE} \times \%Elec_{DRY}))] - [(Cap/IMEF_{EE} \times N) \times (CW_{EE} + (DHW_{EE} \times \%Elec_{DHW}) + (Dry_{EE} \times \%Elec_{DRY}))]$$

$$\text{Unit Peak kW Savings} = \text{Unit kWh Savings per Year} / \text{Hours} \times CF$$

$$\text{Unit Dth Savings per Year} = [[(Cap/IMEF_{BASE} \times N) \times (DHW_{BASE} \times (1 - \%Elec_{DHW})) + Dry_{BASE} \times (1 - \%Elec_{DRY}))] - [(Cap/IMEF_{EE} \times N) \times (DHW_{EE} \times (1- \%Elec_{DHW})) + Dry_{EE} \times (1 - \%Elec_{DRY}))]] \times 0.003412$$

Where:

Cap	= Clothes washer capacity (ft^3); If unknown, assume 3.45 ft^3 (Ref. 12)
$IMEF_{BASE}$	= See Table 1; Baseline product Integrated Modified Energy Factor (ft^3/kWh/cycle)
$IMEF_{EE}$	= See Table 2; Efficient product Integrated Modified Energy Factor (ft^3/kWh/cycle)
N	= For SF: 258 cycles/yr (Ref. 2); for MF: 1241 cycles/yr (Ref. 14)
CW_{BASE}	= 7% (Ref. 4); Percentage of total electric energy consumption for clothes washer operation, baseline
CW_{EE}	= 6%(Ref. 4), Percentage of total electric energy consumption for clothes washer operation, efficient
DHW_{BASE}	= 33%(Ref. 4); Percentage of total energy consumption for water heating, baseline
DHW_{EE}	= 31%(Ref. 4); Percentage of total energy consumption for water heating, baseline
Dry_{BASE}	= 59%(Ref. 4); Percentage of total energy consumption for dryer operation, baseline
Dry_{EE}	= 62%(Ref. 4); Percentage of total energy consumption for dryer operation, efficient
$\%Elec_{DHW}$	= See Table 4; Percentage of domestic hot water savings assumed to be electric
$\%Elec_{DRY}$	= See Table 4; Percentage of dryer savings assumed to be electric
0.003412	= Conversion from kWh to Dth
Hours	= For SF: 258 hrs; for MF: 1241 hrs; assumes 1 hour per cycle.
CF	= For SF: 0.038 (Ref. 8); for MF: 0.045 (Ref. 7)

Example:

A residential customer installed a new ENERGY STAR clothes washer (unknown capacity) in a single family home with an electric water heater and electric dryer.

Unit kWh Savings per Year = [(3.45 / 1.64 x 258) x (7% + (33% x 100%) + (59% x 100%))]

` - [(3.45 / 2.56 x 258) x (6% + (31% x 100%) + (62% x 100%))]

= 193.10 kWh

Unit Peak kW Savings = 193.10 / 258 x 0.038 = 0.028 kW

Deemed Input Tables

Table 1. Baseline Clothes Washer Performance Characteristics (Ref. 3 & Ref. 13)

Unit Type	$IMEF_{BASE}$	IWF	Used for Savings Calculations
Federal Minimum Front-Loading Unit, ≥ 1.6 ft^3	≥ 1.84	≤ 4.7	
Federal Minimum Top-Loading Unit, ≥ 1.6 ft^3	≥ 1.57	≤ 6.5	
Federal Minimum Top & Front-Load Average	**1.64**		**Single family**
Federal Minimum Front-Loading Commercial Front-Load	**2.00**		**Multifamily**
Federal Minimum Top-Loading Commercial Front-Load	1.35		

Table 2. Proposed Clothes Washer Performance Characteristics (Ref. 8)

Unit Type	$IMEF_{EE}$	IWF	Used for Savings Calculations
ENERGY STAR Front-Loading Unit, > 2.5 ft^3	≥ 2.92	≤ 3.0	
ENERGY STAR Top-Loading Unit, > 2.5 ft^3	≥ 2.20	≤ 3.7	
ENERGY STAR Unit (undefined loading) ≤ 2.5 ft^3	≥ 2.20	≤ 3.7	
ENERGY STAR Top & Front-Load Average	**≥ 2.56**	≤ 3.35	**Single family**
ENERGY STAR Commercial Front-Load	**≥ 2.20**	≤ 4.0	**Multifamily**

Table 3. Distribution of Energy Use (Ref. 4)

	Clothes Washer Operation (CW)	Domestic Hot Water Heating (DHW)	Dryer Operation (Dry)
Base	7%	33%	59%
EE	6%	31%	62%

Table 4. Fuel Type Factors (Ref. 5 & Ref. 6)

Fuel Type	$\%Elec_{DHW}$	$\%Elec_{DRY}$
Electric	100%	100%
Gas	0%	0%
Unknown	39%	86%

Table 5. Incremental Costs (Ref. 11)

Unit Type	Incremental Cost
Top-Loading Clothes Washer	$28.79
Front-Loading Clothes Washer	$210.12
Average for Top & Front-Load Unit	**$163.49**

Table 6. Deemed Savings Values for SF, 3.45 ft^3 capacity

	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer	Unknown DHW Unknown Dryer
Energy Savings, kWh	193.10	121.78	88.45	17.13	134.94
Demand Savings, kW	0.028	0.018	0.013	0.003	0.020
Gas Savings, Dth	-	0.24	0.36	0.60	0.20

Table 7. Deemed Savings Values for MF, 3.45 ft^3 capacity

	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer	Unknown DHW Unknown Dryer
Energy Savings, kWh	928.82	585.76	425.45	82.40	649.08
Demand Savings, kW	0.034	0.021	0.015	0.003	0.024
Gas Savings, Dth	-	1.17	1.72	2.89	0.95

Table 8. Determination of Annual Loads

Clothes Washer Use	West North Central Census Division (IA, KS, MN, MO, ND, NE, SD) (Ref. 4)	Average Loads per Week
Use a Clothes Washer		
0 Loads per Week		0
1 to 4 Loads Each Week	4.1	2.5
5 to 9 Loads Each Week	1.9	7
10 to 15 Loads Each Week	0.8	12.5
More than 15 Loads Each Week		15
Do Not Use a Clothes Washer at Home	1.2	
Weighted Average		**4.93**
Estimated Annual Loads		**258**

Table 9. Determination of front vs top loading

Clothes Washer Use	West North Central Census Division (IA, KS, MN, MO, ND, NE, SD) (Ref. 15)	% of population
Top-Loading	5.2	74%
Front-Loading	1.8	26%

References

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3. 10 CFR Part 430 [Docket Number EERE–2008–BT–STD– 0019] RIN 1904–AB90 Energy Conservation Program for Consumer Products: Energy Conservation and Water Conservation

Standards. https://www.ecfr.gov/cgi-bin/text-idx?SID=86e70cbc87e5af18caca2e5c205bd107&mc=true&node=se10.3.430_132&rgn=div8

4. The percentage of total energy consumption that is used for the machine, heating the hot water or by the dryer is different depending on the efficiency of the unit. Values are based on a sales weighted average of top loading and front loading units based on data from Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/clothes_washers_support_stakeholder_negotiations.htm.
5. The percentage of total (gas and electric fuel types) water heating units that are electric calculated from 2015 Residential Energy Consumption Survey (RECS) data. https://www.eia.gov/consumption/residential/data/2015/hc/php/hc8.7.php Fuel used by main water heater section.
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13. Code of Federal Regulations. Title 10, Chapter II, Subchapter D, Part 431, §431.156. https://www.ecfr.gov/current/title-10/part-431
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Revision History

Version	Description	Author	Date
1.0	Put together algorithm, algorithm from IL TRM	Franklin Energy Services	8/15/2012
2.1	Added text to clarify that Tables 3-5 are for 3.5 ft^3 washers; Changed End Use from HVAC to Plug Load	Joe Plummer	4/2/2013
2.2	Added new ENERGY STAR standards to notes. Updated algorithm and savings to new ENERGY STAR standard, updated loads per week, and cost.	Franklin Energy Services	8/1/2014
2.4	Corrected example, added unknown DHW, Dryer to summarized savings values, rearranged tables, corrected gas algorithm, corrected typos	Joe Plummer	1/6/2015
2.5	Updated notes to include future federal standards. Updated table numbers and added standard summary table	Franklin Energy Services	8/17/2016
2.6	Updated to include new federal minimum and ENERGY STAR Clothes Washers Version 8.0 requirements. Updated gas and electric water heater recovery efficiency. Updated example calculations	Franklin Energy Services	12/4/2017
3.0	Updated to include MF units, updated average capacity, number of cycles per year, IMEF standards	Cadmus	10/1/2018
5.0	Updated ENERGY STAR performance standard to v9.0. Updates to example outputs and deemed savings outputs	Cadmus	7/1/2025

Residential Appliances – Clothes Dryers

Measure Detail	Measure Value
Measure ID	1.09.02
Target Market Segments	Residential
Target End Uses	Plug Loads, Other
Applicable To	Residential customers in single-family homes and multifamily housing of 2 or more units (including 3- and 4-family homes, duplexes, townhomes and apartment complexes)
Actions	Replace on Fail, Replace Working
Required from Customer/Contractor	Confirmation of ENERGY STAR performance criteria met, electric or gas dryer, Product class (standard or compact and, if electric, vented or ventless, 120V or 240V)
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	14 (Ref. 1)
Unit Participant Incremental Cost	$152 (Ref. 2)

Measure Description

This measure includes replacement of failed or working clothes dryers in existing homes with clothes dryers that meet current ENERGY STAR performance criteria, or installation of a clothes dryer that meets current ENERGY STAR performance criteria in a new home. Compliant efficient appliances do not need to be ENERGY STAR qualified through the EPA program but would need to meet the ENERGY STAR performance criteria specified within this measure.

Algorithms

For electric and gas dryers

kWh_{SAVED} = Load x (1 / CEF_{BASE} – 1 / CEF_{EFF}) x N_{CYCLES} x %Electric / ADJ_{CEF}

kW_{SAVED} = kWh_{SAVED} / Hours x CF

For gas dryers

Dth_{SAVED} = Load x (1 / CEF_{BASE} – 1 / CEF_{EFF}) x N_{CYCLES} x 0.003412 x %Gas / ADJ_{CEF}

Where:

Load = Average total weight of clothes per drying cycle per Table 1 (Ref. 3, Ref. 9, see Notes). If compact or standard size is unknown, assume standard. If vented or unvented is unknown, assume vented.

CEF_{BASE} = Combined energy factor of baseline unit; See Table 1 (Ref. 4). If compact or standard size is unknown, assume standard. If vented or unvented is unknown, assume vented.

CEF_{EFF}	= Combined energy factor of efficient unit: See Table 1 (Ref. 3). If compact or standard size is unknown, assume standard. If vented or unvented is unknown, assume vented.
N_{CYCLES}	= Annual number of dryer cycles; See Table 2 (Ref. 5)
%Electric	= Percentage of energy savings from electricity, = 100% for electric dryers and 16% for gas dryers (Ref. 6, see Notes)
%Gas	= Percentage of energy savings from gas, = 0% for electric dryers and 84% for gas dryers (Ref. 6, see Notes)
ADJ_{CEF}	= CEF adjustment factor, = 0.7 for standard dryers and 1.2 for compact dryers (Ref. 5)
Hours	= Annual run hours of clothes dryer = 234 (Ref. 7, See Assumptions)
CF	= Coincidence factor = 2.9% (Ref. 8)
0.003412	= Conversion from kWh to Dth

Example:

A customer installed a new standard sized vented gas clothes dryer in an existing single family home.

kWh_{SAVED} = 8.45 x (1 / 3.30 – 1 / 3.65) x 285 x 0.16 / 0.7 = 16 kWh

kW_{SAVED} = 16 / 234 x 0.029 = 0.002 kW

Dth_{SAVED} = 8.45 x (1 / 3.30 – 1 / 3.65) x 285 x 0.003412 x 0.84 / 0.7 = 0.287 Dth

Deemed Input Tables

Table 1. Loads and CEF Values Across Dryer Types (Ref 3,4,9)

Product Class	Load (lbs)	CEF_{BASE}	CEF_{EFF}
Electric, Ventless or Vented, Standard	8.45	3.73	≥ 5.20
Electric, Ventless or Vented, Compact (120V)	8.45*	3.61	≥ 6.30
Electric, Vented, Compact (240V)	8.45*	3.27	≥ 5.50
Electric, Ventless, Compact (240V)	8.45*	2.55	≥ 5.50
Gas, Vented, Standard	8.45	3.30	≥3.65
Gas, Vented, Compact	8.45*	3.30	≥ 3.65

* While the ENERGY STAR criteria assume 3 lb loads for compact dryers, they are likely higher (Ref. 5)

Table 2. Dryer Cycles Per Year (Ref 5)

Housing Type	N_{CYCLES}	
	Existing (default)	New Construction (if known)
Single family	285	350
Multifamily	185	195
Unknown	265	

Notes

Some of the savings from gas dryers comes from electricity (motors, controls, etc). The Consumer Savings tab of the ENERGY STAR Residential Clothes Dryer Data and Analysis spreadsheet (Ref. 6) shows 30 kWh (102 kBtu) electric and 540 kbtu gas annual savings. Gas savings are therefore 540 / (540 + 102) = 84% of total reduced energy consumption.

NEEA's dryer field study (Ref. 7) showed a mean dryer cycle length of 56 minutes. Annual run hours are therefore 250 x 56 / 60 = 234.

A recent field assessment of heat pump clothes dryers (Ref. 5) recommends some modifications to the above algorithm for traditional dryers. From its metering results, it found that the CEF ratings for standard-size dryers underestimate energy consumption, and that the ratings for compact dryers overestimate consumption. It recommends that different yearly load numbers be used across single-family and multifamily housing types, based on more recent RECS data. Finally, it reasons that an assumption of 3 pounds per load for compact dryers must be incorrect, and that it is more appropriate to use the standard dryer value of 8.45 pounds.

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Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Cadmus	11/2018
4.0	Updated to reflect CARD study findings	Cadmus	9/2021
5.0	Updated with ENERGY STAR performance criteria v2.0	Cadmus	7/1/2025

Residential Appliances – Dishwashers

Measure Detail	Measure Value
Measure ID	1.09.03
Target Market Segments	Residential
Target End Uses	Plug Loads
Applicable To	Residential customers in single-family homes and multifamily housing of 2 or more units (including 3- and 4-family homes, duplexes, townhomes and apartment complexes)
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Electric or gas water heater, unit size (standard or compact). Standard-sized is defined as having capacity for least 8 place settings plus 6 serving pieces. Compact-sized is defined as having capacity for less than 8 place settings plus 6 serving pieces. (Ref. 6)
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	12 (Ref. 1)
Unit Participant Incremental Cost	$18.49 (Ref. 2)

Measure Description

This measure includes replacement of failed or working dishwashers in existing homes dishwashers that meet current ENERGY STAR performance criteria, or installation of dishwashers that meet current ENERGY STAR performance criteria in new homes. Compliant efficient appliances do not need to be ENERGY STAR qualified through the EPA program but would need to meet the ENERGY STAR performance criteria specified within this measure.

Algorithms

Unit kWh Savings per Year = (kWh_base - kWh_EE) + (Loads x (WF_base – WF_EE) x EPG x %ElecDHW / ConversionFactor1 / R_eff)

Unit Peak kW Savings = Unit kWh Savings per Year / Hours x CF

Unit Dth Savings per Year = Loads x (WF_base – WF_EE) x EPG x (1-%ElecDHW) / ConversionFactor2/R_eff

Where:

kWh_EE = 240 kWh for standard unit or 155 kWh for compact unit; Energy consumed by efficient dishwasher (Ref. 6)

kWh_base = 307 kWh for standard unit or 222 kWh for compact unit; Energy consumed by minimum efficiency dishwasher (Ref. 7)

WF_base = 5.0 gallons/cycle for standard unit or 3.5 gallons/cycle for compact unit (Ref. 7)

WF_EE	= 3.2 gallons/cycle for standard unit or 2.0 gallons/cycle for compact unit (Ref. 6)
EPG	= Energy per Gallon to heat water.
	= SpecificHeat x Density x (Thot – Tcold)
SpecificHeat =	1.0 Btu / (lb x °F)
Density	= 8.34 lb / gal
Thot	= 130 °F (assumed average starting temperature)
Tcold	= Average groundwater temperature per Table 1 (Ref. 9)
%Elec_DHW	= 100% (electric water heating) = 0% (gas water heating) = 39% (if unknown) (Ref. 3)
R_eff	= Typical gas recovery efficiency is 0.78; a typical electric recovery efficiency is 0.98. (Ref. 2).
Hours	= 323 hours (Ref. 4)
Loads	= 179 (Ref. 4)
CF	= 0.10; electrical peak coincidence factor (Ref. 5)

ConversionFactor1 = 3,412 Btu/kWh

ConversionFactor2 = 1,000,000 Btu/Dth

Example:

A residential customer installed a new Standard-sized ENERGY STAR dishwasher in a home with electric water heat.

EPG = 1.0 Btu/lb-°F x 8.34 lb/gal x (130°F – 49.0°F) = 675.54 Btu/gal

Unit kWh Savings per Year = (307 kWh - 240 kWh) + (179 load x (5.0 gal/cycle – 3.2 gal/cycle) x (675.54 Btu per gal / 3412 Btu per kWh) / 0.98) = 132.1 kWh

Unit Peak kW Savings = (132.1 kWh / 323 hours) x 0.10 = 0.04 kW

Notes

Federal Standard requires standard sized dishwashers manufactured after 5/30/2013 use ≤ 307 kWh/yr and ≤ 5.0 gallons of water/cycle (Ref. 7)

Federal Standard requires compact sized dishwashers manufactured after 5/30/2013 use ≤ 222 kWh/yr and ≤ 3.5 gallons of water/cycle (Ref. 7)

ENERGY STAR requires standard sized dishwashers manufactured after 7/19/2023 use ≤ 240 kWh/yr and ≤ 3.2 gallons of water/cycle. ENERGY STAR has defined standard sized as a dishwasher having the capacity of equal to or greater than eight place settings plus six serving pieces, as specified in ANSI/AHAM (DW-1-2010). If unknown, assume standard sized (Ref. 6).

ENERGY STAR requires compact sized dishwashers manufactured after 7/19/2023 use ≤ 155 kWh/yr and ≤ 2.0 gallons of water/cycle (Ref. 6). ENERGY STAR has defined compact sized as a dishwasher having the capacity of less than eight place settings plus six serving pieces, as specified in ANSI/AHAM (DW-1-2010). If unknown, assume standard sized (Ref. 6).

As of September 2016, the US Department of Energy is currently undertaking a rulemaking to consider new energy conservation standards for residential dishwashers (Ref. 8).

Deemed Input Tables

Table 1. Average groundwater temperatures (Ref. 9)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3
MN statewide average, or if location unknown	**49.0**

Table 2. Summarized per unit savings, ENERGY STAR Standard Units, location unknown

Water Heater	Peak kW	kWh	therms
Electric	0.049	132.1	0
Gas	0.025	67	0.279
Unknown	0.034	92.4	0.135

Table 3. Summarized per unit savings, ENERGY STAR Compact Units, location unknown

Water Heater	Peak kW	kWh	therms
Electric	0.045	121.2	0
Gas	0.025	67	0.232
Unknown	0.033	88.156	0.112

References

1. ENERGY STAR U.S. EPA Consumer Messaging Guide for ENERGY STAR Certified Appliances. https://www.energystar.gov/sites/default/files/asset/document/ES_Consumer_Messaging_Guide_2018_508-c.pdf. Accessed November 4, 2022. Page 9.
2. State of Illinois Energy Efficiency Technical Reference Manual, Version 10.0, Volume 3: Residential Measures, Effective January 1, 2022. Pages 20-24.
3. Percentage of total (gas and electric fuel types) water heating units that are electric calculated from Residential Energy Consumption Survey (RECS) "Table from “Highlights for Water Heating in U.S. Homes by States, 2020". https://www.eia.gov/consumption/residential/data/2020/index.php?view=state&src=%E2%80%B9%20Consumption%20%20%20%20%20%20Residential%20Energy%20Consumption%20Survey%20(RECS)-f2, accessed November 4, 2022.
4. ENERGY STAR U.S. EPA Consumer Messaging Guide for ENERGY STAR Certified Appliances. https://www.energystar.gov/sites/default/files/asset/document/ES_Consumer_Messaging_Gui

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5. Franklin Energy Services internal standard value
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8. Appliance and Equipment Standards Rulemakings and Notices: Consumer Dishwashers, https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=38&action=viewlive. Accessed September 6, 2016.
9. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules* http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html, accessed September 6, 2016.

Revision History

Version	Description	Author	Date
1.0	Put together algorithm	Franklin Energy Services	8/15/2012
1.1	Correct kWh_base and kWh_prop (values were reversed)	Joe Plummer	4/2/2013
1.2	Changed Target End Use from HVAC to Plug Load	Joe Plummer	4/2/2013
1.3	Updated to current ENERGY STAR and federal standards	Franklin Energy Services	9/6/2016
1.4	Updated performance criteria to ENERGY STAR standard 7.0. Updated reference links where needed. Updated deemed savings values based on v7.0 ENERGY STAR criteria.	Cadmus	11/1/2022

Residential Appliances – Refrigerators and Freezers

Measure Detail	Measure Value
Measure ID	1.09.04
Target Market Segments	Residential
Target End Uses	Plug Loads
Applicable To	Residential customers in single-family homes and multifamily housing of 2 or more units (including 3- and 4-family homes, duplexes, townhomes and apartment complexes)
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Appliance (refrigerator (≥7.75 ft^3), compact refrigerator (<7.75 ft^3), or freezer ((≥7.75 ft^3)), Product Class (see Table 1 through Table 3), confirmation of performance criteria met
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	14 years for refrigerators, 11 years for freezers (Ref. 1)
Unit Participant Incremental Cost	$20 (refrigerators), $0 (compact refrigerators), $0 (freezers) (Ref. 2)

Measure Description

This measure includes the replacement of failed or working refrigerators or freezers in residential homes, as well as installation of high-efficiency refrigerators and freezers in new homes. Compliant efficient appliances do not need to be ENERGY STAR qualified through the EPA program but would need to meet the ENERGY STAR performance criteria specified within this measure.

Algorithms

Unit kWh Savings per Year = kWh_base - kWh_ee

Unit Peak kW Savings = (Unit kWh Savings per Year) / 8,760

Where:

kWh_base = Annual energy consumption of the baseline efficiency unit (Refer to Tables 1 through 3 based on Product Class)

kWh_ee = Annual energy consumption of the energy efficient (ENERGY STAR) unit (Refer to Tables 1 through 3 based on Product Class)

8,760 = Assumed annual operating hours per year

Example:

A conventional side-by-side refrigerator with automatic defrost is replaced with a similar ENERGY STAR side-by-side refrigerator.

Electric Energy Savings (kWh/yr) = 426 - 384 = 42 kWh/yr

Electric Peak Demand Savings (kW) = 42 kWh / 8,760 = 0.0048 peak kW

Deemed Input Tables

Table 1. High-Efficiency and Conventional Refrigerator Default Energy Usage and Incremental Cost (Ref. 4)

Product Class	ENERGY STAR Rated Model (kWh/year)	Conventional Model (kWh/year)
Refrigerator-freezer or refrigerator only (manual or partial-auto defrost)	311	346
Top-mounted freezer or refrigerator only (automatic defrost)	320	356
Side-by-side (automatic defrost)	384	426
Side-by-side with through-the-door ice (automatic defrost)	514	562
Bottom-mounted freezer (automatic defrost)	406	451
Bottom-mounted freezer with through-the-door ice (automatic defrost)	562	615

Table 2. High-Efficiency and Conventional Compact Refrigerator Default Values (Ref. 4)

Product Class	ENERGY STAR Rated Model (kWh/year)	Conventional Model (kWh/year)
Compact refrigerator or compact refrigerator-freezer (manual defrost)	260	289
Compact refrigerator-freezer (partial automatic defrost)	324	360
Compact top-mounted freezer or refrigerator only (automatic defrost)	349	387
Compact bottom-mounted freezer (automatic defrost)	349	387

Table 3. High-Efficiency and Conventional Freezer Default Values (Ref. 4)

Product Class	ENERGY STAR Rated Model (kWh/year)	Conventional Model (kWh/year)
Chest	272	302
Compact chest	345	383
Compact upright (manual defrost)	411	456
Compact upright (auto defrost)	560	623
Upright (manual defrost)	308	342
Upright (auto defrost)	412	458

Notes

The Federal efficiency standards in place as of September 2016 for residential refrigerators and freezers are as follows:

Table 4. Correction Factor and Adjusted Volume Algorithm by Product Class (Ref. 5)

Product Class	Correction Factor (CRF)	Adjusted Volume (AV) Algorithm
Freezers with Automatic Icemakers*	1.76	AV = (VT x CRF)
Refrigerator-Freezers	1.63	AV = (VF x CRF) + VFF
All-Refrigerators	1.00	AV = (VF x CRF) + VFF
Refrigerators (other than All-Refrigerators)	1.44	AV = (VF x CRF) + VFF
Freezers	1.73	AV = (VT x CRF)

VT = Total Refrigerated Volume (ft^3)
VF = Freezer Compartment Volume (ft^3)
VFF = Fresh Food Compartment Volume (ft^3)
* The volume occupied by the automatic icemaker, including its ice storage bin, is to be included in the volume measurement (VT).

Table 5. Federal and ENERGY STAR Maximum Energy Use Algorithm by Product Class (Ref. 6, 7)

Product Class	Federal Maximum Energy Use Algorithm	ENERGY STAR Maximum Energy Use Algorithm
Refrigerators		
1. Refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost.	7.99 x AV + 225.0	7.19 x AV + 202.5
1A. All-refrigerators–manual defrost.	6.79 x AV + 193.6	6.11 x AV + 174.2
2. Refrigerator-freezers–partial automatic defrost	7.99 x AV + 225.0	7.19 x AV + 202.5
3. Refrigerator-freezers–automatic defrost with top-mounted freezer without an automatic icemaker.	8.07 x AV + 233.7	7.26 x AV + 210.3
3-BI. Built-in refrigerator-freezer–automatic defrost with top-mounted freezer without an automatic icemaker.	9.15 x AV + 264.9	8.24 x AV + 238.4
3I. Refrigerator-freezers–automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service.	8.07 x AV + 317.7	7.26 x AV + 294.3
3I-BI. Built-in refrigerator-freezers–automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service.	9.15 x AV + 348.9	8.24 x AV + 322.4
3A. All-refrigerators–automatic defrost.	7.07 x AV + 201.6	6.36 x AV + 181.4
3A-BI. Built-in All-refrigerators–automatic defrost.	8.02 x AV + 228.5	7.22 x AV + 205.7
4. Refrigerator-freezers–automatic defrost with side-mounted freezer without an automatic icemaker.	8.51 x AV + 297.8	7.66 x AV + 268.0
4-BI. Built-In Refrigerator-freezers–automatic defrost with side-mounted freezer without an automatic icemaker.	10.22 x AV + 357.4	9.20 x AV + 321.7
4I. Refrigerator-freezers–automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service.	8.51 x AV + 381.8	7.66 x AV + 352.0

Product Class	Federal Maximum Energy Use Algorithm	ENERGY STAR Maximum Energy Use Algorithm
4I-BI. Built-In Refrigerator-freezers–automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service.	10.22 x AV + 441.4	9.20 x AV + 405.7
5. Refrigerator-freezers–automatic defrost with bottom-mounted freezer without an automatic icemaker.	8.85 x AV + 317.0	7.97 x AV + 285.3
5-BI. Built-In Refrigerator-freezers–automatic defrost with bottom-mounted freezer without an automatic icemaker.	9.40 x AV + 336.9	8.46 x AV + 303.2
5I. Refrigerator-freezers–automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service.	8.85 x AV + 401.0	7.97 x AV + 369.3
5I-BI. Built-In Refrigerator-freezers–automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service.	9.40 x AV + 420.9	8.46 x AV + 387.2
5A. Refrigerator-freezer–automatic defrost with bottom-mounted freezer with through-the-door ice service.	9.25 x AV + 475.4	8.33 x AV + 436.3
5A-BI. Built-in refrigerator-freezer–automatic defrost with bottom-mounted freezer with through-the-door ice service.	9.83 x AV + 499.9	8.85 x AV + 458.3
6. Refrigerator-freezers–automatic defrost with top-mounted freezer with through-the-door ice service.	8.40 x AV + 385.4	7.56 x AV + 355.3
7. Refrigerator-freezers–automatic defrost with side-mounted freezer with through-the-door ice service.	8.54 x AV + 432.8	7.69 x AV + 397.9
7-BI. Built-In Refrigerator-freezers–automatic defrost with side-mounted freezer with through-the-door ice service.	10.25 x AV + 502.6	9.23 x AV + 460.7
Freezers		
8. Upright freezers with manual defrost.	5.57 x AV + 193.7	5.01 x AV + 174.3
9. Upright freezers with automatic defrost without an automatic icemaker.	8.62 x AV + 228.3	7.76 x AV + 205.5
9I. Upright freezers with automatic defrost with an automatic icemaker.	8.62 x AV + 312.3	7.76 x AV + 289.5
9-BI. Built-In Upright freezers with automatic defrost without an automatic icemaker.	9.86 x AV + 260.9	8.87 x AV + 234.8
9I-BI. Built-in upright freezers with automatic defrost with an automatic icemaker.	9.86 x AV + 344.9	8.87 x AV + 318.8
10. Chest freezers and all other freezers except compact freezers.	7.29 x AV + 107.8	6.56 x AV + 97.0
10A. Chest freezers with automatic defrost.	10.24 x AV + 148.1	9.22 x AV + 133.3

Product Class	Federal Maximum Energy Use Algorithm	ENERGY STAR Maximum Energy Use Algorithm
Compact Refrigerators		
11. Compact refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost.	9.03 x AV + 252.3	8.13 x AV + 227.1
11A.Compact all-refrigerators–manual defrost.	7.84 x AV + 219.1	7.06 x AV + 197.2
12. Compact refrigerator-freezers–partial automatic defrost	5.91 x AV + 335.8	5.32 x AV + 302.2
13. Compact refrigerator-freezers–automatic defrost with top-mounted freezer.	11.80 x AV + 339.2	10.62 x AV + 305.3
13I. Compact refrigerator-freezers–automatic defrost with top-mounted freezer with an automatic icemaker.	11.80 x AV + 423.2	10.62 x AV + 389.3
13A. Compact all-refrigerators–automatic defrost.	9.17 x AV + 259.3	8.25 x AV + 233.4
14. Compact refrigerator-freezers–automatic defrost with side-mounted freezer.	6.82 x AV + 456.9	6.14 x AV + 411.2
14I. Compact refrigerator-freezers–automatic defrost with side-mounted freezer with an automatic icemaker.	6.82 x AV + 540.9	6.14 x AV + 495.2
15. Compact refrigerator-freezers–automatic defrost with bottom-mounted freezer.	11.80 x AV + 339.2	10.62 x AV + 305.3
15I. Compact refrigerator-freezers–automatic defrost with bottom-mounted freezer with an automatic icemaker.	11.80 x AV + 423.2	10.62 x AV + 389.3
Freezers		
16. Compact upright freezers with manual defrost.	8.65 x AV + 225.7	7.79 x AV + 203.1
17. Compact upright freezers with automatic defrost.	10.17 x AV + 351.9	9.15 x AV + 316.7
18. Compact chest freezers.	9.25 x AV + 136.8	8.33 x AV + 123.1

References

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2. Incremental costs from ENERGY STAR Appliance Savings Calculator: https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx, accessed 09/15/16. Based on EPA research on available models, 2014.
3. Annual energy use based on default unit volumes, Federal energy standards, and ENERGY STAR requirements as given in the ENERGY STAR calculator referenced above. Accessed 08/30/12.
4. Savings Calculator for ENERGY STAR-Qualified Appliances; workbook tabs 'Refrigerator Calcs,' 'Compact Refrigerator Calcs,' and 'Freezer Calcs.' https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx. Accessed 08/18/16.
5. Code of Federal Regulations: Title 10, Chapter II, Subchapter D, Part 430, Subpart B, Appendices A1 (Electric Refrigerators and Electric Refrigerator-Freezers) & B1 (Electric Freezers). https://www.gpo.gov/fdsys/browse/collectionCfr.action?collectionCode=CFR&searchPath=Title+10%2FChapter+II%2FSubchapter+D%2FPart+430%2FSubpart+B&oldPath=Title+10%2FChapter+

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6. Energy Conservation Program: Standards for Residential Refrigerators, Refrigerator-Freezers, and Freezers; Final Rule, Table 1. https://www.regulations.gov/document?D=EERE-2008-BT-STD-0012-0133. Accessed 08/18/16.
7. ENERGY STAR Program Requirements for Residential Refrigerators and Freezers, Table I.1. https://www.energystar.gov/ia/partners/product_specs/program_reqs/Refrigerators_and_Freezers_Program_Requirements_V5.0.pdf?5509-e2b6. Accessed 08/18/16.

Revision History

Version	Description	Author	Date
2.3	Updated all standard and ENERGY STAR default savings values, added federal standards in Notes, updated references, updated example with new standard values.	Franklin Energy Services	9/15/2016

Residential Appliances – Secondary Refrigerator/Freezer Removal

Measure Detail	Measure Value
Measure ID	1.09.05
Target Market Segments	Residential
Target End Uses	Appliances
Applicable To	Residential customers in single-family homes, duplexes, and townhomes
Actions	Remove
Required from Customer/Contractor	Equipment type being recycled (freezer or refrigerator), confirmation of working unit, confirmation of secondary unit, confirmation of performance criteria
Version No.	3.0
Unit kWh Savings per Year	See algorithm (Ref. 1)
Unit Peak kW Savings	See algorithm (Ref. 1)
Unit Dth Savings per Year	0
Measure Lifetime (years)	8 (Ref. 2)
Unit Participant Incremental Cost	$110.00 (Ref. 1)

Measure Description

This measure includes the removal and recycling of unneeded secondary residential refrigerators and freezers. Existing units must be working, secondary, refrigerators or freezers. Units must be recycled or otherwise rendered inoperable.

Algorithms

Unit kWh Savings per Year = $kWh_{UNADJUSTED}$ x PUF

Unit Peak kW Savings = $kWh_{UNADJUSTED}$ / HOU x P x PUF

Where:

$kWh_{UNADJUSTED}$ = The assumed gross savings from removing and recycling a refrigerator or freezer that would have been plugged in for the entire year (Refer to Table 1).

PUF = Part-Use Factor, to account for units that may not have been plugged in before being recycled. (Refer to Table 1)

HOU = Annual operating hours, 8,760

P = Peak intensity factor; this captures the increase in compressor cycling time in summer peak conditions relative to average annual conditions (Refer to Table 1)

Example:

A secondary refrigerator with unknown use throughout the year is retired and properly recycled.

Unit kWh Savings per Year = 962 x 0.86 = 827

Unit Peak kW Savings = 962 / 8,760 x 0.86 x 1.01 = 0.095

Deemed Input Tables

Table 1. Gross Annual kWh, kW Savings per Unit (Ref. 1)

Appliance Type	$kWh_{UNADJUSTED}$	PUF	P	Annual kWh	Gross kW
Refrigerator or Combo Unit	962	0.86	1.01	827	0.095
Freezer Only	926	0.76	1.08	704	0.087

Methodology and Assumptions

Energy savings are based on a linear regression, using metered data and modeling in Wisconsin.

References

1. Cadmus and Public Service Commission of Wisconsin. *Wisconsin Focus on Energy 2019 Technical Reference Manual*. 2019. Page 1,313. https://focusonenergy.com/sites/default/files/inline-files/Focus%20on%20Energy%202021%20TRM.pdf
2. KEMA, "Residential Refrigerator Recycling Ninth Year Retention Study," July 22, 2004

Revision History

Version	Description	Author	Date
1.0	New specification based on Nexant version	Joe Plummer	
2.0	Added measure description; Changed algorithm and source for algorithm for energy savings and demand savings; Added sources for default values; Added required information from customer/contractor; Changed measure life and EUL source; Changed measure incremental cost and cost source; Added example	Franklin Energy Services	7/30/2012
2.1	Added confirmation of working unit, secondary unit to Required Inputs, revised appliance descriptions for clarity	Joe Plummer	3/29/14
3.0	Updated to reflect more recent analysis in nearby state	Cadmus	9/2021

Residential Appliances – Compact Refrigerator/Freezer Recycling

Measure Detail	Measure Value
Measure ID	1.09.06
Target Market Segments	Residential
Target End Uses	Appliances
Applicable To	Residential customers in single-family homes, duplexes, and townhomes
Actions	Removal and recycling of a compact refrigerator/refrigerator-freezer from residential property
Required from Customer/Contractor	Appliance type being recycled, volume of refrigerator or freezer, confirmation of working unit
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	5 (Ref 1)
Unit Participant Incremental Cost	$0.00

Measure Description

This measure includes the removal and recycling of working compact (mini) refrigerator unit, compact refrigerator/freezer combination unit, or compact freezer unit. The appliance must be removed permanently, not to be replaced with another refrigerator of any type. A compact refrigerator/freezer is defined as having a total appliance interior volume of less than 7.75 ft3 (Ref 2).

Algorithms

Unit kWh Savings per Year = $kWh_{UNADJUSTED}$ x PUF

Unit Peak kW Savings = $kWh_{UNADJUSTED}$ / HOU x P x PUF

Algorithm Inputs:

Variable	Definition	Units	Ref	Table Ref
$kWh_{UNADJUSTED}$	Annual Power Consumption. See Table 2, calculated from the adjusted volume (AV) of the unit.	kWh	2,3,4	2
AV	Adjusted Volume; Vol_{REFRIG} + (Vol_{FREEZE} * 1.63). The sum of the refrigerator compartment volume in cubic feet, the freezer compartment volume in cubic feet, and the product of an adjustment factor and the net freezer compartment volume.	Cubic feet	2	
Vol_{REFRIG}	Refrigerator compartment volume in cubic feet, provided by customer/contractor (if only freezer, = 0)	Cubic feet		
Vol_{FREEZE}	Freezer compartment volume in cubic feet, provided by customer/contractor (if only refrigerator, = 0)	Cubic feet		
PUF	Part-Use Factor; See Table 1. To account for units that are occasionally installed and operating for only	%	1	1

	part of the year, a Part-Use Factor has been developed and embedded within the Annual Energy and Peak Demand Savings Algorithms for these units to establish average annual per unit deemed electric savings.			
HOU	Annual hours of use, Deemed value of 8,760 hours	hours	3	1
P	Peak Intensity Factor; This captures the increase in compressor cycling time in summer peak conditions relative to average annual conditions. See Table 1.	%	1	1

Example:

A compact refrigerator-freezer combination unit with partial automatic defrost and a manufacturer specified total volume of 4.3 ft^3 (3.8 refrigerator, 0.5 freezer) is removed from a residence and properly recycled.

AV = 3.8 CF + (0.5 CF x 1.63) = 4.615 CF

$kWh_{UNADJUSTED}$ = 5.91 x 4.615 CF + 335.8 = 363 kWh

Unit kWh Savings per Year = 363 kWh x 0.86 = 312 kWh

Unit Peak kW Savings = (312 kWh / 8760 hours) x 92.5% x 86% = 0.03 kW

Deemed Input Tables

Table 1. Part Use Factors (PUF), Peak Intensity Factors (P) by Appliance type (Ref 1)

Appliance Type	PUF	P
Compact Refrigerator	86%	92.5%
Compact Refrigerator/Combo Unit	86%	92.5%
Compact Freezer	76%	94.7%

Table 2. Power Usage by Appliance Type (Ref. 2)

Appliance Type	$kWh_{UNADJUSTED}$ Equation
Compact refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost	9.03 x AV + 252.3
Compact all refrigerators - manual defrost	7.84 x AV + 219.1
Compact refrigerator-freezers - partial automatic defrost	5.91 x AV + 335.8
Compact refrigerator-freezers - automatic defrost with top-mount freezer	11.80 x AV + 339.2
Compact refrigerator-freezers - automatic defrost with top-mount freezer with an automatic icemaker	11.80 x AV + 423.2
Compact all refrigerators - automatic defrost	9.17 x AV + 259.3
Compact refrigerator-freezers - automatic defrost with side-mount freezer	6.82 x AV + 456.9

Compact refrigerator-freezers - automatic defrost with side-mount freezer with an automatic icemaker	6.82 x AV + 540.9
Compact refrigerator-freezers - automatic defrost with bottom-mount freezer	11.80 x AV + 339.2
Compact refrigerator-freezers - automatic defrost with bottom-mount freezer with an automatic icemaker	11.80 x AV + 423.2
Compact upright freezers with manual defrost	8.65 x AV + 225.7
Compact upright freezers with automatic defrost	10.17 x AV + 351.9
Compact chest freezers	9.25 x AV + 136.8

Methodology and Assumptions

This measure has been developed using the same algorithm that appears in the MN TRM Residential Appliances - Secondary Refrigerator/ Freezer Removal measure . The Part Use Factor (PUF) input has also been derived from the same measure.

References

1. Michigan Energy Measure Database, 2024, Measure N-RE-AP-010321-E-XX-XX-XX-XX-03. https://www.michigan.gov/mpsc/regulatory/energy-optimization/michigan-energy-measures-database
2. ENERGY STAR Program Requirements Product Specification for Residential Refrigerators – Eligibility Criteria v5.0, US Environmental Protection Agency. https://www.energystar.gov/sites/default/files/specs/private/ENERGY%20STAR%20Final%20Version%205.0%20Residential%20Refrigerators%20and%20Freezers%20Program%20Requirements.pdf
3. New York State Technical Resource Manual, 2023. New York State Joint Utilities. Refrigerator and Freezer Recycling Measure, pg 75.https://dps.ny.gov/technical-resource-manual-trm
4. 10 CFR, 430.32 (a) Refrigerators/ refrigerator-freezer, freezers, Energy and water conservation standards and their compliance dates. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32

Revision History

Version	Description	Author	Date
4.2	New Measure “Compact Refrigerator/Refrigerator-Freezer/Freezer Removal”	MN Department of Commerce	2024

Residential Appliances – Air Purifiers

Measure Detail	Measure Value
Measure ID	1.09.07
Target Market Segments	Residential
Target End Uses	Plug loads, Appliances
Applicable To	Residential customers in single-family homes and multifamily housing of 2 or more units (including 3- and 4-family homes, duplexes, townhomes and apartment complexes)
Actions	Replace on Fail, Replace Working
Required from Customer/Contractor	Air purifier capacity in cubic feet per minute
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	0
Measure Lifetime (years)	9 (Ref. 1)
Unit Participant Incremental Cost	See Table 2 (Ref. 1)

Measure Description

This measure covers the purchase and installation of an air purifier unit meeting ENERGY STAR specification (Ref. 2) in place of a Base unit. Base unit is defined as meeting the Federal minimum standard within 10 CFR Part 430.32, established December 31 2023. The EPA has updated the specification criteria in version 3.0 to be based on the Integrated Energy Factor (IEF) in place of the operational and standby wattage and efficiency of the unit. The EPA followed the DOE method for calculating IEF (Ref 4). The PM2.5 CADR was calculated based on the Smoke CADR and Dust CADR. The IEF was calculated using the PM2.5 CADR and the Annual Energy Consumption (AEC). Compliant efficient appliances do not need to be ENERGY STAR qualified through the EPA program but would need to meet the ENERGY STAR performance criteria specified within this measure.

Algorithms

The algorithm follows savings as calculated by the ENERGY STAR appliance savings calculator (Ref. 1)

Unit kWh Savings per Year $= kWh_{BASE} - kWh_{EFF}$

$kWh_{BASE} = (PM_{2.5}\ CADR_{BASE} * (1 / IEF_{BASE})) \times HOU / 1{,}000$

$kWh_{EFF} = (PM_{2.5}\ CADR_{EFF} * (1 / IEF_{EFF})) \times HOU / 1{,}000$

Unit Peak kW Savings per Year $=$ kWh Savings / HOU x CF

Algorithm Inputs:

Variable	Definition	Units	Ref
$PM_{2.5}$ $CADR_{BASE}$	Clean air delivery rate (CADR) of $PM_{2.5}$ for base unit (CFM), see Table 1, If unknown set to equal $CADR_{Eff}$. The PM2.5 CADR was calculated by combining the CADR of cigarette smoke particle sizes ranging from 0.1 to 0.5 µm with the CADR of dust particles that fall in the range of 0.5 to 2.5 µm and performing a geometric average calculation = Sqrt ((Smoke CADR (0.1- 0.5 µm) x Dust CADR (0.5 - 2.5 µm))	CFM	1,2
IEF_{BASE}	Integrated Energy Factor. The measured PM2.5 CADR (CFM) per watt for base unit, see Table 1. IEF = ((CADR / (AEC / 5,840 hrs x 1000 Wh))	CFM/Watt	1
HOU	5,840 hours; annual hours of operation	Hours Per Year	
$PM_{2.5}$ $CADR_{Eff}$	Clean air delivery rate (CADR) of $PM_{2.5}$ for efficient unit (CFM), see Table 1. The PM2.5 CADR was calculated by combining the CADR of cigarette smoke particle sizes ranging from 0.1 to 0.5 µm with the CADR of dust particles that fall in the range of 0.5 to 2.5 µm and performing a geometric average calculation = Sqrt ((Smoke CADR (0.1- 0.5 µm) x Dust CADR (0.5 - 2.5 µm))	CFM	1,2
IEF_{Eff}	Integrated Energy Factor. The measured PM2.5 CADR (CFM) per watt for efficient unit, see Table 1. IEF = ((CADR / (AEC / 5,840 hrs x 1000 Wh))	CFM/Watt	1,2
CF	0.67; coincidence factor (= 5,840 / 8,760)		
1000	Watts to KW conversion		

Example:

A customer installed an ENERGY STAR qualified air purifier with a PM2.5 clean air delivery rate (CADR) of 75 cubic feet per minute.

kWh Savings = 75 CFM * (1 / (1.7 CADR/W)) x5,840 hours/year / 1,000 watts

– 75 CUFT/min * (1 / (4.4 CADR/W)) x 5,840 hours/year / 1,000 watts

= 158.10 kWh

Peak kW Savings = 158.10 / 5,840 hours/year * 0.67 CF = 0.02 kW

Deemed Input Tables

Table 1. Clean Air Delivery Rates, Efficiencies and Savings (Ref. 1,2,3, 4)

PM2.5 CADR Range (CFM)	PM2.5 CADR used for Deemed Savings Calculation (CFM)	IEF BASE (CFM/ Watt) of PM2.5	IEF EFF (CFM/ Watt) of PM2.5	kWh_{SAVED}	kW_{SAVED}
30 ≤ PM2.5 CADR < 100	75	1.7	4.4	158.10	0.02
100 ≤ PM2.5 CADR < 150	125	1.9	5.4	249.03	0.03
150 ≤ PM2.5 CADR < 200	175	2.0	5.6	328.50	0.04
200 ≤ PM2.5 CADR < 300	250	2.0	5.6	469.29	0.05
300 ≤ PM2.5 CADR < 400	350	2.0	5.6	657.00	0.08
400 ≤ PM2.5 CADR < 500	450	2.0	5.6	844.71	0.10
500 ≤ PM2.5 CADR < 600	550	2.0	5.6	1,032.43	0.12

Table 2. Average Installed Cost and Payback for ENERGY STAR Qualified Equipment (Ref. 1)

CAP Smoke CADR Range (CFM)	Smoke CADR/W	Average Purchase Cost of ENERGY STAR Equipment	Average Purchase Cost of Baseline Equipment	Incremental Cost
30 ≤ PM2.5 CADR < 100	4.4	$117	$117	$0
100 ≤ PM2.5 CADR < 150	5.4	$193	$117	$76
150 ≤ PM2.5 CADR	5.6	$398	$343	$55

References

1. EPA ENERGY STAR. Savings Calculator for ENERGY STAR Appliances. *ENERGY STAR Room Air Cleaners Final 3.0 Data Package*. January 6, 2025. https://www.energystar.gov/room-air-cleaners-v30
2. EPA ENERGY STAR. *ENERGY STAR Program Requirements, Produce Specification for Room Air Cleaners*. Version 3.0. Effective January 6, 2025. https://www.energystar.gov/sites/default/files/2025-01/ENERGY%20STAR%20Version%203.0%20Room%20Air%20Cleaners%20Final%20Specification%20with%20Partner%20Commitments.pdf
3. Code of Federal Regulations at 10 CFR 430. Effective December 31 2023. https://www.energystar.gov/room-air-cleaners-v30
4. DOE Energy Efficiency and Renewable Energy Office. Energy Conservation Program: Test Procedure for Air Cleaners; Final Rule. March 5, 2023. https://www.regulations.gov/document/EERE-2021-BT-TP-0036-0036

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Cadmus	11/9/2018
4.2	Updated ENERGY STAR performance criteria to version 2.0, released May 2022. Added incremental costs from ENERGY STAR v2.0 data package calculator.	Cadmus	8/1/2024
5.0	Updated ENERGY STAR performance criteria to version 3.0, released January 2025.	Cadmus	7/1/2025

Residential Appliances – Induction Cooktops, Ovens and Ranges

Measure Detail	Measure Value
Measure ID	1.09.08
Target Market Segments	Residential
Target End Uses	Residential appliances
Applicable To	Residential Customers
Actions	Replace Working, Replace on Fail, New purchase without existing equipment
Required from Customer/Contractor	Confirmation of baseline case being replaced to determine algorithm applicable. If available, annual energy consumption specification of induction unit being installed.
Measure Energy Type	Electric, Gas, EFS
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	16 year (ref 5)
Unit Participant Incremental Cost	Incremental cost of induction cooktop: $736 (Ref 1,4) Incremental cost of range: $1,294 (Ref 1,4)

Measure Description

This measure is designed for the replacement of a residential electric resistance range (range defined as containing oven and cooktop components), freestanding electric resistance cooktop, freestanding gas cooktop, or gas range configured with a gas cooktop paired with either a gas oven or electric oven. The performance case is an electric induction range or freestanding induction cooktop where induction technology is the primary heating technology. For example, some induction cooktops contain a single electric resistance back burner for warming, and most induction ranges have traditional electric resistance heating for the oven portion, and both examples would still qualify as the performance case. There is no specified performance criteria defined for this measure in terms of an annual energy consumption threshold, as long as the annual energy consumption of the installed induction appliance is less than the deemed electric resistance value noted in the variable inputs of the algorithm. This measure is applicable to new construction only where electric induction cooktops are not already required by building codes. This measure may include efficient fuel switching energy savings resulting from residential induction range/cooktops replacing fossil fuel powered range/cooktops.

The Minnesota Energy Conservation and Optimization Act (Ref. 8,9) allows for efficient fuel switching (EFS) improvements where electricity or natural gas replaces another fuel used by the customer (i.e. natural gas, fuel oil, propane, etc) provided that the following criteria are met for each measure pursued:

1. The proposed efficient fuel switching measure results in a net reduction in the amount of source energy consumed for a particular use, measured on a fuel-neutral basis, using the utility's annual system average efficiency, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.

2. The proposed efficient fuel switching measure results in a net reduction of statewide greenhouse gas emissions (Ref 10), over the lifetime of the improvement. For an efficient fuel-switching improvement installed by an electric utility, the reduction in emissions must be measured using the utility's annual average emissions factor, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.
3. The proposed efficient fuel switching measure is cost-effective, considering the costs and benefits from the perspective of the utility, participants, and society.
4. The proposed efficient fuel switching measure should produce a similar or higher level of quality, service, or output as the technical assumptions identified in the baseline technology to be eligible (Ref. 11).

Utilities can pursue efficient fuel switching energy savings as part of their ECO programs if an applicable incentive/program/rate is offered to customers and has measured participation. Annual participation within the applicable measure should be tracked to claim savings for any efficient fuel switching savings claimed.

This measure potentially includes the efficient fuel switching energy savings resulting from conversion of some or all of the non-electric heating energy of the baseline equipment to electric heating energy in the proposed equipment.

Algorithms

Electric Resistance Range or Cooktop Baseline:

Unit kWh Savings per Year = AEC_ER_CKT – AEC_IN_CKT

Unit Peak kW Savings = Unit kWh Savings per Year / HOU x CF

Gas Range (cooktop and oven) Baseline, EFS:

Unit kWh Savings per Year = AEC_GAS_ELECTRICAL – (AEC_IN_CKT + AEC_IN_OVN)

Unit Peak kW Savings = 0

Unit Gas Savings per Year = AEC_GAS_OVN + AEC_GAS_CKT

Net MMBtu Savings per Year = Unit Gas Savings + (Unit kWh Savings / 293.07)

Electric Oven and Gas Cooktop Baseline, EFS:

Unit kWh Savings per Year = - (AEC_IN_CKT)

Unit Peak kW Savings = 0

Unit Gas Savings per Year = AEC_GAS_CKT

Net MMBtu Savings per Year = Unit Gas Savings + (Unit kWh Savings / 293.07)

Algorithm Inputs:

Variable	Definition	Units	Ref
AEC_ER_CKT	Annual energy consumption of electric resistance cooktop. If unknown, use 125 kWh. If a full range is being installed, the electric oven is assumed to consume the same annual energy in both the baseline and performance case, therefore the oven variables drop out of the savings equation.	kWh/yr	2,3
AEC_IN_CKT	Annual energy consumption of electric induction cooktop. Provided by customer specification of new product. If unknown, use 111 kWh.	kWh/yr	2
HOU	365 annual hours of use	hours	3
CF	Coincidence Factor, 0.29		6
AEC_IN_OVN	Annual energy consumption of electric oven. Provided by customer specification of new product. If unknown, use 172 kWh. If a full range is being installed in the gas oven baseline, the independent induction cooktop and oven variables can be replaced with the integrated annual energy consumption (IAEC) of the cumulative range, listed in product specifications.	kWh/yr	4
AEC_GAS_Electrical	Annual electric consumption of gas range, for auxiliary components, standby and ignition power, 54.3 kWh/yr	kWh/yr	6
AEC_GAS_OVN	Annual gas consumption of gas oven, 2.04 MMBtu/yr	Dth/yr or MMBtu/yr	4,5
AEC_GAS_CKT	Annual gas consumption of gas cooktop, 1.06 MMBtu/yr	Dth/yr or MMBtu/yr	4,5
293.07	Conversion factor kWh to MMBtu	kWh/MMBtu	

Fossil Fuel Example:

An existing residential customer is replacing their fossil fuel stand alone cooktop with an induction cooktop. All above noted deemed values are used for the calculation of savings.

Unit kWh Savings per Year = 54.3 kWh – (111 kWh + 172 kWh) = –228.70 kWh (penalty)

Unit Peak kW Savings = 0

Unit Gas Savings per Year = 2.03 Dth + 1.06 Dth = 3.09 Dth

Net MMBtu Savings per Year = 3.09 Dth + (–228.70 kWh / 293.07) = 2.31 MMBtu

Electric Resistance Example:

An existing residential customer is replacing their electric resistance range with an induction range. All above noted deemed values are used for the calculation of savings.

Unit kWh Savings per Year = 125 kWh – 111 kWh = 14 kWh

Unit Peak kW Savings = 14 kWh / 365 x 0.29 = 0.01 kW

Deemed Tables

Table 1: Deemed Savings by Baseline Scenario

Baseline	kW demand Savings	kWh Savings (Penalty)	Dth Savings	MMBtu Savings
Electric Resistance Range or Cooktop	0.01	14.00	0	N/A
Gas Range (cooktop and oven), **EFS**	0	(228.70)	3.09	2.31
Electric Oven and Gas Cooktop, **EFS**	0	(111.00)	1.06	0.68

References

1. CA eTRM. Measure Characterization Induction Cooking Electric Range Residential SWAP015-03. Effective Start Date 1/1/2024. https://www.caetrm.com/measure/SWAP015/03/
2. ENERGY STAR, Emerging Technology. 2021-2022 Residential Induction Cooking Tops. https://www.energystar.gov/about/2021_residential_induction_cooking_tops
3. Frontier Energy. Residential Cooktop Performance and Energy Comparison Study. Report # 501318071-R0, Prepared for SMUD. July 2019. https://cao-94612.s3.amazonaws.com/documents/Induction-Range-Final-Report-July-2019.pdf
4. CA eTRM. Measure Characterization Cooking Appliances Residential Fuel Substitution SWAP013-06. Accessed 9/1/2025. https://www.caetrm.com/measure/SWAP013/06/
5. Department of Energy (DOE) Energy Conservation Program: Energy Conservation Standards for Consumer Conventional Cooking Products proposed rule, U.S. Energy Information Administration's (EIA) Residential Energy Consumption 2019 Survey (RECS).
6. Illinois Statewide Technical Reference Manual, Volume 3. Measure 5.1.14 Residential Induction Cooking Appliances. Version 13, 9/20/2024.
7. The EUL was developed for the U.S. Department of Energy (DOE) Energy Conservation Program, Energy Conservation Standards for Residential Conventional Cooking Products as part of the 2016 supplemental notice of proposed rulemaking (SNOPR).
8. Minn. Stat. § 216B.2402, subd. 4(2023). https://www.revisor.mn.gov/statutes/cite/216B.2402
9. Laws of Minn. 2024, art. 6, sec. 14. https://www.revisor.mn.gov/laws/2024/0/Session+Law/Chapter/126/
10. Minn. Stat. § 216H.01 subd. 2 (2016). https://www.revisor.mn.gov/statutes/cite/216H/full#stat.216H.01
11. Minnesota Department of Commerce Division of Energy Resources, Decision In the Matter of Technical Guidance for the Inclusion of Efficient Fuel-Switching, Load Management, and Pre-Weatherization Measures in CIP, (March 15, 2022). Docket No. E,G999/CIP-21-837. (eDocket No. 20223-183807-01). At 13. https://efiling.web.commerce.state.mn.us/edockets/searchDocuments.do?method=showPoup&documentId=%7B90098F7F-0000-C11B-B04F-C063DF81A5F9%7D&documentTitle=20223-183807-01

Revision History

Version	Description	Author	Date
5.0	Measure developed	Cadmus	9/1/2025

Transportation

Residential/Commercial Transportation – Electric Vehicle Sales Charging Consumption

Measure Detail	Measure Value
Measure ID	1.10.01
Target Market Segments	Residential, Commercial
Target End Uses	Transportation
Applicable To	Residential and Commercial customers
Actions	Electric vehicle (EV) charging sales consumption (kWh) subtraction for added electric vehicles in a utility territory
Required from Customer/Contractor	Quantity by type in utility service territory per year
Measure Energy Type	Electric, Gasoline, EFS
Unit kWh Savings per Year	See deemed values by equipment type
Unit Peak kW Savings	See deemed values by equipment type
Unit Dth Savings per Year	See deemed values by equipment type
Measure Lifetime (years)	1 year
Unit Participant Incremental Cost	See deemed values by equipment type

Measure Description

The Minnesota Energy Conservation and Optimization Act Ref. 1) allows utilities to subtract sales associated with electric vehicle charging from the utility's gross annual retail energy sales, provided the utility offers and actively markets a program, rate or tariff that is designed to optimize the timing of electric vehicle charging. Minn. Stat. § 216B.1614 requires each public utility to have a tariff specifically designed for EV charging that offers time-of-day or off-peak rates to customers who own EVs. Time-of-use rates adjust the price of electricity based on the time that it is consumed, with low prices during low-demand periods and high prices during peak demand. Using rate design to encourage charging during times of low demand can help the electric grid absorb and accommodate the new load created by EVs without the need for new generation or distribution infrastructure, thereby enhancing the efficient use of existing infrastructure. Smart or managed charging programs potentially provide greater control over management of the EV charging load. Matching EV charging with wind generation, which is typically greatest during overnight hours, could allow utilities to best utilize wind as a resource and potentially support increased wind generation (Ref. 1).

Annual energy consumption values for electric vehicles connected to the grid are shown in Table 1. Applicable electric vehicles include fully battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). Hybrid electric vehicles that do not plug into an external electricity source are not applicable. BEVs and PHEVs registered in Minnesota are documented by the MN Public Utilities Commission. The data is broken down by vehicle type and by utility service territory. The most recent data can be obtained from the MN PUC website (Ref. 2). The MN PUC data is generally updated and

released on an annual basis. It is recommended that savings resulting from this measure are evaluated annually with the current data available.

Algorithms

kWh Charging Consumption of EV Sales = (BEV Charging Consumption x BEV Units) + (PHEV Charging Consumption x PHEV Units)

Where:

BEV/PHEV Charging Consumption = Deemed annual electricity charging consumption of individual vehicle by type, see Table 1 below.

Units = Number of registered vehicles by type within the utility service territory

Example:

A utility service territory has 100 qualifying EVs and 50 qualifying PHEVs registered by the PUC. The annual electric EV charging sales subtraction the utility can claim can be quantified by the following equation:

kWh Charging Consumption of EV Sales = (100 x 4,055) + (50 x 2,718)

= 541,400 kWh / year

Deemed Input Tables

Table 1. Electric Vehicle Consumption and Savings per Vehicle by Type (Ref. 2 - 4)

Metric	Unit	BEV (Battery Electric Vehicle)	PHEV (Plug-in Hybrid Electric Vehicle)
Charging Consumption	kWh/yr	4,055	2,718
	BTU/yr	13,835,719	9,274,069
	MMBtu/yr	13.8	9.3

Methodology and Assumptions

The electric vehicle values in Table 1 represent annual consumption of a single vehicle, by type, based on 11,361 miles driven per year (Ref. 3), and by vehicle efficiency in kWh per mile. Grid loss has been incorporated into the charging load assumptions (Ref. 4). The MN PUC registered EV dataset from December 2021 has been used in the charging consumption analysis conducted (Ref. 2). The MN PUC dataset does not currently distinguish residential vehicles from commercial vehicles, therefore the values in Table 1 apply to both commercial and residential vehicles uniformly. If future MN PUC datasets distinguish residential from commercial vehicles, Table 1 will be revised to also distinguish savings associated.

References

1. Minn. Stat. § 216B.2402, subd. 4(2023). https://www.revisor.mn.gov/statutes/cite/216B.2402
2. Minnesota Public Utilities Commission. Electric Vehicle Sales. Dataset accessed: December 2021. https://mn.gov/puc/activities/economic-analysis/electric-vehicles/
3. U.S. Dept of Transportation: Federal Highway Administration. OHPI Highway Statistics. Accessed October 1, 2022. https://www.fhwa.dot.gov/ohim/onh00/onh2p11.htm
4. EPA. Data Explorer eGrid. Website dataset last updated April 26, 2022. https://www.epa.gov/egrid/data-explorer

Revision History

Version	Description	Author	Date
4.0	New measure and content	Cadmus	11/01/2022

Residential/Commercial Transportation – Electric Vehicles

Measure Detail	Measure Value
Measure ID	1.10.02
Target Market Segments	Residential, Commercial
Target End Uses	Miscellaneous, Efficient Fuel switching
Applicable To	Residential and Commercial customers
Actions	Replace Working, Replace on Fail, New purchase without existing equipment
Required from Customer/Contractor	Quantity by type (BEV, PHEV) in service territory per year
Measure Energy Type	Electric, gasoline, EFS
Unit kWh Savings per Year	See deemed values by equipment type
Unit Peak kW Savings	See deemed values by equipment type
Unit Dth Savings per Year	See deemed values by equipment type
Measure Lifetime (years)	8 years
Unit Participant Incremental Cost	Actuals if known, or default of $7,500 per vehicle (Ref 13)

Measure Description

The Minnesota Energy Conservation and Optimization Act (Ref. 9, 10) allows for efficient fuel switching (EFS) improvements where electricity or natural gas replaces the use of another fuel used by the customer (i.e. natural gas, fuel oil, propane, etc) provided that the following criteria are met for each measure pursued:

1. The proposed efficient fuel switching measure results in a net reduction in the amount of source energy consumed for a particular use, measured on a fuel-neutral basis, using the utility's annual system average efficiency, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.
2. The proposed efficient fuel switching measure results in a net reduction of statewide greenhouse gas emissions (Ref 11), over the lifetime of the improvement. For an efficient fuel-switching improvement installed by an electric utility, the reduction in emissions must be measured using the utility's annual average emissions factor, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.
3. The proposed efficient fuel switching measure is cost-effective, considering the costs and benefits from the perspective of the utility, participants, and society;
4. The proposed efficient fuel switching measure should produce a similar or higher level of quality, level of service or output as the technical assumptions identified in the baseline technology to be eligible (Ref. 12).

Utilities can pursue efficient fuel switching energy savings as part of their ECO programs if an applicable incentive/program/rate is offered to customers and has measured participation. Annual participation within the applicable measure should be tracked in order to claim savings for any efficient fuel switching savings claimed. This measure includes the efficient fuel switching energy savings resulting from electric vehicles (BEVs and PHEVs) replacing traditional gasoline-powered vehicles (baseline) measured on an

annual basis. Annual energy and emission assumptions for electric vehicles connected to the grid are shown in Table 1 and Table 2. Applicable electric vehicles include fully battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) added within the program year as part of participation in a program/rate/incentive offered by the utility. Hybrid electric vehicles that do not plug into an external electricity source are not applicable.

Algorithms

kWh Added per Year = Charging Consumption x Units

Gasoline Saved per Year (MMBtu) = Gasoline Consumption x CF x Units

Net MMBtu Savings per year = EFS Savings (MMBtu) x Units

Where:

Charging Consumption = Deemed annual charging consumption in kWh, by type, see Table 1 below.

Gasoline Consumption = Deemed annual gasoline consumption displaced, in gallons, by type, see Table 1 below.

CF = Conversion of gallons of gasoline to MMBtu of energy = 0.125 MMBtu per gallon of gasoline

EFS Savings = Deemed annual fuel consumption savings from the fuel switch, in MMBtu, by type, see Table 1 below.
EFS savings (MMBtu) = electric charging consumption (MMBtu) – gasoline displaced (MMBtu). Savings can alternatively be calculated in kWh by using the kWH EFS savings in Table 1.

Units = Quantity of registered vehicles by type in the utility service territory

Example:

A utility territory has tracked the addition of 100 qualifying EVs and 50 qualifying PHEVs to the utility territory within a given program year. The annual efficient fuel switching energy savings can be quantified by the following equation:

EFS Savings per year = (39.3 MMBtu x 100 BEVs) + (22.1 MMBtu x 50 PHEVs)

= 5,035 MMBtu / year

In this example, a single BEV will consume 4,055 kWH (13.8 MMBtu) per year from the electric grid, will fully displace 442 gallons of gasoline (55.3 MMBtu) being consumed per year by an equivalent gasoline powered vehicle, and will result in a net energy savings of 41.4 MMBtu per year measured on a fuel neutral basis. A single PHEV will consume 2,718 kWH (9.3 MMBtu) per year from the electric grid. Gasoline is only partially displaced in a PHEV, with 181 gallons consumed and 261 gallons displaced (32.6 MMBtu) by electricity each year. Cumulatively on a fuel neutral basis, each PHEV saves 23.4 MMBtu per year.

Deemed Input Tables

Table 1. Electric Vehicle Consumption and Savings per Vehicle by Type (Ref. 3 - 7, 8)

Metric	Unit	BEV (Battery Electric Vehicle)	PHEV (Plug-in Hybrid Electric Vehicle)
Charging Consumption	kWh/yr	4,055	2,718
	BTU/yr	13,835,660	9,273,816
	MMBtu/yr	13.8	9.3
Gasoline Displaced	Gallons/yr	442	261
	BTU/yr	53,250,000	32,625,000
	MMBtu/yr	55.3	32.6
Energy Efficient Fuel Switching Savings	BTU/yr	41,414,340	23,351,184
	MMBtu/yr	41.4	23.4

Table 2. Electric Vehicle Emissions per Vehicle by Type (Ref. 1 – 7)

Metric	Source	BEV (Battery Electric Vehicle)	PHEV (Plug-in Hybrid Electric Vehicle)
Emissions Emitted (Mt CO2e/yr)	Electric	1.70	1.14
	Gasoline	0	1.61
	Total	1.70	2.75
Emissions Displaced (Mt CO2e/yr)	Gasoline	3.92	2.31
Emissions Saved (Mt CO2e/yr)	Gasoline	2.21	1.17

Methodology and Assumptions

The electric vehicle values in Table 1 represent annual consumption of a single vehicle, by type, based on 11,361 miles driven per year (Ref. 6), and by vehicle efficiency in kWh per mile. Grid loss has been incorporated into the charging load assumptions (Ref. 2). The MN PUC registered EV dataset from December 2021 has been used in the charging consumption analysis conducted (Ref. 2). The MN PUC dataset does not currently distinguish residential vehicles from commercial vehicles, therefore the values in Table 1 apply to both commercial and residential vehicles uniformly. If future MN PUC datasets distinguish residential from commercial vehicles Table 1 will be revised to also distinguish.

The emissions values presented in this measure represent emissions from stationary combustion of the specified fuel irrespective of the timing of the combustion or the efficiency of the method of combustion. These values are not derived from hourly emissions models specific to Minnesota or more granular utility territories within Minnesota, as required by the most recent resource plan approved by the commission under section 216B.2422. Hourly emissions models are still under development by utility groups, emissions values currently presented within the TRM will be revisited with hourly modeled data when available. Emissions values currently outlined within the TRM are meant to serve as guardrails and placeholders until more granular data is available. Utilities able to analyze territory emissions on an hourly basis should utilize hourly emissions specific to their territory in place of TRM provided emissions data.

References

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Revision History

Version	Description	Author	Date
4.0	New measure and content	Cadmus	11/01/2022
5.0	Emissions values altered in Appendix F, outputs modified within this measure based on Appendix F	Cadmus	9/1/2025

Residential Transportation – Level 2 Electric Vehicle Charger

Measure Detail	Measure Value
Measure ID	1.10.03
Target Market Segments	Residential
Target End Uses	Transportation
Applicable To	Residential customers
Actions	Purchase and installation of applicable charger
Delivery Methods	Retail, Direct Install
Required from Customer/Contractor	Networked or non networked charger
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	10 (Ref. 4)
Unit Participant Incremental Cost	See Table 2 (Ref. 4)

Measure Description

This measure is for the savings associated with the installation of an ENERGY STAR rated Level 2, 240V AC electric vehicle charger for residential applications. A networked charger refers to EV chargers connected to an online Energy Management tool(s). A non networked charger does not have an online management component.

Algorithms

Unit kWh Savings per Year $= (((Hours_{PLUG_STANDBY} + Hours_{UNPLUG_STANDBY}) \times SP_{BASE}) - ((Hours_{PLUG_STANDBY} \times SP_{EE_PLUG}) + (Hours_{UNPLUG_STANDBY} \times SP_{EE_UNPLUG})))/ 1000$

Unit Peak kW Savings $= kW_{AVERAGE} \times CF$

kW Avg $= (((SP_{BASE} - SP_{EE_PLUG}) \times Hours_{PLUG_STANDBY} / Hours_{TOTAL_STANDBY}) + ((SP_{BASE} - SP_{EE_UNPLUG}) \times Hours_{UNPLUG_STANDBY} / Hours_{TOTAL_STANDBY})) / 1000$

Algorithm Inputs:

Variable	Definition	Units	Ref	Table Ref
$Hours_{CHARGE}$	Annual hours plugged in and actively charging. Default of 278 hours.	Hours	1,3	1
$Hours_{PLUG}$	Annual hours plugged in. Default of 3,511 hours.	Hours	1,3	1
$Hours_{PLUG_STANDBY}$	Annual hours plugged in and in standby mode. Difference of annual hours plugged in (3,511) and annual hours plugged in and actively charging (278) = difference is default of 3,233 hours.	Hours	1,3	1
$Hours_{UNPLUG_STANDBY}$	Annual hours unplugged. The difference between 8760 hours and annual plugged in hours (3,511) = difference is default of 5,249 hours.	Hours	1,3	1
$Hours_{TOTAL_STANDBY}$	Sum of hours plugged in and in standby mode (3,233) and hours unplugged and in standby mode (5,249) = default of 8,482 hours.	Hours	1,3	1

SP_{BASE}	Baseline average standby power. See Table 1.	Watt	3	1
SP_{EE_PLUG}	Efficient average standby power with vehicle plugged in. See Table 1.	Watt	3	1
SP_{EE_UNPLUG}	Efficient average standby power with no vehicle plugged in. See Table 1.	Watt	3	1
CF	Summer peak coincidence factor = 1.0		1	

Example:

Residential installation of level 2 ENERGY STAR rated EV charger used for residential duty passenger vehicle. The charger is networked. See the ENERGY STAR eligibility criteria v1.2 for this equipment (Ref 4).

Unit kWh Savings per Year = {[(3,233 + 5,249) x 9.9] – [3,233 x 3.2 + 5,249 x 2.5]}/1000 = 61 kWh

$kW_{AVERAGE}$ = {[(9.9 - 5.8) x 3,233 / 8,482)] + [(9.9 - 2.5) x 5,249 / 8,482]}/1000 = 0.007 kW

Unit Peak kW Savings per Year = 0.007 x 1 = 0.007 kW

Deemed Input Tables

Table 1. Standby Hours and Deemed Energy Values (Ref. 1,2,3)

Variable		Deemed Energy Value
$Hours_{CHARGE}$		278
$Hours_{PLUG}$		3,511
$Hours_{PLUG_STANDBY}$		3,233
$Hours_{UNPLUG_STANDBY}$		5,249
$Hours_{TOTAL_STANDBY}$		8,482
SP_{Base}	Networked	9.9
	Non-Networked	3.7
$SP_{EE\ PLUG}$	Networked	3.2
	Non-Networked	3.5
$SP_{EE\ UNPLUG}$	Networked	2.5
	Non-Networked	2.1

Table 2. Deemed Unit kWh Savings per Year, $kW_{Average}$, Unit Peak kW Savings, and Incremental Costs (Ref. 1,2,3)

Unit kWh Savings per Year (kWh)		Unit Peak kW Savings (kW) *equal to $kW_{AVERAGE}$ since CF=1*		Incremental Cost ($)	
Networked	Non-Networked	Networked	Non-networked	Networked	Non-networked
61	9	0.007	0.001	$50.60	$89.51

Methodology and Assumptions

Values for ENERGY STAR rated level 2 chargers power consumption is based on INL testing data.

Baseline steady-state power consumption values were based on power measurements before charging and after charging, with the average established at the baseline.

References

1. Illinois Statewide Technical Reference Manual v.12.0 Vol 3. September 2023. Measure 5.7.3 Level 2 Electric Vehicle Charger, pp. 487-489. https://www.icc.illinois.gov/programs/Illinois-Statewide-Technical-Reference-Manual-for-Energy-Efficiency
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Revision History

Version	Description	Author	Date
4.2	New Measure	MN Department of Commerce	2024

Residential Transportation – Electric Bicycles

Measure Detail	Measure Value
Measure ID	1.10.04
Target Market Segments	Residential
Target End Uses	Transportation, Efficient Fuel switching
Applicable To	Residential customers
Actions	Replace Working, Replace on Fail, New purchase without existing equipment
Required from Customer/Contractor	Quantity of equipment purchased
Measure Energy Type	Electric, Gasoline, EFS
Unit kWh Savings per Year	-56 kWh
Unit Peak kW Savings	-0.001 kW
Unit Dth Savings per Year	3.9 Dth
Measure Lifetime (years)	10 years
Unit Participant Incremental Cost	$2,792.71 / unit

Measure Description

This measure includes the efficient fuel switching energy savings resulting from the purchase of an electric bicycle replacing some of the customers car miles traveled. Electric bicycles have a range of uses from purely recreational to dedicated commuting. The performance case in this measure considers the entire charging load for an electric bicycle, not just the charging load for the car displacement miles traveled. The baseline case in this measure focuses on quantifying the gasoline consumption from the limited car miles that can reasonably and conservatively be replaced by an electric bicycle operated in Minnesota.

The Minnesota Energy Conservation and Optimization Act (Ref. 7,8) allows for efficient fuel switching (EFS) improvements where electricity or natural gas replaces another fuel used by the customer (i.e. natural gas, fuel oil, propane, etc) provided that the following criteria are met for each measure pursued:

1. The proposed efficient fuel switching measure results in a net reduction in the amount of source energy consumed for a particular use, measured on a fuel-neutral basis, using the utility's annual system average efficiency, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.
2. The proposed efficient fuel switching measure results in a net reduction of statewide greenhouse gas emissions (Ref 9), over the lifetime of the improvement. For an efficient fuel-switching improvement installed by an electric utility, the reduction in emissions must be measured using the utility's annual average emissions factor, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.
3. The proposed efficient fuel switching measure is cost-effective, considering the costs and benefits from the perspective of the utility, participants, and society.

4. The proposed efficient fuel switching measure should produce a similar or higher level of quality, service, or output as the technical assumptions identified in the baseline technology to be eligible (Ref. 10).

Algorithms

kWh Added per Year = $kWh_{CHARGING}$ x Qty

Peak kW Savings (Penalty) = -Added kWh per Year / Peak Hours x CF

Gasoline Savings per Year (MMBtu) = $Fuel_Energy_{GASOLINE}$ x Displaced_Miles / MPG_{CAR}

Net MMBtu Savings per Year = Gasoline Saved per Year (MMBTU) - (Added kWh x Conversion $_{MMBtu}$)

Algorithm Inputs:

Variable	Definition	Units	Ref	Table Ref
$kWh_{CHARGING}$	Annual kWh consumed by charging e bike for all use cases, default of 56 kWh annually	kWh	1,4	
Qty	Quantity of e bikes purchased, deemed savings assume 1x multiplier	unit		
$Fuel_Energy_{GASOLINE}$	Conversion factor from gallons gasoline to MMBtu. 0.125 gallons gasoline per MMBtu	Gallons gasoline/ MMBtu	3	Apx F
Displaced_Miles	Annual displaced car miles, now traveled via E Bike. Default of 760 miles annually.	Miles	1,5	Notes
MPG_{CAR}	Average miles per gallon (MPG) fuel economy for 'cars' in the US, 2024. Default of 24.4.	miles per gallon	2	
Conversion MMBtu	Conversion factor from kWh to MMBtu. Default of 0.003412	kWh/MMBtu		
Peak Hours	410 Summer peak demand period hours during which charging could occur, see Methodology for definition.	hours		
CF	Coincidence factor, 0.11, see Methodology for definition			

Example:

Quantity one Electric bike purchased. All other variables deemed, calculations outlined below:

Unit kWh Added per Year = 56 kWh x 1 Unit = 56 kWh

Unit Peak kW Savings (Penalty) = -56 kWh / 410 x 0.11 = -0.015 (penalty)

Unit Gasoline Savings per Year (MMBtu) = 0.125 x 760 miles / 24.4 = 3.9 MMBtu

Net MMBtu Savings per Year (MMBtu) = 3.9 MMBtu - (56 kWh x 0.003412) = 3.7 MMBtu

Deemed Input Tables

Table 1: Measure Emissions Savings

Metric	Source	MtCO2e Annual Emissions per 1x E Bike
Emissions Emitted (Mt CO2e/yr)	Electric	0.02
Emissions Displaced (Mt CO2e/yr)	Gasoline	0.28
Emissions Saved (Mt CO2e/yr)	Gasoline	0.25

Methodology and Assumptions

The majority of the deemed values proposed within this measure were derived from an Efficiency Vermont electric bike survey and analysis (Ref. 1), and were cross checked by all other references noted below.

The potential charging hours during peak summer period for this measure is defined by Monday through Friday (excepting holidays) for a period of 17 weeks (June - September) during the daytime hours of 1pm - 6pm = 410 hours. The load shape for electric bicycle battery charging demonstrates 11% of total annual draw occurs during this defined window.

References

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2. US Department of Energy, Energy Efficiency & Renewable Energy. Average Fuel Economy by Major Vehicle Category. January 2024. Reference to "Car" category only. https://afdc.energy.gov/data/10310
3. MN TRM, Appendix F. Gasoline (mobile combustion) conversion from gallons gasoline to mmBtu
4. Electric Bike Review - Compare Tool. Battery capacity specifications taken specifically from Radwagon 4 Electric Cargo Bike. See notes for further analysis. https://electricbikereview.com/rad-power-bikes/radwagon/
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Weatherization Measures in CIP, (March 15, 2022). Docket No. E,G999/CIP-21-837. (eDocket No. 20223-183807-01). At 13. https://efiling.web.commerce.state.mn.us/edockets/searchDocuments.do?method=showPoup&documentId=%7B90098F7F-0000-C11B-B04F-C063DF81A5F9%7D&documentTitle=20223-183807-01

Revision History

Version	Description	Author	Date
4.2	New measure created	Cadmus	8/1/2024
5.0	Emissions values altered in Appendix F, outputs modified within this measure based on Appendix F	Cadmus	9/1/2025

Miscellaneous

Residential Misc. – Variable Speed Pool Pumps

Measure Detail	Measure Value
Measure ID	1.11.01
Target Market Segments	Residential
Target End Uses	Misc. Electric Loads
Applicable To	Residential customers
Actions	Replace Working, Replace on Fail, New Construction
Required from Customer/Contractor	Model number, pool size, pump type, hp, hydraulic hp (hhp)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	10 (Ref. 1, Page 10)
Unit Participant Incremental Cost	Use actual, or $809 (Ref. 2, Page 18)

Measure Description

This measure involves installation of variable speed pool pumps to replace single-speed units.

Algorithms

Unit kWh Savings per Year = (V_{POOL} x N_{TURN}) x (1/WEF_{BASE} - 1/WEF_{EFF}) x Days / 1,000

Unit Peak kW Savings = Unit kWh Savings per Year / (Days x 24) x CF

Where:

WEF_{BASE}	= Baseline weighted energy factor, kgal/kWh, based on pump type and hydraulic horsepower, see Table 1
WEF_{EFF}	= Efficient weighted energy factor, kgal/kWh, use actual
V_{POOL}	= 22,000 gallons, if unknown. Volume of swimming pool. (Ref. 2, Page 33)
N_{TURN}	= 2 turnovers/day; (Ref. 2, Page 11)
Days	= 122 days; Annual day pool is in operation. (Ref. 2, Page 33)
24	= Hours per day
CF	= 0.78 (Ref. 3)

Example:

A residential customer installed a new self-priming 0.5 hhp variable speed pool pump with WEF = 7.7.

WEF_{BASE} = -1.3 x ln(0.5) + 2.9 = 3.8

Unit kWh Savings per Year = (22,000 gal x 2 turnovers/day) x (1/3.8 - 1/7.7 WEF) x 122 days / (1,000 W / kW) = 715 kWh

Unit Peak kW Savings = 715 kWh / (122 days x 24 hr/day) x 0.78 = 0.190 kW

Deemed Input Tables

Table 1. Baseline WEF Formulas and WEF Values from ENERGY STAR Database

Equipment Class			Baseline WEF		Mean WEF from ENERGY STAR		
Pool Pump Type	hhp range	Motor phase	Standard	Value Range	Base	New	Model Count
Self-priming, w/ filter	hhp < 0.13	single	5.55	5.55	3.7	10.4	41
	0.13 ≤ hhp < 0.771		-1.3 × ln(hhp) + 2.9	3.24 to 5.55			
	0.771 ≤ hhp < 2.5		-2.3 × ln(hhp) + 6.59	4.49 to 7.16	6.1	7.7	152
Non self-priming, w/ filter	hhp < 0.13	any	4.60	4.60	4.6	8.2	8
	0.13 ≤ hhp < 2.5		-0.85 × ln(hhp) + 2.87	2.09 to 4.60			
Pressure cleaner booster	any	any	0.42	0.42	0.4	0.6	5

Methodology and Assumptions

Pump motor must be EC, DC brushless, or permanent magnet style. Pump motor must be capable of variable speed operation. Motor must include integrated "smart" controls that will modulate flow based on demand. If hydraulic horsepower is unknown, the average values from the ENERGY STAR database may be used, per the rightmost columns of Table 1.

References

1. "Analysis of Standards Options for Residential Pool Pumps, Motors, and Controls," Davis Energy Group 2004. Accessed 07/20/15. http://consensus.fsu.edu/FBC/Pool-Efficiency/CASE_Pool_Pump.pdf.
2. CEE High-Efficiency Residential Swimming Pool Initiative. Accessed 5/21/15. https://library.cee1.org/system/files/library/9986/CEE_Res_SwimmingPoolInitiative_01Jan2013_Corrected.pdf.
3. Cadmus. Wisconsin Focus on Energy 2020 Technical Reference Manual. https://www.focusonenergy.com/sites/default/files/Focus_on_Energy_2020_TRM.pdf
4. ENERGY STAR. Certified Product List for variable speed pool pumps. Accessed August 2020. https://www.energystar.gov/productfinder/download/certified-pool-pumps/

Revision History

Version	Description	Author	Date
1.0	Measure created	Franklin Energy Services	11/10/2015
2.0	Updated to new standard	Cadmus	9/2020

Residential Misc. – Outdoor Lawn Equipment

Measure Detail	Measure Value
Measure Energy Type	1.11.02
Target Market Segments	Residential
Target End Uses	Miscellaneous, Efficient Fuel switching
Applicable To	Residential customers
Actions	Replace Working, Replace on Fail, New purchase without existing equipment
Required from Customer/Contractor	Quantity of equipment purchased and type classification
Measure Energy Type	Electric, Gasoline, EFS
Unit kWh Savings per Year	See deemed values by equipment type
Unit Peak kW Savings	See deemed values by equipment type
Unit Dth Savings per Year	See deemed values by equipment type
Measure Lifetime (years)	See Table 1
Unit Participant Incremental Cost	See deemed values by equipment type

Measure Description

This measure includes the efficient fuel switching energy savings resulting from residential electric outdoor equipment (performance) replacing traditional gas-powered outdoor equipment (baseline). This measure characterizes energy efficient fuel savings from electric push and riding lawn mowers, trimmers, chainsaws and leaf blowers for residential applications.

The Minnesota Energy Conservation and Optimization Act (Ref. 1, 6) allows for efficient fuel switching (EFS) improvements where electricity or natural gas replaces the use of another fuel used by the customer (i.e. natural gas, fuel oil, propane, etc) provided that the following criteria are met for each measure pursued:

1. The proposed efficient fuel switching measure results in a net reduction in the amount of source energy consumed for a particular use, measured on a fuel-neutral basis, using the utility's annual system average efficiency, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.
2. The proposed efficient fuel switching measure results in a net reduction of statewide greenhouse gas emissions (Ref 9), over the lifetime of the improvement. For an efficient fuel-switching improvement installed by an electric utility, the reduction in emissions must be measured using the utility's annual average emissions factor, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.
3. The proposed efficient fuel switching measure is cost-effective, considering the costs and benefits from the perspective of the utility, participants, and society;
4. The proposed efficient fuel switching measure should produce a similar or higher level of quality, level of service or output as the technical assumptions identified in the baseline technology to be eligible (Ref. 10).

Utilities can pursue efficient fuel switching energy savings as part of their ECO programs if an applicable incentive/program/rate is offered to customers and has measured participation.

Algorithms

kWh Added per Year = Charging Consumption x Units

kW Savings = Battery Draw x CF

Gasoline Savings per Year (MMBtu) = Gasoline Consumption x 0.125 x Units

Net MMBtu Savings per year = Unit Gasoline Savings per year - (Unit kWh Savings x 0.003412)

Where:

Charging Consumption = Deemed annual charging consumption in kWh, by type, see Table 1 below.

Units = Quantity of customer purchased equipment, by type.

Gasoline Consumption = Deemed annual gasoline consumption displaced, in gallons, by type, see Table 1 below.

0.125 = Conversion of gallons of gasoline to MMBtu of energy = 0.125 MMBtu per gallon of gasoline

0.003412 = Conversion from kWh to MMBtu

Battery Draw = Battery draw during charging (in negative kW to demonstrate kW penalty), see Table 3.

CF = Coincidence Factor, 0.3

Net Savings = Deemed annual fuel consumption savings from the fuel switch, in MMBtu, by equipment type, see Table 1 below, or calculated via algorithm above.

Example:

A residential customer purchases an electric push lawn mower (1x) to replace a failed gasoline push lawn mower, instead of purchasing a like for like replacement of the gasoline push lawn mower.

Unit kWh Added = 40 kWh/yr x 1 Unit = 40 kWh/yr

Unit kW Savings = -0.42 x 0.3 CF = -0.126 kW

Unit Gasoline Savings per Year (MMBtu) = 4 gallons/yr x 0.125 x 1 Unit = 0.5 MMBtu

Net Savings per year (MMBtu) = (40 kWh/yr x 0.003412) + 0.5 MMBtu = 0.36 MMBtu

In this example, the new electric push mower will consume 40 kWH (0.14 MMBtu) per year from the electric grid, will fully displace 4 gallons of gasoline (0.5 MMBtu) being consumed per year by an equivalent gasoline powered push mower, and will result in a net energy savings of 0.36 MMBtu measured on a fuel neutral basis.

Deemed Input Tables

Table 1. Equipment Consumption and Savings by Type (Ref. 4, 5, 7, 8)

	Push Mower	Riding Mower	Leaf Blower	Trimmer	Chainsaw
Annual hours of Use	25	36	15	18	15
Electric Charging Consumption (kWh/yr)	40.0	349.2	25.5	14.4	21.0
Electric Energy Input (kW/hr)	1.6	9.7	1.7	0.8	1.4
Fuel Efficiency (Gal/hr)	0.16	1.00	0.15	0.10	0.15
Gasoline Consumption (Gal/yr)	4.00	36.00	2.25	1.80	2.25
Gasoline Consumption (MMBtu/yr)	0.50	4.50	0.28	0.23	0.28
Deemed Net Savings (MMBtu/yr)	0.36	3.31	0.19	0.18	0.21

Table 2. Peak Demand Penalty by Type (Ref. 8)

	Push Mower	Riding Mower	Leaf Blower	Trimmer	Chainsaw
Battery Draw (kW)	-0.42	-0.57	-0.20	0	0
Coincidence Factor	0.3	0.3	0.3	N/A	N/A
kW Penalty	-0.13	-0.17	-0.06	0	0

Table 3. Incremental Costs and EUL by Type (Ref. 2,3,4)

	Push Mower	Riding Mower	Leaf Blower	Trimmer	Chainsaw
Incremental Costs	$75.00	$380.00	$60.00	$60.00	$60.00
EUL	10	10	5	7	5

Table 4. Equipment Emissions by Type (Ref. 2, 3, 4)

	Push Mower	Riding Mower	Leaf Blower	Trimmer	Chainsaw
Emissions Emitted (Mt CO2e/yr) *Electric*	0.017	0.147	0.011	0.006	0.009
Emissions Displaced (Mt CO2e/yr) *Gasoline*	0.037	0.334	0.021	0.016	0.021
Emissions Saved (Mt CO2e/yr) *Gasoline*	0.020	0.187	0.010	0.010	0.012

Methodology and Assumptions

The emissions values presented in this measure represent emissions from stationary combustion of the specified fuel irrespective of the timing of the combustion or the efficiency of the method of combustion. Utilities able to analyze territory emissions on an hourly basis should utilize hourly emissions specific to their territory in place of TRM provided emissions data.

References

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Revision History

Version	Description	Author	Date
4.0	New measure and content	Cadmus	11/01/2022
4.2	Additional equipment added, some revision of outline of measure algorithm	Cadmus	9/1/2024
5.0	Emissions values altered in Appendix F, outputs modified within this measure based on Appendix F	Cadmus	9/1/2025

Commercial and Industrial

Lighting

C/I Lighting – Lighting End Use

Measure Detail	Measure Value
Measure ID	2.01.01
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Lighting
Required from Customer/Contractor	Existing fixtures and quantities (retrofits only), installed fixtures and quantities, building type, HVAC system (heating only, heating & cooling, exterior/unconditioned)
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	see Table 3
Unit Participant Incremental Cost	see Appendix B

Measure Description

The commercial lighting measures use a standard set of variables for hours of use, HVAC cooling interaction effects, and coincident factors. The following section provides the algorithms used for energy savings and the tables of supporting information. In compliance with the EISA efficiency standards, the baseline wattage for all screw-in bulbs will be a minimum of 45 lumens per watt efficacy, even if actual efficacy of existing bulb is lower, or the baseline denoted in appendix B is lower.

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = CF x (kW_Base - kW_EE) x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_heating_penalty_factor

Where:

kW_Base = Baseline fixture wattage (kW per fixture): see Appendix B. In compliance with the EISA efficiency standards, the baseline wattage for all screw-in bulbs will be a minimum of 45 lumens per watt efficacy, even if actual efficacy of existing bulb is lower, or the baseline denoted in appendix B is lower. See table 4 below.

kW_EE = High-efficiency fixture wattage (kW per fixture): see Appendix B or deemed table 4 below.

Hrs = Deemed annual operating hours from Table 2 based on building type

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in Table 2.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting from Table 1.

Example:

Replace (1) screw-in 60W incandescent with a 9W, 1,000 lumen LED lamp in an office space with heating and cooling. The baseline for this lamp is a 23 W bulb (based on 45 lumens per watt efficacy) per EISA.

kWh Savings = (0.023-0.009) x 4,439 x 1.095 = 68.05 kWh

kW Savings = 0.7 x (0.023-0.009) x 1.254 = 0.01 kW

Heating Penalty = (0.023-0.009) x 4,439 x -0.0023 = -0.143 Dth/year

Deemed Input Tables

Table 1. HVAC Interactive Factors by HVAC System (Ref. 2)

Lighting Measures	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only or Heating & Cooling
All Except Exterior/ Unconditioned	1.00	1.254	1.00	1.095	-0.0023
Exterior/ Unconditioned Space	1.00	1.00	1.00	1.00	0

Table 2. Deemed Peak Demand Coincidence Factors (Ref. 3) and Annual Operating Hours by Building Type (Ref. 4)

Building Type	CF	Hrs
Office	70%	4,439
Restaurant	80%	3,673
Retail	83%	4,719
Grocery/Supermarket	90%	5,802
Warehouse	70%	4,746
Elementary School	71%	2,422
Secondary School	58%	4,311
College	81%	3,540
Health	75%	5,095
Hospital	75%	6,038
Hotel/Motel	21%	3,044
Manufacturing	92%	5,200
Other/Misc.	66%	4,576
24-Hour Facility	100%	8,760
Safety or Code Required	100%	8,760
Exterior Lighting	0%	4,380

Table 3. Measure Life

Installed Technology	Measure Life (yrs)	Reference
Ceramic Metal Halide	13	8
Ceramic Metal Halide - Integrated Ballast	13	8
High Bay Fluorescent	15	6
High Bay LED	11.3	20
LED Exterior Canopy	10.2	7
LED Exterior (Wall & Area)	10.2	7
Low wattage plug-in CFL	1.8	16
Low wattage T8	15	6
Pulse Start Metal Halide	15	9
CFL Standard to Low Wattage	2.3	1
Controls (not networked lighting controls)	8	6
Networked lighting controls	11	
Exit Sign Retrofit with LED/LEC	16	6
Exterior Canopy/Soffit Retrofit with LEDs	10.2	7
Exterior Wall Pack Retrofit with LEDs	10.2	7
Parking Garage Fluorescent	15	6
High Pressure Sodium	15	18
Interior LED Screw-in Lamps	3.4	14
Interior LED Luminaire	11.3	15
Pin-Based CFL	2.3	9
Pin-Based LED	11.3	21

Installed Technology	Measure Life (yrs)	Reference
T5 fixtures	15	6
T8 fixtures	15	6
Refrigerator/Freezer Case LEDs	10	10
Stairwell Fixtures with Integral Occupancy	14.4	11
T8 Standard to Low Wattage Retrofit	8.1	12
Energy Standard Exempt T12 HO ballasts for outdoor signs and electronic ballast T12s	15	6
Nonexempt 8-foot magnetic ballast T12s are 4 years in 2013, 3 years in 2014, 2 years in 2015, and 1 year in 2016, 1 year in 2017, 1 year in 2018, 1 year in 2019	1	13
T8 Optimization	15	6
LED Linear Replacement Lamp	11.3	22

Table 4. Fixture Wattage (Ref. 23, 25, 26) and Costs (Ref. 24)

Type	Wattage Equivalence (Reference to incandescent)	Efficient Case – LED Replacement Bulb				Baseline Deemed Wattage	Incremental Cost ($)
		Deemed Wattage	Wattage Range	Deemed Lumens	Lumen Range		
A Line	100	16	15 – 18	1650	>1300	37	$8.66
A Line	75	13	11 – 14.9	1100	1000 - 1299	25	$8.66
A Line	60	9	8 – 10.9	800	600 - 999	18	$4.84
A Line	40	5	4 – 7.9	450	350 - 599	10	$3.73
A Line	25	3	1 – 3.9	250	<350	6	$1.45
Globe	100	13	>10	1100	>900	25	$8.66
Globe	60	7	6-9.9	680	550-899	16	$4.84
Globe	40	5	4.5 – 5.9	500	<550	12	$3.73
Directional	325	30	>27	3000	>2500	67	$10.00
Directional	250	22	19 – 26.9	2100	1800-2499	47	$10.00
Directional	150	15	13 – 18.9	1500	1300-1799	34	$10.00
Directional	90	11	10 – 12.9	1000	900-1299	23	$7.52
Directional	75	9	8 – 9.9	700	600-899	16	$6.02
Directional	50	6	<8	500	<600	12	$9.58
Specialty	100	6.5	>6	900	>700	20	$3.73
Specialty	60	5	4.6 – 6	500	450 - 699	12	$3.73
Specialty	40	4	3 – 4.5	350	300-450	8	$5.87
Specialty	25	2.5	<3	200	<300	5	$5.87

Methodology and Assumptions

HVAC cooling and heating interactive factor data based on DOE2/eQuest building simulation. The prototypes building models are based on the California DEER study prototypes (see http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf), and modified for local construction practices and code. Simulations were run using TMY3 weather data

for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Notes

New construction requirements and information is available in the New Construction section.

References

1. CFL lamp-rated hours of 10,000 is divided by the average operating hours (except safety, 24-hr, and exterior) of 4,431 hours to arrive at 2.3 years for measure life.
2. HVAC cooling and heating interactive factor data based on DOE2/eQuest building simulation. The prototypes building models are based on the California DEER study prototypes (see http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf), and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).
3. Database of Energy Efficient Resources 2008 Measure Energy Analysis Revisions Version 2008.2.05-09-11 Planning/Reporting Version.
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5. Lighting Efficiency input wattage guide, Xcel Energy, July 2008, kW.
6. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08.
7. Product life based on 50,000 minimum rated life from Design Lights Consortium V4.0 Specification. https://designlights.org/resources/file/TRT_V40_Final_FULLTABLE_FINAL_highlights 50,000 divided by the exterior hours of 4,903 arrives at 10.2 years.
8. State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation *Business Programs: Measure Life Study* Final Report: August 25, 2009.
9. Residential and Commercial/Industrial Lighting and HVAC Measures for use as Energy Efficiency Measures/Programs Reference Document for the ISO Forward Capacity Market (FCM) June 2007 GDS Associates, Inc.
10. Assumes 6,205 hrs, per year, operation (17 hrs/day) and a lifetime of approximately 62,082 hours (this is the average rated life from DLC qualified product list). Accessed 7/31/12.
11. Xcel Energy 2013-2015 Triennial CIP Plan (Docket No. E,G002/CIP-12-447). Average of fixture lifetime (20 years) and control lifetime (~8 years).

12. Product life assumption of 36,000 hours determined from survey of on-line retailers, July 2012. 36,000 hours is divided by the average operating hours (except safety, 24-hr, and exterior) of 4,431 hours to arrive at 8.1 years for measure life.
13. Measure life reduction due to legislation and market. See T12 up to 4-Foot Retrofit section for more information.
14. LED lamp rated hours of 15,000 (ENERGY STAR qualified minimum) is divided by the average operating hours (except safety, 24-hr, and exterior) of 4,431 hours to arrive at 3.4 years for measure life.
15. Product life based on 50,000 minimum rated life from Design Lights Consortium V4.0 Specification https://designlights.org/resources/file/TRT_V40_Final_FULLTABLE_FINAL_highlights LED luminaire rated hours of 50,000 is divided by the average operating hours (except safety, 24-hr, and exterior) of 4,431 hours to arrive at 11.3 years for measure life.
16. Measure life for low wattage plug-in CFL lamps is based on 8,000 hours of life divided by the average annual operating hours of 4,431 to arrive at 1.81 years.
17. CFL lamps rated hours of 10,000 is divided by the average operating hours (except safety, 24-hr, and exterior) of 4,431 hours to arrive at 2.3 years for measure life.
18. Xcel Energy uses 20 years in 2013-2015 Minnesota CIP Triennial Plan (Docket No. E,G002/CIP-12-447), per communication with Commerce staff. Fixture may be considered permanent once installed; however, life was decreased to 15 years for consistency with maximum lifetimes for other technologies.
19. ANSI/ASHRAE/IES Standard 90.1-2010 edition.
20. LED highbay-rated hours of 50,000 is divided by the average operating hours (except safety, 24-hr, and exterior) of 4,431 hours to arrive at 11.3 years.
21. DLC is expected to adopt this category of lamps in late 2016; minimum rate lifetime will be 50,000 hours. 50,000 is divided by the average operating hours (except safety, 24-hr, and exterior) of 4,431 hours to arrive at 11.3 years.
22. Minimum rated lifetime will be 50,000 hours. 50,000 is divided by the average operating hours (except safety, 24-hr, and exterior) of 4,431 hours to arrive at 11.3 years.
23. Baseline wattages are from EISA minimum 45 lumen/watt efficiency requirements. ENERGY STAR efficient wattages are from product information and available qualified products.
24. Costs are based on manufacturer product surveys and Midwest program data, on field data collected by CLEAResult and provided by ComEd, on Wisconsin Focus on Energy historical data obtained from Spectrum, and from Consortium of Retail Energy Efficiency Data (CREED) 2019,
25. EPA ENERGY STAR. Luminaires v2.2 Criteria. Effective August 15, 2019. https://www.energystar.gov/products/light_fixtures/partners
26. EPA ENERGY STAR. Lamps v2.1 Criteria. Effective January 2, 2017. https://www.energystar.gov/products/light_bulbs/partners

Revision History

Below is a summary of the revision history for the entire C/I Lighting section.

Version	Description	Author	Date
2.0	Updated format, baseline and efficient wattages, costs, energy standards, and requirements where applicable through the lighting section. Added fluorescent to LED High Bay and LED Troffer Measures	Franklin Energy Services	11/12/2015
2.1	Updated measure lives to reflect ENERGY STAR Version 2.0 for Lamps and Design Lights Consortium Version 4.0 Specifications	Franklin Energy Services	9/30/2016
2.2	Added LED Linear Replacement Lamps. Decreased exterior lighting hours to 4,383	Franklin Energy Services	8/4/2017
2.3	Updated EUL for networked lighting controls	Cadmus	10/2020
2.4	EISA updates to baseline for screw-in bulbs only	Cadmus	11/01/2022

C/I Lighting – CFL Standard to Low Wattage Retrofit

Measure Detail	Measure Value
Measure ID	2.01.02
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Lighting
Applicable To	Commercial, Industrial, and Public Buildings
Actions	Replace Working, Replace on Fail
Measure Energy Type	Electric

Measure Description

This measure replaces standard wattage plug-in CFL lamps with lower wattage plug-in CFL lamps, nominally 40 watt lamps replaced by 28 watt or 25 watt lamps. These lamps plug into the fixture and can be used with the existing ballast and base. Commonly referred to as Dulux, Biax, or PL lamps.

Algorithm and Assumptions

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages. In compliance with the EISA efficiency standards, the baseline wattage for all screw-in bulbs will be a minimum of 45 lumens per watt efficacy, even if actual efficacy of existing bulb is lower, or the baseline denoted in appendix B is lower.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	9/28/2016
3.5	EISA updates to baseline for screw-in bulbs only	Cadmus	11/01/2022

C/I Lighting – Controls

Measure Detail	Measure Value
Measure ID	2.01.03
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Lighting
Applicable To	Commercial, Industrial, and Public Buildings
Actions	Modify (all) New Construction (some)
Required from Customer/Contractor	Control type/quantity, connected load (kW) to each control, building type, HVAC system (heating only, heating & cooling, exterior/unconditioned)
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	11 years or fixture lifetime for NLC with LLLC (see Notes), 8 years for other controls including NLC without LLLC (Ref. 1)
Unit Participant Incremental Cost	See Table 2

Measure Description

Lighting control technologies reduce energy use by automatically turning lights off and adjusting brightness levels, rather than relying on people to remember to switch lights off when leaving a space. There are several different lighting control technologies, including:

- **Occupancy sensors**. These measure the movement of people within a space. When movement is detected, the lights turn on automatically; they then shut off after a period of not sensing movement.
- **Daylight sensors**. These take advantage of available daylight in perimeter building spaces (open spaces within 10' to 15' of windows) or other areas that have access to daylight infiltration. Daylight sensor lighting controls can be used to turn lights on or off, stepped dimming (high/low or inboard/outboard), or continuous dimming based on light levels from available daylight.
- **Personal tuning**. This consists of adjusting individual light levels by occupants according to their personal preferences. Requires continuous or multilevel dimming, and largely applies to private offices and individual cubicles in open offices.
- **Task tuning**. Also known as institutional tuning or high-end trim, this is similar to personal tuning but involves tuning light levels broadly across an entire office or other space, often through commissioning, and often involving the provision of switches or controls for areas or groups of occupants.
- **Networked lighting controls (NLC)**. Also known as connected lighting controls, this consists of an intelligent network of individually addressable luminaires and control devices, allowing for the interactive application of multiple control strategies. Sensor mechanisms for NLC may be integrated into the fixtures themselves. This practice is called luminaire-level lighting controls

(LLLC), and there is evidence that it saves more energy than NLC with sensors that are separate from the fixtures.

Note that Minnesota state energy code as of March 31, 2020 (Ref. 7) follows 2018 IECC standards (Ref. 8). These standards require that occupancy sensors are required in classrooms, office spaces, restrooms, locker rooms, storage rooms, warehouses, and more, and that daylight controls are employed in sidelit and toplit zones. For new construction in these spaces, these controls shall be the baseline.

Algorithms

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Unit kWh Savings per Year = kW x (SF_new - SF_old) x Hrs x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = CF x kW x (SF_new - SF_old) x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = kW x (SF_new - SF_old) x Hrs x HVAC_heating_penalty_factor

Where:

kW = Total connected fixture load, determined as the sum of stipulated fixture wattages from the Retrofit Tables in the C/I Lighting Measure.

Hrs = Deemed annual operating hours from Table 2 based on building type, in Lighting End Use section.

SF_new = Deemed Savings Factor for newly installed lighting control per Table 1 and Table 2.

SF_old = Savings factor for existing lighting control, or often occupancy or daylighting controls for New Construction, per Table 1.

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in table 2, in Lighting End Use section.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from lighting from Table 1, in Lighting End Use section. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from lighting from Table 1, in Lighting End Use section. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from lighting control from Table 1, in Lighting End Use section.

Example:

Install a wall mounted occupancy sensor with a connected load of 0.560 kW (10 - 2L 32W T8 fixtures) in an office space.

kWh = 0.560kW x 0.22 x 4,439 x 1.095 = 598.8 kWh

kW = 0.7 x 0.560 x 0.22 x 1.254 = 0.108 kW

Deemed Input Tables

Table 1. Deemed Savings Factors

Control Type	Building type	Savings Factor	SF Source
Occupancy Sensor	Office	0.22	Ref. 2, Table 7 For warehouse new construction, occupancy sensors with 50% dimming are required (Ref. 8). This reduces the baseline NC savings factor in this scenario to SF_{OCC} x (1 - 0.50) = 0.31 x 0.50 = 0.16
	Warehouse	0.31 (upgrade) 0.16 (NC baseline)	
	Lodging	0.45	
	Education	0.18	
	Assembly	0.36	
	Healthcare, outpatient	0.23	
	Other / unknown	0.24	Ref. 2, Abstract
Daylighting	Office	0.27	Ref. 2, Table 7
	Warehouse	0.28	
	Education	0.29	
	Retail	0.29	
	Assembly	0.36	
	Other / unknown	0.28	Ref. 2, Abstract
Personal tuning	Office	0.21	Ref. 2, Ref. 5: 0.35 x 0.22 / 0.36 = 0.21 (see Notes)
	Education	0.04	Ref. 2, Ref. 5: 0.06 x 0.22 / 0.36 = 0.04 (see Notes)
	Other / unknown	0.19	Ref. 2, Ref. 5: 0.31 x 0.22 / 0.36 = 0.19 (see Notes)
Task tuning	Office	0.37	Ref. 6 and Ref. 9, see Notes
	Education	0.26	
	Manufacturing	0.05	
	Warehouse	0.07	
	Other / unknown	0.22	Ref. 5
Multiple of the above		0.38	Ref. 2, Abstract

Table 2. Deemed Savings Factors for NLC

Control Type	Subtype	Savings Factor			SF Source
		With LLLC	Without LLLC	Unknown	
Networked lighting controls	Assembly	0.32	0.24	0.28	Ref. 3, Table 1 and Table 7, see Notes
	Manufacturing	0.51	0.26	0.40	Ref. 3, Table 1 and Table 7
	Office	0.77	0.40	0.64	Ref. 3, Table 1 and Table 7
	Education	0.52	0.35	0.41	Ref. 3, Table 1 and Table 7
	Restaurant	0.67	0.51	0.59	Ref. 3, Table 1 and Table 7, see Notes
	Retail	0.50	0.38	0.44	Ref. 3, Table 1 and Table 7, see Notes
	Warehouse	0.78	0.58	0.68	Ref. 3, Table 1 and Table 7, see Notes
	Other / unknown	0.63	0.35	0.49	Ref. 3, Table 1 and Table 7

Table 3. Deemed Incremental Costs

Control Type	Subtype	Incremental Cost	IC Source
Occupancy Sensor	Wall switch mount	$55 per sensor	Ref. 4
	Fixture mount	$67 per sensor	
	Remote or wall mount	$125 per sensor	
	Integrated	$40 per sensor	
Daylighting	Fixture mount	$50 per sensor	Ref. 4
	Remote or wall mount	$65 per sensor	
Dual occupancy and daylighting sensor	Integrated	$50 per sensor	Ref. 4
	Fixture-mounted	$100 per sensor	
Personal tuning		Actual, or $0.06 per sq ft controlled	Ref. 5
Institutional tuning			
Networked lighting controls		Actual cost	

Notes

Because networked lighting controls with LLLC are installed integrated into fixtures, the measure lifetime for networked lighting controls with LLLC is assumed to match the fixtures themselves, generally 11 years for LEDs per the lighting end use section. However, if the lifetimes of the LED units being installed with networked lighting controls with LLLC are known to be higher than 11 years, those lifetimes may be applied to networked lighting controls associated with those units.

Savings fractions by building type for task tuning were derived from Table 2 of a 2020 Slipstream paper (Ref. 6), which shows savings fractions by space type, and space type splits for each building type (Ref. 9). Those values are seen in Table 3 below.

Table 3. Savings Factors for Task Tuning by Building

Space Type	Space Type Savings Factor (Ref. 6)	Space Distribution by Building Type (Ref. 9)			
		Office	Education	Manufacturing	Warehouse
Office	39%	70%	5%	10%	10%
Conference	34%	4%	0%	0%	0%
Warehouse	4%	0%	0%	25%	87%
Storage	0%	6%	3%	0%	0%
Corridor	86%	10%	21%	0%	0%
Other	0%	10%	34%	5%	3%
Manufacturing	0%	0%	0%	60%	0%
Classroom	17%	0%	35%	0%	0%
Weighted Average Building Savings Factor		**37%**	**26%**	**5%**	**7%**

The savings fractions for personal tuning employ values from Ref. 2 (Table 7 for Office and Education, Abstract for Other) but normalizes based on findings from Ref. 5 showing that the institutional tuning SF = 0.22 on average, rather than 0.31 from the Ref. 2 Abstract. The savings factor for personal tuning is normalized from the Ref. 2 values by 0.22 / 0.36 = 61%.

Savings fractions for NLC for three building types (manufacturing, office, education) and other / unknown buildings were derived directly from Table 7 of a NEEA study examining NLC with and without LLLC (Ref. 3). This study found sufficient diversity in savings across NLCs with and without LLLC for these three building types that their savings factors were listed.

For the other four building types (assembly, restaurant, retail, warehouse), the study only lists savings factors for NLC as a whole, without a differentiation for having or not having LLLC. While the study did find that LLLC produced more savings on average across all surveyed buildings together, it cautions this may not be the case for each individual building type and that more study is needed. However, for this measure an attenuated difference is applied for those four other building types.

Savings for those building types with and without LLLC are normalized by the "Other / unknown" (overall) savings, with a 50% attenuation: LLLC savings are normalized by [(0.63 / 0.49 – 1) x 0.5] + 1 = 1.14, and non-LLLC savings are normalized by [(0.35 / 0.49 – 1) x 0.5] + 1 = 0.86. Therefore, for instance, assembly buildings with LLLC are deemed a savings factor of 0.28 x 1.14 = 0.32. As new research on LLLC is produced, these savings fractions will be revisited.

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7. U.S. Department of Energy Building Energy Codes Program. Minnesota. https://www.energycodes.gov/adoption/states/minnesota
8. 2018 International Energy Conservation Code. Chapter 4 section C405.2. https://codes.iccsafe.org/content/iecc2018/chapter-4-ce-commercial-energy-efficiency
9. Review of DOE Prototype Models and eQuest Wizard defaults

Revision History

Version	Description	Author	Date
4.0	Modified savings values and references, added several control methods	Cadmus	9/2020
4.1	Added separate savings for LLLC, updated savings for NLC, added costs	Cadmus	9/2021

C/I Lighting – Exit Sign Retrofit with LED/LEC

Measure Detail	Measure Value
Measure ID	2.01.04
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Lighting
Applicable To	Commercial, Industrial, and Public Buildings
Actions	Replace Working, Replace on Fail
Measure Energy Type	Electric

Measure Description

This measure evaluates the retrofit and replacement of incandescent exit signs with energy efficient LED and LEC exit signs. ENERGY STAR labeled exit signs operate on five watts or less per sign, compared to the standard signs, which use as much as 40 watts per sign.

Algorithm and Assumptions

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Notes

EPA suspended the ENERGY STAR Exit Sign specification effective May 1, 2008. In EPAct 2005, Congress passed a new minimum federal efficiency standard for electrically-powered, single-faced exit signs with integral light sources that are equivalent to ENERGY STAR levels for input power demand. EPAct 2005 references the ENERGY STAR Version 2.0 specification. All exit signs manufactured on or after January 1, 2006 must have an input power demand of 5 watts or less per face.

References

1. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08
2. Calculated through energy modeling by FES 2012
3. Lighting Efficiency input wattage guide, Xcel Energy, July, 2008, kW
4. NYSERDA Deemed Savings Database, Labor cost assumes 25 minutes @ $18/hr taken from the State of Illinois Technical Reference Manual 2012 and 2012 manufacturer product survey and project data.

Revision History

Version	Description	Author	Date

C/I Lighting – Exterior Canopy/Soffit Retrofit with LEDs

Measure Detail	Measure Value
Measure ID	2.01.05
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Lighting
Applicable To	Exterior canopy/soffit lighting at any facility type
Actions	Replace Working, Replace on Fail
Measure Energy Type	Electric

Measure Description

Exterior high pressure sodium, metal halide, mercury vapor, and pulse start metal halide fixtures can all be replaced with energy efficient LED exterior light fixtures in canopy and soffit applications. Utilizing LED lighting, a large energy savings can be accomplished without a great lumen reduction in the area.

Algorithm and Assumptions

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages. In compliance with the EISA efficiency standards, the baseline wattage for all screw-in bulbs will be a minimum of 45 lumens per watt efficacy, even if actual efficacy of existing bulb is lower, or the baseline denoted in appendix B is lower.

Requirements

It is suggested that all LED fixtures and retrofits appear on the Design Lights Consortium Qualified Product list available at www.designlights.org.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	9/28/2016
3.5	EISA updates to baseline for screw-in bulbs only	Cadmus	11/01/2022

C/I Lighting – Exterior Wall Pack Retrofit with LEDs

Measure Detail	Measure Value
Measure ID	2.01.06
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Lighting
Applicable To	Exterior wall pack lighting at any facility type
Actions	Replace Working, Replace on Fail
Measure Energy Type	Electric

Measure Description

Exterior high pressure sodium, metal halide, mercury vapor, and pulse start metal halide fixtures can all be replaced with energy efficient LED exterior wall pack fixtures. Utilizing LED lighting, a large energy savings can be accomplished without a great lumen reduction in the area.

Algorithm and Assumptions

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Requirements

It is suggested that all LED fixtures and retrofits appear on the Design Lights Consortium Qualified Product list available at www.designlights.org.

Revision History

Version	Description	Author	Date

C/I Lighting – Fluorescent to LED High Bay Systems

Measure Detail	Measure Value
Measure ID	2.01.07
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Lighting
Applicable To	Commercial, Industrial, and Public Buildings
Actions	Replace Working
Measure Energy Type	Electric

Measure Description

LED high bay fixtures offer increased efficiency with nearly equivalent light output as compared to linear fluorescent high bay systems. Integrated LED high bays also offer advanced controllability leading to an even greater increase in efficiency.

LED systems are often utilized in high bay ceiling applications over 15 feet. LED fixtures also offer an increased life time, reduced maintenance, and no decreased in operational performance in colder temperatures.

Algorithm and Assumptions

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Requirements

It is suggested that LED High Bay fixtures appear on the Design Lights Consortium Qualified Product List under the High Bay category.

Revision History

Version	Description	Author	Date

C/I Lighting – High Pressure Sodium Retrofit

Measure Detail	Measure Value
Measure ID	2.01.08
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Lighting
Applicable To	Commercial, Industrial, and Public Buildings
Actions	Replace on Fail, Replace Working
Measure Energy Type	Electric

Measure Description

This measure evaluates high pressure sodium fixtures replaced by pulse start metal halides, high bay fluorescent fixtures, parking garage fluorescent, and ceramic metal halides.

Pulse start metal halide systems typically consume 20%less energy than high pressure sodium systems, produce the same light at lower wattages, and can often use more efficient ballasts depending on the application.

High bay fluorescent systems are often utilized in high bay ceiling applications over 15 feet. High bay fluorescent and parking garage fluorescent systems offer lower depreciation rates, better dimming options, virtually instant start-up and re-strike, better color rendition, and reduced glare.

Ceramic metal halides can be utilized to replace high pressure sodium in lower wattage applications and result in better color rendition, lower wattage consumption, and improved color temperature.

Algorithm and Assumptions:

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Notes

New construction wattage tables are available in the CI Lighting New Construction file.

The Energy Independence and Security Act of 2007 legislation sets standards for ballasts used in new metal halide luminaires that operate lamps from 150 to 500 watts. New metal halide luminaires must contain ballasts that meet new efficiency standards. Pulse-start metal halide ballasts must have a minimum ballast efficiency of 88%, magnetic probe-start ballast a minimum efficiency of 94%. New metal halides operating lamps of 150-500 watts manufactured on or after January 1, 2009 contain pulse-start, magnetic or electronic, metal halide ballasts with a minimum efficiency of 88%.

Revision History

Version	Description	Author	Date

C/I Lighting – Incandescent Over 100W Retrofit

Measure Detail	Measure Value
Measure ID	2.01.10
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Lighting
Applicable To	Commercial, Industrial, and Public Buildings
Actions	Replace Working, Retrofit
Measure Energy Type	Electric

Measure Description

This measure replaces Incandescent fixtures over 100 watts with various technologies including ceramic metal halides, high pressure sodium fixtures, integrated ballast ceramic metal halides, LED lamps, LED luminaire, pin-based CFL, pulse start metal halides, T5 fixtures, and T8 fixtures. The replacement fixture technology will depend on the specific application and environment.

Algorithm and Assumptions

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages. In compliance with the EISA efficiency standards, the baseline wattage for all screw-in bulbs will be a minimum of 45 lumens per watt efficacy, even if actual efficacy of existing bulb is lower, or the baseline denoted in appendix B is lower.

Requirements

It is suggested that all LED fixtures and retrofits appear on the Design Lights Consortium Qualified Product list available at www.designlights.org and LED and CFL lamps appear on the ENERGY STAR Qualified Product list available at www.energystar.gov.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	9/28/2016
3.4	EISA updates to baseline for screw-in bulbs only	Cadmus	11/01/2022

C/I Lighting – LED Pin-Base Lamps Replacing CFLs

Measure Detail	Measure Value
Measure ID	2.01.11
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Lighting
Applicable To	Commercial, Industrial, and Public Buildings
Actions	Replace Working, Replace on Fail
Measure Energy Type	Electric

Measure Description

This measure replaces CFL pin-base lamps, commonly referred to as Dulux, Biax, or PL lamps, with LED pin-base lamps. These lamps plug into the existing fixture and can be used with the existing ballast and socket.

As of September 2016, Lighting Design Lab (www.lightingdesignlab.com) maintains a qualified product list of pin-base CFL replacement products. Design Lights Consortium is expected to have a qualified product list available for this category in late 2016.

Algorithm and Assumptions

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.

Revision History

Version	Description	Author	Date

C/I Lighting – LED Screw-In Lamps in Walk-in Coolers and Freezers

Measure Detail	Measure Value
Measure ID	2.01.12
Target Market Segments	Commercial, Industrial
Target End Uses	Lighting
Applicable To	Grocery stores, convenience stores and other refrigerated sales facilities; refrigerated warehouses
Actions	Replace on Fail, Replace Working
Required from Customer/Contractor	Unit type (refrigerator or freezer), existing wattage, installed wattage
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	15,000/Hrs; default = 1.7 (Ref. 2)
Unit Participant Incremental Cost	Proposed lamp cost. See Appendix B.

Measure Description

This measure involves replacement of existing incandescent screw-in lamps with LED screw-in lamps in walk-in coolers and freezers or refrigerated warehouses which meet current ENERGY STAR performance critiera. Compliant efficient products do not need to be ENERGY STAR qualfied through the EPA program but would need to meet the ENERGY STAR performance criteria specified within this measure.

Algorithm

Unit kWh Savings per Year = (kW_base - kW_EE) x Hrs x (1 + Refr_Factor)

Unit Peak kW Savings = CF x (kW_base - kW_EE) x (1 + Refr_Factor)

Where:

kW_base = Baseline lamp wattage, see Appendix B. In compliance with the EISA efficiency standards, the baseline wattage for all screw-in bulbs will be a minimum of 45 lumens per watt efficacy, even if actual efficacy of existing bulb is lower, or the baseline denoted in appendix B is lower.

kW_EE = Efficient lamp wattage, see Appendix B

Hrs = 8,760 hours or estimate on-time if controlled (Ref. 1)

CF = 1.0; peak electrical coincidence factor (Ref. 1)

Refr_Factor = 0.40 (for refrigerator applications, assumes COP of 2.5) (Ref. 3)
= 0.77 (for freezer applications, assumes COP of 1.3) (Ref. 3)

Example:

A convenience store retrofits its walk-in cooler with 9W, 1,000 lumen ENERGY STAR-qualified LED lamps. The existing lamps are screw-in 60W incandescent. The baseline for this lamp is a 23W bulb (based on 45 lumens per watt efficacy) per EISA.

Unit kWh Savings per Year = (0.023 - 0.009) x 8,760 x (1 + 0.40) = 171.7 kWh

Unit Peak kW Savings = 1.0 x (0.023 - 0.009) x (1 + 0.40) = 0.02 kW

References

1. Without lighting controls, walk-in cooler and freezer lighting is considered always on.
2. Assumes 8,760 hrs per year operation and a lifetime of approximately 15,000 hours (ENERGY STAR minimum requirement from V2.0); equates to 1.7 years.
3. US DOE Publication #46230-00, “Energy Savings Potential for Commercial Refrigeration Equipment", 1996, Arthur C. Little, Inc

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	9/28/2016
1.1	EISA updates to baseline for screw-in bulbs only	Cadmus	11/01/2022

C/I Lighting – LED Troffer Retrofit Kits

Measure Detail	Measure Value
Measure ID	2.01.13
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Lighting
Applicable To	Commercial, Industrial, and Public Buildings
Actions	Replace Working
Measure Energy Type	Electric, Gas

Measure Description

LED Troffers offer an energy efficient alternative to T8 linear fluorescent fixtures. Kits are available to convert an existing recessed troffer to LED without requiring removal of the fixture. LED integrated fixtures offer similar light output with a reduction of energy consumption. Integrated LED fixtures also offer controllability beyond capabilities of linear fluorescent technology and integration with many complex control systems.

Algorithm and Assumptions

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Requirements

It is suggested that all LED fixtures and retrofits appear on the Design Lights Consortium Qualified Product list available at www.designlights.org.

Revision History

Version	Description	Author	Date

C/I Lighting – LED Troffers

Measure Detail	Measure Value
Measure ID	2.01.13
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Lighting
Applicable To	Commercial, Industrial, and Public Buildings
Actions	Replace Working
Measure Energy Type	Electric, Gas

Measure Description

LED Troffers offer an energy efficient alternative to T8 linear fluorescent fixtures. The LED integrated fixtures offer similar light output with a reduction of energy consumption. Integrated LED fixtures also offer controllability beyond capabilities of linear fluorescent technology and integration with many complex control systems.

Algorithm and Assumptions

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Requirements

It is suggested that all LED fixtures and retrofits appear on the Design Lights Consortium Qualified Product list available at www.designlights.org.

Revision History

Version	Description	Author	Date

C/I Lighting – LED Tube Replacement Lamps

Measure Detail	Measure Value
Measure ID	2.01.14
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Lighting
Applicable To	Commercial, Industrial, and Public Buildings
Actions	Replace Working, Replace on Fail
Measure Energy Type	Electric, Gas

Measure Description

LED Tube replacement lamps offer an energy efficient alternative to traditional linear fluorescent lamps. These are available in three types: Underwriters Laboratory (UL) Type A (direct replacement), UL Type B (hard wired), or UL Type C (remote driver). The three variations allow for a retrofit in nearly every linear fluorescent application.

Type A tubes contain an internal driver that allows the tube to operate directly from an existing fluorescent ballast. Type B tubes contain an integrated driver that is designed to be powered directly from line voltage supplied to the existing fluorescent fixture. Type C tubes are designed to be powered from a remote driver.

Algorithm and Assumptions

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Requirements

It is suggested that all LED lamps appear on the Design Lights Consortium Qualified Product list available at www.designlights.org.

Revision History

Version	Description	Author	Date

C/I Lighting – LED Grow Lights

Measure Detail	Measure Value
Measure ID	2.01.15
Target Market Segments	Agricultural
Target End Uses	Lighting
Applicable To	Agricultural
Actions	Replace on Fail, Replace Working
Required from Customer/Contractor	Crop Type/Growth Stage, Qty, PPF of Fixture (DLC Listing), kWee (DLC Listing)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	None
Measure Lifetime (years)	9.5 (Ref. 1)
Unit Participant Incremental Cost	$501 (Ref. 2)

Measure Description

This measure is designed for interior horticultural applications that use artificial light stimulation in an indoor conditioned space. Qualified LED grow fixtures must meet all criteria below:

- have a reduced wattage from baseline fixture,
- be listed on the Design Lights Consortium (DLC) qualified products list,
- be UL Listed,
- have a power factor (PF) ≥0.90,
- a photosynthetic photon efficacy (PPE) of no less than 2.5 micromoles per joule,
- a minimum rated lifetime of 50,000 hours,
- and a minimum warranty of 5 years for the fixture.

Algorithms

Unit kWh Savings per Year = $[((Qty \times PPF_{PROPOSED})/(PPE_{BASELINE} \times 1000)) - kW_{ee}] \times Hours \times HVAC\ Cooling\ kWh\ Savings\ Factor$

Unit kW = $[((Qty \times PPF_{PROPOSED})/(PPE_{BASELINE} \times 1000)) - kW_{ee}] \times CF \times HVAC\ Cooling\ kW\ Savings\ Factor$

Algorithm Inputs:

Variable	Definition	Units	Ref	Table Ref
$PPE_{BASELINE}$	Photosynthetically-active Photon Flux Efficiency of the assumed baseline individual fixture for a specific growth phase. See Table 1 for deemed baseline values by growth phases or plant types. If considering multiple crops or phases, the savings algorithm should be calculated and summed for each crop/phase.	µmol/J	3,4	1

Variable	Definition	Units	Ref	Table Ref
$PPF_{PROPOSED}$	The Photosynthetically-active Photon Flux Efficiency of the proposed individual fixture installed for a specific growth phase. If considering multiple crops or phases, the savings algorithm should be calculated and summed for each crop/phase.	µmol/s	7	
Qty	The installed quantity of efficient fixtures.			
1,000	Watts to kilowatts conversion factor			
kW_{ee}	Total power of the installed fixtures for a specific growth phase. If considering multiple crops or phases, the savings algorithm should be calculated and summed for each crop/phase.	kW	7	
Hours	Annual operating hours. See Table 1 for deemed values by growth phase or plant type. If considering multiple crops or phases, the savings algorithm should be calculated and summed for each crop/phase.	Hours	5	1
HVAC Cooling kWh Savings Factor	Waste heat factor for energy to account for cooling savings from efficient lighting in cooled buildings. Use 1.21 if space is cooled, or 1.00 if no cooling or unknown.		6	
HVAC Cooling kW Savings Factor	Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings. Use 1.22 if spaced is cooled or 1.00 if none or unknown;		6	
CF	Coincidence Factor, 0.95 default		6	

Example:

A cannabis growth facility is installing 100 efficient LED fixtures in their flowering spaces. Using the manufacturer and model number, the DLC Qualified Products List for horticulture lighting lists these fixtures as consuming 529W and having a Photosynthetic Photon Efficiency (PPE) of 3.3 µmol/J and producing 1,722 µmol/s. One hundred (100) fixtures at 529W each is a total lighting power of 52.9 kW. The baseline PPE is 1.7 µmol/J.

Unit kWh Savings per Year = [((100 x 1,700 µmol/s) / (1.7 µmol/J x 1000)) – 52.9 kW] x 4,200 x 1.21 = 245,939 kWh

Unit kW = [((100 x 1,722 µmol/s) / (1.7 µmol/J x 1000)) – 52.9 kW] x 0.95 x 1.22 = 56.09 kW

Deemed Input Tables

Table 1. $PPE_{Baseline}$ and Hours by Crop Type/Growth Stage (Ref. 3, 4, 5)

Crop Type/Growth Stage	Baseline Technology	$PPE_{Baseline, i}$	Hours
Flowering and Vine Crops	High Pressure Sodium	1.7	4,200
Vegetative Growth	Metal Halide	1.25	6,300
Leafy Greens	T5 HO Fixture	1.0	6,300
Propagation	T5 HO Fixture	1.0	4,200
Cannabis – Flowering Stage	High Pressure Sodium	1.7	4,200

Cannabis – Vegetative Stage	Metal Halide	1.25	6,300
Cannabis – Cloning, Seedling, and Propagation	T5 HO Fixture	1.0	2,120

Methodology and Assumptions

The savings and costs for this measure are evaluated with the replacement of HID and/or linear fluorescent grow lights with LED fixtures. Grow light efficacy is measured by photosynthetic photon flux density (PPFD), rather than lumens.

References

1. Based on 50,000 hours lifetime and 5,250 hours per year of use (average hours of use per year using flowering and vegetative rooms).
2. Incremental costs are sourced from the Wisconsin Focus on Energy 2025 Technical Reference Manual, January 29, 2025 – Grow Light System, Agriculture, and include an estimated blend of baseline HID fixtures that fit the measure replacement scenario.
3. Jacob A. Nelson, Bruce Bugbee, "Economic Analysis of Greenhouse Lighting: Light Emitting Diodes vs. High Intensity Discharge Fixtures." Utah State University.
4. D.S. de Villiers, L.D. Albright, and R. Tuck, "Next Generation, Energy Efficient, Uniform Supplemental Lighting for Closed-System Plant Production." International Society for Horticultural Science.
5. Annual hours of operation were found by multiplying hours per day (defined within: Sole-Source Lighting of Plants. Technically Speaking by Erik Runkle. Michigan State University Extension. September 2017.) by 350 operating days per year. Assuming 5 crop cycles with 3 days of downtime between each cycle.
6. Illinois Statewide Technical Reference Manual v14.0 Vol. 2 – Commercial and Industrial Measures, 4.1.11Commercial LED Grow Lights, September 19, 2025.
7. Design Light Consortium – Horticultural Lighting, Testing and Reporting Requirements for LED-Based Horticultural Lighting, version 4.0, effective April 18, 2025. To date, all horticultural lamps certified by the DLC specification are LEDs.

Revision History

Version	Description	Author	Date
5.0	New Measure "C/I Lighting – LED Grow Lights"	MN Department of Commerce	2025

C/I Lighting – Mercury Vapor Retrofit

Measure Detail	Measure Value
Measure ID	2.01.16
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Lighting
Applicable To	Commercial, Industrial, and Public Buildings
Actions	Replace on Fail, Replace Working
Measure Energy Type	Electric

Measure Description

This measure evaluates mercury vapor fixtures replaced by pulse start metal halides, high bay fluorescent fixtures, high pressure sodium fixtures, parking garage fluorescent fixtures, and ceramic metal halides.

Pulse start metal halide systems typically consume 20%less energy than mercury vapor systems, produce the same light at lower wattages, and can often use more efficient ballasts depending on the application.

High bay fluorescent systems are often utilized in high bay ceiling applications over 15 feet. High bay fluorescent and parking garage fluorescent systems offer lower depreciation rates, better dimming options, virtually instant start-up and re-strike, better color rendition, and reduced glare.

Ceramic metal halides can be utilized to replace mercury vapor systems in lower wattage applications and result in better color rendition, lower wattage consumption, and improved color temperature.

Algorithm and Assumptions

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Revision History

Version	Description	Author	Date

C/I Lighting – Metal Halide Retrofit

Measure Detail	Measure Value
Measure ID	2.01.17
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Lighting
Applicable To	Commercial, Industrial, and Public Buildings
Actions	Replace on Fail, Replace Working
Measure Energy Type	Electric

Measure Description

This measure evaluates probe start metal halides replaced by pulse start metal halides, high bay fluorescent fixtures, and ceramic metal halides. Pulse start metal halide systems typically consume 20% less energy than standard metal halide systems, produces the same light at lower wattages, and can often use more efficient ballasts depending on the application.

High bay fluorescent and parking garage fluorescent systems are often utilized in high bay ceiling applications over 15 feet. High bay fluorescent and parking garage fluorescent systems offer lower depreciation rates, better dimming options, virtually instant start-up and re-strike, better color rendition, and reduced glare.

Ceramic metal halides can be utilized to replace probe start metal halides in lower wattage applications and result in better color rendition, lower wattage consumption, and improved color temperature.

Algorithm and Assumptions

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Revision History

Version	Description	Author	Date

C/I Lighting – New Construction

Measure Detail	Measure Value
Measure ID	2.01.18
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Lighting
Applicable To	Commercial, Industrial, and Public Buildings
Actions	New Construction
Measure Energy Type	Electric, Gas

Measure Description

The following measures are used in new construction in place of the less efficient standard practice. New construction technologies include ceramic metal halide, integral ballast ceramic metal halide, high bay fluorescent, LED exterior canopy, LED exterior wall packs and area/pole lighting, LED parking garage wall pack and area lighting, LED lamps and fixtures, LED troffers, LED street lighting, low wattage plug-in CFLs, low wattage T8, Pin-based CFLs, and pulse start metal halides.

Algorithm and Assumptions

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Notes

EPAct 2005 and 2000 DOE Ballast Rule. 2000 DOE Ballast Rule no longer allows ballasts that do not pass the new requirements to be manufactured after July 1, 2010 and EPAct 2005 no longer allows ballasts that do not pass the new requirements to be sold after October 1, 2010.

Ballasts affected by the rulemaking are those that operate:

- T12 4-foot linear and 2-foot U-shaped Rapid Start lamps with medium bi-pin bases
- T12 8-foot Instant Start lamps with single pin bases
- T12 8-foot Rapid Start HO lamps with recessed double contact (RDC) bases

Exceptions to the ballast standards:

- Dimming ballasts that dim to 50% or less of maximum output
- T12 HO ballasts capable of starting at ambient temperatures as low as -20° F or less and for use in outdoor illuminated signs
- Ballasts having a power factor of less than 0.90 and designed and labeled for use only in residential applications.
- 2 foot and 3 foot lamp and ballast systems

2009 DOE Lamp Rulemaking for GSFL and IRL Lamps. New efficiency standards for General Service Fluorescent lamps (GSFLs), linear and U-shaped require these covered lamp types to meet minimum lumen per watt (LPW) requirements; products that do not meet the minimum LPW requirements as of July 14, 2012 can no longer be produced.

The following lamp types are affected by these standards:

- Lamp Type| Energy Conservation Standard (lm/W)
- 4-foot (T8-T12) Medium Bi-pin ≥25W 89/88
- 2-foot (T8-T12) U-Shaped ≥25W 84/81
- 8-foot (T8-T12) Single Pin Slimline ≥52W 97/93
- 8-foot (T8-T12) High Output 92/88
- 4-foot (T5) Miniature Bi-pin Standard Output ≥26W 86/81
- 4-foot (T5) Miniature Bi-pin high Output ≥49W 76/72
- New T12 lamps that meet the new standards are now available in the market allowing T12s to still be installed.

ASHRAE 90.1 2010 Section 9 (ref 6) states the following:

> The alteration of lighting systems in any building space or exterior area shall comply with the lighting power density (LPD) requirements of Section 9 applicable to that space or area and the automatic shutoff requirements of 9.4.1.1. Such alterations shall include all luminaires that are added, replaced, or removed. This requirement shall also be met for alterations that involve only the replacement of lamps plus ballasts. Alterations do not include routine maintenance or repair situations.
>
> Exception: Alterations that involve less than 10% of the connected lighting load in a space or area need not comply with these requirements provided that such alterations do not increase the LPD.

Maximum LPDs using Building Area Method are shown below.

Table 1. Lighting Power Densities Using Building Area Method (Ref 22). Refer to ASHRAE 90.1-2010, Table 9.6.1 for Lighting Power Densities using the Space-by-Space Method.

Building Area Type	LPD (W/ft2)
Automotive Facility	0.82
Convention Center	1.08
Courthouse	1.05
Dining: Bar lounge/leisure	0.99
Dining: cafeteria/fast food	0.90
Dining: Family	0.89
Dormitory	0.61
Exercise Center	0.88
Fire Station	0.71
Gymnasium	1.00
Health-care clinic	0.87
Hospital	1.21
Hotel	1.00
Library	1.18
Manufacturing Facility	1.11

Building Area Type	LPD (W/ft2)
Motel	0.88
Motion picture theater	0.83
Multifamily	0.60
Museum	1.06
Office	0.90
Parking Garage	0.25
Penitentiary	0.97
Performing arts theater	1.39
Police station	0.96
Post office	0.87
Religious building	1.05
Retail	1.40
School/university	0.99
Sports arena	0.78
Town hall	0.92
Transportation	0.77
Warehouse	0.66
Workshop	1.20

Requirements

It is suggested that all LED fixtures and retrofits appear on the Design Lights Consortium Qualified Product list available at www.designlights.org and LED and CFL lamps appear on the ENERGY STAR Qualified Product list available at www.energystar.gov.

Revision History

Version	Description	Author	Date

C/I Lighting – Pulse Start Metal Halide Retrofit

Measure Detail	Measure Value
Measure ID	2.01.19
Target Market Segments	Commercial, Industrial, Public, Other
Target End Uses	Lighting
Applicable To	Commercial, Industrial, and Public Buildings
Actions	Replace on Fail, Replace Working
Measure Energy Type	Electric

Measure Description

This measure evaluates pulse start metal halide fixtures replaced by lower wattage pulse start metal halides, high bay fluorescent fixtures, and ceramic metal halides.

Pulse start metal halide fixtures can be replaced by lower wattage pulse start metal halides when the space they are in is considered over lit.

High bay fluorescent and fluorescent systems are often utilized in high bay ceiling applications over 15 feet. High bay fluorescent and fluorescent systems offer lower depreciation rates, better dimming options, virtually instant start-up and re-strike, better color rendition, and reduced glare.

Ceramic metal halides can be utilized to replace pulse start metal halides in lower wattage applications and result in better color rendition, lower wattage consumption, and improved color temperature.

Algorithm and Assumptions

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Revision History

Version	Description	Author	Date

C/I Lighting – Refrigerator/Freezer Case LEDs

Measure Detail	Measure Value
Measure ID	2.01.20
Target Market Segments	Commercial, Industrial
Target End Uses	Lighting
Applicable To	Grocery stores, convenience stores and other refrigerated sales facilities
Actions	Replace on Fail, Replace Working
Required from Customer/Contractor	Unit type (refrigerator or freezer), existing fixture wattage, proposed fixture wattage
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	10 (Ref. 1)
Unit Participant Incremental Cost	See Appendix B or use actual proposed fixture cost

Measure Description

This measure involves replacement of existing vertical and horizontal fluorescent refrigerated case lighting with more efficient LED lighting. It is recommended that qualifying product criteria include presence on the Design Lights Consortium Qualified Product List at www.designlights.org.

Algorithms

Unit kWh Savings per Year = (kW_base – kW_EE) x Hrs x (1+Refr_Factor)

Unit Peak kW Savings = CF x (kW_base – kW_EE) x (1+Refr_factor)

Where:

kW_base = Baseline fixture wattage (kW per fixture): see Appendix B

kW_EE = Proposed fixture wattage (kW per fixture) see Appendix B

Hrs = 6,205 (Ref. 3); annual case light hours.

Refrig_Factor = 0.40 (for refrigerator applications, assumes COP of 2.5) (Ref. 4)
= 0.77 (for freezer applications, assumes COP of 1.3) (Ref. 4)

CF = 0.9; electrical peak coincidence factor (Ref. 5)

Example:

A DLC-qualified LED strip light replaces a 6-foot T8 fluorescent lamp in a reach-in cooler. The fixture wattage will be reduced from 81W (0.081 kW) to 40W (0.040 kW).

Unit kWh Savings per Year = (0.081-0.040) x 6205 x (1+0.4) = 356 kWh

Unit Peak kW Savings = 0.9 x (0.081-0.040) x (1+0.0.4) = 0.05 kW

Notes

The Design Lights Consortium is a collaboration of utility companies and regional energy efficiency organizations that provide criteria and guidelines as well as a qualified products list (QPL) for high-efficiency, high-quality LED products. For more information visit: www.designlights.org

References

1. LED lifetime of 10 years assumes 6,205 hrs per year operation (17 hrs/day) and a lifetime of approximately 62,082 hours, the averaged rated life from DLC qualified product list. Accessed 7/31/12.
2. Illuminating Engineering Society (IES) Handbook, 9th edition, Figure 6-34, p. 6-29.
3. State of Ohio Technical Reference Manual, 2010. Source: Theobald, M. A., Emerging Technologies Program: Application Assessment Report #0608, LED Supermarket Case Lighting Grocery Store, Northern California, Pacific Gas and Electric Company, January 2006. Assumes refrigerated case lighting typically operates 17 hours per day, 365 days per year.
4. US DOE Publication #46230-00, “Energy Savings Potential for Commercial Refrigeration Equipment", 1996, Arthur C. Little.
5. State of Wisconsin Public Service Commission of Wisconsin "Focus on Energy Evaluation Business Programs: Deemed Savings Parameter Development”, KEMA, November 13, 2009, Page A-14.

Revision History

Version	Description	Author	Date
2.3	Added horizontal lighting	Franklin Energy Services	12/5/16

C/I Lighting – Refrigerator/Freezer Case Occupancy Controls

Measure Detail	Measure Value
Measure ID	2.01.21
Target Market Segments	Commercial, Industrial
Target End Uses	Lighting
Applicable To	Commercial facilities having refrigerated cases with internal LED lighting; mainly retail spaces
Actions	Modify
Required from Customer/Contractor	Unit type (refrigerator or freezer), connected fixture wattage per sensor
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	10 (Ref. 1)
Unit Participant Incremental Cost	$125 installed cost per sensor (Ref. 2)

Measure Description

This measure involves installing occupancy controls for refrigerated cases with internal LED lighting. Without occupancy sensors, case lighting typically runs at 100% power on a continuous basis. Installing sensors allows lights to turn fully on only when motion is detected in the store aisle. When no motion is detected for a preset period of time, the lights automatically dim to a lower power state, generating substantial energy savings.

Unlike fluorescent lighting, LED lighting can be turned on and off in cooler conditions without adversely affecting the life of the equipment; in fact, the effective lifespan of the LEDs may actually increase compared to being left at 100% power continuously (Ref. 7). As the market penetration of LED lighting in refrigerated cases increases, the opportunity for occupancy control follows.

Algorithms

Unit kWh Savings per Year = kW_base x SF x Hrs x (1+Refr_Factor)

Unit Peak kW Savings = CF x kW_base x SF x (1+Refr_factor)

Where:

kW_base = Total connected fixture load in kW, provided by customer/contractor.

SF = 0.31 (Ref. 3); savings factor for occupancy sensor representing reduction in relative full load power hours.

Hrs = 6,205 (Ref. 4); annual case light hours.

Refrig_Factor = 0.40 (for refrigerator applications, assumes COP of 2.5) (Ref. 5)
= 0.77 (for freezer applications, assumes COP of 1.3) (Ref. 5)

CF = 0.9; electrical peak coincidence factor (Ref. 6)

Example:

An occupancy sensor is installed to control the lighting in a 5-door reach-in cooler case with LEDs. The total connected lighting wattage is 120 W or 0.12 kW.

Unit kWh Savings per Year = 0.12 x 0.31 x 6205 x (1 + 0.40) = 323 kWh

Unit Peak kW Savings = 0.9 x 0.12 x 0.31 x (1 + 0.40) = 0.05 kW

Methodology and Assumptions

Lifetime of sensors is assumed to be the same as LED lighting.

References

1. Lifetime of sensors is assumed to be the same as LED lighting. LED lifetime of 10 years assumes 6,205 hrs per year operation (17 hrs/day) and a lifetime of approximately 62,082 hours, the averaged rated life from DLC qualified product list. Accessed 7/31/12.
2. *Demonstration Assessment of Light-Emitting Diode (LED) Freezer Case Lighting.* Prepared for the U.S. Department of Energy by Pacific Northwest National Laboratory, October 2009. Section 3.2, p. 11. Occupancy sensor and installation cost was $125 for a 5-door case.
3. *Ibid.* Section 3.1, p. 9. Results of a field study in which occupancy sensors were installed on individual cases to reduce LED lighting power to 20% of full power when no motion is detected for 30 seconds. The store was open 18 hours per day, with case lighting on 24/7 in the baseline.
4. State of Ohio Technical Reference Manual, 2010. Source: Theobald, M. A., Emerging Technologies Program: Application Assessment Report #0608, LED Supermarket Case Lighting Grocery Store, Northern California, Pacific Gas and Electric Company, January 2006. Assumes refrigerated case lighting typically operates 17 hours per day, 365 days per year.
5. US DOE Publication #46230-00, "Energy Savings Potential for Commercial Refrigeration Equipment", 1996, Arthur C. Little.
6. State of Wisconsin Public Service Commission of Wisconsin "Focus on Energy Evaluation Business Programs: Deemed Savings Parameter Development", KEMA, November 13, 2009, Page A-14.
7. "Watt Stopper/Legrand Helps Wal-Mart Achieve Environmental Goals". *Lighting Controls Association,* September 2007. http://lightingcontrolsassociation.org/projects/watt-stopper-legrand-helps-wal-mart-achieve-environmental-goals/, accessed 9/29/16.
8. Illuminating Engineering Society (IES) Handbook, 9th edition, Figure 6-34, p. 6-29.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	12/5/16

C/I Lighting – Stairwell Fixtures with Integral Occupancy Sensors

Measure Detail	Measure Value
Measure ID	2.01.22
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Lighting
Applicable To	Commercial, Industrial, and Public Buildings
Actions	Replace on Fail, Replace Working
Measure Energy Type	Electric

Measure Description

This measure involves replacement of existing fluorescent stairwell fixtures with fluorescent or LED stairwell fixtures with integral occupancy sensors and step-dimming ballasts, allowing for automatic adjustment of light output based on stairwell occupancy.

Algorithm and Assumptions

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Methodology and Assumptions

The efficient wattages in Appendix B include multipliers reflecting the rated level of dimming and an average duty cycle of 3% determined from M&V of a large installation sponsored by Xcel Energy.

Notes

In 2009 the Department of Energy announced new lamp rulemaking for general service fluorescent lamps. The efficiency standard requires general service fluorescent lamps covered in this rulemaking to meet minimum lumen per watt (LPW) requirements; products that do not meet the minimum LPW requirements as of July 14, 2012 can no longer be produced. 700 series T8 lamps affected by this rulemaking have been postponed for two years until July 2014. T12 lamps remain on the same timeline.

Requirements

It is suggested that all LED fixtures and retrofits appear on the Design Lights Consortium Qualified Product list available at www.designlights.org.

Revision History

Version	Description	Author	Date

C/I Lighting – T12 8-Foot Retrofit

Measure Detail	Measure Value
Measure ID	2.01.23
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Lighting
Applicable To	Commercial, Industrial, and Public Buildings
Actions	Replace on Fail, Replace Working
Measure Energy Type	Electric, Gas

Measure Description

This measure evaluates the replacement of 8 foot T12 lamps and magnetic or electronic ballasts with energy efficient T8, T5, and T5HO lamps and ballasts. The replacements can be 8 foot or 4 foot lamps. Changing from T12 lamp and ballast systems to T8, T5, or T5HO systems will reduce the energy consumption of the system while maintaining similar light outputs.

Algorithm and Assumptions

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Methodology and Assumptions

Measure Life is reduced based on remaining useful life of magnetic ballasts in the market place. Using the analysis completed in the Texas Docket 39146 Appendix C, a current remaining useful life of T12 magnetic ballasts at the end of 2012 is 4.1 years, or 4 years. The following documents were used in this analysis:

- "Fluorescent Lamp Ballasts Preliminary Analytical Tools: National Impact Analysis" (Ref. 7)
- "Fluorescent Lamp Ballast Technical Support Document for the Final Rule, 2000" (Ref. 8)

The Illinois Statewide Technical Reference Manual goes further to conclude the measure life should decrease from four years in 2012 to three years in 2013, two years in 2014, and one year in 2015. (Ref. 9)

Notes

EPAct 2005 and 2000 DOE Ballast Rule. 2000 DOE Ballast Rule no longer allows ballasts that do not pass the new requirements to be manufactured after July 1, 2010 and EPAct 2005 no longer allows ballasts that do not pass the new requirements to be sold after October 1, 2010.

Ballasts affected by the rulemaking are those that operate:

- T12 4-foot linear and 2-foot U-shaped Rapid Start lamps with medium bi-pin bases
- T12 8-foot Instant Start lamps with single pin bases
- T12 8-foot Rapid Start HO lamps with recessed double contact (RDC) bases

Exceptions to the ballast standards:

- Dimming ballasts that dim to 50% or less of maximum output
- T12 HO ballasts capable of starting at ambient temperatures as low as -20° F or less and for use in outdoor illuminated signs
- Ballasts having a power factor of less than 0.90 and designed and labeled for use only in residential applications.
- 2 foot and 3 foot lamp and ballast systems
- 2009 DOE Lamp Rulemaking for GSFL and IRL Lamps. New efficiency standards for General Service Fluorescent lamps (GSFLs), linear and U-shaped require these covered lamp types to meet minimum lumen per watt (LPW) requirements; products that do not meet the minimum LPW requirements as of July 14, 2012 can no longer be produced.

The following lamp types are affected by these standards:

- Lamp Type| Energy Conservation Standard (lm/W)
- 4-foot (T8-T12) Medium Bi-pin ≥25W 89/88
- 2-foot (T8-T12) U-Shaped ≥25W 84/81
- 8-foot (T8-T12) Single Pin Slimline ≥52W 97/93
- 8-foot (T8-T12) High Output 92/88
- 4-foot (T5) Miniature Bi-pin Standard Output ≥26W 86/81
- 4-foot (T5) Miniature Bi-pin high Output ≥49W 76/72
- New T12 lamps that meet the new standards are now available in the market allowing T12s to still be installed

References

1. DOE 2010b "Fluorescent Lamp Ballasts Preliminary Analytical Tools: National Impact Analysis" U.S. Department of Energy: 2010.
2. DOE 2000b. "Fluorescent Lamp Ballast Technical Support Document for the Final Rule, 2000." September 2000.
3. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 6.5.

Revision History

Version	Description	Author	Date

C/I Lighting – T12 Up to 4-Foot Retrofit

Measure Detail	Measure Value
Measure ID	2.01.24
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Lighting
Applicable To	Commercial, Industrial, and Public Buildings
Actions	Replace Working, Retrofit
Measure Energy Type	Electric, Gas

Measure Description

This measure evaluates the replacement of T12 lamps and magnetic or electronic ballasts up to 4 feet in length with energy efficient T8, T5, and T5HO lamps and ballasts. The replacement of T12 lamps and ballasts with T8, T5, and T5HO lamp and ballast systems results in a lower wattage system with similar light output.

Algorithm and Assumptions

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Methodology and Assumptions

Measure Life is reduced based on remaining useful life of magnetic ballasts in the market place and the July 14, 2012 Federal Standards eliminating standard T12 lamps.

Reviewing the market and a pending study of the T12s in the Minnesota market, the measure life is 1 year at full savings for T12s. The remaining 14 years of the measure life will utilize T8 baseline for savings.

This is set to be re-visited at the completion of the T12 market study.

Notes

EPAct 2005 and 2000 DOE Ballast Rule. 2000 DOE Ballast Rule no longer allows ballasts that do not pass the new requirements to be manufactured after July 1, 2010 and EPAct 2005 no longer allows ballasts that do not pass the new requirements to be sold after October 1, 2010.

Ballasts affected by the rulemaking are those that operate:

- T12 4-foot linear and 2-foot U-shaped Rapid Start lamps with medium bi-pin bases
- T12 8-foot Instant Start lamps with single pin bases
- T12 8-foot Rapid Start HO lamps with recessed double contact (RDC) bases

Exceptions to the ballast standards:

- Dimming ballasts that dim to 50% or less of maximum output
- T12 HO ballasts capable of starting at ambient temperatures as low as -20° F or less and for use in outdoor illuminated signs

- Ballasts having a power factor of less than 0.90 and designed and labeled for use only in residential applications.
- 2 foot and 3 foot lamp and ballast systems

2009 DOE Lamp Rulemaking for GSFL and IRL Lamps. New efficiency standards for General Service Fluorescent lamps (GSFLs), linear and U-shaped require these covered lamp types to meet minimum lumen per watt (LPW) requirements; products that do not meet the minimum LPW requirements as of July 14, 2012 can no longer be produced.

The following lamp types are affected by these standards:

- Lamp Type| Energy Conservation Standard (lm/W)
- 4-foot (T8-T12) Medium Bi-pin ≥25W 89/88
- 2-foot (T8-T12) U-Shaped ≥25W 84/81
- 8-foot (T8-T12) Single Pin Slimline ≥52W 97/93
- 8-foot (T8-T12) High Output 92/88
- 4-foot (T5) Miniature Bi-pin Standard Output ≥26W 86/81
- 4-foot (T5) Miniature Bi-pin high Output ≥49W 76/72
- New T12 lamps that meet the new standards are now available in the market allowing T12s to still be installed

Requirements

It is suggested that high performance and reduced wattage T8 lamps appear on the Consortium for Energy Efficiency Qualified Product List available at www.cee1.org.

References

1. DOE 2010b "Fluorescent Lamp Ballasts Preliminary Analytical Tools: National Impact Analysis" U.S. Department of Energy: 2010.
2. DOE 2000b. "Fluorescent Lamp Ballast Technical Support Document for the Final Rule, 2000." September 2000.
3. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 6.5.
4. ANSI/ASHRAE/IES Standard 90.1-2010 edition

Revision History

Version	Description	Author	Date

C/I Lighting – T8 Optimization

Measure Detail	Measure Value
Measure ID	2.01.25
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Lighting
Applicable To	Commercial, Industrial, and Public Buildings
Actions	Replace Working
Measure Energy Type	Electric

Measure Description

Optimization means reducing the light output of a fluorescent fixture in an overlit space through permanently reducing the quantity of linear fluorescent lamps used in a fixture, or switching to a shorter length fixture with the same quantity of lamps. Optimization must be done properly so as to maintain the minimum light level required by code. This measure includes both lamp and ballast changes and not lamp changes only.

Algorithm and Assumptions

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Revision History

Version	Description	Author	Date

C/I Lighting – T8 Standard to Low Wattage Retrofit

Measure Detail	Measure Value
Measure ID	2.01.26
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Lighting
Applicable To	Commercial, Industrial, and Public Buildings
Actions	Replace on Fail, Replace Working, New Construction
Measure Energy Type	Electric

Measure Description

High performance T8 lighting with low wattage lamps incorporates improvements to lamp and ballast technologies. They deliver light levels comparable with standard 32 watt T8 systems at lower wattages and with improved lamp life. This measure replaces 32W standard T8 systems with low watt T8 systems.

Algorithm and Assumptions

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Requirements

It is suggested that all low wattage T8 lamps appear on the Consortium for Energy Efficiency Qualified Product list available at www.cee1.org.

Revision History

Version	Description	Author	Date

Public Lighting – LED Traffic Signal

Measure Detail	Measure Value
Measure ID	2.01.27
Target Market Segments	Public
Target End Uses	Lighting
Applicable To	Exterior traffic signals
Actions	Replace Working, Replace on Fail, New Construction
Required from Customer/Contractor	Efficient lamp type/quantity
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	See Table 1
Unit Participant Incremental Cost	See Table 3

Measure Description

Light Emitting Diode (LED) Traffic Signals are an efficient and effective alternative to traditional incandescent signals. The two main advantages of LED signals are – very low power consumption and very long life. When compared with the typical energy needs of an incandescent bulb, the savings resulting from the low energy usage of LED signals can be as high as 93%.

Algorithms

Unit kWh Savings per Year = (kW_Base – kW_EE) x Hrs

Unit Peak kW Savings = (kW_Base – kW_EE) X DF

Where:

kW_Base = Baseline fixture wattage (kW per fixture) determined from Table 2

kW_EE = High-efficiency fixture wattage (kW per fixture) determined from Table 2

Hrs = Deemed annual operating hours from Table 1 based on lamp type

DF = Deemed diversity factor, see Table 1

Example:

Replace (1) incandescent 12” red ball lamp with (1) LED 12” red ball lamp

kWh Savings = (0.135-0.011) x 4,820 = 597.7 kWh

kW Savings = (0.135-0.011) x 0.55 = 0.0682 kW

Deemed Input Tables

Table 1. Diversity Factor (Ref. 1), Hours (Ref. 1), Measure Life (Ref. 2)

LED Lamp Type	Diversity Factor	Hours	Measure Life
12" Red Arrow	0.90	7,885	6.3
8" Red Arrow	0.90	7,885	6.3
12" Green Ball	0.43	3,675	13.6
8" Green Ball	0.43	3,675	13.6
12" Red Ball	0.55	4,820	10.4
8" Red Ball	0.55	4,820	10.4
12" Yellow Ball	0.02	175	20*
8" Yellow Ball	0.02	175	20*
12" and 8" Yellow Arrow	0.02	701	20*
12" and 8" Green Arrow	0.10	701	20*
Combination walking man/hand large	0.96	4,380	11.4
Walking Man Large	0.21	4,380	11.4
Orange Hand Large	0.75	4,380	11.4
Combination walking man/hand small	0.96	4,380	11.4
Walking Man Small	0.21	4,380	11.4
Orange Hand Small	0.75	4,380	11.4

*Measure life capped for persistence due to an extremely long calculated lifetime based on annual operating hours.

Table 2. Fixture Wattage (Ref.3) and Costs (Ref. 4)

Baseline Device	Efficient Device	kW_base	kW_EE	Incremental Cost
Incandescent, 12" Red Arrow	LED, 12" Red Arrow	0.135	0.009	$60.00
Incandescent, 8" Red Arrow	LED, 8" Red Arrow	0.069	0.007	$115.00
Incandescent, 12" Green Ball	LED, 12" Green Ball	0.135	0.015	$115.00
Incandescent, 8" Green Ball	LED, 8" Green Ball	0.069	0.012	$115.00
Incandescent, 12" Red Ball	LED, 12" Red Ball	0.135	0.011	$60.00
Incandescent, 8" Red Ball	LED, 8" Red Ball	0.069	0.008	$48.00
Incandescent, 12” Yellow Ball	LED, 12” Yellow Ball	0.150	0.013	$60.00
Incandescent, 8” Yellow Ball	LED, 8” Yellow Ball	0.069	0.010	$48.00
Incandescent, 12” and 8” Yellow Arrow	LED, 12” and 8” Yellow Arrow	0.116	0.007	$100.00
Incandescent, 12” and 8” Green Arrow	LED, 12” and 8” Green Arrow	0.116	0.007	$100.00
Incandescent, Pedestrian Large	LED, Combination Walking Man/Hand Large	0.116	0.010	$90.00
Incandescent, Pedestrian Large	LED, Walking Man Large	0.116	0.010	$90.00
Incandescent, Pedestrian Large	LED, Orange Hand Large	0.116	0.010	$90.00
Incandescent, Pedestrian Small	LED, Combination Walking Man/Hand Small	0.069	0.008	$70.00

Baseline Device	Efficient Device	kW_base	kW_EE	Incremental Cost
Incandescent, Pedestrian Small	LED, Walking Man Small	0.069	0.008	$70.00
Incandescent, Pedestrian Small	LED, Orange Hand Small	0.069	0.008	$70.00

References

1. Technical Reference User Manual Efficiency Vermont 2010, Combination walking man/hand signals used the combined walk & hand signal CFs because it is assumed they will be on the same total time.
2. Measure life in years determined by dividing product lifetime of 50,000 hours by annual operating hours.
3. Consortium of Energy Efficiency
4. NWPCC LEDTrafficSignals_rev-1.xls

Revision History

Version	Description	Author	Date
1.0	New version replacing LEDTrafficSignalPedestrian_V01, LEDTrafficSignalRedArrow_v01, LEDTrafficSignalRed_v01, LEDTrafficSignalGreen_v01	Joe Plummer	
1.1	Changed to deemed wattages and incremental costs	Joe Plummer	3/23/2012
1.2	Updated costs, format	Franklin Energy Services	8/31/2012
1.3	Updated CF	Franklin Energy Services	11/15/2012
1.4	Minor revisions	Joe Plummer	2/7/2013
1.5	Added Yellow ball, Yellow Arrow, and Green Arrow signals	Franklin Energy Services	2/27/2014
1.6	Minor formatting revisions	Joe Plummer	5/15/2014
1.7	Sample calculation updated	Franklin Energy Services	1/13/2016

HVAC

C/I HVAC – Chiller Systems

Measure Detail	Measure Value
Measure ID	2.02.01
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC
Applicable To	Commercial and industrial customers where chillers can be installed to meet space cooling requirements
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	New chiller type, nominal cooling capacity in tons, integrated part load value, full load value; building type (refer to Table 2), project location (county), chilled water leaving temperature, condenser leaving temperature and condenser gpm; if water cooled centrifugal chiller is not designed to operate at standard AHRI conditions
Measure Energy Type	Electric
Unit Peak kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	20 years (Ref. 1)
Unit Participant Incremental Cost	See Table 1

Measure Description

This measure analyzes the space cooling savings potential of the installation of high-efficiency chillers including; all air cooled chillers, water cooled screw, scroll, and centrifugal chillers. This measure is applicable to chillers with efficiencies provided at AHRI conditions, but also accommodates water cooled centrifugal chillers with efficiencies provided at other conditions. The incremental cost is associated with base equipment cost and does not include any installation costs.

Algorithms

kWh_{SAVED} = Nominal Capacity x ($IPLV_{BASE}$ – $IPLV_{EE}$) x $EFLH_{COOL}$

kW_{SAVED} = Nominal Capacity x (FLV_{BASE} – FLV_{EE}) x CF

k_{ADJ} = A x B

Where:

Nominal Capacity = the nominal rating of the cooling capacity of the energy efficient chiller (tons)

$IPLV_{EE}$ = the integrated part load value (IPLV) of the energy efficient chiller (kW/ton) at AHRI standard conditions

For efficiencies provided at other than AHRI conditions:

$IPLV_{EE}$ = $IPLV_{CS}$ / K_{ADJ} = the integrated part load value of energy efficient chiller at operating conditions divided by k_{ADJ} for water cooled centrifugal chillers if chiller designed not to operate at AHRI standard conditions

$IPLV_{BASE}$ = the integrated part load efficiency of the baseline chiller (kW/ton), $IPLV_{BASE}$ = $IPLV_{AHRI}$ per Table 1.

$EFLH_{COOL}$ = the equivalent full load hours of cooling per zone from Table 2 per building type

FLV_{EE} = the equivalent full load value of the energy efficient chiller (kW/ton), FLV at AHRI standard conditions, provided by the contractor/customer.

For efficiencies provided at other than AHRI conditions:

FLV_{EE} = FLV_{CS} / k_{ADJ} = the equivalent full load value of the energy efficient chiller at operating conditions divided by k_{ADJ} for water cooled centrifugal chillers if chiller not designed not to operate at AHRI standard conditions

FLV_{BASE} = the full load efficiency of the baseline chiller (kW/ton), FLV_{BASE} = FLV_{AHRI} per Table 1.

CF = Deemed coincident demand factor, equal to 0.90 (Ref. 2)

For Water Cooled Centrifugal Chillers not tested at AHRI Standard Conditions** (Ref. 3):

$IPLV_{CS}$ = for water cooled centrifugal chillers not designed to run at AHRI Standard test conditions*, the integrated part load value provided by customer/contractor at operating conditions (kW/ton)

FLV_{CS} = for water cooled centrifugal chillers not tested at AHRI Standard test conditions*, the equivalent full load value provided by customer/contractor at operating conditions (kW/ton)

A = $0.00000014592 \times (LIFT)^4 - 0.0000346496 \times (LIFT)^3 + 0.00314196 \times (LIFT)^2 - 0.147199 \times (LIFT) + 3.9302$

B = 0.0015 x LvgEvap + 0.934

LIFT = LvgCond – LvgEvap

LvgCond = Full Load Condenser leaving fluid temperature (°F)

LvgEvap = Full Load Evaporator leaving fluid temperature (°F)

Standard AHRI test conditions are 44°F leaving chilled water temperature, 85°F entering condenser water temperature with 3 gpm/ton condenser water flow.

These adjustment factors are applicable to centrifugal chillers designed for a minimum leaving water temperature of at least 36°F and a maximum condenser entering water temperature of 115 °F and LIFT ≥ 20°F and ≤ 80°F.

Example:

Retrofit of an existing water cooled centrifugal chiller installed in a Hospital, 600 ton cooling capacity not rated at AHRI conditions. Design FLV = 0.50 and Design IPLV of 0.45, Climate Zone 3. The new chiller is full-load optimized and designed to operate with a condenser water leaving temperature of 91.16°F and evaporator leaving temperature of 42°F.

Lift = 91.16°F – 42°F = 49.16°F

$A = 0.00000014592 \times (49.16)^4 - 0.0000346496 \times (49.16)^3 + 0.00314196 \times (49.16)^2 - 0.147199 \times (49.16) + 3.9302 = 1.0228$

$B = 0.0015 \times 42 + 0.934 = 0.997$

$K_{ADJ} = 1.0228 \times 0.997 = 1.02$

$FLV_{EE} = 0.50 / 1.02 = 0.49$

$IPLV_{EE} = 0.40 / 1.02 = 0.44$

$kWh_{SAVED} = 600 \times (0.54 - 0.44) \times 1298 = 79{,}865$ kWh

$kW_{SAVED} = 600 \times (0.57 - 0.49) \times 0.9 = 43.0$ kW

Deemed Input Tables

Table 1. Deemed Full Load and Integrated Part Load Baseline Efficiencies per AHRI 550/590 and Incremental Cost (Ref. 4, Ref. 5)

Equipment	PATH A*		PATH B**		Incremental Cost ($/ton)
	FLV_AHRI (kW/ton)	IPLV_AHRI (kW/ton)	FLV_AHRI (kW/ton)	IPLV_AHRI (kW/ton)	
Water Cooled Scroll or Screw Chiller < 75 tons	0.750	0.600	0.780	0.500	130
Water Cooled Scroll or Screw Chiller ≥ 75 and < 150 tons	0..720	0.560	0.750	0.490	90
Water Cooled Scroll or Screw Chiller ≥ 150 and < 300 tons	0.660	0.540	0.680	0.440	90
Water Cooled Scroll or Screw Chiller ≥ 300 tons	0.610	0.520	0.625	0.410	40
Water Cooled Centrifugal Chiller < 150 tons	0.610	0.550	0.695	0.440	130
Water Cooled Centrifugal Chiller ≥ 150 and < 300 tons	0.610	0.550	0.635	0.400	85
Water Cooled Centrifugal Chiller ≥ 300 and < 600 tons	0.560	0.520	0.595	0.390	85

Equipment	PATH A*		PATH B**		Incremental Cost ($/ton)
	FLV_AHRI (kW/ton)	IPLV_AHRI (kW/ton)	FLV_AHRI (kW/ton)	IPLV_AHRI (kW/ton)	
Water Cooled Centrifugal Chiller ≥ 600 tons	0.560	0.500	0.585	0.380	40
Air Cooled Chiller with Condenser < 150 tons	10.1 EER Btu/Wh	13.7 EER Btu/Wh	9.7 EER Btu/Wh	15.8 EER Btu/Wh	110
Air Cooled Chiller with Condenser ≥ 150	10.1 EER Btu/Wh	14.0 EER Btu/Wh	9.7 EER Btu/Wh	16.1 EER Btu/Wh	110

* Path A is for traditional applications and where the intended applications are expected to have significant operating times at full load conditions, typically a non VFD controlled unit.

** All Path B chillers must be equipped with demand limiting controls or VFD controlled units.

*** FLV_AHRI = 12 / EER and IPLV_AHRI = 12 / SEER

Table 2. Equivalent Full Load Hours of Cooling ($EFLH_{COOL}$) per Zone in Minnesota by Building Type (Ref. 6)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	647	825	986
Education – Community College/University	682	782	785
Education – Primary	289	338	408
Education – Secondary	484	473	563
Health/Medical – Clinic	558	738	865
Health/Medical – Hospital	663	1089	1298
Lodging	401	606	754
Manufacturing	347	472	589
Office-Low Rise	257	359	446
Office-Mid Rise	373	529	651
Office-High Rise	669	1061	1263
Restaurant	347	535	652
Retail – Large Department Store	462	588	686
Retail – Strip Mall	307	441	574
Warehouse	164	343	409
Other/Miscellaneous	443	612	729

Methodology and Assumptions

$EFLH_{COOL}$ were determined from based prototypes building models on the California DEER study prototypes modified Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Assumed ventilation rates complied with the requirements of ASHRAE standard 62.1 – 2004.

Notes

Savings are based upon AHRI rated chillers and those water cooled centrifugal chillers operating within the limits of the nonstandard conditions listed above.

Table 1 chiller sizes were expanded to cover the scope the 2015 MN Energy Code, Table C.403.2.3 (7), Minimum Efficiency Requirements: Water Chilling Packages

References

1. ASHRAE, 2007, Applications Handbook, Ch. 36, table 4, Comparison of Service Life Estimates
2. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, and primary data has not been identified.
3. 2015 Minnesota Energy Code, Section C403.2.3.1 Water-cooled centrifugal chilling packages. https://codes.iccsafe.org/public/document/code/357/5880017
4. 2024 Minnesota Energy Code with ANSI/ASHRAE/IES Standard 90.1-2019. Section 6.8.1 Minimum Efficiency Requirement Listed Equipment—Standard Rating and Operating Conditions Effective January 5, 2024. https://codes.iccsafe.org/content/MNEC2024P1/6-heating-ventilating-and-air-conditioning#MNEC2024P1_Ch06_Sec6.8
5. 2008 Deer www.deeresources.com – Average across Tier 1 equivalent equipment.
6. Calculated through energy modeling of California DEER study prototypes modified by Illinois field data with TMY3 Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3) by FES 2012.

Revision History

Version	Description	Author	Date
1.0	New specification replacing ChillersAirCooled_v03 and ChillersCentrifugal_v03. Followed methodology in Xcel Energy 2010-2012 CIP Plan (Docket No. E,G002/CIP-09-198)	Joe Plummer	
1.1	Changed 'Equivalent' to 'Equivalent' for Table 1	SK	
1.2	Revised format to customer's current replacement. Updated Nonstandard conditions calculations. Revised hours in Table 2. Added/updated references 3, 5, and 6. Updated incremental costs. Reordered references and tables to make them sequential. Added Table 3.	Franklin Energy Services	
1.3	Changed 'ARI' to 'AHRI' throughout, wording changes	Joe Plummer	
2.0	Updated measure to reflect new MN Code	Franklin Energy Services	
3.0	Updated FLV and IPLV values	Cadmus	10/2018

C/I HVAC – Chiller Tune-Up

Measure Detail	Measure Value
Measure ID	2.02.02
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC
Applicable To	Commercial and industrial customers where chillers are used to meet space cooling requirements
Actions	O&M
Required from Customer/Contractor	Chiller type, nominal cooling capacity in tons, integrated part load value, full load value; building type (refer to Table 2), project location (county)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	5 (Ref. 1)
Unit Participant Incremental Cost	$5/ton (default/planning figure; Use actual cost of tune-up) (Ref. 2)

Measure Description

Commercial or Industrial air cooled or water chiller tune-up completed in accordance with the following recommended tune-up requirements:

- Clean condenser coil/tubes
- Check cooling tower for scale or buildup
- Check contactors condition
- Check evaporator condition
- Check low-pressure controls
- Check high-pressure controls
- Check filter, replace as needed
- Check belt, replace as needed
- Check crankcase heater operation
- Check economizer operation

Algorithms

kWh_{SAVED} = Nominal Capacity x $IPLV_{BASE}$ x $EFLH_{COOL}$ x MF_E

kW_{SAVED} = Nominal Capacity x FLV_{BASE} x CF x MF_D

Where:

$EFLH_{COOL}$ = the equivalent full load hours of cooling per zone from Table 2 per building type

Capacity = the nominal rating of the cooling capacity of the energy efficient chiller (tons)

Chiller efficiencies = because existing chiller efficiency typically cannot be determined without extensive testing, code minimum efficiencies are recommended for base efficiency.

$IPLV_{BASE}$ = Integrated part load efficiency of the baseline chiller (kW/ton), $IPLV_{BASE}$ = $IPLV_{AHRI}$ per Table 1. Alternatively, actual efficiency may be used if verified via testing.

FLV_{BASE} = Full load efficiency of the baseline chiller (kW/ton), FLV_{BASE} = FLV_{AHRI} per Table 1. Alternatively, actual efficiency may be used if verified via testing.

CF = Coincidence factor = 0.9 (Ref. 3)

MF_E = Maintenance energy saving factor, MF_E = 5 % (Ref. 4)

MF_D = Maintenance demand saving factor, MF_D = 2.5 % (Ref. 4)

Example:

Tune up of a 200 ton air cooled chiller serving community college in Zone 2:

kWh_{SAVED} = 200 x 0.94 x 782 x 0.05 = 7,351 kWh

kW_{SAVED} = 200 x 1.26 x 0.9 x 0.025 = 5.67 kW

Deemed Input Tables

Table 1. Deemed Full Load and Integrated Part Load Baseline Efficiencies per AHRI 550/590 (Ref. 5)

Equipment	PATH A*		PATH B**	
	FLV_AHRI (kW/ton)	IPLV_AHRI (kW/ton)	FLV_AHRI (kW/ton)	IPLV_AHRI (kW/ton)
Water Cooled Scroll or Screw Chiller < 75 tons	0.750	0.600	0.780	0.500
Water Cooled Scroll or Screw Chiller ≥ 75 and < 150 tons	0.720	0.560	0.750	0.490
Water Cooled Scroll or Screw Chiller ≥ 150 and < 300 tons	0.660	0.540	0.680	0.440
Water Cooled Scroll or Screw Chiller ≥ 300 tons	0.610	0.520	0.625	0.410
Water Cooled Centrifugal Chiller < 150 tons	0.610	0.550	0.695	0.440
Water Cooled Centrifugal Chiller ≥ 150 and < 300 tons	0.610	0.550	0.635	0.400
Water Cooled Centrifugal Chiller ≥ 300 and < 600 tons	0.560	0.520	0.595	0.390
Water Cooled Centrifugal Chiller ≥ 600 tons	0.560	0.500	0.585	0.380

Equipment	PATH A*		PATH B**	
	FLV_AHRI (kW/ton)	IPLV_AHRI (kW/ton)	FLV_AHRI (kW/ton)	IPLV_AHRI (kW/ton)
Air Cooled Chiller with Condenser < 150 tons	10.1 EER Btu/Wh	13.7 EER Btu/Wh	9.7 EER Btu/Wh	15.8 EER Btu/Wh
Air Cooled Chiller with Condenser ≥ 150 tons	10.1 EER Btu/Wh	14.0 EER Btu/Wh	9.7 EER Btu/Wh	16.1 EER Btu/Wh

* Path A is for traditional applications and where the intended applications are expected to have significant operating times at full load conditions, typically a non VFD controlled unit.

** All Path B chillers must be equipped with demand limiting controls or VFD controlled units.

Table 2. Equivalent Full Load Hours of Cooling ($EFLH_{COOL}$) per Zone in Minnesota by Building Type (Ref. 6)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	647	825	986
Education – Community College/University	682	782	785
Education – Primary	289	338	408
Education – Secondary	484	473	563
Health/Medical – Clinic	558	738	865
Health/Medical – Hospital	663	1089	1298
Lodging	401	606	754
Manufacturing	347	472	589
Office-Low Rise	257	359	446
Office-Mid Rise	373	529	651
Office-High Rise	669	1061	1263
Restaurant	347	535	652
Retail – Large Department Store	462	588	686
Retail – Strip Mall	307	441	574
Warehouse	164	343	409
Other/Miscellaneous	443	612	729

Methodology and Assumptions

Measurements and corrections must be performed with standard industry tools and practices, and the results tracked by the efficiency program.

$EFLH_{COOL}$ were determined from based prototypes building models on the California DEER study prototypes modified Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

References

1. Wisconsin Public Service Commission equipment useful life database, 2013
2. State of Wisconsin Public Service Commission, Focus on Energy Evaluation, Business Programs: Incremental Cost Study, 2009. This study is compiled program project cost data. An average value from chiller types and sizes is roughly $5/ton the range is roughly $2 to 8$/ton
3. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, and primary data has not been identified.
4. United States Department of Energy, Building Technologies Program: Hospitals Benefit by Improving Inefficient Chiller systems white paper, August 2011. The paper found that coil cleaning, the primary savings measure associated with this cooling tune-up measure, reduces annual cooling energy consumption by 5-7%. Demand savings are conservatively assumed to be on half this, or 2.5%.
5. 2024 Minnesota Energy Code with ANSI/ASHRAE/IES Standard 90.1-2019. Section 6.8.1 Minimum Efficiency Requirement Listed Equipment—Standard Rating and Operating Conditions Effective January 5, 2024. https://codes.iccsafe.org/content/MNEC2024P1/6-heating-ventilating-and-air-conditioning#MNEC2024P1_Ch06_Sec6.8
6. Calculated through energy modeling of California DEER study prototypes modified by Illinois field data with TMY3 Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3) by FES 2012

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	11/12/15
2.0	Updated FLV and IPLV values	Cadmus	10/2018

C/I HVAC – Computer Room Air Conditioner (CRAC)

Measure Detail	Measure Value
Measure ID	2.02.03
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC
Applicable To	Commercial and industrial customers with data centers or server rooms
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	New CRAC cooling medium, rated net sensible cooling capacity, rated seasonal coefficient of performance (SCOP)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	20 (Ref. 1)
Unit Participant Incremental Cost	$750 per ton may be assumed (Ref. 4). Actual CRAC costs vary widely in practice

Measure Description

This measure analyzes the space cooling savings potential for the replacement or new commissioning of a computer room air conditioner (CRAC). CRACs are installed to meet cooling requirements for computers, servers, and other electronic components.

Algorithms

kWh_{SAVED} = Size x LF x ($12/SEER_{BASE} – 12/SEER_{EE}$) x EFLH

kW_{SAVED} = Size x LF x ($12/SEER_{BASE} – 12/SEER_{EE}$) x CF

Where:

Size	= the nominal rating of the cooling capacity of the energy efficient chiller (tons). 1 ton = 12,000 Btu/h
LF	= Cooling load factor = 0.65 (Ref. 5)
CF	= Coincidence factor = 1 (Default for data centers)
$SEER_{BASE}$	= 3.412 x $SCOP_{BASE}$, minimum seasonal energy efficiency ratio.
$SCOP_{BASE}$	= minimum rated seasonal coefficient of performance. See Table 1.
$SEER_{EE}$	= 3.412 x $SCOP_{EE}$, seasonal energy efficiency ratio of the energy efficient CRAC.
$SCOP_{EE}$	= rated seasonal coefficient of performance (SCOP) for the energy efficient CRAC.
EFLH	= Equivalent full load hour of cooling, 8,760 hours (Default for data centers, Ref. 2)

Example:

Installation of a glycol-cooled downflow CRAC with a rated SCOP of 3.00 and net sensible cooling capacity of 48,000 Btu/h (4 tons).

From Table 1, baseline SCOP efficiency equals 2.50.

$SEER_{BASE}$ is calculated as 3.412 x 2.50 = 8.53

$SEER_{EE}$ is calculated as 3.412 x 3.00 = 10.24

kWh_{SAVED} = 4 x 0.65 x (12/8.53 – 12/10.24) x 8,760 = 5,354 kWh

kW_{SAVED} = 4 x 0.65 x (12/8.53 – 12/10.24) x 1 = 0.61 kW

Deemed Input Tables

Table 1. Baseline SCOP efficiency by cooling medium type and unit type (downflow or upflow) (Ref. 3)

Cooling Medium	Net Sensible Cooling Capacity	Minimum SCOP Efficiency	
		Downflow Units	Upflow Units
Air-Cooled	<80,000 Btu/h	2.70	2.67
	≥80,000 Btu/h and <295,000 Btu/h	2.58	2.55
	≥295,000 Btu/h and <760,000 Btu/h	2.36	2.33
Water-Cooled	<80,000 Btu/h	2.82	2.79
	≥80,000 Btu/h and <295,000 Btu/h	2.73	2.70
	≥295,000 Btu/h and <760,000 Btu/h	2.67	2.64
Water-Cooled with a Fluid Economizer	<80,000 Btu/h	2.77	2.74
	≥80,000 Btu/h and <295,000 Btu/h	2.68	2.65
	≥295,000 Btu/h and <760,000 Btu/h	2.61	2.58
Glycol-Cooled	<80,000 Btu/h	2.56	2.53
	≥80,000 Btu/h and <295,000 Btu/h	2.24	2.21
	≥295,000 Btu/h and <760,000 Btu/h	2.21	2.18
Glycol-Cooled with a Fluid Economizer	<80,000 Btu/h	2.51	2.48
	≥80,000 Btu/h and <295,000 Btu/h	2.19	2.16
	≥295,000 Btu/h and <760,000 Btu/h	2.15	2.12

Methodology and Assumptions

$EFLH_{COOL}$ was determined on prototype operating modules from universal market segment hours for data centers (Ref. 2).

Effective January 1, 2023, HVAC products will be subject to regional minimum efficiencies, according to Seasonal Energy Efficiency Ratio 2 (SEER2). The nomenclature of SEER2, EER2 and HSPF2 will be used to denote the new M1 ratings. Conversion between the new M1 ratings and original M ratings should be done using an AHRI approved method, using the multipliers in Table 2 and Table 3 below.

Table 2. M to M1 Forward Conversion (Ref. 6)

System Type	Multiplier to convert to SEER2	Multiplier to convert to EER2	Multiplier to convert to HSPF2
Ducted	0.95	0.95	0.85
Ductless	1.00	1.00	0.90
Packaged	0.95	0.95	0.84

Table 3. M1 to M Backward Conversion (Ref. 6)

System Type	Multiplier to convert to SEER	Multiplier to convert to EER	Multiplier to convert to HSPF2
Split System Air Conditioner	1.05	1.04	N/A
Split System Heat Pump	1.05	1.04	1.18
Packaged Air Conditioner	1.04	1.04	N/A
Packaged Heat Pump	1.04	1.04	1.18
Ductless Heat Pump	1.00	1.00	1.12
Space Constrained System	1.01	1.00	1.17
Small Duct High Velocity System	1.00	1.00	1.18

References

1. ASHRAE, 2007, Applications Handbook, Ch. 36, table 4, Comparison of Service Life Estimates
2. Commercial Buildings Energy Consumption Survey, 2003 referenced in Xcel Energy Cooling Efficiency DEPACC Technical Assumptions, Deemed Savings, Nov. 2013.
3. 2024 Minnesota Energy Code with ANSI/ASHRAE/IES Standard 90.1-2019. Section 6.8.1 Minimum Efficiency Requirement Listed Equipment—Standard Rating and Operating Conditions Effective January 5, 2024. https://codes.iccsafe.org/content/MNEC2024P1/6-heating-ventilating-and-air-conditioning#MNEC2024P1_Ch06_Sec6.8
4. Franklin Energy Services workpaper FES-H15 for Michigan programs, referencing cost data provided by a local Liebert distributor showing an average incremental cost of $750/ton or $62.50/MBTUH. CRAC costs vary greatly in practice.
5. Chapter 4. Energy Use Characterization, Technical Support Document to Final Rule: Standards, Federal Register, 77 FR 28928:28994-5, May 16, 2012. https://www.regulations.gov/document?D=EERE-2011-BT-STD-0029-0039, accessed 12/4/2016.
6. Consortium for Energy Efficiency. CEE Residential Electric HVAC Specification. Published October 18, 2023. https://cee1.my.site.com/s/resources?id=a0V2R00000sUQbyUAG

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	12/4/2016
4.1	Clarification to SEER2, EER2 and HSPF2 conversions	Cadmus	11/1/2023

C/I HVAC – Condensing Furnaces

Measure Detail	Measure Value
Measure ID	2.02.04
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC
Applicable To	Commercial and industrial customers
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Input Btu/h of new unit, project location (county), AFUE of the new equipment, building type
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	20 (Ref. 1)
Unit Participant Incremental Cost	See Table 2

Measure Description

This measure includes installation of gas-fired high-efficiency, condensing residential-style forced air furnaces in commercial/industrial buildings.

Algorithms

Unit Dth Savings per Year = Btuh_in x Load_Factor x $EFLH_{HEAT}$ x Eff_High x (1/Eff_Base – 1/Eff_high) / 1,000,000

Where:

Btuh_in	= the nominal rating of the input capacity of the new furnace or boiler in Btu/h
Load_Factor =	the load factor, assumed to be 0.77 (implies 30% oversizing) (Ref. 2)
$EFLH_{HEAT}$	= Effective Full Load Hours of Heating, see Table 1
Eff_base	= 80%, efficiency (AFUE) of the baseline, i.e., standard replacement, equipment. (Ref. 4)
Eff_high	= Efficiency (AFUE) of the new furnace or boiler, supplied by customer/contractor.
1,000,000	= Conversion from Btu to Dth

Example:

Retrofit furnace installed in a low-rise office building in Climate Zone 3. Input btu/h = 60,000, AFUE = 95%.

Unit Dth Savings per Year = 60,000 x 0.77 x 1,610 x 0.95 x (1/0.80 – 1/0.95) / 1,000,000 = 13.9 Dth

Deemed Input Tables

Table 1. Equivalent Full Load Hours of heating per zone in Minnesota by building type (Ref. 3)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	1,887	1,699	1,546
Education – Community College/University	1,972	1,776	1,616
Education – Primary	2,394	2,156	1,961
Education – Secondary	2,561	2,306	2,098
Health/Medical – Clinic	2,234	2,012	1,830
Health/Medical – Hospital	2,508	2,258	2,054
Lodging	2,361	2,126	1,934
Manufacturing	1,397	1,258	1,144
Multifamily	2,324	2,092	1,904
Office – Low Rise	1,966	1,770	1,610
Office – Mid Rise	2,189	1,971	1,793
Office – High Rise	2,149	1,935	1,760
Restaurant	1,868	1,681	1,530
Retail – Large Department Store	1,763	1,587	1,444
Retail – Strip Mall	1,701	1,531	1,393
Warehouse	1,872	1,685	1,533
Other/Miscellaneous	2,123	1,911	1,739

Table 2. Incremental Costs (Ref. 5)

Equipment Type	Incremental Cost ($/unit)
New furnace, AFUE ≥ 90% and < 92%	$1,254
New furnace, AFUE ≥ 92% and < 94%	$1,342
New furnace, AFUE ≥ 94% and < 96%	$1,429
New furnace, AFUE ≥ 96%	$1,517

Methodology and Assumptions

Assumes dedicated exhaust installation for furnaces and chimney liner for water heaters.

Notes

On May 1, 2013, federal standards prohibiting the sale or import of non-weatherized furnaces with AFUEs of less than 90% were set to take effect in the Northern Region (including MN).This standard has been postponed.

AFUE does not include any electrical power savings.

References

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc. June 2007 http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf
2. PA Consulting, KEMA, Focus on Energy Evaluation, Business Programs: Deemed Savings ManualV1.0, March 22, 2010. This factor implies that boilers are 30% oversized on average.
3. FES scaled EFLH from those provided in the Illinois Technical Reference Manual based on Minnesota weather data. EFLH for the Illinois Technical Reference Manual were based on California DEER study prototypes modified by Illinois field data to closely match EFLH from the modeling to those calculated from field data.
4. 2024 Minnesota Energy Code with ANSI/ASHRAE/IES Standard 90.1-2019. Section 6.8.1 Minimum Efficiency Requirement Listed Equipment—Standard Rating and Operating Conditions Effective January 5, 2024. https://codes.iccsafe.org/content/MNEC2024P1/6-heating-ventilating-and-air-conditioning#MNEC2024P1_Ch06_Sec6.8
5. Xcel Energy 2017-2019 CIP Triennial (Docket No. E,G002/CIP-16-115). https://www.xcelenergy.com/staticfiles/xe-responsive/Company/Rates%20&%20Regulations/Regulatory%20Filings/2017-2019%20CIP%20Triennial%20Plan.pdf

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	9/19/2017
1.1	Updated incremental costs	Cadmus	10/2018

C/I HVAC – Destratification Fan

Measure Detail	Measure Value
Measure ID	2.02.05
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC
Applicable To	All areas with less than a 50' ceiling height where stratification has been observed to be a problem
Actions	New Construction (addition on new or existing building)
Required from Customer/Contractor	Ceiling height, area being destratified, project location (county) Optional: Heat transfer coefficient for roof, area being destratified in square feet, hours per day of fan operation in heating season, heating system efficiency
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	15 years (Ref. 1)
Unit Participant Incremental Cost	See Table 1 (Ref. 2)

Measure Description

This measure analyzes the heating savings potential of destratification fans in new and existing buildings. This measure includes High Volume Low Speed and High Volume High Speed fans.

Algorithms

Unit Dth Savings per Year = (U x A x ΔT_C x HH x HrsPerDay/24) / η / 1,000,000

Where:

A	= Area served by destratification fan. If unknown see Table 1. (ref 3)
HrsPerDay	= Hours/day of operation. If unavailable assume 12. (ref.4)
HH	= Heating Hours in season below 65°F. See Table 2. (Ref. 5)
ΔT_C	= Difference in ceiling air temperature (°F) in stratified and unstratified spaces. If unknown see Table 2 (Ref. 6).
U	= Average heat transfer coefficient for the roof (BTU / h · ft ^2 · °F). If unknown see Table 2. (Ref. 7)
η	= Efficiency of heating equipment. If unknown use 0.8 (Ref. 8)
1,000,000	= Conversion factor for BTU to Dth

Example:

Install destratification fan per 1000 sq. ft. in 108,000 sq. ft. manufacturing facility operating on average 20 hours per day. The ceiling height is 25 ft. The building is located in Zone 3.

Dth Savings per Year = (0.08 x 1,000 x 10 x 20/24 x 6242) / 0.8 / 1,000,000 = 5.2 Dth per fan

108 fans total, 5.2 x 108 = 561.6 Dth per year total.

Table 1. Default square footages for fan applications and incremental costs

Ceiling Height (ft)	Destratification Area (ft^2) (Ref. 3)	Incremental Cost / sq. ft. (Ref. 2)
10 – 30	1000	$1.09
31 – 50	750	$1.45

Table 2. Ceiling Temperature differences, hours and U values

Zone #	ΔT_C (°F) (Ref. 6)	Heating Hours (Ref. 5)	U (Ref. 7) BTU/h·ft^2·°F
Northern: #1	10	7066	0.08
Central: #2	10	6643	0.08
Southern: #3	10	6242	0.08

Methodology and Assumptions

Assumed a noticeable stratification temperature is 10 °F or more.

Applicable to High Volume Low Speed and High Volume High Speed fans.

Assumes whole area is covered by stratification fans.

Notes

ASHRAE Advanced Design Guide for Manufacturing Facilities recommends destratification fans for ASHRAE zones 5-8.

There is a kW and kWh penalty not addressed in these calculations.

References

1. "Measured Life Report Residential and Commercial/Industrial Lighting and HVAC Measures", June 2007, by GDS Associates, Inc.pg. 1-3, modified to fan application and engineering judgment
2. "Technology Evaluation of Thermal Destratifiers and Other Ventilation Technologies", by Joel C Hughes, Naval Facilities Engineering Center, pg. 8, average of examples
3. "Technology Evaluation of Thermal Destratifiers and Other Ventilation Technologies", by Joel C. Hughes, Naval Facilities Engineering Center, pg. 3, rounded values
4. Average number of occupied hours in day, FES.
5. National Climate Data Center – National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.
6. "Technology Evaluation of Thermal Destratifiers and Other Ventilation Technologies", by Joel C. Hughes, example 1 of measured ceiling temperatures normalized for HDD, FES

7. Composite U value for Deer Manufacturing Model modified to reflect lower U values, FES
8. Assumed standard combustion efficiency of heating equipment, FES

Revision History

Version	Description	Author	Date
1.0	New savings specification for retrofit/incorporation of destratification fans.	Franklin Energy Services	8/1/2012
1.1	Changed statement "Assumed a noticeable stratification temperature is 5° or more" to "10° or more" per FES comment response, changed measure name, made some inputs optional per variable definitions, minor revisions	Joe Plummer	2/12/2013
1.2	Corrected typos in algorithm, added heating system efficiency to optional inputs	Joe Plummer	4/2/2014

C/I HVAC – ECM Blower Motors

Measure Detail	Measure Value
Measure ID	2.02.06
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC
Applicable To	Commercial or industrial buildings with residential-style forced-air furnaces. Measure applies to replacements of single-speed PSC motors only
Actions	Replace Working, Modify
Required from Customer/Contractor	Central AC present (yes/no), furnace AFUE
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	9 years (Ref. 6)
Unit Participant Incremental Cost	$475 (Ref. 3)

Measure Description

This measure is the retrofit of a less efficient (PCS) motor to a two-stage BPM or ECM motor in an existing furnace. The target age range for existing furnaces is 10-12 years. This measure characterizes only the electric savings associated with the fan.

Savings improve when the blower is used for cooling as well and when it is used for continuous ventilation, but only if the non-ECM motor would have been used for continuous ventilation too.

New standards for residential furnace blower motor fans, also applicable to residential-style forced-air furnaces in commercial or industrial buildings (Ref. 8), require the incorporation of ECMs, thereby making ECMs the baseline. Accordingly, this measure does not apply to new construction or replace on fail actions.

Algorithms

Unit kWh Savings per Year = Heating Savings + Cooling Savings + Shoulder Season Savings

Unit Peak kW Savings = Cooling Watts Savings x CF / 1000

Unit Dth Savings per Year = -Heating Savings x 0.003412 / AFUE

Where:

Heating Savings = Fan motor energy savings in heating season. Deemed value 126 kWh (Ref. 4)

Cooling Savings = Fan motor energy savings in cooling season. Deemed value 68 kWh if AC is present (Ref. 5), = 0 if no AC is present or variable is omitted from algorithm.

Shoulder Season Savings = Fan motor energy savings in shoulder seasons between heating and cooling seasons. Deemed value 54 kWh (Ref. 7)

Cooling Watts Savings	=	220 if retrofit of single-speed PSC motor and AC is present (Ref. 3), = 0 if no AC is present
CF	=	Coincidence factor = 0.9 (Ref. 2)
0.003412	=	Converts kWh to Dth
AFUE	=	Efficiency of Furnace provided by customer. If unknown assume 80%

Example:

An ECM blower is installed in place of an existing single-speed PSC motor in a building where central AC is present and AFUE of furnace is unknown.

Unit kWh Savings per Year = 126 + 68 + 54 = 248 kWh

Unit Peak kW Savings = 220 x 0.9/1000 = 0.198 kW

Unit Dth Savings per year = -126 x 0.003412 / 0.8 = -0.54 Dth

Methodology and Assumptions

All the assumptions were made based on furnaces analysis in Wisconsin described in study "PA Consulting Group/Patrick Engineering Residential Deemed Savings Review for Focus on Energy, 2009" (Ref. 1) and the values were adapted for Minnesota.

References

1. PA Consulting Group/Patrick Engineering Residential Deemed Savings Review for Focus on Energy, 2009
2. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified.
3. "Evaluation of Retrofit Variable-Speed Furnace Fan Motors", R. Aldrich and J. Williamson, Consortium for Advanced Residential Buildings, January 2014
4. Ibid. The Evaluation referenced noted a difference of 126 Watts. Over the course of 1000 hour heating system, "Electricity Savings from Variable-Speed Furnaces in Cold Climates", Scott Pigg, Energy Center of Wisconsin and Tom Talerico, Glacier Consulting Group, the kWH savings = 126 Wattsx 1000 hrs / 1000 W/KW = 126 kWh.
5. Ibid. The Evaluation referenced noted a difference of 220 Watts. Over the course of 310 hour cooling system, "State of Wisconsin Public Service Commission, Focus on Energy Evaluation, Residential Programs: CY09 Deemed Savings Review", March 26, 2010, the kWH savings = 220 Wattsx 310 hrs / 1000 W/KW = 68 kWh.
6. Massachusetts Common Assumption: The early replacement measure life of 9 years was determined by subtracting the estimated target age range of existing equipment between 10 and 12 years old from the 20 year measure life for new equipment.

7. Modified by the ratio of Watt savings 422 watts (Ref. 7) / 400 watts (Ref. 3) x 51 kWh = 54 kWh.
8. Electronic Code of Federal Regulations. Title 10, Chapter II, Subchapter D, Part 430, Subpart C, §430.32. https://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	9/25/16
1.1	Removed replace on fail and new construction actions, consistent with new federal standards	Cadmus	10/2018

C/I HVAC – ECM Circulators

Measure Detail	Measure Value
Measure ID	2.02.07
Target Market Segments	Commercial
Target End Uses	Pumps
Applicable To	Commercial facilities with domestic hot water and space heating/cooling circulation pumps
Actions	Replace Working, Replace on Fail, New Construction
Required from Customer/Contractor	Motor wattage, motor application
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	See Table 4 (Ref. 2)

Measure Description

Electronically commutated (EC) circulators (pumps) are high-efficiency brushless DC motors. They are typically fractional horsepower motors that have several benefits over the more common permanent split capacitor (PSC) fractional horsepower motor. This measure outlines savings resulting from ECM motor replacement for domestic hot water circulation, cooling water circulation or hot water circulation. For applications where the motor serves both heating water and cooling water circulation (heat pump), total hours of operation should be the sum of heating water and cooling water hours of operation in Table 1.

Algorithms

$kWh_{SAVED} = (W_{BASE} \times HOU_{BASE} - W_{ECM} \times HOU_{EFF}) / 1{,}000$

$kW_{SAVED} = (W_{BASE} - W_{ECM}) / 1{,}000 \times CF$

Where:

W_{BASE}	= W_{ECM} / 18% (Ref. 3), or actual existing motor wattage (if given in HP, = HP x 745.7 watts)
W_{ECM}	= Actual motor wattage (if given in HP, = HP x 745.7 Watts). If unknown or if savings are deemed by size, see Table 2 and 3 for deemed sizes. (Ref. 4)
HOU_{BASE}	= Hours of motor use by equipment type, See Table 1
HOU_{EFF}	= Hours of motor use by equipment type, See Table 1
1,000	= Conversion from watts to kW
CF_{DHW}	= Coincidence factor for domestic hot water circulation motor, = 1.0 (Ref. 5)
CF_{CW}	= Coincidence factor for cooling water circulation motor, = 0.7 (Ref. 6)
CF_{HW}	= Coincidence factor for heating water circulation motor, = 0

Example:

A customer installed a new 250-watt ECM pump on their domestic hot water circulation loop.

kWh_{SAVED} = (250 W / 18% x 4,000 hours – 250 W x 2,190 hours) / 1,000 = 5,008 kWh

kW_{SAVED} = (250 W / 18% - 250 W) / 1,000 x 1.0 = 1.140 kW

Deemed Input Tables

Table 1. Annual Hours of Operation

HOU	DHW Circulator (Ref. 7, 8)	Heating Water Circulator (Ref. 9)	Cooling Water Circulator (Ref. 10)
Baseline	4,000	2,582	1,191
Proposed	2,190	2,582	1,191

Table 2. Deemed Peak Demand Savings (kW) by Motor Size

EC Motor Size	DHW Circulator	Heating Water Circulator	Cooling Water Circulator
< 100 W (50 W deemed, 1/16 HP)	0.23	0	0.16
100 - 250 W (185 W deemed, 1/4 HP)	0.84	0	0.59
250 – 500 W (375 W deemed, 1/2 HP)	1.71	0	1.20
500 – 1,000 W (750 W deemed, 1 HP)	3.42	0	2.39
1,000 – 1,500 W (1,500 W deemed, 2 HP)	6.83	0	4.78
1,500 – 2,500 W (2,200 deemed, 3 HP)	10.02	0	7.02

Table 3. Deemed Energy Savings (kWh) by Motor Size

EC Motor Size	DHW Circulator	Heating Water Circulator	Cooling Water Circulator
< 100 W (50 W deemed, 1/16 HP)	1,002	588	271
100 - 250 W (185 W deemed, 1/4 HP)	3,706	2,176	1,004
250 – 500 W (375 W deemed, 1/2 HP)	7,512	4,411	2,035
500 – 1,000 W (750 W deemed, 1 HP)	15,024	8,822	4,069
1,000 – 1,500 W (1,500 W deemed, 2 HP)	30,048	17,644	8,139
1,500 – 2,500 W (2,200 deemed, 3 HP)	44,071	25,877	11,936

Table 4. Incremental Costs (Ref 2)

EC Motor Size	PSC Motor Cost	ECM Motor Cost	Incremental Cost
< 100 W (50 W deemed, 1/16 HP)	$526.02	$1,589.14	$1,063.11
100 - 250 W (185 W deemed, 1/4 HP)	$891.83	$2,062.15	$1,170.32
250 – 500 W (375 W deemed, 1/2 HP)	$891.83	$2,062.15	$1,170.32
500 – 1,000 W (750 W deemed, 1 HP)	$1,714.90	$3,126.43	$1,411.53
1,000 – 1,500 W (1,500 W deemed, 2 HP)	$2,629.42	$4,308.97	$1,679.54
1,500 – 2,500 W (2,200 deemed, 3 HP)	$3,726.85	$5,728.01	$2,001.16

Methodology and Assumptions

- Pump motor must be EC, DC brushless, or permanent magnet style
- Pump motor must be capable of variable speed operation
- Motor must include integrated "smart" controls that will modulate flow based on demand
- Motor must be < 3 hp

References

1. Pump Life Cycle Costs: A Guide to LCC Analysis for Pumping Systems. January 2001. Page 4. Accessed 6/11/14. https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/pumplcc_1001.pdf
2. Pricing research, November 2014. PSC and ECM pump motors from Viridian, Stratos, Star, Top, and other brands were cross examined..
3. The Cadmus Group, Inc. Impact Evaluation of the 2011–2012 ECM Circulator Pump Pilot Program. October 18, 2012. Table 2. Pump Spot Measurements.
4. Guidehouse. ECM Circulator Deemed Savings Update Memorandum. September 30, 2021. https://api-plus.anbetrack.com/etrm-gateway/etrm/api/v1/etrm/documents/616996543b0e447ee97cdfc3/view?authToken=3187157a6f71c346a7939268d347299b779ee6c0fdf54d249d3c74e73bed931ba193655c0e8b1b43ca44711bc12abf51385a268946a3962d2de54fe59af21cc90bd55b333d0b0a
5. Assumes baseline pump would be operating during the peak period. Franklin Energy Services.
6. Cadmus. Cadmus and Focus on Energy Coincidence Factor Load Profile Memorandum, September 3, 2024.
7. Estimate based on EPRI Report Assessment of New Energy Efficient Circulator Pump Technology (40% x 8,760 hr = 3,504 hr) and recommendation by Grundfos (60% x 8,760 hr = 5,256 hr).
8. Hours of use for pumps with an aqua-stat control in multifamily applications (6 hr/d x 365 d = 2,190 hr). DHW Recirculation System Control Strategies, Final Report 99-1. NYSERDA, January 1999. Page 3-30. http://www.emra.com/NYSERDA%20DHW%20Report%2099-1%20(Recirc%20Control)%20(a5-0).pdf.
9. Estimated based on an average of HDD65. Hours = HDD65 x 24/(70°F-Design Temps).
10. Estimated based on an average of CDD65. Hours = CDD65 x 24/(Design Temps-70°F).

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	11/10/2015
5.0	Updated several references to more current sources of data. Modified algorithm layout and variables for clarity. Modified deemed savings based on different sized motors	Cadmus	8/1/2025

C/I HVAC – ECM Fan Motors

Measure Detail	Measure Value
Measure ID	2.02.08
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC
Applicable To	Commercial and industrial buildings for space heating and cooling applications
Actions	Motors < 1/12 hp: Replace on Fail, Replace Working, New Construction Motors ≥ 1/12 hp and < 3 hp: Replace Working only
Required from Customer/Contractor	Design CFM, building type, climate zone
Measure Energy Type.	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	20 (Ref. 1)
Unit Participant Incremental Cost	$120 (Ref. 2) for Replace on Fail, New Construction, Modify Full cost of new motor for Replace Working

Measure Description

This measure includes efficiency gains for an electronically commutated motor (ECM) < 3 horsepower being applied within fan-powered terminal boxes, fan coils, and HVAC supply fans on small unitary equipment. Motors ≥ 3 horsepower should employ the C/I HVAC – Motor Replacement measure.

Note that Minnesota state energy code as of March 31, 2020 (Ref. 3) follows 2018 IECC standards (Ref. 4). These standards require that motors equal to or larger than 1/12 hp (82 W) must be ECMs or have an efficiency of 70%. Therefore, the application of this measure for motors in this range shall be Replace Working only.

Algorithms

kWh_{SAVED} = Heating kWh Savings + Cooling kWh Savings

kW_{SAVED} = Cooling kW Savings x CF

Dth_{SAVED} = -(Heating kWh Savings) x 0.003412 / $Heat_{EFF}$

Where:

Cooling kWh Savings = (Design CFM) x (Box Size Factor) x LF x $EFLH_{COOL}$ / 1000

Cooling kW Savings = (Design CFM) x (Box Size Factor) x LF / 1000

Heating kWh savings = (Design CFM) x (Box Size Factor) x LF x $EFLH_{HEAT}$ / 1000

Design CFM = Design airflow of fan in cubic feet per minute

Box Size Factor = Savings factor in watts/CFM (Ref. 5)

Design CFM < 1000, Box Size Factor = 0.32 Watts/CFM

Design CFM ≥ 1000, Box Size Factor = 0.21 Watts/CFM

$Heat_{EFF}$ = 80% or use actual if known.

CF = 0.9; electric peak coincidence factor (Ref. 8)

LF = 0.9; load factor (Ref. 9)

EFLH Cool = Effective Full Load Hours in cooling season attributed by climate zone and space type, See table 1

EFLH Heat = Effective Full Load Hours in heating season attributed by climate zone and space type, See table 1

1000 = Conversion watts to kilowatts

0.003412 = Conversion kWh to Dth

Example:

An ECM blower is installed into a 1,000 CFM VAV box in a manufacturing facility located in MN Climate Zone 2, over an existing working PSC motor.

VAV Box Size Factor = 0.21 watts/CFM

$EFLH_{COOL}$ = 472 hrs

$EFLH_{HEAT}$ = 1258 hrs

$kWh_{SAVED\ COOLING}$ = 1000 x 0.21 watts/CFM /1000 x 0.9 x 472 hrs = 89 kWh

$kW_{SAVED\ COOLING}$ = 1000 x 0.21 watts/CFM /1000 x 0.9 x 0.9 = 0.17 kW

$kWh_{SAVED\ HEATING}$ = 1000 x 0.21 watts/CFM /1000 x 0.9 x 1258 hrs = 238 kWh

Unit kW_{SAVED} = 0.17 kW

Unit kWh_{SAVED} = 238 + 89 kWh = 327 kWh

Deemed Input Tables

Table 1. Equivalent Full Load Hours of cooling per zone in Minnesota by building type (Ref. 6)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	647	825	986
Education – Community College/University	682	782	785
Education – Primary	289	338	408
Education – Secondary	484	473	563
Health/Medical – Clinic	558	738	865
Health/Medical – Hospital	663	1089	1298
Lodging	401	606	754
Manufacturing	347	472	589
Office-Low Rise	257	359	446
Office-Mid Rise	373	529	651
Office-High Rise	669	1061	1263
Restaurant	347	535	652
Retail – Large Department Store	462	588	686
Retail – Strip Mall	307	441	574
Warehouse	164	343	409
Other/Miscellaneous	443	612	729

Table 2. Equivalent Full Load Hours of heating per zone in Minnesota by building type (Ref. 7)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	1887	1699	1546
Education – Community College/University	1972	1776	1616
Education – Primary	2394	2156	1961
Education – Secondary	2561	2306	2098
Health/Medical – Clinic	2234	2012	1830
Health/Medical – Hospital	2508	2258	2054
Lodging	2361	2126	1934
Manufacturing	1397	1258	1144
Office-Low Rise	1966	1770	1610
Office-Mid Rise	2189	1971	1793
Office-High Rise	2149	1935	1760
Restaurant	1868	1681	1530
Retail – Large Department Store	1763	1587	1444
Retail – Strip Mall	1701	1531	1393
Warehouse	1872	1685	1533
Other/Miscellaneous	2123	1911	1739

Methodology and Assumptions

The annual energy and power savings for ECMs are site-specific and can be determined on a case-by-case basis. Use the residential ECM HVAC profile for dwellings only.

Notes

Effective full load hours were not developed for multifamily central cooling plants. Select Lodging as the building type to approximate EFLH for multifamily central cooling.

References

1. Measure Life Study, Prepared for the Massachusetts Joint Utilities. Energy & Resource Solutions, 2005. Table 1-1.
2. *Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment.* US Department of Energy, 2013. Table 4.10. https://www.energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf
3. U.S. Department of Energy Building Energy Codes Program. Minnesota. https://www.energycodes.gov/adoption/states/minnesota
4. 2018 International Energy Conservation Code. Chapter 4 section C403.8.4. https://codes.iccsafe.org/content/iecc2018/chapter-4-ce-commercial-energy-efficiency
5. Massachusetts Technical Reference Manual: 2013-2015 Program Years – Plan Version, October 2012. Savings factors based on engineering analysis developed at National Grid.
6. FES calculated EFLH from energy models based on California DEER study prototypes modified by Illinois field data with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone 3) 2012.
7. FES scaled EFLH from those provided in the Illinois Technical Reference Manual based on Minnesota weather data. EFLH for the Illinois Technical Reference Manual were based on California DEER study prototypes modified by Illinois field data to closely match EFLH from the modeling to those calculated from field data.
8. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified.
9. An assumed load factor of 0.9 reflects that motors are not typically 100% loaded.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	9/24/2016
2.0	Limited to Replace Working for most sizes	Cadmus	10/2020
5.0	Modified upper limit of HP applicable to 3 HP. Minor modifications to the measure write up for clarity and error correction	Cadmus	7/1/2025

C/I HVAC – Motor Replacement

Measure Detail	Measure Value
Measure ID	2.02.09
Target Market Segments	Commercial, Industrial
Target End Uses	Fans, Pumps, Motors, HVAC, Process
Applicable To	Motors in industrial and HVAC applications
Actions	Replace on Failure, Replace Working, New Construction
Required from Customer/Contractor	New Motor Enclosure Type (ODP/TEFC), RPM, Horsepower, Efficiency; Action Type (Replace on Fail, Replace Working, or New Construction); Building Type and Application (see Table 2)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	6 years (Replace Working), 20 years (Replace on Fail, New Construction) (Ref. 1, 2, 4)
Unit Participant Incremental Cost	Incr. Cost for EPACT to NEMA Premium Efficiency or EPACT to Enhanced NEMA Premium (Replacing Working); Incr. Cost for NEMA Premium Efficiency to Enhanced NEMA Premium (Replace on Fail and New Construction). See Appendix C. (Ref. 6)

Measure Description

This measure includes one-for-one replacement of working or failed/near-failure 1-200 hp motors with motors that meet or exceed NEMA Premium Efficiency levels in industrial and nonindustrial applications, as well as installation of motors in new construction.

For replacement of working motors, the new motor efficiency must be at least NEMA Premium Efficiency. For replacement of failed/near-failure motors or new construction, the new motor efficiency must exceed NEMA Premium Efficiency.

Algorithms

Unit kWh Savings per Year = HP x LF x Conversion x (1/Eff_base – 1/Eff_EE) x Hrs

Unit Peak kW Savings = HP x LF x Conversion x (1/Eff_base – 1/Eff_EE) x CF

Where:

Hrs	=	Deemed annual operating hours by end use (nonindustrial applications, see Table 2) or motor HP (industrial applications, see Table 1.)
LF	=	Motor load factor, deemed at 75% (Ref. 1, 4)
HP	=	Rated horsepower of new motor
Eff_EE	=	Efficiency of new motor. Eff_EE = NEMA Premium Efficiency or NEMA Premium Efficiency + 1%. See Appendix C.

Eff_base	=	Baseline motor efficiency. Eff_base = EPACT efficiency (Replace Working), NEMA Premium Efficiency (Replace on Fail, New Construction). See Appendix C.
Conversion	=	Standard conversion from hp to kW = 0.746 kW/hp
CF	=	Coincidence Factor = 0.78 (Ref. 1, 2)

Deemed Input Tables

Table 1. Deemed annual operating hours by motor horsepower for industrial applications (Ref. 3)

Motor HP	Hrs
5	2,745
7.5	3,391
10	3,391
15	3,391
20	3,391
25	4,067
30	4,067
40	4,067
50	4,067
60	5,329
75	5,329
100	5,329
125	5,200
150	5,200
200	5,200

Table 2. Deemed annual operating hours by building type and application (Ref. 4)

Building Type and Application	Hrs
Office HVAC Pump	2,000
Retail HVAC Pump	2,000
Hospitals HVAC Pump	2,754
Elem/Sec Schools HVAC Pump	2,190
Restaurant HVAC Pump	2,000
Warehouse HVAC Pump	2,241
Hotels/Motels HVAC Pump	4,231
Grocery HVAC Pump	2,080
Health HVAC Pump	2,559
College/Univ HVAC Pump	3,641
Office Ventilation Fan	6,192
Retail Ventilation Fan	3,261
Hospitals Ventilation Fan	8,374
Elem/Sec Schools Ventilation Fan	3,699

Building Type and Application	Hrs
Restaurant Ventilation Fan	4,155
Warehouse Ventilation Fan	6,389
Hotels/Motels Ventilation Fan	3,719
Grocery Ventilation Fan	6,389
Health Ventilation Fan	2,000
College/Univ Ventilation Fan	3,631
Office Other Non-Industrial Application	4,500
Retail Other Non-Industrial Application	4,500
Hospitals Other Non-Industrial Application	4,500
Elem/Sec Schools Other Non-Industrial Application	4,500
Restaurant Other Non-Industrial Application	4,500
Warehouse Other Non-Industrial Application	4,500
Hotels/Motels Other Non-Industrial Application	4,500
Grocery Other Non-Industrial Application	4,500
Health Other Non-Industrial Application	4,500
College/Univ Other Non-Industrial Application	4,500
Industrial/Manufacturing	See Table 1

Methodology and Assumptions

Measure lives for replacement of failed motors or motors in new construction was 15-20 years in most TRMs prior to the EISA standard for motors taking effect in December 2010. No sources were found for lifetime of early replacement motors since most states have disallowed rebates for industrial Premium Efficiency motors. However, a review of several TRMs showed that for other measures, the lifetime of early replacements is typically about one-third of the full measure life. Therefore, the lifetime of this measure was set to 6 years (approximately one-third of 15-20 years.)

Notes

According to the EISA standard, general purpose motors (subtype I) manufactured after December 19, 2010, with a power rating of at least 1 horsepower but not greater than 200 horsepower, shall have a nominal full-load efficiency that is not less than as defined in NEMA MG– 1 (2006) Table 12–12 (aka "NEMA Premium®" efficiency levels).

References

1. NYSERDA (New York State Energy Research and Development Authority); NY Energy $mart Programs Deemed Savings Database - Source for coincidence factor, measure life, and motor load factor
2. Franklin Energy Services review, November 2013
3. United States Industrial Electric Motor Systems Market Opportunities Assessment, EERE, US DOE, Dec 2002 - Source for operating hours for industrial motors and source for motor load factor data (Tables 1-18 and 1-19)

4. Efficiency Vermont's Technical Reference User Manual, 2004 - Source for operating hours for commercial motors (p.15) and source for measure life and source for existing motor efficiencies and source for motor load factor default value
5. CEE (Consortium for Energy Efficiency) Premium Efficiency Motors Initiative – source for premium motor efficiencies
6. Xcel Energy Minnesota Electric and Natural Gas Conservation Improvement Program Plan for 2013-2015 (Docket No. E,G002/CIP-12-447) – source for incremental costs.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Joe Plummer	11.13.13
2.0	Design changes to accommodate Replace on Fail and New Construction in addition to Replace Working, corrected incremental cost information	Joe Plummer	5.9.14

C/I HVAC – Heat Pump Systems

Measure Detail	Measure Value
Measure ID	2.02.10
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC
Applicable To	Commercial and Industrial customers where heat pump unitary equipment can be installed
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Equipment size (tons); IEER, SEER or EER of new equipment; IEER, SEER or EER of existing equipment (if program includes early replacements); HSPF or COP of new equipment; HSPF or COP of existing equipment (if program includes early replacements); existing equipment condition (working or failed, if program includes early replacements); building type (see Table 1), project location (county)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	15 years (Ref. 1)
Unit Participant Incremental Cost	Actuals preferred when known, See Tables 7, 8 and 9 by system.

Measure Description

This measure includes replacement of non-working and working unitary air source heat pump (ASHP), ground water source heat pump (GWSHP), ground source heat pump (GSHP), and packaged terminal heat pump (PTHP) equipment. This measure analyzes the heating and cooling savings potential of the installation of higher efficiency heat pumps systems of like kind. To quality, efficient models must meet the performance requirements of current ENERGY STAR criteria although do not need to be qualified through the program. The incremental cost is associated with base equipment cost and does not include any installation costs.

Algorithms

For ASHP units < 5.5 tons:

kWh_{SAVED} = Size x 12 x [$EFLH_{COOL}$ x (1 / $SEER_{BASE}$ – 1 / $SEER_{EE}$) + $EFLH_{HEAT}$ x (1/$HSPF_{BASE}$ – 1/$HSPF_{EE}$)]

For all other units:

kWh_{SAVED} = Size x [$EFLH_{COOL}$ x 12 x (1 / $IEER_{BASE}$ – 1 / $IEER_{EE}$) + $EFLH_{HEAT}$ x 3.52 x (1 / COP_{BASE} – 1 / COP_{EE})]

kW_{SAVED} = Size x 12 x (1 / EER_{BASE} – 1 / EER_{EE}) x CF

Where:

CF	= Deemed coincidence factor, equal to 0.9 (Ref. 4)
COP_{BASE}	= Heating coefficient of performance for baseline or existing equipment, provided by customer/contractor. If unknown see Tables 3, 4 and 5 (Ref. 5)
COP_{EE}	= Heating coefficient of performance for efficient equipment, provided by customer/contractor. See Tables 5, 7, 8 for efficiency requirements by equipment type and size.
EER_{BASE}	= Energy efficiency ratio of the baseline equipment, based on the 2015 Minnesota Energy-coded minimal efficiency ratings. See Tables 3 and 4 (Ref. 5)
EER_{EE}	= Energy efficiency ratio of the high-efficiency equipment, provided by the customer/contractor. If unknown, use EER = 1.12 x SEER – 0.02 x $SEER^2$ if SEER given (Ref. 7). See Tables 5, 7, 8 for efficiency requirements by equipment type and size.
$EFLH_{COOL}$	= Equivalent full load cooling hours based on the building type. See Table 1. (Ref. 7)
$EFLH_{HEAT}$	= Equivalent full load heating hours based upon the building type. See Table 2. (Ref 8)
$HSPF_{BASE}$	= Heating system performance factor of baseline or existing equipment, provided by customer/contractor or if unknown see Table 3 (Ref. 5)
$HSPF_{EE}$	= Heating system performance factor of efficient ASHP, provided by customer/contractor. See Table 5 for efficiency requirements by equipment type and size.
Size	= Nominal Cooling capacity in tons of the new equipment (1 ton = 12,000 btu/h)
$IEER_{BASE}$	= Integrated energy efficiency ratio of the baseline equipment, based on the 2015 Minnesota Energy Code requirements. See Table 3, 4 and 5 (Ref. 5). For GSHP which are typically rated only with EER, exchange IEER for EER in both baseline and performance efficiency values.
$IEER_{EE}$	= Integrated energy efficiency ratio of the high-efficiency equipment, provided by the customer/contractor. For GSHP which are typically rated only with EER, exchange IEER for EER in both baseline and performance efficiency values. See Tables 5, 7, 8 for efficiency requirements by equipment type and size.
$SEER_{BASE}$	= Seasonal energy efficiency ratio of the baseline equipment, based on the 2015 Minnesota Energy Code requirements. See Table 3 (Ref. 5)
$SEER_{EE}$	= Seasonal energy efficiency ratio of the high-efficiency equipment, provided by the customer/contractor. See Tables 5, 7, 8 for efficiency requirements by equipment type and size.

Example:

New ASHP packaged rooftop installed in midrise office, 7.5-ton cooling capacity, SEER 14 (EER 11.8) and COP of 3.4, Climate Zone 3.

kWh_{SAVED} = 7.5 x [651 x 12 x (1 / 12 – 1 / 14) + 1793 x 3.52 x (1 / 3.3 – 1 / 3.4)] = 1,119 kWh

kW_{SAVED} = 7.5 x 12 x [1 /11 – 1 / (11.8)] x 0.9 = 0.50 kW

Deemed Input Tables

Table 1. Equivalent Full Load Hours of cooling, per zone, in Minnesota by building type (Ref. 7)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	647	825	986
Education – Community College/University	682	782	785
Education – Primary	289	338	408
Education – Secondary	484	473	563
Health/Medical – Clinic	558	738	865
Health/Medical – Hospital	663	1,089	1,298
Lodging	401	606	754
Manufacturing	347	472	589
Office – Low Rise	257	359	446
Office – Mid Rise	373	529	651
Office – High Rise	669	1,061	1,263
Restaurant	347	535	652
Retail – Large Department Store	462	588	686
Retail – Strip Mall	307	441	574
Warehouse	164	343	409
Other/Miscellaneous	443	612	729

Table 2. Equivalent Full Load Hours of heating, per zone, in Minnesota by building type (Ref. 8)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	1,887	1,699	1,546
Education – Community College/University	1,972	1,776	1,616
Education – Primary	2,394	2,156	1,961
Education – Secondary	2,561	2,306	2,098
Health/Medical – Clinic	2,234	2,012	1,830
Health/Medical – Hospital	2,508	2,258	2,054
Lodging	2,361	2,126	1,934
Manufacturing	1,397	1,258	1,144
Office – Low Rise	1,966	1,770	1,610
Office – Mid Rise	2,189	1,971	1,793
Office – High Rise	2,149	1,935	1,760
Restaurant	1,868	1,681	1,530

Retail – Large Department Store	1,763	1,587	1,444
Retail – Strip Mall	1,701	1,531	1,393
Warehouse	1,872	1,685	1,533
Other/Miscellaneous	2,123	1,911	1,739

Table 3. Deemed baseline efficiency for ASHP, GSHP (Ref. 2, 5, 11)

Equipment Type	Size Class	Type	Minimum Efficiency	
			M metrics	M1 metrics (post 1/1/2023)
Heat Pumps, Air-Cooled (Cooling Mode)	<65,000 Btu/h	Split System, all heating types	15.0 SEER; 12.5 EER; 8.5 HSPF (single phase); 14.0 SEER (three phased)	14.3 SEER2 7.5 HSPF2
		Single Package system, all heating types	15.0 SEER; 12.0 EER; 8.2 HSPF (single phase); 14.0 SEER (three phased)	13.4 SEER2 6.7 HSPF2
	≥65,000 Btu/h <135,000 Btu/h	Electric Resistance Heat	11.8 EER; 12.8 IEER; 3.4 COP at 47ºF	14.1 IEER 3.4 COP at 47ºF 2.25 COP at 17ºF
		All other heat	11.6 EER; 12.6 IEER; 3.4 COP at 47ºF	13.9 IEER 3.4 COP at 47ºF 2.25 COP at 17ºF
	≥135,000 Btu/h <240,000 Btu/h	Electric Resistance Heat	10.9 EER; 12.0 IEER; 3.3 COP at 47ºF	13.5 IEER 3.3 COP at 47ºF 2.05 COP at 17ºF
		All other heat	10.7 EER; 11.8 IEER; 3.3 COP at 47ºF	13.3 IEER 3.3 COP at 47ºF 2.05 COP at 17ºF
	≥240,000 Btu/h	Electric Resistance Heat	9.5 EER; 10.6 IEER 3.2 COP at 47ºF	12.5 IEER 3.2 COP at 47ºF 2.05 COP at 17ºF
		All other heat	9.3 EER; 10.4 IEER 3.2 COP at 47ºF	12.3 IEER 3.2 COP at 47ºF 2.05 COP at 17ºF

Table 4. Deemed baseline efficiency for GSHP (Ref 5)

System Type	Single Stage		Multistage	
	EER*	COP**	EER	COP
Closed Loop Water-to-Air	14.1	3.2	EER= (highest rated capacity EER + lowest rated capacity EER) / 2	COP= (highest rated capacity COP + lowest rated capacity COP) / 2
Open Loop Water-to-Air	18.0	3.7		
Closed Loop Water-to-Water	12.1	2.5		
Open Loop Water-to-Water	16.3	3.1		
Direct Geoexchange DGX-to-Air	14.1	3.2		
Direct Geoexchange DGX-to-Water	12.1	2.5		

*EER values rated at entering water temperature 77°F for closed loop systems, and 59°F for open loop systems.
**COP values rated at entering water temperature 32°F for closed loop systems, and 50°F for open loop systems.

Table 5. PTHP minimum efficiencies (Ref. 11)

Equipment	Cooling Capacity (Btu/h)	EER_base*	COP_base*	
PTHP, Standard Size (used for New Construction)	< 7,000	11.9	3.3	
	7,000-15,000	14-(0.3 x Cap/1000)	3.7-(0.052 x Cap/1000)	
	> 15,000	9.5	2.9	
PTHP, Non-Standard Size (used for Replacements** Only)	< 7,000	9.3	2.7	
	7,000-15,000	10.8 – (0.213 x Cap/1000)	2.9 – (0.026 x Cap/1000)	
	> 15,000	7.6	2.5	

* Cap = cooling capacity in Btu/h at 95°F, outdoor dry-bulb temperature

Table 6. Criteria for ENERGY STAR-Certified Light Commercial Heat Pumps (in M1 metrics) (Ref. 15)

Equipment Type	Cooling Capacity	Heating Section Type	Minimum Energy Efficiency Criteria
Very Small CUHP (Single Package)	< 65,000 Btu/h	All	15.2 SEER2; 10.6* EER2; 7.2 HSPF2
Very Small CUHP (Split System)	< 65,000 Btu/h	All	16.0 SEER; 12.1 EER; 9.2 HSPF OR 15.2 SEER2; 11.7 EER2; 7.8 HSPF2
Small Air-Cooled Heat Pump	≥ 65,000 Btu/h – < 135,000 Btu/h	Electric Resistance (or None)	11.8 EER; 15.3 IEER; 3.5 COP at 47°F; 2.4 COP at 17°F
		All other	11.6 EER; 15.1 IEER; 3.5 COP at 47°F; 2.4 COP at 17°F
Large Air-Cooled Heat Pump	≥ 135,000 Btu/h – < 240,000 Btu/h	Electric Resistance (or None)	11.1 EER; 14.5 IEER; 3.4 COP at 47°F; 2.1 COP at 17°F
		All other	10.9 EER; 14.3 IEER; 3.4 COP at 47°F; 2.1 COP at 17°F

*Where ENERGY STAR efficiency criteria are lower than the current Federal minimum efficiency standard, eligible equipment must meet or exceed the Federal minimum efficiency indicated in Table 3.

Table 7. ASHP units 5.4 tons or less Incremental Cost (Ref. 3)

Efficiency Level	Incremental Cost
SEER 15	$274/ton
SEER 16	$411/ton
SEER 17	$548/ton
SEER 18	$685/ton

Table 8. Criteria for ENERGY STAR-Certified Geothermal HPs and Costs (Ref. 16, 13)

Equipment Type	Heating Section Type	Minimum Energy Efficiency Criteria (*all notes below)	Incremental Costs
Water to Air	Closed Loop Water-to-Air	17.1 EER, 3.6 COP	See notes below
	Open Loop Water-to-Air	21.1 EER, 4.1 COP	
Water to Water	Closed Loop Water-to-Water	16.1 EER, 3.1 COP	
	Open Loop Water-to-Water	20.1 EER, 3.5 COP	
Direct Geoexchange (DGX)	DGX-to-Air	16.0 EER, 3.6 COP	
	DGX-to-Water	15.0 EER, 3.1 COP	

*Where ENERGY STAR efficiency criteria are lower than the current Federal minimum efficiency standard, eligible equipment must meet or exceed the Federal minimum efficiency indicated in Table 3.
**Qualifying multistage models shall be qualified by average EER and COP, calculated with the highest rated capacity EER and the lowest rated capacity EER (or COP to determine avg COP).
*** Ground source heat pump efficiency (EER) is based on an entering water temperature of 77°F for closed loop systems, and 59°F for open loop systems. COP is based on an entering water temperature of 32°F for closed loop systems, and 50°F for open loop systems.

GSHP incremental costs vary by size and baseline equipment. For Time of Sale and new construction, the actual installed cost should be used minus the assumed installation cost of the baseline equipment. Defaults are $3,957 per ton for new GSHP, $6,562 + $500 per ton for ASHP, $4,053 for fossil fuel heating system and $952 per ton for new central AC system (Ref. 2). Add $500 to the incremental cost when a desuperheater is installed as part of the GSHP upgrade.

Table 9. Criteria for ENERGY STAR-Certified PTHP and Costs (Ref. 17, 12)

Equipment	Cooling Capacity (Btu/h)	EER_base*	COP_base*	Incremental Cost
PTHP, Standard Size (used for New Construction)	< 7,000	≥ 12.9	≥ 3.5	$250/ton
	7,000-15,000	≥ 14.9 -(0.324 x Cap/1000)	≥ 4.0-(0.064 x Cap/1000)	$250/ton
	> 15,000	≥ 10.0	≥ 3.0	$250/ton
PTHP, Non-Standard Size (used for Replacements** Only)	< 7,000	≥ 9.9	≥ 2.9	$250/ton
	7,000-15,000	≥ 11.5 – (0.226 x Cap/1000)	≥ 3.1 – (0.025 x Cap/1000)	$250/ton
	> 15,000	≥ 8.1	≥ 2.7	$250/ton

* Cap = cooling capacity in Btu/h at 95°F, outdoor dry-bulb temperature

Methodology and Assumptions

$EFLH_{COOL}$ was determined from based prototypes building models on the California DEER study prototypes, modified Illinois field data, and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

$EFLH_{HEAT}$ was determined from based prototypes building models on the California DEER study prototypes, modified Illinois field data, and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3). Values were scaled as follows: $EFLH_{MN} = EFLH_{IL} \times HDD_{55,\,MN} / HDD_{55,\,IL} \times DTD_{IL} / DTD_{MN}$, where DTD is the design temperature difference.

Table 10. Heating Degree Days and Design Temperature Differences

Geography	HDD55	DTD
Chicago, IL	4,029	73.5
MN Zone 1	6,956	92
MN Zone 2	5,888	86.5
MN Zone 3	5,233	84.5

Assumed ventilation rates complied with the requirements of ASHRAE standard 62.1 – 2004.

Effective January 1, 2023, HVAC products will be subject to regional minimum efficiencies, according to Seasonal Energy Efficiency Ratio 2 (SEER2). The nomenclature of SEER2, EER2 and HSPF2 will be used to denote the new M1 ratings. Conversion between the new M1 ratings and original M ratings should be done using an AHRI approved method, using the multipliers in the Tables below.

Table 11. M to M1 Forward Conversion (Ref. 14)

System Type	Multiplier to convert to SEER2	Multiplier to convert to EER2	Multiplier to convert to HSPF2
Ducted	0.95	0.95	0.85
Ductless	1.00	1.00	0.90
Packaged	0.95	0.95	0.84

Table 12. M1 to M Backward Conversion (Ref. 14)

System Type	Multiplier to convert to SEER	Multiplier to convert to EER	Multiplier to convert to HSPF2
Split System Air Conditioner	1.05	1.04	N/A
Split System Heat Pump	1.05	1.04	1.18
Packaged Air Conditioner	1.04	1.04	N/A
Packaged Heat Pump	1.04	1.04	1.18
Ductless Heat Pump	1.00	1.00	1.12

Space Constrained System	1.01	1.00	1.17
Small Duct High Velocity System	1.00	1.00	1.18

References

1. Measure Life Report, Residential and Commercial/Industrial Lighting, and HVAC Measures, by GDS Associates, Inc. June 2007, pg. 6.
2. Comparison of Electric/Gas Fired Unitary equipment costs from DEER 2008 Database Technology and Measured Cost Data and Electric/Gas Fired Unitary and Heat Pump equipment costs from RSMeans Mechanical Cost Data.
3. DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).
4. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9; primary data has not been identified.
5. 2024 Minnesota Energy Code with ANSI/ASHRAE/IES Standard 90.1-2019. Section 6.8.1 Minimum Efficiency Requirement Listed Equipment—Standard Rating and Operating Conditions Effective January 5, 2024. https://codes.iccsafe.org/content/MNEC2024P1/6-heating-ventilating-and-air-conditioning#MNEC2024P1_Ch06_Sec6.8
6. ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment.
7. FES calculated EFLH from energy models based on California DEER study prototypes modified by Illinois field data with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3) 2012.
8. FES scaled EFLH from those provided in the Illinois Technical Reference Manual based on Minnesota weather data. EFLH for the Illinois Technical Reference Manual were based on California DEER study prototypes modified by Illinois field data to closely match EFLH from the modeling to those calculated from field data.
9. Title 10, Code of Federal Regulations, Part 431 – Energy Efficiency Program for Certain Commercial and Industrial Equipment. https://www.ecfr.gov/cgi-bin/text-idx?SID=ded1dbd4f1450bfd666ff67a75d7aba8&mc=true&node=pt10.3.431&rgn=div5 Table 3 to §431.97
10. EER approximated as EER = 1.12 x SEER – 0.02 x $SEER^2$ if SEER or EER given.
11. Title 10, Code of Federal Regulations, Part 431 – Energy Efficiency Program for Certain Commercial and Industrial Equipment. November 2023. https://www.federalregister.gov/documents/2016/05/24/2016-12279/energy-conservation-program-for-certain-industrial-equipment-energy-conservation-standards-for-small. https://www.energy.gov/femp/incorporate-minimum-efficiency-requirements-heating-and-cooling-products-federal-acquisition
12. PTHP incremental costs assumed to be approximately equal to PTAC incremental costs; see C/I HVAC – Unitary and Split Systems.
13. Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference*

Manual for Energy Efficiency. Version 13.0. Volume 2. 2024. Measure 5.3.8. https://www.ilsag.info/technical-reference-manual/illinois-statewide-technical-reference-manual-version-13-0/

14. Consortium for Energy Efficiency. CEE Residential Electric HVAC Specification. Published October 18, 2023. https://cee1.my.site.com/s/resources?id=a0V2R00000sUQbyUAG
15. ENERGY STAR Program Requirement Product Specification for Light Commercial HVAC, Version 4.0, Rev. January 1st 2023. https://www.energystar.gov/products/heating_cooling/light_commercial_heating_cooling/light_commercial_hvac_key_product_criteria
16. ENERGY STAR Program Requirement Product Specification for Geothermal Heat Pumps, Version 3.2. https://www.energystar.gov/sites/default/files/2025-04/Geothermal%20Heat%20Pump%20Version%203.2%20Final%20Specification%20with%20PCs.pdf
17. ENERGY STAR Program Requirement Product Specification for PTHPs, Version 1.0. January 10, 2025. https://www.energystar.gov/sites/default/files/2025-01/ENERGY%20STAR%20Version%201.0%20PTHP%20Final%20Draft%20Specification_0.pdf

Revision History

Version	Description	Author	Date
1.0	New deemed savings specification replacing/utilizing Heat Pump Units	Franklin Energy Services	
1.1	Corrected table references, Required Inputs	Joe Plummer	6/6/14
2.0	Changed from Heating Degree Days to $EFLH_{HEAT}$. Updated Table 2 to include building types, Added Other/Miscellaneous building type for $EFLH_{COOL}$. Correct reference to COPs, Changed base line to 2015 Minnesota Energy Code.	Franklin Energy Services	11/12/15
2.1	Updated minimum efficiencies according to new federal standards, Updated GSHP and GWSHP efficiencies to align with test conditions used in AHRI listings, Added packaged terminal heat pumps, Updated example calculation.	Franklin Energy Services	9/15/17
3.1	Streamlined equations, added split vs. packaged variations for < 5.4 ton baselines, updated costs for air source systems.	Cadmus	10/2018
4.1	Corrected EFLH heating value errors in Table 2 due to MF space type removal in v2.0. Clarification to SEER2, EER2 and HSPF2 conversions	Cadmus	11/2023
5.0	Added performance criteria tables for GSHP and PTHP, update to incremental costs.	Cadmus	9/2025

C/I HVAC – Heat Pump RTU

Measure Detail	Measure Value
Measure ID	2.02.11
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC, EFS
Applicable To	Commercial and industrial customers
Actions	Replace Working, Replace on Fail, New purchase without existing equipment
Required from Customer/Contractor	Heating and cooling capacity and efficiency of existing and new RTU system, confirmation of baseline RTU fuel type.
Measure Energy Type	Electric, Gas, EFS
Unit kWh Savings per Year	See algorithm and deemed savings by capacity bin and space type
Unit Peak kW Savings	See algorithm and deemed savings by capacity bin and space type
Unit Dth Savings per Year	See algorithm and deemed savings by capacity bin and space type
Measure Lifetime (years)	15 years
Unit Participant Incremental Cost	Actuals, Default of $2,000/ton

Measure Description

This measure applies to the installation of heat pump rooftop units (RTU) to replace existing failed or working non HP RTUs meeting federal minimum standards, or new construction non HP RTUs meeting current code standards. The baseline equipment is considered to be RTUs providing cooling and heating (either gas or electric) without integrated heat pump capabilities. Qualifying efficient equipment are electric heat pump RTUs meeting CEE Tier 0 (or higher) criteria for units equal to or larger than 65,000 btu/hr, and current ENERGY STAR or CEE Tier 1 (or higher) criteria for units less than 65,000 Btu/hr. Where CEE Tier 1 and ENERGY STAR criteria differ, the lower of the two constitutes the minimum required performance criteria that must be met (Ref 3,4).

RTUs provide an all-in-one heating, ventilation, and air-conditioning (HVAC) solution for commercial and industrial buildings and are installed in approximately 80% of commercial buildings in the state (Ref 1). The heating fuel type of existing and new construction Minnesota RTUs is generally natural gas (97% of RTUs as of 2017), and the RTU heating efficiency has improved only 1% over the last 30 years (Ref 1). Heat pump RTU installations provide an opportunity to dramatically improve the efficiency of commercial HVAC energy consumption.

The Minnesota Energy Conservation and Optimization Act (Ref. 9, 10) allows for efficient fuel switching (EFS) improvements where electricity or natural gas replaces another fuel used by the customer (i.e. natural gas, fuel oil, propane, etc) provided that the following criteria are met for each measure pursued:

1. The proposed efficient fuel switching measure results in a net reduction in the amount of source energy consumed for a particular use, measured on a fuel-neutral basis, using the utility's annual system average efficiency, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.

2. The proposed efficient fuel switching measure results in a net reduction of statewide greenhouse gas emissions (Ref 11), over the lifetime of the improvement. For an efficient fuel-switching improvement installed by an electric utility, the reduction in emissions must be measured using the utility's annual average emissions factor, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.
3. The proposed efficient fuel switching measure is cost-effective, considering the costs and benefits from the perspective of the utility, participants, and society.
4. The proposed efficient fuel switching measure should produce a similar or higher level of quality, service, or output as the technical assumptions identified in the baseline technology to be eligible (Ref. 12).

This measure potentially includes the efficient fuel switching energy savings resulting conversion of non-electric heating energy of the baseline equipment to electric heating energy in the proposed HP RTU equipment.

Baseline equipment for this measure is assumed to include commercial sized RTUs with heating provided by electric resistance, gas or oil. The proposed efficient technology is a heat pump RTU. To meet the same quality of service the baseline provides, the HP RTU should be sized to meet the demand served by the baseline equipment.

Algorithms

Unit kWh Savings (penalty)	= Cooling usage kWh_Baseline- (Cooling usage kWh_Eff + Heating usage kWh_Eff)
Cooling usage kWh_Baseline	= (Capacity x EFLHCOOL x 12,000 / 1,000) / IEER_Base
Cooling usage kWh Eff	= (Capacity x EFLHCOOL x 12,000 / 1,000) / IEER_Eff
Heating usage kWh_Eff	= ((Capacity x EFLHHEAT x 12,000 x HP Utilization) / 3412) / COPH_heating_Eff
Unit Dth Savings per Year	= Heating usage dth_Baseline - Heating usage dth_Eff
Heating usage Dth_Baseline	= (Capacity x EFLHHEAT x 12,000 / 1,000,000) / AFUE_Base
Heating usage Dth_Eff	= ((Capacity x EFLHHEAT x 12,000 x (1- HP Utilization)) / 1,000,000) / AFUE_backup_Eff
Net MMBtu Savings per Year	= Unit Dth Savings per Year + (Unit kWh Savings / 293.07)
Unit Peak kW Savings (penalty)	= Capacity x (12,000 / 3,412) x (1 / EER_Base - 1 / EER_Eff) x CF

Algorithm Inputs:

Variable	Definition	Units	Ref	Table Ref
Capacity	Nominal cooling capacity in tons of the new equipment (1 ton = 12,000 btu/h). See table 1 for binned capacity categories used for deemed savings	tons	1	1
$EFLH_{COOL}$	Effective full load hours in cooling mode. See table 2. Cumulative metric of (Capacity x $EFLH_{COOL}$ x 12,000) can also be replaced by the annual cooling load in btu	hours	7	2
$EFLH_{HEAT}$	Effective full load hours in heating mode. See table 3. Cumulative metric of (Capacity x $EFLH_{HEAT}$ x 12,000) can also be replaced by the annual heating load in btu	hours	8	3
12,000	Conversion tons to btu	btu / tons		
1,000	Conversion watts to kilowatts	W/kW		
1,000,000	Conversion btu to mmbtu (= Dth)	btu/ mmbtu		
3,412	conversion btu to kWh	btu/kWh		
293.07	conversion kWh to mmbtu (=Dth)	kWh/ mmbtu		
IEER_Base	Integrated energy efficiency ratio of the baseline equipment, based on minimum code compliance. See Table 1.		5	1
IEER_Eff	Integrated energy efficiency ratio. See Table 1 for assumptions used to model savings. IEER_Eff has been defined by manufacturer data representative of Level 1 and Level 2 products available on the market.		3,4	1
SEER2_Base	Seasonal energy efficiency ratio of the baseline equipment, based on minimum code compliance. See Table 1. Used in place of IEER for smaller units, replace IEER with SEER in algorithm. Interchangeable with SEER2 as long as baseline and efficient both use same metrics.		3,4	1
SEER2_Eff	Seasonal energy efficiency ratio of the high-efficiency equipment, provided by the customer/contractor. See Table 1. Used in place of IEER for smaller units, replace IEER with SEER in algorithm. Interchangeable with SEER2 as long as baseline and efficient both use same metrics.		3,4	1
AFUE_Base	Average fuel utilization efficiency of baseline equipment, based on minimum code compliance. Default of 81% AFUE.		5	
AFUE_Backup_Eff	Average fuel utilization efficiency for the gas backup equipment. See Table 1 for assumptions used to model savings. AFUE_Backup_Eff has been defined by manufacturer data representative of Level 1 and Level 2 products available on the market. Default of 81% AFUE.		3,4	
$SCOP_H$_Heating_Eff	Seasonal COP_H. The COP_H of a dual fuel heat pump RTU changes with OSAT and switch over temperature stpt. Seasonal load weighted average COP_H is calculated via modeling informed by field monitoring. The temperature dependent curve is representative of the level 1 and level 2 products available on the market. See Table 4 for calculated seasonal COP values to be used in the algorithm. Note that seasonal COP differs from		1	4

	rated COP, which offers ratings at fixed OSA temperatures, 47 degrees and 17 degrees.			
HSPF2	Heating Seasonal Performance Factor of the high-efficiency equipment, provided by the customer/contractor. See Table 1. Used in place of COP for smaller units, replace COP_H with HSPF2 in algorithm.		3,4	1
EER_Base	Energy efficiency ratio of the baseline equipment, based on minimum code compliance. See Table 1 for assumptions used to model savings. Interchangable with EER2 as long as baseline and efficient both use same metrics.		5	1
EER_Eff	Energy efficiency ratio of the high-efficiency equipment, provided by the customer/contractor. If unknown, use EER = 1.12 x SEER – 0.02 x SEER2 (Ref. 2). See Table 1 for assumptions used to model savings. EER_Eff has been defined by manufacturer data representative of level 1 and level 2 products available on the market. Interchangable with EER2 as long as baseline and efficient both use same metrics.		3,4	1
HP Utilization	The heat pump utilization factor is the percentage of the annual heating load delivered by the electric heat pump in the efficient scenario, utilized above the switch over temperature. The remainder (1-HP Utilization) is the percentage of the annual heating load delivered by the backup heating system, utilized below the switch over temperature. See Table 4	%	1	4
CF	Coincidence factor = 0.9			

Example:

A new HP RTU is installed in a zone 3 low rise office building. Capacity is 7 tons, but the binned average of 8.35 tons will be used for the calculations. All variables use the Table default values for baseline and efficient minimum performance metrics.

Unit kWh Savings (penalty) = 1,039 - (867 + 4,755) = - 7,480

Cooling usage kWh_Baseline = (8.35 x 446 x 12,000 / 1,000) / 12.6 = 3,215

Cooling usage kWh Eff = (8.35 x 446 x 12,000 / 1,000) / 15.1 = 3,061

Heating usage kWh_Eff = ((8.35 x 1610 x 12,000 x 35.2%) / 3412) / 2.18 = 7,634

Unit Dth Savings per Year = 199 - 129 = 70

Heating usage dth_Baseline = (8.35 x 1,610 x 12,000 / 1,000,000) / 81% = 199

Heating usage dth_Eff = ((8.35 x 1,610 x 12,000 x (1- 35.2%)) / 1,000,000) / 81% = 129

Net Savings per Year (MMBTU) = 70 + (7,411 / 293.07) = 45

Unit Peak kW Savings (penalty) = 8.35 x (12,000 / 3,412) x (1 / 10.8 - 1 / 11.6) x 0.9 = 0.17

Deemed Input Tables

Table 1: Baseline and Efficient RTU Heat Pump Performance Criteria (in M1 metrics, post 2024) (Ref. 3,4,5)

RTU HP Size Category	MN Code Minimum (ASHRAE 90.1-2019) - BASELINE	CEE Tier 0	CEE Tier 1	ENERGY STAR
<65,000 Btu/h (5.4 tons) Average size of bin modeled = 4.2 tons	13.4 SEER2 10.6 EER2 6.7 HSPF2	N/A	15.2 SEER2; 10.6 EER2; 7.2 HSPF2	15.2 SEER2; 10.6 EER2*; 7.2 HSPF2
≥65,000 Btu/h (5.4 tons) <135,000 Btu/h (11.25 tons) Average size of bin modeled = 8.35 tons	13.9 IEER; 10.8 EER; 3.4 COP at 47ºF	14.6 IEER; 10.8 EER; 3.5 COP at 47°F	15.1 IEER; 11.6 EER; 3.5 COP at 47°F	15.1 IEER; 11.6 EER; 3.5 COP at 47°F
≥135,000 Btu/h and <240,000 Btu/h Average size of bin modeled = 15.65 tons	13.3 IEER; 10.4 EER; 3.3 COP at 47ºF	13.8 IEER; 10.4 EER; 3.4 COP at 47°F	14.3 IEER; 10.9 EER; 3.4 COP at 47°F	14.3 IEER; 10.9 EER; 3.4 COP at 47°F
≥240,000 Btu/h Average size of bin modeled = 22.5 tons	12.3 IEER; 9.3 EER; 3.2 COP at 47ºF	12.8 IEER; 9.3 EER; 3.3 COP at 47°F	13.3 IEER; 10.1 EER; 3.3 COP at 47°F	N/A

Table 2: Equivalent Full Load Hours of cooling, per zone, in Minnesota by building type (Ref. 7)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	647	825	986
Education – Community College/University	682	782	785
Education – Primary	289	338	408
Education – Secondary	484	473	563
Health/Medical – Clinic	558	738	865
Health/Medical – Hospital	663	1,089	1,298
Lodging	401	606	754
Manufacturing	347	472	589
Office – Low Rise	257	359	446
Office – Mid Rise	373	529	651
Office – High Rise	669	1,061	1,263
Restaurant	347	535	652
Retail – Large Department Store	462	588	686
Retail – Strip Mall	307	441	574
Warehouse	164	343	409
Other/Miscellaneous	443	612	729

Table 3: Equivalent Full Load Hours of heating, per zone, in Minnesota by building type (Ref. 8)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	1,887	1,699	1,546
Education – Community College/University	1,972	1,776	1,616
Education – Primary	2,394	2,156	1,961
Education – Secondary	2,561	2,306	2,098
Health/Medical – Clinic	2,234	2,012	1,830
Health/Medical – Hospital	2,508	2,258	2,054
Lodging	2,361	2,126	1,934
Manufacturing	1,397	1,258	1,144
Office – Low Rise	1,966	1,770	1,610
Office – Mid Rise	2,189	1,971	1,793
Office – High Rise	2,149	1,935	1,760
Restaurant	1,868	1,681	1,530
Retail – Large Department Store	1,763	1,587	1,444
Retail – Strip Mall	1,701	1,531	1,393
Warehouse	1,872	1,685	1,533
Other/Miscellaneous	2,123	1,911	1,739

Table 4: Modeled Heat Pump Utilization by Climate Zone (Ref. 1)

Climate Zone	Zone 1
Climate Zone 1	38.2%
Climate Zone 2	31.1%
Climate Zone 3	35.2%

Table 5: Seasonal COP_H Modeled at 30 F change over weighted by OSA in load range (Ref. 1)

Climate Zone	Climate Zone	Modeled Seasonal COP_H
Bin 4.2 tons	Climate Zone 1	2.23
	Climate Zone 2	2.24
	Climate Zone 3	2.22
Bin 8.35 tons	Climate Zone 1	2.19
	Climate Zone 2	2.20
	Climate Zone 3	2.18
Bin 15.65 tons	Climate Zone 1	2.16
	Climate Zone 2	2.17
	Climate Zone 3	2.15
Bin 22.5 tons	Climate Zone 1	2.05
	Climate Zone 2	2.06
	Climate Zone 3	2.05

Table 6: Deemed calculated savings by binned capacity, and space type in Zone 1 (Ref 1)

Climate Zone 1					
Savings Type	**Space Type**	**Bin 4.2 tons**	**Bin 8.35 tons**	**Bin 15.65 tons**	**Bin 22.5 tons**
Electric Savings (Penalty) kWh	Convenience Store	(4,496)	(9,459)	(18,055)	(27,229)
	Education - Primary	(5,941)	(12,184)	(23,178)	(35,001)
	Education - Secondary	(6,278)	(12,974)	(24,706)	(37,293)
	Health/Medical Clinic	(5,416)	(11,270)	(21,482)	(32,415)
	Health/Medical Hospital	(6,064)	(12,640)	(24,098)	(36,359)
	Office - Low Rise	(4,870)	(9,999)	(19,024)	(28,727)
	Office - Mid Rise	(5,384)	(11,103)	(21,138)	(31,911)
	Office - High Rise	(5,151)	(10,796)	(20,597)	(31,068)
	Restaurant	(4,582)	(9,465)	(18,024)	(27,207)
	Retail - Large Dept Store	(4,264)	(8,887)	(16,942)	(25,562)
	Retail - Strip Mall	(4,176)	(8,622)	(16,417)	(24,782)
	Warehouse	(4,673)	(9,549)	(18,156)	(27,422)
	Other / Unknown	(4,659)	(9,594)	(16,826)	(24,782)
Gas Savings Dth	Convenience Store	45	89	167	240
	Education - Primary	57	113	212	305
	Education - Secondary	61	121	227	326
	Health/Medical Clinic	53	106	198	285
	Health/Medical Hospital	60	119	222	319
	Office - Low Rise	47	93	174	250
	Office - Mid Rise	52	103	194	279
	Office - High Rise	51	102	190	274
	Restaurant	44	88	166	238
	Retail - Large Dept Store	42	83	156	225
	Retail - Strip Mall	40	80	151	217
	Warehouse	45	88	166	238
	Other / Unknown	45	89	154	217
Net Savings MMBtu	Convenience Store	30	57	106	147
	Education - Primary	37	72	133	186
	Education - Secondary	39	77	143	199
	Health/Medical Clinic	35	67	125	174
	Health/Medical Hospital	39	75	140	195
	Office - Low Rise	30	59	109	152
	Office - Mid Rise	34	66	122	170
	Office - High Rise	34	65	120	168
	Restaurant	29	56	104	145
	Retail - Large Dept Store	27	53	98	137
	Retail - Strip Mall	26	51	95	132
	Warehouse	29	56	104	145
	Other / Unknown	29	57	97	132

Table 7: Deemed calculated savings by binned capacity, and space type in Zone 2 (Ref 1)

Climate Zone 2					
Savings Type	**Space Type**	**Bin 4.2 tons**	**Bin 8.35 tons**	**Bin 15.65 tons**	**Bin 22.5 tons**
Electric Savings (Penalty) kWh	Convenience Store	(3,120)	(6,774)	(12,982)	(19,543)
	Education - Primary	(4,275)	(8,841)	(16,836)	(25,408)
	Education - Secondary	(4,523)	(9,418)	(17,950)	(27,080)
	Health/Medical Clinic	(3,801)	(8,104)	(15,495)	(23,349)
	Health/Medical Hospital	(4,150)	(9,005)	(17,257)	(25,980)
	Office - Low Rise	(3,473)	(7,230)	(13,780)	(20,789)
	Office - Mid Rise	(3,810)	(8,006)	(15,279)	(23,039)
	Office - High Rise	(3,499)	(7,673)	(14,723)	(22,154)
	Restaurant	(3,212)	(6,799)	(12,988)	(19,578)
	Retail - Large Dept Store	(2,996)	(6,390)	(12,219)	(18,412)
	Retail - Strip Mall	(2,946)	(6,209)	(11,853)	(17,870)
	Warehouse	(3,306)	(6,882)	(13,118)	(19,790)
	Other / Unknown	(3,467)	(6,914)	(12,637)	(17,870)
Gas Savings Dth	Convenience Store	33	65	122	176
	Education - Primary	42	83	155	223
	Education - Secondary	45	89	166	239
	Health/Medical Clinic	39	77	145	208
	Health/Medical Hospital	44	87	163	234
	Office - Low Rise	34	68	127	183
	Office - Mid Rise	38	76	142	204
	Office - High Rise	37	74	139	200
	Restaurant	32	65	121	174
	Retail - Large Dept Store	31	61	114	164
	Retail - Strip Mall	30	59	110	159
	Warehouse	33	65	121	174
	Other / Unknown	35	65	118	159
Net Savings MMBtu	Convenience Store	22	42	78	109
	Education - Primary	27	53	98	137
	Education - Secondary	29	56	105	146
	Health/Medical Clinic	26	50	92	129
	Health/Medical Hospital	29	56	104	145
	Office - Low Rise	22	43	80	112
	Office - Mid Rise	25	48	90	126
	Office - High Rise	25	48	89	125
	Restaurant	22	41	77	107
	Retail - Large Dept Store	20	39	73	102
	Retail - Strip Mall	20	38	70	98
	Warehouse	21	41	77	107
	Other / Unknown	23	42	74	98

Table 8: Deemed calculated savings by binned capacity, and space type in Zone 3 (Ref 1)

Climate Zone 3					
Savings Type	**Space Type**	**Bin 4.2 tons**	**Bin 8.35 tons**	**Bin 15.65 tons**	**Bin 22.5 tons**
Electric Savings (Penalty) kWh	Convenience Store	(3,181)	(6,985)	(13,410)	(20,178)
	Education - Primary	(4,411)	(9,152)	(17,440)	(26,317)
	Education - Secondary	(4,662)	(9,747)	(18,594)	(28,047)
	Health/Medical Clinic	(3,900)	(8,373)	(16,027)	(24,143)
	Health/Medical Hospital	(4,232)	(9,285)	(17,822)	(26,818)
	Office - Low Rise	(3,572)	(7,475)	(14,262)	(21,511)
	Office - Mid Rise	(3,909)	(8,272)	(15,804)	(23,824)
	Office - High Rise	(3,559)	(7,904)	(15,194)	(22,850)
	Restaurant	(3,293)	(7,025)	(13,436)	(20,246)
	Retail - Large Dept Store	(3,076)	(6,606)	(12,645)	(19,048)
	Retail - Strip Mall	(3,006)	(6,403)	(12,243)	(18,450)
	Warehouse	(3,408)	(7,123)	(13,588)	(20,496)
	Other / Unknown	(3,418)	(7,223)	(13,603)	(18,603)
Gas Savings Dth	Convenience Store	34	67	126	181
	Education - Primary	43	85	160	230
	Education - Secondary	46	91	171	246
	Health/Medical Clinic	40	80	149	215
	Health/Medical Hospital	45	89	168	241
	Office - Low Rise	35	70	131	189
	Office - Mid Rise	39	78	146	210
	Office - High Rise	39	77	144	206
	Restaurant	33	67	125	179
	Retail - Large Dept Store	32	63	118	169
	Retail - Strip Mall	30	61	114	163
	Warehouse	34	67	125	180
	Other / Unknown	34	68	126	165
Net Savings MMBtu	Convenience Store	23	43	80	112
	Education - Primary	28	54	100	140
	Education - Secondary	30	58	108	150
	Health/Medical Clinic	27	51	95	132
	Health/Medical Hospital	31	58	107	149
	Office - Low Rise	23	45	83	115
	Office - Mid Rise	26	50	92	129
	Office - High Rise	26	50	92	128
	Restaurant	22	43	79	110
	Retail - Large Dept Store	21	40	75	104
	Retail - Strip Mall	20	39	72	100
	Warehouse	22	42	79	110
	Other / Unknown	23	44	80	101

Methodology and Assumptions

This measure has been developed from a study completed by Center for Energy Environment (Ref 1) for the Minnesota Efficient Technology Accelerator (ETA) in 2024. Given the difficulty in developing an algorithm that can accurately encompass the savings of this strategy, the savings outlined in this measure were generated from energy models discussed in detail within the study report. See the study report (Ref 1) and the TRM workbook for this measure for the complete model inputs and assumptions. This measure outlines the per-unit savings for each tonnage range based on current inputs, outlined within the study. The tonnage and efficiency inputs will likely vary year to year, and the savings outlined in this measure will be updated based on current market data as it changes.

Effective January 1, 2023, HVAC products will be subject to regional minimum efficiencies, according to Seasonal Energy Efficiency Ratio 2 (SEER2). The nomenclature of SEER2, EER2 and HSPF2 will be used to denote the new M1 ratings. Conversion between the new M1 ratings and original M ratings should be done using an AHRI approved method, using the multipliers in Table 9 and Table 10 below.

Table 9: M to M1 Forward Conversion (Ref. 6)

System Type	Multiplier to convert to SEER2	Multiplier to convert to EER2	Multiplier to convert to HSPF2
Convenience Store	0.95	0.95	0.85
Ducted	1.00	1.00	0.90
Ductless	0.95	0.95	0.84

Table 10: M to M1 Backward Conversion (Ref. 6)

System Type	Multiplier to convert to SEER	Multiplier to convert to EER	Multiplier to convert to HSPF
Split System Air Conditioner	1.05	1.04	N/A
Split System Heat Pump	1.05	1.04	1.18
Packaged Air Conditioner	1.04	1.04	N/A
Packaged Heat Pump	1.04	1.04	1.18
Ductless Heat Pump	1.00	1.00	1.12
Space Constrained System	1.01	1.00	1.17
Small Duct High Velocity System	1.00	1.00	1.18

References

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2. Measure Life Report, Residential and Commercial/Industrial Lighting, and HVAC Measures, by GDS Associates, Inc. June 2007, pg. 6.

3. Consortium for Energy Efficiency (CEE) Commercial Unitary Air Conditioning and Heat Pump Specification. Effective January 1, 2024. https://cee1.org/images/pdf/CEE_CommACHP_UnitarySpec2024_corrected.pdf
4. ENERGY STAR Program Requirement Product Specification for Light Commercial HVAC, Version 4.0, Rev. January 1st 2023. https://www.energystar.gov/products/heating_cooling/light_commercial_heating_cooling/light_commercial_hvac_key_product_criteria
5. 2024 Minnesota Energy Code with ANSI/ASHRAE/IES Standard 90.1-2019. Section 6.8.1 Minimum Efficiency Requirement Listed Equipment—Standard Rating and Operating Conditions Effective January 5, 2024. https://codes.iccsafe.org/content/MNEC2024P1/6-heating-ventilating-and-air-conditioning#MNEC2024P1_Ch06_Sec6.8
6. Consortium for Energy Efficiency. CEE Residential Electric HVAC Specification. Published October 18, 2023.
7. FES calculated EFLH from energy models based on California DEER study prototypes modified by Illinois field data with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3) 2012.
8. FES scaled EFLH from those provided in the Illinois Technical Reference Manual based on Minnesota weather data. EFLH for the Illinois Technical Reference Manual were based on California DEER study prototypes modified by Illinois field data to closely match EFLH from the modeling to those calculated from field data.
9. Minn. Stat. § 216B.2402, subd. 4(2023). https://www.revisor.mn.gov/statutes/cite/216B.2402
10. Laws of Minn. 2024, art. 6, sec. 14. https://www.revisor.mn.gov/laws/2024/0/Session+Law/Chapter/126/
11. Minn. Stat. § 216H.01 subd. 2 (2016). https://www.revisor.mn.gov/statutes/cite/216H/full#stat.216H.01
12. Minnesota Department of Commerce Division of Energy Resources, Decision In the Matter of Technical Guidance for the Inclusion of Efficient Fuel-Switching, Load Management, and Pre-Weatherization Measures in CIP, (March 15, 2022). Docket No. E,G999/CIP-21-837. (eDocket No. 20223-183807-01). At 13. https://efiling.web.commerce.state.mn.us/edockets/searchDocuments.do?method=showPoup&documentId=%7B90098F7F-0000-C11B-B04F-C063DF81A5F9%7D&documentTitle=20223-183807-01

Revision History

Version	Description	Author	Date
4.2	New Measure	Cadmus	9/1/2024
5.0	Added 'Other / Unknown' category with data from the study team's expanded findings	Cadmus	8/1/2025

C/I HVAC – Mini Split Ductless Systems (A/C or Heat Pump)

Measure Detail	Measure Value
Measure ID	2.02.12
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC
Applicable To	Commercial and industrial customers with < 65,000 Btu/hr cooling systems where mini-split ductless equipment (both cooling-only and heat pump versions) can be installed
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	(1) Existing HVAC system type (air-source heat pump, electric heat with split system, or other thru-the-wall air conditioner), (2) mini-split system size, (3) furnace system size (if applicable), (4) proposed system heating HSPF, (5) proposed system cooling SEER
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	Actual costs should be used. For planning purposes, an averaged full installed cost was determined to be $2,500 per ton (Ref. 2)

Measure Description

This measure includes replacing non-working and working air-source heat pump equipment, electric resistance heating systems with split system air conditioning systems, and electric resistance heating with mini-split ductless air conditioner or heat pump systems. To quality, efficient models must meet current ENERGY STAR performance criteria, but do not need to be qualified through the program.

Systems functioning as the primary heating and cooling systems are applicable for savings and rebates. Backup heating systems are not applicable. In circumstances where the mini-split heating system is installed in conjunction with an existing heating or cooling systems, the existing system must be controlled as the backup heating or cooling.

Algorithms

Air-source heat pump or electric resistance heat with air conditioner baseline

Unit kWh Savings per Year = $Cap_{COOL} \times 12 \times EFLH_{COOL} \times (1 / SEER_{BASE} - 1 / SEER_{EE})$

$+ Cap_{HEAT} \times 12 \times EFLH_{HEAT} \times (1 / HSPF_{BASE} - 1 / HSPF_{EE})$

Unit Peak kW Savings = $Cap_{COOL} \times 12 \times (1 / EER_{BASE} - 1 / EER_{EE}) \times CF$

Electric resistance heat only baseline

Unit kWh Savings per Year = Cap_{HEAT} x 12 x $EFLH_{HEAT}$ x (1 / $HSPF_{BASE}$ – 1 / $HSPF_{EE}$) – Cap_{COOL} x 12 x $EFLH_{COOL}$ / $SEER_{EE}$

Unit Peak kW Savings = -Cap_{COOL} x 12 / EER_{EE} x CF

Where:

Cap_{COOL}	= Mini-split ductless cooling capacity in tons (1 ton = 12,000 Btu/h)
Cap_{HEAT}	= Mini-split ductless heating capacity in tons (1 ton = 12,000 Btu/h)
12	= Unit conversion, EER to kW/ton
$EFLH_{COOL}$	= Equivalent full-load cooling hours, see Table 3 (Ref. 6)
$SEER_{BASE}$	= SEER in cooling mode for the baseline HVAC system, see Table 2
$SEER_{EE}$	= Actual SEER of mini-split ductless system, from AHRI database (Ref. 9)
$EFLH_{HEAT}$	= Equivalent full-load heating hours, see Table 4 (Ref. 7)
$HSPF_{BASE}$	= HSPF in heating mode for the baseline HVAC system, see Table 1
$HSPF_{EE}$	= Actual HSPF in heating mode for proposed heat pump, from AHRI database (Ref. 9)
EER_{BASE}	= EER of baseline system (= 1.12 x SEER – 0.02 x $SEER^2$ if SEER given
EER_{EE}	= EER of proposed system (= actual, or EER = 1.12 x SEER – 0.02 x $SEER^2$ if SEER given)
CF	= 0.90, coincidence factor (Ref. 8)

Example:

Assume a 2.5-ton air-source heat pump being replaced by a mini-split system in a low-rise office building in climate zone 1. Assume that two 1-ton mini-splits and one 1/2-ton mini-split will be installed. All SEER2 of 20, EER2 of 14.4, and HSPF2 of 9.5. Baseline SEER2 of 14.3, EER2 of 11.8, and HSPF2 of 7.5 according to Tables 1 and 2. The selected performance unit(s) exceed the required performance criteria illustrated in Table 5 for a very small split system CUHP.

Unit kWh Savings per Year = 2.5 x 12 x 257 x (1 / 14.3 – 1 / 20) + 1,966 x (1 / 7.5 – 1 / 9.5)] = 1,809 kWh

Unit Peak kW Savings = 2.5 x 12 x (1 / 11.8 – 1 / 14.4) x 0.9 = 0.39 kW

Deemed Input Tables

Table 1. Baseline HSPF (Ref 4, 10)

Baseline Heating System	$HSPF_{BASE}$ (M metric)	$HSPF_{BASE}$ (M1 metric, post 1/1/2023)
Existing Commercial Air-Source Heat Pump	8.5	7.5
Existing Electric Resistance	3.412	3.412
Thru-the-Wall Heat Pump	8.5	7.5

Table 2. Baseline SEER (Ref 4,10)

Baseline Cooling System	$SEER_{BASE}$ (M metric)	$SEER_{BASE}$ (M1 metric, post 1/1/2023)
Existing Commercial Air-Source Heat Pump	15	14.3
Existing Commercial Split System Air Conditioner	15.0	13.4
Thru-the-Wall Air Conditioner	15	13.4

Table 3. Equivalent Full-Load Hours for Cooling

Building Type	Zone 1 (Northern MN)	Zone 2 (Central MN)	Zone 3 (Southern MN)
Convenience Store	647	825	986
Education – Community College/University	682	782	785
Education – Primary	289	338	408
Education – Secondary	484	473	563
Health/Medical – Clinic	558	738	865
Health/Medical – Hospital	663	1,089	1,298
Lodging	401	606	754
Manufacturing	347	472	589
Office – Low Rise	257	359	446
Office – Mid Rise	373	529	651
Office – High Rise	669	1,061	1,263
Restaurant	347	535	652
Retail – Large Department Store	462	588	686
Retail – Strip Mall	307	441	574
Warehouse	164	343	409
Other/Miscellaneous	443	612	729

Table 4. Equivalent Full-Load Hours for Heating

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	1,887	1,699	1,546
Education – Community College/University	1,972	1,776	1,616
Education – Primary	2,394	2,156	1,961
Education – Secondary	2,561	2,306	2,098
Health/Medical – Clinic	2,234	2,012	1,830
Health/Medical – Hospital	2,508	2,258	2,054
Lodging	2,361	2,126	1,934
Manufacturing	1,397	1,258	1,144
Office – Low Rise	1,966	1,770	1,610
Office – Mid Rise	2,189	1,971	1,793
Office – High Rise	2,149	1,935	1,760
Restaurant	1,868	1,681	1,530
Retail – Large Department Store	1,763	1,587	1,444
Retail – Strip Mall	1,701	1,531	1,393
Warehouse	1,872	1,685	1,533

Building Type	Zone 1	Zone 2	Zone 3
Other/Miscellaneous	2,123	1,911	1,739

Table 5. Criteria for ENERGY STAR-Certified Light Commercial Heat Pumps (Ref. 12)

Equipment Type	Cooling Capacity	Heating Section Type	Minimum Energy Efficiency Criteria M1 metrics
Very Small CUHP (Single Package)	< 65,000 Btu/h	All	15.2 SEER2; 10.6 EER2; 7.2 HSPF2
Very Small CUHP (Split System)	< 65,000 Btu/h	All	15.2 SEER2; 11.7 EER2; 7.8 HSPF2
Small Air-Cooled Heat Pump	≥ 65,000 Btu/h – < 135,000 Btu/h	Electric Resistance (or None)	11.8 EER; 15.3 IEER; 3.5 COP at 47°F; 2.4 COP at 17°F
		All other	11.6 EER; 15.1 IEER; 3.5 COP at 47°F; 2.4 COP at 17°F
Large Air-Cooled Heat Pump	≥ 135,000 Btu/h – < 240,000 Btu/h	Electric Resistance (or None)	11.1 EER; 14.5 IEER; 3.4 COP at 47°F; 2.1 COP at 17°F
		All other	10.9 EER; 14.3 IEER; 3.4 COP at 47°F; 2.1 COP at 17°F

Table 6. Criteria for ENERGY STAR-Certified Light Commercial Air Conditioners (Ref. 12)

Equipment Type	Cooling Capacity	Heating Section Type	Minimum Energy Efficiency Criteria M1 metrics
Very Small CUAC (single package)	< 65,000 Btu/	All	15.2 SEER2; 11.5 EER2
Very Small CUAC (split system)	< 65,000 Btu/	All	15.2 SEER2; 12.0 EER2
Small Air-Cooled Central Air Conditioner	≥ 65,000 Btu/h – < 135,000 Btu/h	Electric Resistance (or None)	12.7 EER; 18.0 IEER
		All other	12.5 EER; 17.8 IEER
Large Air-Cooled Central Air Conditioner	≥ 135,000 Btu/h – < 240,000 Btu/h	Electric Resistance (or None)	12.2 EER; 17.0 IEER
		All other	12.0 EER; 16.8 IEER

Notes

For new construction, it is recommended that the air-source heat pump baselines be used. However, if it can be documented that electric resistance heat is common for the region, a hybrid baseline may be used.

$EFLH_{COOL}$ was determined from prototypes building models based on the California DEER study prototypes with modified Illinois field data and scaled with Minnesota weather data for Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis–St. Paul (Zone3).

$EFLH_{HEAT}$ was determined from prototypes building models based on the California DEER study prototypes with modified Illinois field data and scaled with Minnesota weather data Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis–St. Paul (Zone3). Values were scaled as follows: $EFLH_{MN} = EFLH_{IL} \times HDD_{55,MN} / HDD_{55,IL} \times DTD_{IL} / DTD_{MN}$, where DTD is the design temperature difference.

Table 7. Heating Degree Days and Design Temperature Difference

Geography	HDD55	DTD
Chicago, IL	4,029	73.5
MN Zone 1	6,956	92
MN Zone 2	5,888	86.5
MN Zone 3	5,233	84.5

Proposed mini-split ductless should meet ENERGY STAR minimum performance criteria (14.5 SEER, 8.2 HSPF). Multi-head system capacity is the minimum of the total indoor unit capacity and outdoor unit capacity.

Effective January 1, 2023, HVAC products will be subject to regional minimum efficiencies, according to Seasonal Energy Efficiency Ratio 2 (SEER2). The nomenclature of SEER2, EER2 and HSPF2 will be used to denote the new M1 ratings. Conversion between the new M1 ratings and original M ratings should be done using an AHRI approved method, using the multipliers in Table 8 and Table 9 below.

Table 8. M to M1 Forward Conversion (Ref. 11)

System Type	Multiplier to convert to SEER2	Multiplier to convert to EER2	Multiplier to convert to HSPF2
Ducted	0.95	0.95	0.85
Ductless	1.00	1.00	0.90
Packaged	0.95	0.95	0.84

Table 9. M1 to M Backward Conversion (Ref. 11)

System Type	Multiplier to convert to SEER	Multiplier to convert to EER	Multiplier to convert to HSPF2
Split System Air Conditioner	1.05	1.04	N/A
Split System Heat Pump	1.05	1.04	1.18
Packaged Air Conditioner	1.04	1.04	N/A
Packaged Heat Pump	1.04	1.04	1.18
Ductless Heat Pump	1.00	1.00	1.12
Space Constrained System	1.01	1.00	1.17
Small Duct High Velocity System	1.00	1.00	1.18

Through-the-wall units in a commercial scenario are assumed to be packaged terminal units. As packaged terminal air conditioners and packaged terminal heat pumps are rated differently than mini-split heat pumps, conservative assumptions are used, deemed equal to split systems.

References

1. GDS Associates, Inc. *Measure Life Report – Residential and Commercial/Industrial Lighting and HVAC Measures*. June 2007. http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf
2. Swift, Joseph R, and Rebecca A. Meyer, The Connecticut Light and Power Company. *Ductless Heat Pumps for Residential Customers in Connecticut*. 2010 ACEEE Summer Study on Energy Efficiency in Buildings (2-292).
   NEEP. *Northeast/Mid-Atlantic Air-Source Heat Pump Market Strategies Report*. January 2014.
3. Title 10, Code of Federal Regulations, Part 430 – Energy Conservation Program for Consumer Products, Subpart C, Section 430.32. November 2023.
   https://www.federalregister.gov/documents/2016/05/24/2016-12279/energy-conservation-program-for-certain-industrial-equipment-energy-conservation-standards-for-small.
   https://www.energy.gov/femp/incorporate-minimum-efficiency-requirements-heating-and-cooling-products-federal-acquisition
4. Title 10, Code of Federal Regulations, Part 431 – Energy Efficiency Program for Certain Commercial and Industrial Equipment, November 2023.
   https://www.federalregister.gov/documents/2016/05/24/2016-12279/energy-conservation-program-for-certain-industrial-equipment-energy-conservation-standards-for-small.
   https://www.energy.gov/femp/incorporate-minimum-efficiency-requirements-heating-and-cooling-products-federal-acquisition
5. U.S. Department of Energy. http://buildingsdatabook.eere.energy.gov/ChapterIntro7.asp
   Though the federal minimum efficiency is 78%, there are very few models available at this efficiency; a review of AHRI shows that most low-efficiency units are 80%.
6. Franklin Energy Services. 2012.
   Calculated EFLH from energy models based on California DEER study prototypes modified by Illinois field data with Minnesota weather data for Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis–St. Paul (Zone3).
7. Franklin Energy Services scaled EFLH from those provided in the *Illinois Technical Reference Manual* based on Minnesota weather data. EFLH for the *Illinois Technical Reference Manual* were based on California DEER study prototypes modified by Illinois field data to closely match EFLH from the modeling to those calculated from field data.
8. 0.9 is a typical value used for central HVAC equipment in many programs. The range is 0.74 to 1.0, with most being very close to 0.9. Primary data has not been identified.

9. Air-Conditioning, Heating, & Refrigeration Institute. "AHRI Directory of Certified Product Performance." www.ahridirectory.org
10. 2024 Minnesota Energy Code with ANSI/ASHRAE/IES Standard 90.1-2019. Section 6.8.1 Minimum Efficiency Requirement Listed Equipment—Standard Rating and Operating Conditions Effective January 5, 2024. https://codes.iccsafe.org/content/MNEC2024P1/6-heating-ventilating-and-air-conditioning#MNEC2024P1_Ch06_Sec6.8
11. Consortium for Energy Efficiency. CEE Residential Electric HVAC Specification. Published October 18, 2023. https://cee1.my.site.com/s/resources?id=a0V2R00000sUQbyUAG
12. ENERGY STAR Program Requirement Product Specification for Light Commercial HVAC, Version 4.0, Rev. January 1st 2023. https://www.energystar.gov/products/heating_cooling/light_commercial_heating_cooling/light_commercial_hvac_key_product_criteria

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	7/31/2015
3.0	Streamlined equations, removed furnace baseline, clarified requirements for backup systems, updated and clarified baselines	Cadmus	11/1/2018
4.1	Removed Multifamily space type from EFLH Heating table, intended to be removed in 2.0 updates to C/I Heat Pump EFLH updates made. Clarification to SEER2, EER2, and HSPF2 conversions. Updates to federal and ENERGY STAR efficiency criteria standards.	Cadmus	11/1/2023
5.0	Measure title change and minor description updates, updates to example	Cadmus	8/1/2025

C/I HVAC – Cooling Unitary and Split Systems

Measure Detail	Measure Value
Measure ID	2.02.13
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC
Applicable To	Commercial and Industrial customers where DX unitary equipment can be installed
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	New equipment type, new equipment nominal cooling capacity in tons, new equipment EER/SEER, building type (refer to Table 1), project location (county)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	15 years (Ref. 1)
Unit Participant Incremental Cost	See Tables 3 and 9, $150/ton for AC systems

Measure Description

This measure includes installation of electric DX packaged, split, and condensing units, and PTACs in replacement and new construction applications. This measure analyzes the cooling savings potential of the installation of higher efficiency air-conditioning equipment. This measure is applicable to DX cooling only, DX cooling and electric heat, and DX cooling and gas heat units. The incremental cost is associated with base equipment cost and does not include any installation costs. To quality, efficient models must meet current ENERGY STAR performance criteria (v4.0 for Light Commercial HVAC), but do not need to be qualified through the program.

Algorithms

For packaged, split units less than or equal to 5.4 tons, and PTAC units:

Unit kWh Savings per Year = Size x (12/SEER_base – 12/SEER_EE) x EFLH_cool

For packages and split units greater than 5.4 tons:

Unit kWh Savings per Year = Size x (12/IEER_base – 12/IEER_EE) x EFLH_cool

Unit Peak kW Savings = Size x (12/EER_base – 12/EER_EE) x CF

Where:

Size = Nominal cooling capacity in tons of the new equipment (1 ton = 12,000 btu/h)

SEER_base = Seasonal energy efficiency ratio of the baseline equipment, based on federal manufacturing requirements. See Table 3 for DX Packaged, Split and Condensing Units; see Table 2 for PTAC units

SEER_EE	=	Seasonal energy efficiency ratio of the high-efficiency equipment, provided by the customer/contractor (Ref. 2)
IEER_base	=	Integrated energy efficiency ratio of the baseline equipment, based on federal manufacturing requirements. See Table 3 for DX Packaged, Split and Condensing Units
IEER_EE	=	Integrated energy efficiency ratio of the high-efficiency equipment, provided by the customer/contractor. EER = 1.12 x SEER – 0.02 x $SEER^2$ if SEER given.
EFLH_cool	=	Effective full-load cooling hours based on the building type. See Table 1
EER_base	=	Energy efficiency ratio of the baseline equipment, based on federal manufacturing requirements. See Table 3 for DX Packaged, Split, and Condensing Units; see Table 2 for PTAC units
EER_EE	=	Energy efficiency ratio of the high-efficiency equipment, provided by the customer/contractor. If unknown, use EER = 1.12 x SEER – 0.02 x $SEER^2$ (Ref. 2)
CF	=	Deemed coincidence factor, equal to 0.9 (Ref. 3)

Example 1:

Retrofit packaged rooftop installed in Medical Clinic, 7.5-ton cooling capacity, EER 12.0, IEER 13.0, Climate Zone 3.

IEER_base = 12.7

IEER_EE = 13.0

EER_base = 11.0

EER_EE = 12.0

Unit kWh Savings per Year = 7.5 x (12 / 12.7 – 12 /13.0) x 865 = 141 kWh

Unit Peak kW Savings per Year = 7.5 x (12 /11.0 – 12 /12.0) x 0.9 = 0.539 kW

Example 2:

Replacement PTAC unit installed in motel, 9,000 Btu/hr cooling capacity, EER 13.0, SEER 15, Climate Zone 2.

EER_base = 10.9 – (0.213 x 9,000/1,000) = 8.96

EER_EE = 13.0

SEER_base = 10

SEER_EE = 15

Unit kWh Savings per Year = 9,000/12,000 x (12/10.24 – 12/14.86) x 606 = 165.76 kWh

Unit Peak kW Savings per Year = 9,000/12,000 x (12/8.96 – 12/13.0) x 0.9 = 0.28 kW

Deemed Input Tables

Table 1. Equivalent full load hours of cooling, per zone, in Minnesota by building type (Ref. 4)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	647	825	986
Education – Community College/University	682	782	785
Education – Primary	289	338	408
Education – Secondary	484	473	563
Health/Medical – Clinic	558	738	865
Health/Medical – Hospital	663	1,089	1,298
Lodging	401	606	754
Manufacturing	347	472	589
Office – Low Rise	257	359	446
Office – Mid Rise	373	529	651
Office – High Rise	669	1,061	1,263
Restaurant	347	535	652
Retail – Large Department Store	462	588	686
Retail – Strip Mall	307	441	574
Warehouse	164	343	409
Other/Miscellaneous	443	612	729

Table 2. Deemed baseline efficiency and incremental costs for PTAC Units (Ref. 5, 7, 9)

Equipment	Cooling Capacity (Btu/h)	EER_base	Incremental Cost
PTAC, Standard Size (used for New Construction)	< 7,000	11.9	$250/ton
	7,000-15,000	14.0 – (0.300 x Cap/1000)	$250/ton
	> 15,000	9.5	$250/ton
PTAC, Non-Standard Size (used for Replacements* only)	< 7,000	9.4	$250/ton
	7,000-15,000	10.9 – (0.213 x Cap/1000)	$250/ton
	> 15,000	7.7	$250/ton

*Replacement unit shall be factory labeled as follows "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS". Replacement efficiencies apply only to units with existing sleeves less than 16 inches (406mm) in height and less than 42 inches (1067 mm)

Table 3. Deemed baseline efficiency for AC, ASHP (Ref. 5, 6, 7, 9, 10)*

Equipment Type	Size Class	Type	Minimum Efficiency	
			M Metrics	M1 Metrics
Heat Pumps, Air-Cooled (Cooling Mode)	<65,000 Btu/h	Split System, all heating types	15.0 SEER; 12.5 EER; 8.5 HSPF (single phase); 14.0 SEER (3 phased)	14.3 SEER2 7.5 HSPF2
		Single Package system, all heating types	15.0 SEER; 12.0 EER; 8.2 HSPF (single phase); 14.0 SEER (3 phased)	13.4 SEER2 6.7 HSPF2
	≥65,000 Btu/h <135,000 Btu/h	Electric Resistance Heat	11.8 EER; 12.8 IEER; 3.4 COP at 47ºF	14.1 IEER 3.4 COP at 47ºF
		All other heat	11.6 EER; 12.6 IEER; 3.4 COP at 47ºF	13.9 IEER 3.4 COP at 47ºF
	≥135,000 Btu/h <240,000 Btu/h	Electric Resistance Heat	10.9 EER; 12.0 IEER; 3.3 COP at 47ºF	13.5 IEER 3.3 COP at 47ºF
		All other heat	10.7 EER; 11.8 IEER; 3.3 COP at 47ºF	13.3 IEER 3.3 COP at 47ºF
	≥240,000 Btu/h	Electric Resistance Heat	9.5 EER; 10.6 IEER 3.2 COP at 47ºF	12.5 IEER 3.2 COP at 47ºF
		All other heat	9.3 EER; 10.4 IEER 3.2 COP at 47ºF	12.3 IEER 3.2 COP at 47ºF
Air Conditioners, Air-Cooled (Cooling Mode)	<65,000 Btu/h	Split System	15.0 SEER; 12.5 EER (single phase); 13.0 SEER (three phased)	13.4 SEER2
		Single Package System	15.0 SEER; 12.0 EER; (single phase); 14.0 SEER (three phased)	13.4 SEER2
	≥65,000 Btu/h <135,000 Btu/h	Electric Resistance Heat	11.8 EER; 12.8 IEER; 3.4 COP at 47ºF	14.8 IEER
		All other heat	11.6 EER; 12.6 IEER; 3.4 COP at 47ºF	14.6 IEER
	≥135,000 Btu/h <240,000 Btu/h	Electric Resistance Heat	10.9 EER; 12.0 IEER; 3.3 COP at 47ºF	14.2 IEER
		All other heat	10.7 EER; 11.8 IEER; 3.3 COP at 47ºF	14.0 IEER
	≥240,000 Btu/h	Electric Resistance Heat	9.5 EER; 10.6 IEER	13.2 IEER
		All other heat	9.3 EER; 10.4 IEER	13.0 IEER

Methodology and Assumptions

EFLH_Cool data based on DOE2/eQuest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Assumed ventilation rates complied with the requirements of ASHRAE standard 62.1 – 2004.

Effective January 1, 2023, HVAC products will be subject to regional minimum efficiencies, according to Seasonal Energy Efficiency Ratio 2 (SEER2). The nomenclature of SEER2, EER2 and HSPF2 will be used to denote the new M1 ratings. Conversion between the new M1 ratings and original M ratings should be done using an AHRI approved method, using the multipliers in Table 2 and Table 3 below.

Table 4. M to M1 Forward Conversion (Ref. 10)

System Type	Multiplier to convert to SEER2	Multiplier to convert to EER2	Multiplier to convert to HSPF2
Ducted	0.95	0.95	0.85
Ductless	1.00	1.00	0.90
Packaged	0.95	0.95	0.84

Table 5. M1 to M Backward Conversion (Ref. 10)

System Type	Multiplier to convert to SEER	Multiplier to convert to EER	Multiplier to convert to HSPF2
Split System Air Conditioner	1.05	1.04	N/A
Split System Heat Pump	1.05	1.04	1.18
Packaged Air Conditioner	1.04	1.04	N/A
Packaged Heat Pump	1.04	1.04	1.18
Ductless Heat Pump	1.00	1.00	1.12
Space Constrained System	1.01	1.00	1.17
Small Duct High Velocity System	1.00	1.00	1.18

Table 6. Criteria for ENERGY STAR-Certified Light Commercial Air Conditioners (Ref. 8)

Equipment Type	Cooling Capacity	Heating Section Type	Minimum Energy Efficiency Criteria
Very Small CUAC (single package)	< 65,000 Btu/	All	16.0 SEER; 12.0 EER OR 15.2 SEER2; 11.5 EER2
Very Small CUAC (split system)	< 65,000 Btu/	All	16.0 SEER; 12.5 EER OR 15.2 SEER2; 12.0 EER2
Small Air-Cooled Central Air Conditioner	≥ 65,000 Btu/h – < 135,000 Btu/h	Electric Resistance (or None)	12.7 EER; 18.0 IEER
		All other	12.5 EER; 17.8 IEER
Large Air-Cooled Central Air Conditioner	≥ 135,000 Btu/h – < 240,000 Btu/h	Electric Resistance (or None)	12.2 EER; 17.0 IEER
		All other	12.0 EER; 16.8 IEER

Table 7. Criteria for ENERGY STAR-Certified Light Commercial Heat Pumps (Ref. 8)

Equipment Type	Cooling Capacity	Heating Section Type	Minimum Energy Efficiency Criteria
Very Small CUHP (Single Package)	< 65,000 Btu/h	All	15.2 SEER2; 10.6 EER2*; 7.2 HSPF2
Very Small CUHP (Split System)	< 65,000 Btu/h	All	16.0 SEER; 12.1 EER; 9.2 HSPF OR 15.2 SEER2; 11.7 EER2; 7.8 HSPF2
Small Air-Cooled Heat Pump	≥ 65,000 Btu/h – < 135,000 Btu/h	Electric Resistance (or None)	11.8 EER; 15.3 IEER; 3.5 COP at 47°F; 2.4 COP at 17°F
		All other	11.6 EER; 15.1 IEER; 3.5 COP at 47°F; 2.4 COP at 17°F
Large Air-Cooled Heat Pump	≥ 135,000 Btu/h – < 240,000 Btu/h	Electric Resistance (or None)	11.1 EER; 14.5 IEER; 3.4 COP at 47°F; 2.1 COP at 17°F
		All other	10.9 EER; 14.3 IEER; 3.4 COP at 47°F; 2.1 COP at 17°F

*Where ENERGY STAR efficiency criteria are lower than the current Federal minimum efficiency standard, eligible equipment must meet or exceed the Federal minimum efficiency indicated in Table 2.

Table 8. Criteria for ENERGY STAR-Certified VRF Multi-Split Systems (Ref. 8)

Equipment Type	Cooling Capacity	Heating Section	Minimum Energy Efficiency Criteria
Very Small VRF Air-Cooled Air Conditioner	< 65,000 Btu/h	All	15.2 SEER2; 12.0 EER2
Small VRF Air-Cooled Air Conditioner	≥ 65,000 Btu/h - < 135,000 Btu/h	All	12.0 EER; 17.4 IEER
Large VRF Air-Cooled Air Conditioner	≥ 135,000 Btu/h - < 240,000 Btu/h	All	11.3 EER; 16.4 IEER
Very small VRF Air-Cooled Heat Pump	< 65,000 Btu/h	All	16.0 SEER; 12.0 EER OR 15.2 SEER2; 11.7 EER2; 7.8 HSPF2
Small VRF Air-Cooled Heat Pump	≥ 65,000 Btu/h – < 135,000 Btu/h	Without Heat Recovery	11.8 EER; 17.4 IEER; 3.4 COP at 47°F
		With Heat Recovery	11.6 EER; 17.2 IEER; 3.4 COP at 47°F
Large VRF Air-Cooled Heat Pump	≥ 135,000 Btu/h – < 240,000 Btu/h	Without Heat Recovery	10.9 EER; 16.4 IEER; 3.25 COP at 47°F
		With Heat Recovery	10.7 EER; 16.2 IEER; 3.25 COP at 47°F

Table 9. ASHP units 5.4 tons or less incremental cost (Ref. 11)

Efficiency Level	Incremental Cost
SEER 15	$274/ton
SEER 16	$411/ton
SEER 17	$548/ton
SEER 18	$685/ton

References

1. GDS Associates, Inc. Measure Life Report – Residential and Commercial/Industrial Lighting and HVAC Measures. June 2007. Page 6. http://library.cee1.org/sites/default/files/library/8842/
2. CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment
3. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified
4. Calculated through energy modeling of California DEER study prototypes modified by Illinois field data with TMY3 Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3) by FES 2012
5. Title 10, Code of Federal Regulations, Part 431 – Energy Efficiency Program for Certain Industrial Equipment, Energy Conservation Standards for Small, Large, and Very Large Air-Cooled

Commercial Package Air Conditioning and Heating Equipment and Commercial Warm Air Furnaces. November 2023. https://www.federalregister.gov/documents/2016/05/24/2016-12279/energy-conservation-program-for-certain-industrial-equipment-energy-conservation-standards-for-small. https://www.energy.gov/femp/incorporate-minimum-efficiency-requirements-heating-and-cooling-products-federal-acquisition

6. Xcel MN Workpapers 2010
7. Based on a review of TRM incremental cost assumptions from Vermont, Wisconsin, and California. This assumes that baseline shift from IECC 2006 to IECC 2009 carries the same incremental costs
8. ENERGY STAR Program Requirement Product Specification for Light Commercial HVAC, Version 4.0, Rev. January 1st 2023. https://www.energystar.gov/products/heating_cooling/light_commercial_heating_cooling/light_commercial_hvac_key_product_criteria
9. 2024 Minnesota Energy Code with ANSI/ASHRAE/IES Standard 90.1-2019. Section 6.8.1 Minimum Efficiency Requirement Listed Equipment—Standard Rating and Operating Conditions Effective January 5, 2024. https://codes.iccsafe.org/content/MNEC2024P1/6-heating-ventilating-and-air-conditioning#MNEC2024P1_Ch06_Sec6.8
10. Consortium for Energy Efficiency. CEE Residential Electric HVAC Specification. Published October 18, 2023. https://cee1.my.site.com/s/resources?id=a0V2R00000sUQbyUAG
11. DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).

Revision History

Version	Description	Author	Date
2.0	Updated to energy code, including IEER efficiencies, included Other/Miscellaneous building type	Franklin Energy Services	11/12/15
2.1	Updated minimum equipment efficiencies. Added ENERGY STAR Program Requirements Version 3.1 equipment efficiencies	Franklin Energy Services	7/31/17
4.0	Modification to EUL to align with WI TRM and more recent reference source	Cadmus	11/1/2022
4.1	Clarification to SEER2, EER2 and HSPF2 conversions. Update to Federal and ENERGY STAR performance criteria	Cadmus	11/1/2023

C/I HVAC – Air Conditioner Tune-ups

Measure Detail	Measure Value
Measure ID	2.02.14
Target Market Segments	Commercial and Industrial
Target End Uses	HVAC
Applicable To	Commercial and industrial customers
Actions	O&M
Required from Customer/Contractor	Nameplate SEER or IEER, Nameplate Capacity, Tune-up Component, Location, (if refrigerant charge correction is conducted) what fraction low or high the original refrigerant charge was
Measure Energy Type	Electric
Unit kWh Savings per Year	Varies
Unit Peak kW Savings	Varies
Unit Dth Savings per Year	0
Measure Lifetime (years)	3 (Ref. 1)
Unit Participant Incremental Cost	$35/ton (Ref. 2)

Measure Description

Tune up non-residential unitary or split air conditioners using any or all of procedures outlined, including a condenser coil cleaning, evaporator cleaning, and refrigerant charge correction.

Algorithms

Unit kWh Savings per Year = CAP x $EFLH_{COOL}$ / (SEER x (1 – SF)) x SF

Unit kW Savings per Year = CAP x CF / (EER x (1 – SF)) x SF

Where:

CAP	= Actual capacity of unit in kBtu/h
$EFLH_{COOL}$	= Full load cooling hours, varies by building type and zone, see Table 2
SEER	= Actual nameplate SEER (or IEER) of equipment. Can substitute SEER2, IEER2.
SF	= Savings factor for different tune-up actions, see Table 3
EER	= Actual nameplate EER of equipment, or EER = 1.12x SEER – 0.02 x $SEER^2$ if SEER given. Can substitute EER2.
CF	= Coincidence factor = 0.9

Example:

A customer with a 13 SEER (11.2 EER), 60 kBtu/h rooftop air conditioner in a low-rise office located in zone 1 receives a tune-up that includes both condenser cleaning and evaporator cleaning.

kWh_{SAVED} = 60 x 257 / (13 x (1 – 6.32%)) x 6.32% = 80.02 kWh

kW_{SAVED} = 60 x 0.9 / (11.2) x (1 – 6.32%)) x 6.32% = 0.28 kW

Deemed Input Tables

Table 1. $EFLH_{COOL}$ per Zone in Minnesota by Building Type (Ref. 3)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	647	825	986
Education – Community College/University	682	782	785
Education – Primary	289	338	408
Education – Secondary	484	473	563
Health/Medical – Clinic	558	738	865
Health/Medical – Hospital	663	1089	1298
Lodging	401	606	754
Manufacturing	347	472	589
Office-Low Rise	257	359	446
Office-Mid Rise	373	529	651
Office-High Rise	669	1061	1263
Restaurant	347	535	652
Retail – Large Department Store	462	588	686
Retail – Strip Mall	307	441	574
Warehouse	164	343	409
Other/Miscellaneous	443	612	729

Table 2. Savings Factor (SF) per Tune-Up Component (Ref. 3)

Tune-Up Component	SF
Condenser Cleaning	6.10%
Evaporator Cleaning	0.22%
Refrigeration Charge Off. ≤20%	0.68%
Refrigeration Charge Off. >20%	8.44%

Methodology and Assumptions

Effective January 1, 2023, HVAC products will be subject to regional minimum efficiencies, according to Seasonal Energy Efficiency Ratio 2 (SEER2). The nomenclature of SEER2, EER2 and HSPF2 will be used to denote the new M1 ratings. Conversion between the new M1 ratings and original M ratings should be done using an AHRI approved method, using the multipliers in Table 2 and Table 3 below.

Table 3. M to M1 Forward Conversion (Ref. 4)

System Type	Multiplier to convert to SEER2*	Multiplier to convert to EER2	Multiplier to convert toHSPF2
Ducted	0.95	0.95	0.85
Ductless	1.00	1.00	0.90
Packaged	0.95	0.95	0.84

Table 4. M1 to M Backward Conversion (Ref. 4)

System Type	Multiplier to convert to SEER	Multiplier to convert to EER	Multiplier to convert to HSPF2
Split System Air Conditioner	1.05	1.04	N/A
Split System Heat Pump	1.05	1.04	1.18
Packaged Air Conditioner	1.04	1.04	N/A
Packaged Heat Pump	1.04	1.04	1.18
Ductless Heat Pump	1.00	1.00	1.12
Space Constrained System	1.01	1.00	1.17
Small Duct High Velocity System	1.00	1.00	1.18

References

1. DEER2014 EUL Table. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx
2. Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual, Version 6.0, Volume 2: Commercial and Industrial Measures.* Accessed 10/31/2018: http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_2_C_and_I_020817_Final.pdf.
3. Calculated through energy modeling of California DEER study prototypes modified by Illinois field data with TMY3 Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3) by FES 2012.
4. Consortium for Energy Efficiency. CEE Residential Electric HVAC Specification. Published October 18, 2023. https://cee1.my.site.com/s/resources?id=a0V2R00000sUQbyUAG

Revision History

Version	Description	Author	Date
3.0	Created new workpaper	Cadmus	10/31/2018
4.1	Clarification to SEER2, EER2 and HSPF2 conversions	Cadmus	11/1/2023

C/I HVAC – Unitary Equipment Economizer Addition or Repair

Measure Detail	Measure Value
Measure ID	2.02.15
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC
Applicable To	Commercial and industrial customers where air unitary equipment has been installed, or has failed closed
Actions	Modify
Required from Customer/Contractor	Existing equipment type, existing equipment nominal cooling capacity in tons, existing equipment EER/SEER, building type (refer to Table 1), project location (county)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	0
Measure Lifetime (years)	10 years (Ref. 1)
Unit Participant Incremental Cost	For economizer addition, see Table 2 (Ref. 2) For economizer repair, use actual cost

Measure Description

This measure includes the retrofit of existing equipment or the optional addition of an air side economizer on new equipment where not required by code. This measure analyzes the cooling savings potential of the installation of an air side economizer on unitary equipment. This measure is applicable to dx and water cooled air systems.

This measure also includes the repair of economizers that have failed closed, or been manually disabled in a closed position. This is a common occurrence that often costs less to rectify than installing a new economizer, while providing the same savings as that action. This measure does not apply to economizers that have failed open, cases of which are generally noticed and rectified soon after onset.

Algorithms

Unit kWh Savings per Year = Size x (12/SEER_EE) x $EFLH_{COOL}$ x SF x SM Unit

Where:

Size	= Nominal Cooling capacity in tons of the new equipment (1 ton = 12,000 btu/h)
$EFLH_{COOL}$	= Equivalent full load cooling hours based on the building type. See Table 1. (Ref. 3)
SEER_EE	= Energy efficiency ratio of the existing equipment, provided by the customer. (Ref. 4) Assume SEER = 10.9 if unavailable. (Ref. 5). Can substitute SEER2.

SF = Deemed savings factor based upon zone. See Table 2. (Ref. 6)

SM = Deemed System Multiplier. SM = 1 for Constant Air Volume (CAV) Systems and SM = 1.4 for Variable Air Volume (VAV) systems. (Ref. 7)

Example:

Install an economizer by retrofitting a packaged rooftop installed in a Health Care Clinic, 20 ton cooling capacity, SEER 14.4, VAV system, Climate Zone 1.

Unit kWh Savings per Year = 20 x (12 / 14.4) x 558 x 0.24 x 1.4 = 3,125 kWh

Deemed Input Tables

Table 1. Equivalent Full Load Hours of cooling ($EFLH_{COOL}$) per Zone in Minnesota by Building Type (Ref. 3)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	647	825	986
Education – Community College/University	682	782	785
Education – Primary	289	338	408
Education – Secondary	484	473	563
Health/Medical – Clinic	558	738	865
Health/Medical – Hospital	663	1089	1298
Lodging	401	606	754
Manufacturing	347	472	589
Office-Low Rise	257	359	446
Office-Mid Rise	373	529	651
Office-High Rise	669	1061	1263
Restaurant	347	535	652
Retail – Large Department Store	462	588	686
Retail – Strip Mall	307	441	574
Warehouse	164	343	409
Other/Miscellaneous	443	612	729

Table 2. Deemed Savings Factor for Zone and Incremental Costs

Equipment	Savings Factor (Ref. 6)			Incremental
	Zone 1	Zone 2	Zone 3	Cost** (Ref. 2)
Units* less than or equal to 10 tons	0.240	0.130	0.100	$1,500
Units* 11-20 tons	0.240	0.130	0.100	$1,900
Units* 21-30 tons	0.240	0.130	0.100	$2,100
Units* 31-60 tons	0.240	0.130	0.100	$2,500
Units* 61-100 tons	0.240	0.130	0.100	$4,000

* Units include packaged and built up air-handler units.

** An additional $1,000 should be included when retrofitting existing units.

Methodology and Assumptions

$EFLH_{COOL}$ were determined from based prototypes building models on the California DEER study prototypes modified Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Assumed ventilation rates complied with the requirements of ASHRAE standard 62.1 – 2004.

Methodology assumes 30% savings for VAV over CV systems. Savings were derived through energy modeling using fixed dry bulb control with a high temperature limit of 65˚F.

Incremental costs include controls and programming and assume similar cost between dx and water cooled equipment.

Savings assume economizer is given preference over demand control ventilation strategy.

Effective January 1, 2023, HVAC products will be subject to regional minimum efficiencies, according to Seasonal Energy Efficiency Ratio 2 (SEER2). The nomenclature of SEER2, EER2, and HSPF2 will be used to denote the new M1 ratings. Conversion between the new M1 ratings and original M ratings should be done using an AHRI approved method, using the multipliers in Table 2 and Table 3 below.

Table 3. M to M1 Forward Conversion (Ref. 9)

System Type	Multiplier to convert to SEER2	Multiplier to convert to EER2	Multiplier to convert to HSPF2
Ducted	0.95	0.95	0.85
Ductless	1.00	1.00	0.90
Packaged	0.95	0.95	0.84

Table 4. M1 to M Backward Conversion (Ref. 9)

System Type	Multiplier to convert to SEER	Multiplier to convert to EER	Multiplier to convert to HSPF2
Split System Air Conditioner	1.05	1.04	N/A
Split System Heat Pump	1.05	1.04	1.18
Packaged Air Conditioner	1.04	1.04	N/A
Packaged Heat Pump	1.04	1.04	1.18
Ductless Heat Pump	1.00	1.00	1.12
Space Constrained System	1.01	1.00	1.17
Small Duct High Velocity System	1.00	1.00	1.18

Notes

Current code requires incorporation of economizer on all cooling systems 2.75 tons and greater for all three Minnesota weather zones with exceptions (Ref 8):

1. Where more than 25% of the air designed to be supplied by the system is to spaces that are designed to be humidified above 35°F (1.7 °C) dew-point temperature to satisfy process needs.
2. Systems expected to operate less than 20 hours per week.
3. Where the use of *outdoor air* for cooling will affect supermarket open refrigerated casework.

References

1. "Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures", by GDS Associates, Inc. June 2007, pg. 6
2. "Economizers for Packaged Air Systems", Energy Efficiency Office, Department of Natural Resources, Canada
3. Calculated through energy modeling by FES 2012
4. "ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment"
5. "Small Commercial HVAC, Surveying the Frontier of Energy Efficiency", by Lee DeBallie, PE – Energy Center of Wisconsin
6. Calculated through energy modeling of California DEER study prototypes modified by Illinois field data with TMY3 Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3) by FES 2012
7. Calculated from the inverse of 0.7. Typical energy consumption of VAV systems are 70% of CV systems. Multiplier verified through energy modeling by FES 2012 and modeling results verified by "Energy Cost and IAQ Performance of Ventilation Systems and Controls – Project Report#2: Assessment of CV and VAV Ventilation Systems and Outdoor Air Control Strategies", pg. 7, by Indoor Environmental Division, EPA, January 2000
8. 2015 Minnesota Energy Code, Section C403.3.1 Economizers.
9. Consortium for Energy Efficiency. CEE Residential Electric HVAC Specification. Published October 18, 2023. https://cee1.my.site.com/s/resources?id=a0V2R00000sUQbyUAG

Revision History

Version	Description	Author	Date
1.0	New savings specification for retrofit/incorporation of air economizer on air systems.	Franklin Energy Services	
1.1	Minor Edits	Joe Plummer	
1.2	Changed Action Type from Replace Working to Modify	Joe Plummer	6/6/2014
2.0	Added/Updated economizer code requirements	Franklin Energy Services	11/12/2015
3.0	Added option for economizer repair	Cadmus	10/2018
4.1	Clarification to SEER2, EER2 and HSPF2 conversions	Cadmus	11/1/2023

C/I HVAC – Parking Garage Exhaust Fan CO Control and Heating

Measure Detail	Measure Value
Measure ID	2.02.16
Target Market Segments	Commercial: Assembly, Big Box Retail, Grocery, Large Office, and Industrial customers.
Target End Uses	HVAC
Applicable To	Commercial and industrial customers
Actions	Modify, New Construction
Required from Customer/Contractor	Motor size, efficiency, heating type
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	$800/HP (Ref. 2)

Measure Description

The proposed measure would allow for demand-controlled ventilation in enclosed parking garages by monitoring CO levels. By modulating airflow based on need rather than running at constant volume, the system will save energy, increase fan belt life, and increase motor life. If the parking garage is also heated, this reduction in airflow will lead to energy savings from a lower heating load.

ASHRAE 90.1-2010 requires that enclosed garages have systems that automatically detect contaminant levels and stage fans or modulate fan airflow rates to 50% or less of design capacity, with exceptions (see Methodology and Assumptions).

Algorithms

Unit kWh Savings per Year = $(HP \times LF \times UF \times C_1 \times t \times SF) / \eta_{motor}$

Unit Peak kW Savings = $(HP \times LF \times UF \times C_1 \times CF) / \eta_{motor}$

Heating kWh Savings per Year (if Electric) = $(HP \times C_2 \times t_{heating} \times (T_{set} - T_{cold}) \times C_3 \times SF) / (C_4 \times \eta_{heating})$

Unit Dth Savings per Year = $(HP \times C2 \times t_{heating} \times (T_{set} - T_{cold}) \times C_3 \times SF) / (C_4 \times \eta_{heating})$

Where:

HP	= Unit motor horsepower of a typical ventilation fan, 1.0 HP
LF	= Motor load factor, 0.70 (Ref. 3)
UF	= Motor usage factor, 1.00 (Ref. 3)
t	= Annual operating hours, typically 8,760
SF	= Annual reduction in operating hours, 33% (Ref. 3)

CF	= Coincidence Factor of 0.88[4] (Ref. 3)
$t_{heating}$	= Annual hours of heating, 4043 (Ref. 4)
T_{cold}	= Average outdoor temperature when the temperature is below Tset, 20.1°F (Ref. 5)
T_{set}	= Temperature below which the parking garage is heated, 40°F (Ref. 6)
C_1	= 0.746 kW/HP
C_2	= 1,000 CFM/HP
C_3	= 1.08 Btu / (hr·CFM·°F)
C_4	= Electric: 3,412 Btu / kWh, Gas: 1.0 x10^6 Btu / Dth
η_{motor}	= Motor efficiency for typical motor, 91.0% (Ref. 7)
$\eta_{heating}$	= Electric: 100%, Gas: 80% (Ref. 8)

Example:

A customer installed a new demand-controlled parking garage ventilation system. The size of the motor is 1 HP and its nominal efficiency is 91.0%. The parking garage is heated by natural gas.

Unit kWh Savings per Year = [1 HP x 0.70 x 1.00 x 0.746 kW/HP x 8,760 x (33%)] / 0.91 = 1,660 kWh

Unit Peak kW Savings = 1 HP x 0.7 LF x 0.746 kW/HP x 0.88 CF / 91.0% Eff = 0.505 kW

Heating Dth Savings per Year = [1 HP x 1,000 CFM/HP x 4043 hrs x (33%) x (40 – 20.1) °F x 1.08 Btu/(hr·CFM·°F)] / (1.0x 10^6 Btu/Dth x 80%) = 35.8 Dth

Methodology and Assumptions

Enclosed parking garage ventilation systems shall automatically detect contaminant levels and stage fans or modulate fan airflow rates to 50% or less of design capacity provided acceptable contaminant levels are maintained. Exceptions:

- Garages less than 30,000 ft2 with ventilation systems that do not utilize mechanical cooling or mechanical heating.
- Garages that have a garage area to ventilation system motor nameplate hp ratio that exceeds 1500 ft2/hp and do not utilize mechanical cooling or mechanical heating.
- Where not permitted by the authority have jurisdiction. (Ref. 9)

[4] Comparing Ref. 3 with the 2015 ASHRAE Handbook, the coincidence factor matches up with what was shown in the Enclosed Vehicular Facilities section for the Profile 3 scenario of an on/off system during peak hours.

References

1. Michigan Energy Measures Database, Demand Control Ventilation (DCV) 2015 MEMD Master with Weather-Sensitive Weighting Tool (Zipped File), Measure: W-CO-HV-100036-C-WR-WR-WR-WR-01. Accessed 07/24/15. http://www.michigan.gov/mpsc/0,4639,7-159-52495_55129---,00.html
2. Based on a survey of DCV case studies provided by Nagle Energy and AirTest, project cost averaged out to approximately $1,000 per controlled horsepower. These projects all included the installation of VSDs, so the presumed cost of the VSD ($200/hp) was removed from the estimate. See accompanying calculation file for more details.
3. KEMA workpaper for 'Demand Control Ventilation – Parking Garage', Source: Manufacturer Data.
4. 4,043 hours is the average total number of hours that the temperature is below 40°F. National Solar Radiation Data Base. Cities used: Duluth, International Falls, Minneapolis / St. Paul, Rochester. Accessed 07/28/15. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/
5. 20.1°F is the average annual temperature below 40°F. National Solar Radiation Data Base. Cities used: Duluth, International Falls, Minneapolis / St. Paul, Rochester. Accessed 07/28/15. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/
6. ENERGY STAR Technical Reference – Parking and the ENERGY STAR Score. Page 3. Accessed 07/28/15. http://www.energystar.gov/sites/default/files/buildings/tools/ENERGY%20STAR%20Score%20for%20Parking.pdf
7. Consortium for Energy Efficiency Premium-Efficiency Motors Initiative, 2007. 7.5 HP, Open Drip-Proof, 1800 RPMs (Page 16 of 18). Accessed 07/24/15. http://library.cee1.org/sites/default/files/library/4928/CEE_IndMMS_guidancespec_Jun2007.pdf
8. Franklin Energy Services (FES) Estimate
9. ASHRAE 90.1-2010 6.4.3.4.5

Revision History

Version	Description	Author	Date
1.0	Created standalone specifications for parking garage exhaust fan CO controls and heating	Franklin Energy Services	11/12/15
1.1	Corrected constant in Dth Savings algorithm	Franklin Energy Services	11/30/15

C/I HVAC – Steam Trap

Measure Detail	Measure Value
Measure ID	2.02.17
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC, Industrial Process
Applicable To	Commercial customers with natural gas fired low-pressure (≤ 15 psig) steam boilers used for space heating, industrial customers with process steam systems
Actions	Replace on Fail
Required from Customer/Contractor	Orifice diameter in inches, steam system pressure in psig, project location (county), trap installed cost OR steam system type, steam pressure control (see Table 4) Optional inputs from customer/contractor: Efficiency of steam boiler
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	6 (Ref. 1)
Unit Participant Incremental Cost	Use actual or refer to Table 4 if unavailable

Measure Description

This measure includes the replacement of leaking steam traps that are part of a HVAC steam distribution system, or an industrial process steam system.

Algorithms

Unit Dth Savings per Year = Rate_Loss x h_fg x Loss_Factor x $EFLH_{HEAT}$ x CCF_Space Heating / (Heat_Eff x 1,000,000)

Where:

Rate_Loss = rate of steam loss, determined by steam gage pressure and steam trap orifice diameter, determined using Grashof's Equation: lb/hr = 0.70 x 0.0165 x 3600 x A x $p^{0.97}$ (Ref. 2).

A = the area of the steam trap orifice in square inches = $\pi d^2/4$, d = diameter of steam trap orifice in inches

P = system pressure in pounds per square inch absolute (psia), psia = psig (gauge pressure) + 14.7 psi at sea level

h_fg = latent enthalpy of vaporization at specified conditions, from Table 3

Loss_Factor = A factor to account for the percentage of the orifice that is open. Assumed to be 50%

$EFLH_{HEAT}$ = equivalent full load hours of heating, from Table 2. For process traps use hours provided by customer. If unknown use 8,760.

CCF_Space_Heating = valve control correction factor determined by type of piping leg equipment control serving steam supplied to trap, see Table 1 (Ref. 3) Applicable to space heating traps only.

Heat_Eff = efficiency of the steam boiler. If unknown, use typical value of 80%

1,000,000 = Conversion from Btu to Dth

Example:

Replace a leaking 1/8" HVAC steam trap that is part of a 5 psig heating system in a High Rise Office in Climate Zone 1. The heating system incorporates a heat timer.

Rate_Loss = 0.70 x 0.0165 x 3600 x (π x (1/8)^2/4) x $(14.7 + 5)^{0.97}$ = 9.2 lb/hr

Dth Savings per Year = 9.2 lb/hr x 960 x 50% x 2149 x 1.0 / 80% / 1,000,000 = 11.9 Dth

Deemed Input Tables

Table 1. Control Correction Factor

Space Heating Control Type – Examples	CCF (Ref. 3)
Uncontrolled, By-Pass Damper on Air Handler Heating Coil	3.5
TRV, Modulating, Heat Timer	1.0
Manual Control Valves, Unknown Control Type	2.25

Table 2. Equivalent Full Load Hours of heating per zone in Minnesota by building type (Ref. 4)

Building Type – Application	Zone 1	Zone 2	Zone 3
Production End use (Ref. 7)	4567	4567	4567
Convenience Store	1887	1699	1546
Education – Community College/University	1972	1776	1616
Education – Primary	2394	2156	1961
Education – Secondary	2561	2306	2098
Health/Medical – Clinic	2234	2012	1830
Health/Medical – Hospital	2508	2258	2054
Lodging	2361	2126	1934
Manufacturing	1397	1258	1144
Multifamily	2324	2092	1904
Office-Low Rise	1966	1770	1610
Office-Mid Rise	2189	1971	1793
Office-High Rise	2149	1935	1760
Restaurant	1868	1681	1530
Retail – Large Department Store	1763	1587	1444
Retail – Strip Mall	1701	1531	1393
Warehouse	1872	1685	1533
Other/Miscellaneous	2123	1911	1739

Table 3. Latent Heat of Vaporization for Various Pressures (Ref. 5)

PSIG	Latent Enthalpy of Vaporization (h_fg) (BTU/lb)
2	966
5	960
10	953
15	946
25	934
50	912
75	895
100	880
125	868
150	857
200	837
250	820
300	805

Table 4. Cost Per Steam Trap for Various System Types (Ref. 6)

Steam System Type	Cost per Trap
Commercial Dry Cleaners	$77.00
Commercial Heating , low pressure steam	$77.00
Industrial Medium Pressure >15 psig < 30 psig	$180.00
Steam Trap, Industrial Medium Pressure ≥30 <75 psig	$223.00
Steam Trap, Industrial High Pressure ≥75 <125 psig	$276.00
Steam Trap, Industrial High Pressure ≥125 <175 psig	$322.00
Steam Trap, Industrial High Pressure ≥175 <250 psig	$370.00
Steam Trap, Industrial High Pressure ≥250 psig	$418.00
Steam Trap, Industrial Medium Pressure ≥30 <75 psig	$223.00
Steam Trap, Industrial High Pressure ≥75 <125 psig	$276.00
Steam Trap, Industrial High Pressure ≥125 <175 psig	$322.00
Steam Trap, Industrial High Pressure ≥175 <250 psig	$370.00
Steam Trap, Industrial High Pressure ≥250 psig	$418.00

$EFLH_{HEAT}$ were determined from based prototypes building models on the California DEER study prototypes modified Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3). Values were scaled as follows: $EFLH_{MN} = EFLH_{IL} \times HDD_{55,MN} / HDD_{55,IL} \times DTD_{IL} / DTD_{MN}$, where DTD is the design temp difference.

Table 5. Heating Degree Days and Design Temperature Difference

Geography	HDD55	DTD
Chicago, IL	4,029	73.5
MN Zone 1	6,956	92
MN Zone 2	5,888	86.5
MN Zone 3	5,233	84.5

References

1. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values, October 10, 2008
2. Barney L. Capehart, Wayne C. Turner, William J. Kennedy, "Guide To Energy Management, 6 Ed," The Fairmont Press, Inc., 2008
3. FES determined. The correction factor corrects heating usage as a function of sequence of operation of controls maintaining steam supply in piping system serviced by the steam trap as determined by FES. When the CCF = 1, this is equivalent to utilization comparable to the EFLH. When the CCF = 3.5, this is approximately equal to utilization for all hours below 55°F or balance point of the building. When the CCF = 2.25, this is an average utilization for other two utilization rates.
4. FES scaled EFLH from those provided in the Illinois Technical Reference Manual based on Minnesota weather data. EFLH for the Illinois Technical Reference Manual were based on California DEER study prototypes modified by Illinois field data to closely match EFLH from the modeling to those calculated from field data.
5. Keenan, J.H., Keyes, F. G., Hill, P. G., and Moore, J. G. "Steam Tables." John Wiley & Sons, 1969
6. Illinois Statewide Technical Reference Manual-6.4.15 Steam Trap Replacement or Repair, July 18, 2012

Revision History

Version	Description	Author	Date
1.0	Original from Nexant with extraneous tabs hidden	Nexant	
1.1	Changed measure life and measure life source. Changed incremental cost and cost source. Updated HDD65 and design temperatures based on new 30-year averages. The references for HDD65, design temperatures, and tune-up savings were changed. Changed EFLH assumptions and sources. Changed algorithm: Added the variables Oversize_Factor, Conversion_Factor, and Loss_Factor	Franklin Energy Services	7/31/2012
2.0	Specified that low pressure is ≤ 15 psig in Applicable To, changed incremental cost to specify that actual may be used, entered required and optional inputs, minor revisions	Franklin Energy Services	3/4/2013
3.0	Changed to $EFLH_{HEAT}$ algorithm. Added Table 1	Franklin Energy Services	11/12/2015

C/I HVAC – Pipe Insulation

Measure Detail	Measure Value
Measure ID	2.02.18
Target Market Segments	Commercial
Target End Uses	HVAC, DHW
Applicable To	Commercial, Industrial, and Public Buildings
Actions	Modify
Required from Customer/Contractor	Length of pipe insulation, number of joining components insulated, piping system type, pipe location (indoors or outdoors), project location (county), facility type
Measure Energy Type	Gas
Unit Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See Algorithm
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	See Table 8 (Ref. 2)

Measure Description

This measure includes installation of ≥ 1" or ≥ 2" fiberglass, foam, calcium silicate or other types of insulation with similar insulating properties to existing bare pipe on straight piping as well as other pipe components such as elbows, tees, valves, and flanges for commercial applications. Default per linear foot savings estimates are provided for exposed indoor and above ground outdoor piping distributing hot water or steam, heated from natural gas fired systems. System types include:

- Hydronic heating systems. These may or may not have outdoor reset controls. These may have no recirculation (do not circulate water around a central loop and operate upon demand from a thermostat), or they may have recirculation only during the heating season, or they may have year-round recirculation.
- Domestic hot water
- Low- and high-pressure steam systems. These also may have no recirculation, heating season recirculation, or year-round recirculation.

The minimum pipe diameter is 1". Indoor piping must have at least 1" of insulation. Outdoor piping must have 2" of insulation and an all-weather protective jacket. Savings are derived from the measure in the Illinois TRM (Ref. 2), with modification for the Minnesota climate.

Algorithms

Unit Dth Savings per Year = $(L_{PIPE} + L_{COMP}) \times (Q_{BASE} - Q_{INSUL}) \times EFLH \times TRF / (Eff \times 1{,}000{,}000)$

Where:

Q_{BARE} = Heat loss from bare piping, Btu/h per foot. See Table 1.

Q_{INS} = Heat loss from insulated pipe, Btu/h per foot. See Table 1.

L_{PIPE}	= Length of straight pipe to be insulated, feet. User input.
L_{COMP}	= Equivalent length of joining components, i.e., elbows, joints, valves, tees, etc., in feet. See Table 2, Table 3, and Table 4.
Eff	= Efficiency of the boiler being used to generate the hot water or steam. User input or assume 80%.
HOU	= Hours of use. For heating, use EFLH values in Table 5. For year round recirculation use 8,760. For heating season recirculation, use hours with outside air temperature below 55°F in Table 6.
1,000,000	= Conversion from Btu to Dth
TRF	= Thermal regain factor, varies by space type (Table 7)

Example:

A customer in Zone 3 installed an aluminum insulation jacket on two feet of outdoor uninsulated hot water pipe with no outdoor temperature reset.

Unit Dth Savings per Year = 2 x (464 – 15) x 8,760 x 1 / (0.80 x 1,000,000) = 9.8 Dth

Deemed Input Tables

Table 1. Q_{BARE}, Q_{INS} and their Input Assumptions for Various Install Scenarios (Ref. 2, see Notes)

Location		Indoor Piping						Outdoor Piping				
System Type		Hot water			5 psi steam	65 psi steam	Domestic Hot Water	Hot water			5 psi steam	6 psi steam
Insulation thickness		1			2	2.5	1	3			3.5	4
Outdoor Temp Reset		No	Yes	Yes	n/a	n/a	n/a	No	Yes	Yes	n/a	n/a
Recirculation		Any	Heating season	All year	n/a	n/a	n/a	Any	Heating season	All year	n/a	n/a
Ambient T		75°F						Zone 1, Duluth: 41°F Zone 2, St. Cloud: 44°F Zone 3, MSP: 48°F				
Fluid in Pipe T, °F		170	145	130	225	312	125	170	145	130	225	312
Q_{BARE}, Btu/h per foot	**Zone 1**	**114**	**78**	**58**	**232**	**286**	**52**	**489**	**386**	**325**	**754**	**1001**
	Zone 2							**478**	**377**	**318**	**736**	**978**
	Zone 3							**464**	**367**	**309**	**716**	**951**
Q_{INS}, Btu/h per foot	**Zone 1**	**22**	**16**	**12**	**23**	**32**	**13**	**16**	**13**	**11**	**22**	**30**
	Zone 2							**16**	**13**	**11**	**21**	**29**
	Zone 3							**15**	**12**	**10**	**21**	**28**

Table 2. 90 Degree Elbow and Straight Tee Equivalent Length

Nominal Pipe Diameter (in)	Equivalent Length of Other Components (ft)	
	90° Elbow (Ref. 3)	Straight Tee (Ref. 4)
1	0.3	0.38
2	0.66	0.63
3	1.01	0.84
4	1.4	1.03
5	1.76	1.22
6	2.13	1.41
8	2.91	1.75
10	3.65	2.13
12	4.44	2.5

Table 3. Valve Equivalent Length, L_{COMP} (Ref. 2)

ANSI Class (psi)	Equivalent Length of Other Components (ft)			
	1” Valve	2” Valve	3” Valve	4” Valve
150	2	3.56	3.67	3.98
300	5.22	4.73	4.79	5.15
600	5.22	4.73	5.11	6.49
900	6.96	8.37	7.09	7.96

Table 4. Flange Equivalent Length, L_{COMP} (Ref. 2)

ANSI Class (psi)	Equivalent Length of Other Components (ft)			
	1” Flange	2” Flange	3” Flange	4” Flange
150	1.04	1.14	1.16	1.22
300	1.04	1.35	1.44	1.56
600	1.16	1.42	1.48	1.9
900	3.57	2.48	2.02	2.24

Table 5. Equivalent Full Load Hours of heating per zone in Minnesota by building type (Ref. 5)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	1887	1699	1546
Education – Community College/University	1972	1776	1616
Education – Primary	2394	2156	1961
Education – Secondary	2561	2306	2098
Health/Medical – Clinic	2234	2012	1830
Health/Medical – Hospital	2508	2258	2054
Lodging	2361	2126	1934
Manufacturing	1397	1258	1144
Multifamily	2324	2092	1904
Office-Low Rise	1966	1770	1610
Office-Mid Rise	2189	1971	1793
Office-High Rise	2149	1935	1760
Restaurant	1868	1681	1530
Retail – Large Department Store	1763	1587	1444
Retail – Strip Mall	1701	1531	1393
Warehouse	1872	1685	1533
Other/Miscellaneous	2123	1911	1739

Table 6. HOU for Heating Season Recirculation (Ref. 2, see Notes)

Geography	Hours
MN Zone 1	5995
MN Zone 2	5445
MN Zone 3	5046

Table 7. Thermal Regain Factors (Ref. 2)

Pipe Location	Assumed Regain	Thermal Regain Factor
Outdoor	0%	1
Indoor, heated space	85%	0.15
Indoor, semi- heated, (unconditioned space with heat transfer to conditioned space, e.g., boiler room, ceiling plenum, basement, crawlspace, wall)	30%	0.7
Indoor, unheated, (no heat transfer to conditioned space)	0%	1
Location not specified	85%	0.15
Custom	Custom	1 – assumed regain

Deemed Measured Costs

Actual costs should be used if known. Otherwise, the deemed measure cost below may be used. Pipe insulation type are all calcium silicate insulation, PVC jackets for indoor, and aluminum jacket for outdoor. The following table summarizes the estimated costs for this measure per foot added and include installation costs.

Table 8. Incremental Costs (Ref. 2)

Insulation thickness	Total Cost per foot (Indoor)	Total Cost per foot (Outdoor)
1.0”	$16.35	$18.20
1.5”	$22.43	$25.00
2.0”	$26.93	$29.50
2.5”	$31.28	$33.85
3.0”	$35.62	$38.19
3.5”	$40.02	$42.59
4.0”	$44.40	$46.97

Notes

Savings are calculated based on a bare pipe baseline. This measure is not generally valid for new construction applications. Required pipe insulation thickness for new buildings is generally 1” or greater (Ref. 6).

Values for Q_{BASE} and Q_{INS} were derived using 3E Plus v4.0 software (Ref. 7) in the Illinois TRM. These models assumed 2” piping. Q_{BASE} and Q_{INS} values for indoor piping are unaltered. However their values for outdoor piping were weather-normalized to reflect the mean outdoor temperature of Minnesota climate zones, and the corresponding change in mean temperature difference between the pipe fluid and the pipe exterior.

The algorithm described above can be used for prescriptive pipe insulation savings for scenarios meeting the criteria outlined in the Measure Description section. For custom scenarios such as larger diameter pipes, thicker insulation, or exotic insulation materials, 3E Plus Version 4.1 software may be used to calculate Q_{BARE} and Q_{INS}. Pipe type, pipe base metal, pipe size, insulation type, jacket material, process temperature, and ambient temperature can all be specified on the Energy tab of the software, and the Calculation Type can be set to Heat Loss Per Hour. Process and ambient temperatures as specified in Table 1 should be used. For outdoor installations, a wind speed of 5 miles per hour should be specified. Once the inputs are specified, selecting Calculate reveals heat loss values for bare pipe (Q_{BARE}) and for various thicknesses of insulation (Q_{INS}). A report can then be exported specifying the input assumptions and output heat loss values. For more information, consult the 3E Plus manual (Ref. 8).

References

1. Measured Life Report, Residential and Commercial/Industrial Lighting and HVAC measures, GDS Associates, June 2007. Value for Pipe Wrap measure. https://library.cee1.org/system/files/library/8842/CEE_Eval_MeasureLifeStudyLights%2526HVACGDS_1Jun2007.pdf
2. Illinois Stakeholder Advisory Group. *2021 Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 9.0, Volume 2: Commercial and Industrial Measures*. September 25, 2020. https://ilsag.s3.amazonaws.com/IL-TRM_Effective_010121_v9.0_Vol_2_C_and_I_09252020_Final.pdf
3. Based on the dimensions for diameter, long radius, and short radius given by ANSI/ASME 36.19.
4. Based on the center to face and diameter dimensions given by ANSI/ASME B36.19.
5. FES scaled EFLH from those provided in the Illinois Technical Reference Manual based on Minnesota weather data. EFLH for the Illinois Technical Reference Manual were based on California DEER study prototypes modified by Illinois field data to closely match EFLH from the modeling to those calculated from field data.
6. 2020 Minnesota Energy Code with ANSI/ASHRAE/IES Standard 90.1. https://codes.iccsafe.org/content/MNEC2020P1/chapter-4-ce-commercial-energy-efficiency#MNEC2020P1_CE_Ch04_SecC403.3.2
7. North American Insulation Manufacturer's Association. 3E Plus Software. https://insulationinstitute.org/tools-resources/free-3e-plus/
8. North American Insulation Manufacturer's Association. 3E Plus User Guide Version 4.1. August 2012. https://insulationinstitute.org/wp-content/uploads/2016/03/3E-Plus-V4-Users-Manual.pdf

Revision History

Version	Description	Author	Date
1.0	Initial version	Cadmus	9/2021

C/I HVAC – High Volume Low Speed Fans

Measure Detail	Measure Value
Measure ID	2.02.19
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC
Applicable To	Commercial, industrial, or agricultural customers that currently use non HVLS fans
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Size (diameter) of HVLS fans being installed, facility use type
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	15 years (Ref. 1)
Unit Participant Incremental Cost	Refer to Table 3

Measure Description

This measure applies to the installation of large horizontally mounted high volume low speed (HVLS) fans to replace multiple smaller, non HVLS fans in commercial, industrial, or agricultural facilities.

Algorithms

Unit kWh Savings per Year = (kW_base – kW_EE) x Hrs x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = (kW_base – kW_EE) x CF x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = (kW_Base – kW_EE) x Hrs x HVAC_heating_penalty_factor

Where:

kW_Base = Qty_Base x kW_Base_per_Fan

kW_EE = Qty_HVLS x kW_HVLS_per_Fan

Qty_HVLS = the quantity of HVLS fans being installed. The default value is 1 (per unit basis). Qty_Base = the quantity of baseline fans that would be replaced with HVLS fans. Assumed to be 5 standard fans per HVLS fan. (Ref. 3)

kW_HVLS_per_Fan = The rated input Wattage of each HVLS fan, assumed to be 1.0 kW (Ref. 4)

kW_Base_per_Fan = The rated input Wattage of each non-HVLS fan, assumed to be 1.0 kW (Ref. 4)

Hrs = Assumed annual operating hours of fans (Refer to Table 1)

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from reduction in fan energy, see Table 2. Reduction in fan energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from reduction in fan power, see Table 2. Reduction in fan power results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from reduction in fan energy, see Table 2.

CF = Peak coincidence factor = 0.9 (Ref. 5)

Example:

A 20-foot HVLS fan is installed to replace five standard fans, used to provide air circulation in an air conditioned manufacturing facility.

kW_Base = 5 x 1.0 = 5.0 kW kW_EE = 1.0 = 1.0 kW

Electric Energy Savings (kWh/yr) = (5.0 kW – 1.0 kW) x 5,200 x 1.095 = 22,776 kWh

Electric Peak Demand Savings (kW) = (5.0 kW – 1.0 kW) x 0.9 x 1.254 = 4.5 peak kW

Heating Penalty = (5.0kW – 1.0kW) x 5,200 x -0.0023 = -47.8 Dth

Deemed Input Tables

Table 1. Annual Operating Hours by Building Type (Ref. 6)

Building Type	Annual Operating Hours
Office	4,439
Restaurant	3,673
Retail	4,719
Grocery/Supermarket	5,802
Warehouse	4,746
Elementary School	2,422
Secondary School	4,311
College	3,540
Health	5,095
Hospital	6,038
Hotel/Motel	3,044
Manufacturing	5,200
Other/Misc.	4,576
24-Hour Facility	8,760

Table 2. HVAC Interactive Factors by HVAC System (Ref. 7)

Space Type	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
	Heating Only	Heat & Cooling	Heating Only	Heat & Cooling	Heat Only or Heat & Cooling
Conditioned	1.00	1.254	1.00	1.095	-0.0023
Unconditioned	1.00	1.00	1.00	1.00	0

Table 3. Incremental cost of HVLS Fans by Size (Ref. 2)

HVLS Fan Size (Diameter, feet)	Incremental Cost
20 feet	$4,150
22 feet	$4,180
24 feet	$4,225

Notes

There are currently no Federal energy efficiency standards in place for high velocity low speed fans.

References

1. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values, October 10, 2008. EUL value for this measure was assumed to be the same as HVAC Fan Motors.
2. ActOnEnergy, Program Year Three Technical Reference Manual No. 2010-4. Costs are based on the comparison of the prices of seven small (48" diameter) industrial low-speed fans and one HVLS fan. Average costs from three different manufacturers were analyzed.
3. D.W. Kammel, M.E, Raabe, J. J. Kappelman: Design of High Volume Low Speed Fan
4. Supplemental Cooling System in Dairy Free Stall Barns
5. Manufacturer data from Rite Hite, Macro-Air, Big Ass Fans, and laboratory testing data for 48" fans from BESS labs showed that the difference in average input wattage for HVLS and standard fans is negligible. Average input wattage was shown to be around 1.0 kW. (http://bess.illinois.edu/) last accessed 08/31/12
6. 0.9 is a typical value used for central HVAC equipment in many programs. The range is 0.74 to
7. 1.0 with most being very close to 0.9, primary data has not been identified.
8. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 pg 139. The Illinois TRM summarizes recent studies including: DEER 2005, DEER 2008, ComEd FY1 and FY2 evaluations, Ameren Missouri Final Report: Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, and Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010.
9. HVAC cooling and heating interactive factor data based on DOE2/eQuest building simulation. The prototypes building models are based on the California DEER study prototypes (see http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf), and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	8/1/2012
2.0	Added HVAC Cooling kWh and kW savings and Heating penalty factors	Franklin Energy Services	11/12/15

C/I HVAC – Infrared Heater

Measure Detail	Measure Value
Measure ID	2.02.20
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC
Applicable To	Commercial customers with natural gas fired forced air heating systems
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	New infrared heater input Btu/h, project location (county)
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	$1,716 (Ref. 2)

Measure Description

This measure includes replacement of failed or working furnaces and unit heaters in existing buildings with natural gas fired infrared heaters, as well as installation of infrared heaters in new buildings.

Algorithms

Unit Dth Savings per Year = Pre_Annual_Consumption x (1 – Load_Reduction_Factor)

Where:

Pre_Annual_Consumption = Btuh_In x Load_Factor x $EFLH_{HEAT}$ / ConversionFactor

Load_Reduction_Factor = (HDD45 / (55°F – T_design)) / (HDD55 / (65°F – T_design))

Btuh_In = the nominal rating of the input capacity of the new infrared heater in Btu/h

Load_Factor = load factor, assumed to be 77% (Ref. 3)

$EFLH_{HEAT}$ = the heating equivalent full load hours. See Table 2.

HDD55 = the heating degree-days of the climate zone with a 55 degree base. See Table 1. HDD45 = the heating degree-days of the climate zone with a 45 degree base. See Table 1.

T_design = the equipment design temperature of the climate zone, see Table 1

ConversionFactor = 1,000,000 Btu/Dth

Example:

A 300 Mbtuh infrared heater is installed to replace a furnace of the same size in an existing Manufacturing building in Climate Zone 1.

Pre_Annual_Consumption = 300,000 x 0.77 x 1397 /1,000,000 = 323 Dth

Unit Dth Savings per Year = 323 x [1 – (4429 / (55 – (-22))) / (6956 / (65 – (-22)))] = 90.6 Dth

Deemed Input Tables

Table 1. Heating Degrees Days (HDD) and Heating Design Temperature per zone in Minnesota

	Zone 1 (Northern MN)	Zone 2 (Central MN)	Zone 3 (Southern MN/Twin Cities)
HDD55 (Ref. 5)	6,956	5,888	5,233
HDD45	4,429	3,864	3,317
T_design (Ref. 6)	-22 °F	-16.5 °F	-14.5 °F

Table 2. Equivalent Full Load Hours of heating per zone in Minnesota by building type (Ref. 4)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	1887	1699	1546
Education – Community College/University	1972	1776	1616
Education – Primary	2394	2156	1961
Education – Secondary	2561	2306	2098
Health/Medical – Clinic	2234	2012	1830
Health/Medical – Hospital	2508	2258	2054
Lodging	2361	2126	1934
Manufacturing	1397	1258	1144
Multifamily	2324	2092	1904
Office-Low Rise	1966	1770	1610
Office-Mid Rise	2189	1971	1793
Office-High Rise	2149	1935	1760
Restaurant	1868	1681	1530
Retail – Large Department Store	1763	1587	1444
Retail – Strip Mall	1701	1531	1393
Warehouse	1872	1685	1533
Other/Miscellaneous	2123	1911	1739

$EFLH_{HEAT}$ were determined from based prototypes building models on the California DEER study prototypes modified Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3). Values were scaled as follows: $EFLH_{MN} = EFLH_{IL} \times HDD_{55,MN} / HDD_{55,IL} \times DTD_{IL} / DTD_{MN}$, where DTD is the design temperature difference.

Table 3. Heating Degree Days and Design Temperature Difference

Geography	HDD55	DTD
Chicago, IL	4,029	73.5
MN Zone 1	6,956	92
MN Zone 2	5,888	86.5
MN Zone 3	5,233	84.5

Methodology and Assumptions

The calculation methodology for this measure assumes that the space temperature can be dropped 10°F while maintaining occupant comfort levels.

Notes

There are currently no existing Minnesota state-wide or federal efficiency standards for infrared heaters.

References

1. Focus on Energy Evaluation, Business Programs: Measure Life Study, August 25, 2009.
2. Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011
3. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010. This factor implies that heating systems are 30% oversized on average.
4. FES scaled EFLH from those provided in the Illinois Technical Reference Manual based on Minnesota weather data. EFLH for the Illinois Technical Reference Manual were based on California DEER study prototypes modified by Illinois field data to closely match EFLH from the modeling to those calculated from field data.
5. National Climate Data Center – National Oceanic and Atmospheric Administration 1981-2010
6. Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.
7. *2009 ASHRAE Fundamentals Handbook Table 1A Heating and Wind Design Conditions, Heating DB 99.6%*

Revision History

Version	Description	Author	Date
1.0	Original document	Franklin Energy Services	7/30/2012
1.1	Added Industrial to Market Segments, corrected use of Btu/Dth conversion factor in algorithm, changed measure name	Joe Plummer	2/12/2013
2.0	Changed from Heating Degree Days to $EFLH_{HEAT}$. Updated Table 2 to include building types	Franklin Energy Services	11/12/2015

C/I HVAC – Variable Speed Drives

Measure Detail	Measure Value
Measure ID	2.02.21
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC
Applicable To	Commercial and industrial for space heating and cooling applications
Actions	Modify, Replace Working (Retrofit), New Construction (limited sizes, see Notes)
Required from Customer/Contractor	Horsepower, application type, motor efficiency, annual operating hours
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	0
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	See Table 1 (Ref. 2)

Measure Description

This measure applies to variable speed drives installed on HVAC systems including:

- HVAC Fans – supply fans, return fans, and cooling tower fans
- HVAC Pumps – hot water heating and chilled water cooling pumps

The VSD will vary the speed of the motor in a HVAC application with a diversified load.

In the applicable HVAC applications the power of the motor is approximately proportional to the cube of the speed, providing significant energy savings.

Measure Cost

Actual costs should be used, if known. For smaller motors (< 20 HP), default project costs are given in the following table (Ref. 2). VSDs installed on larger motors must use actual costs.

Table 2. Incremental Cost by Motor Horsepower (Ref. 2)

HP	Cost
1 – 5 HP	$ 1,330
7.5 HP	$ 1,622
10 HP	$ 1,898
15 HP	$ 2,518
20 HP	$ 3,059

Algorithms

$$\text{Annual kWh Savings} = \left(0.746 \times \text{HP} \times \frac{\text{LF}}{\text{Eff}}\right) \times \text{Hours} \times \text{ESF}$$

Where:

0.746 = Conversion from HP to kW

HP = Rated Motor horsepower. Actual value.

LF = Motor load factor at the pump or fan design flow rate. Use actual value if known. If unknown, use default value of 65% (Ref. 3)

Eff = Efficiency of motor. Use actual value if known. If unknown, use default NEMA premium efficiency rating by size and type of motor found in Table 4 (Ref. 4)

Hours = Annual operating hours. Actual run hours must be used; justification for run hours assumption must be included in project documentation.

ESF = Energy Savings Factor. ESF is the sum product of DutyCycle and PLR_{BASE} across all flow rates, minus the sum product of DutyCycle and PLR_{EFF} across all flow rates. See Table 5 below for example ESF values.

$$= \sum_{0\%}^{100\%} (\text{DutyCycle} \times PLR_{BASE}) - \sum_{0\%}^{100\%} (\text{DutyCycle} \times PLR_{EFF})$$

DutyCycle = Percentage of motor runtime at each flow rate. At generation facilities, it is expected that a duty cycle will be known with a reasonable degree of accuracy. Duty Cycle should be in the form of Table 2 below. See Table 3 for an example Duty Cycle.

Table 2. Duty Cycle Format

Flow Rate (Percentage of design flow)	Duty Cycle (Percentage of motor runtime at each flow rate)
0% to 10%	
10% to 20%	
20% to 30%	
30% to 40%	
40% to 50%	
50% to 60%	
60% to 70%	
70% to 80%	
80% to 90%	
90% to 100%	

PLR_{BASE} = Part Load Ratio for the baseline control strategy. The ratio of percentage of peak power draw that occurs at each flow rate percentage. Consult Table 6 to find PLR_{BASE} values depending on the existing control strategy.

PLR_{EFF} = Part Load Ratio for the VSD. The ratio of percentage of peak power draw that occurs at each flow rate percentage. Consult Table 6 to find PLR_{EFF} values. They should either be the Pump VSD or Fan VSD values.

Example:

A 100 HP boiler feedwater pump currently using a throttling valve is retrofitted with a VSD. The pump runs for 3,000 hours per year, the motor load factor is 90% and the motor efficiency is 95%. The motor duty cycle is found in Table 3 below.

ESF is calculated using example the duty cycle in Table 3, PLR_{BASE} (from Table 6 – pump throttling valve values), and PLR_{EFF} (from Table 6 – pump VSD values).

Table 3. Example ESF Calculation (Ref. 6)

Flow Rate (Percentage of design flow)	Example Duty Cycle (Percentage of motor runtime at each flow rate)	PLR_{BASE} (Throttling Valve)	PLR_{EFF} (VSD)
10% to 20%	6%	0.67	0.06
20% to 30%	11%	0.73	0.09
30% to 40%	13%	0.78	0.12
40% to 50%	17%	0.82	0.18
50% to 60%	24%	0.87	0.27
60% to 70%	17%	0.90	0.39
70% to 80%	9%	0.94	0.55
80% to 90%	2%	0.97	0.75
90% to 100%	1%	1.00	1.00

ESF = [(0.06 x 0.67) + (0.11 x .73) +(0.13 x 0.78) + (0.17 x 0.82) + (0.24 x 0.87) + (0.17 x 0.90) + (0.09 x 0.94) + (0.02 x 0.97) + (.01 x 1.0)] – [(0.06 x 0.06) + (0.11 x 0.09) + (0.13 x 0.12) + (0.17 x 0.18) + (0.24 x 0.27) + (0.17 x 0.39) + (0.09 x 0.55) + (0.02 x 0.75) + (0.01 x 1)] = 0.8371 – 0.2653 = 0.5718

Unit kWh Savings per Year = (0.746 x 100 x 0.90 / 0.95) x 3,000 x 0.5718 = 121,234 kWh

Deemed Input Tables

Table 4. Default NEMA Premium Motor Efficiencies (Ref. 4)

Size HP	Open Drip Proof (ODP)			Totally Enclosed Fan-Cooled (TEFC)		
	# of Poles			# of Poles		
	6	4	2	6	4	2
	Speed (RPM)			Speed (RPM)		
	1200	1800 Default	3600	1200	1800	3600
1	0.825	0.855	0.770	0.825	0.855	0.770
1.5	0.865	0.865	0.840	0.875	0.865	0.840
2	0.875	0.865	0.855	0.885	0.865	0.855
3	0.885	0.895	0.855	0.895	0.895	0.865
5	0.895	0.895	0.865	0.895	0.895	0.885
7.5	0.902	0.910	0.885	0.910	0.917	0.895
10	0.917	0.917	0.895	0.910	0.917	0.902
15	0.917	0.930	0.902	0.917	0.924	0.910
20	0.924	0.930	0.910	0.917	0.930	0.910
25	0.930	0.936	0.917	0.930	0.936	0.917
30	0.936	0.941	0.917	0.930	0.936	0.917
40	0.941	0.941	0.924	0.941	0.941	0.924
50	0.941	0.945	0.930	0.941	0.945	0.930
60	0.945	0.950	0.936	0.945	0.950	0.936
75	0.945	0.950	0.936	0.945	0.954	0.936
100	0.950	0.954	0.936	0.950	0.954	0.941
125	0.950	0.954	0.941	0.950	0.954	0.950
150	0.954	0.958	0.941	0.958	0.958	0.950
200	0.954	0.958	0.950	0.958	0.962	0.954
250	0.954	0.958	0.950	0.958	0.962	0.958
300	0.954	0.958	0.954	0.958	0.962	0.958
350	0.954	0.958	0.954	0.958	0.962	0.958
400	0.958	0.958	0.958	0.958	0.962	0.958
450	0.962	0.962	0.958	0.958	0.962	0.958
500	0.962	0.962	0.958	0.958	0.962	0.958

Table 5. Example Energy Savings Factors (using example Duty Cycle from Table 3)

Baseline Control Type	ESF
Pump – No Control	0.73
Pump – Bypass Valve	0.67
Pump – Throttling Valve	0.60
Fan – No Control or Bypass Damper	0.71
Fan – Discharge Dampers	0.50
Fan – Outlet Damper, Backward Inclined & Airfoil Fans	0.47
Fan – Inlet Damper Box	0.41
Fan – Inlet Guide Vane, Backward Inclined & Airfoil Fans	0.34
Fan – Inlet Vane Dampers	0.24
Fan – Outlet Damper, Forward Curved Fans	0.22
Eddy Current Drives	0.19
Inlet Guide Vane, Forward Curved Fans	0.10

Table 6. Part Load Ratio for Flow rate bins Based on Control Types for Pumps (Ref. 5) and Fans (Ref. 6)

Control Type	Flow rate (percentage of design flow)								
	10% to 20%	20% to 30%	30% to 40%	40% to 50%	50% to 60%	60% to 70%	70% to 80%	80% to 90%	90% to 100%
Pump Baseline values ($PLR_{Baseline}$)									
No Control	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bypass Valve	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Throttling Valve	0.67	0.73	0.77	0.82	0.87	0.90	0.94	0.97	1.00
Pump VSD value (PLR_{EFF})									
VSD – pump	0.06	0.09	0.12	0.18	0.27	0.39	0.55	0.75	1.0
Fan Baseline values ($PLR_{Baseline}$)									
No Control or Bypass Damper	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Discharge Dampers	0.55	0.63	0.7	0.77	0.83	0.88	0.93	0.97	1.00
Outlet Damper, Backward Inclined & Airfoil Fans	0.53	0.57	0.64	0.72	0.80	0.89	0.96	1.02	1.05
Inlet Damper Box	0.60	0.62	0.64	0.66	0.69	0.74	0.81	0.92	1.07
Inlet Guide Vane, Backward Inclined & Airfoil Fans	0.56	0.57	0.59	0.60	0.62	0.67	0.74	0.85	1.00
Inlet Vane Dampers	0.40	0.42	0.44	0.48	0.53	0.60	0.70	0.83	0.99
Outlet Damper, Forward Curved Fans	0.26	0.30	0.37	0.45	0.54	0.65	0.77	0.91	1.06
Eddy Current Drives	0.20	0.25	0.32	0.41	0.51	0.63	0.76	0.90	1.04
Inlet Guide Vane, Forward Curved Fans	0.22	0.23	0.26	0.31	0.39	0.49	0.63	0.81	1.04
Fan VSD value (PLR_{EFF})									
Fan – VSD	0.10	0.11	0.15	0.20	0.29	0.41	0.57	0.76	1.01

Notes

Speed or capacity control is required by the 2015 Minnesota energy code by size and application; for VAV fan units greater than or equal to 7.5 Hp without variable pitch fan blades, non-multi-stage hydronic pumping systems with a design output greater than 300,000 Btu/h, heat rejection fans greater than or equal to 7.5 HP. It is generally accepted that VSDs provide this capacity control for these sizes, and should be considered the baseline for New Construction. Operation below 30% of design speed is not recommended.

References

1. 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.
2. Ohio TRM 8/6/2010 varies by motor/fan size based on equipment costs from Granger 2008 Catalog pp 286-289, average across available voltages and models. Labor costs from RS Means Data 2008 Ohio average cost adjustment applied.
3. U.S. Department of Energy. *Improving Motor and Drive System Performance; A Sourcebook for Industry*. 2008. Page 18. https://www.energy.gov/sites/prod/files/2014/04/f15/amo_motors_sourcebook_web.pdf
4. Douglass, J. (2005). Induction Motor Efficiency Standards. Washington State University and the Northwest Energy Efficiency Alliance, Extension Energy Program, Olympia, WA. Also listed in the IL Statewide TRM. Retrieved online 12/12/16 at: http://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/motor_efficiency_standards.pdf
5. Curves developed from data obtained by measuring the operating characteristics of various pumps and from information provided in "Flow Control," a Westinghouse publication, Bulletin B-851, F/86/Rev-CMS 8121. https://www.bpa.gov/EE/Sectors/Industrial/Documents/ASDCalculators.xls
6. Del Balso, Ryan Joseph. "Investigation into the Reliability of Energy Efficiency/Demand Side Management Savings Estimates for Variable Frequency Drives in Commercial Applications."

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	8/1/2012
1.1	Minor revisions	Joe Plummer	2/12/2013
1.2	Added annual operating hours as an optional input from customer/contractor, clarified Required Inputs	Joe Plummer	1/6/2014
2.0	Updated energy code requirements for new construction	Franklin Energy Services	11/12/2015
3.0	Updated calculation approach and default values, requiring custom hours of use	Cadmus	11/2018

C/I HVAC – Fan Energy Index

Measure Detail	Measure Value
Measure ID	2.02.22
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC
Applicable To	Commercial and industrial HVAC for space heating and cooling applications. HVAC supply, return and exhaust fans.
Actions	Modify, Replace Working (Retrofit), New Construction
Required from Customer/Contractor	Horsepower, application type, motor efficiency, annual operating hours
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	0
Measure Lifetime (years)	Variable speed: 15 (Ref. 2) Constant speed: 18 (Ref. 3) Other types of fans: 25 (Ref. 3)
Unit Participant Incremental Cost	Actual if available. See Table 1 (Ref. 4)

Measure Description

The Fan Energy Index (FEI) is a fan efficiency metric allowing for the comparison of different fans at application specific operating conditions. The more traditional Fan Efficiency Grade metric is defined at a rated condition only. FEI is incorporated in ASHRAE 90.1-2019 and IECC-2021. The baseline FEI is 1.0 for constant speed and 0.95 for variable speed fan operation, with more efficient fans having a greater FEI value. FEI only applies to stand alone fans, not to embedded fans within packaged equipment. This measure should be used for evaluating fan efficiency of fans with the same control system. The variable speed drive measure should be used to compare control systems. This measure has been largely adopted from the Fan Energy Index measure within the IL Technical Reference Manual v10.0 (Ref. 1).

This measure applies to variable speed drives installed on HVAC systems including: HVAC Fans – supply fans, return fans, exhaust fans and cooling tower fans

Measure Cost

Actual costs should be used, if known. Default measure costs are shown in Table 1 for fans with FEI greater than 1.0 (Ref. 4).

Table 1. Incremental Cost by Motor Horsepower, Application and Type (Ref. 4)

	Early Replacement		New Construction	
Fan Type	**Small (<10 HP)**	**Large (>= 10 hp)**	**Small (<10 HP)**	**Large (>= 10 hp)**
Axial Cylindrical Housed	$3,218	$1,068	$264	$87
Panel	$319	$104	$29	$10
Centrifugal Housed	$1,381	$382	$199	$55
Centrifugal Unhoused	$827	$195	$76	$18
Inline and Mixed Flow	$2,301	$751	$297	$97
Radial	$1,570	$434	$119	$33
Power Roof Ventilator	$1,536	$460	$140	$42

Algorithms

$$\text{Annual kWh Savings} = (1 + \text{IE}) * \text{FEP}_{\text{NEW}} * \left(\frac{FEI_{NEW}}{FEI_{BASE}} - 1\right) \times \text{RHRS} \times \sum_{0\%}^{100\%} (\%\text{FF x PLR})$$

$$\text{kW Demand Savings} = (1 + \text{IE}) * \text{FEP}_{\text{NEW}} * \left(\frac{FEI_{NEW}}{FEI_{BASE}} - 1\right) * PLR_{FFPEAK}$$

Where:

IE = HVAC interactive effects factor (default = 15.7%)

FEP_{New} = Fan Electrical Power of new fan at 100% flow fraction (kW). Use actual if known. If unknown, use the following equation to calculate:

FEP_{New} = (0.746 x HP x LF / Eff_{MOTOR})

Where:

0.746 = Conversion factor from horsepower to kW

HP = Nominal fan horsepower

LF = Loading factor of the fan motor. If unknown, see Table 6.

Eff_{MOTOR} = Rated efficiency of the motor as a percentage

FEI_{New} = Fan Energy Index of new fan at 100% flow fraction

FEI_{Base} = Fan Energy Index of baseline fan at 100% flow fraction. FEI_{BASE} is defined by the actual if known, otherwise 0.95 for variable speed, 1.0 for constant speed. If other, see Table 2.

RHRS = Annual operating hours for fan based on building type, see Table 3. Default hours are provided for HVAC applications which vary by HVAC application and building type. When available (provided via energy management software or metered), actual hours should be used.

%FF = Percentage of run-time spent within a given flow fraction range. See Table 5 and Table 6. Default Fan Duty Cycle Based on 2012 ASHRAE Handbook; HVAC Systems and Equipment, page 45.11, Figure 12.

PLR = Part load ratio for a given flow fraction range, see Table 5 and Table 6

PLR_{Ffpeak} = The part load ratio for the average flow fraction between the peak daytime hours during the weekday peak time period based on the baseline flow control type (default average flow fraction during peak period = 90%)

Example:

A constant speed direct drive centrifugal housed fan is replaced with a variable speed fan in a manufacturing facility with discharge dampers.

Annual kWh Savings $= (1 + 15.7\%) * 4.3\text{kW} * \left(\frac{1.39}{0.92} - 1\right) \times 8{,}706 \times 0.80$ = 17,594 kWH

kW Demand Savings = $(1 + 15.7\%) * 4.3\text{kW} * \left(\frac{1.39}{0.92} - 1\right) * 0.90$ = 2.27 kW

Deemed Input Tables

Table 2. Default Values for FEI Baseline (Ref. 5)

Fan Type	Drive Type		
	Variable Speed – Belt	Constant Speed – Belt	Constant Speed – Direct
Axial Cylindrical Housed	0.88	0.88	0.97
Panel	0.95	0.95	0.88
Centrifugal Housed	0.92	0.92	0.92
Centrifugal Unhoused	0.94	0.94	1.03
Inline and Mixed Flow	0.79	0.79	0.77
Radial	0.81	0.81	0.94
Power Roof Ventilator	0.82	0.82	0.76

Table 3. RHRS Annual Operating Hours Based on Building Type (Ref. 6)

Building Type	Total Fan Run Hours	Model Source
Assembly	7,235	eQuest
Assisted Living	8,760	eQuest
Auto Dealership	7,451	OpenStudio
College	4,836	OpenStudio
Convenience Store	7,004	eQuest
Drug Store	7,156	OpenStudio
Elementary School	3,765	OpenStudio
Emergency Services	8,760	OpenStudio
Garage	7,357	eQuest
Grocery	8,543	OpenStudio
Healthcare Clinic	4,314	OpenStudio
High School	3,460	OpenStudio

Building Type	Total Fan Run Hours	Model Source
Hospital – VAV econ	4,666	OpenStudio
Hospital – CAV econ	8,021	OpenStudio
Hospital – CAV no econ	7,924	OpenStudio
Hospital – FCU	4,055	OpenStudio
Manufacturing Facility	8,706	eQuest
MF – High Rise	8,760	OpenStudio
MF – Mid Rise	8,760	OpenStudio
Hotel/Motel – Guest	2,409	OpenStudio
Hotel/Motel – Common	8,683	OpenStudio
Movie Theater	7,505	eQuest
Office – High Rise – VAV econ	2,369	OpenStudio
Office – High Rise – CAV econ	2,279	OpenStudio
Office – High Rise – CAV no econ	5,303	OpenStudio
Office – High Rise – FCU	1,648	OpenStudio
Office – Low Rise	6,345	OpenStudio
Office – Mid Rise	3,440	OpenStudio
Religious Building	7,380	eQuest
Restaurant	7,302	OpenStudio
Retail – Department Store	7,155	OpenStudio
Retail – Strip Mall	6,921	OpenStudio
Warehouse	6,832	OpenStudio
Unknown	6,241	n/a

Table 4. Part Load Ratio (Ref. 7)

Control Type	Flow Fraction									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
No Control or Bypass Damper	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Discharge Dampers	0.46	0.55	0.63	0.70	0.77	0.83	0.88	0.93	0.97	1.00
Outlet Damper, BI & Airfoil Fans	0.53	0.53	0.57	0.64	0.72	0.80	0.89	0.96	1.02	1.05
Inlet Damper Box	0.56	0.60	0.62	0.64	0.66	0.69	0.74	0.81	0.92	1.07
Inlet Guide Vane, BI & Airfoil Fans	0.53	0.56	0.57	0.59	0.60	0.62	0.67	0.74	0.85	1.00
Inlet Vane Dampers	0.38	0.40	0.42	0.44	0.48	0.53	0.60	0.70	0.83	0.99
Outlet Damper, FC Fans	0.22	0.26	0.30	0.37	0.45	0.54	0.65	0.77	0.91	1.06
Eddy Current Drives	0.17	0.20	0.25	0.32	0.41	0.51	0.63	0.76	0.90	1.04
Inlet Guide Vane, FC Fans	0.21	0.22	0.23	0.26	0.31	0.39	0.49	0.63	0.81	1.04
VFD with duct static pressure controls	0.09	0.10	0.11	0.15	0.20	0.29	0.41	0.57	0.76	1.01
VFD with low/no duct static pressure	0.05	0.06	0.09	0.12	0.18	0.27	0.39	0.55	0.75	1.00

Below are the resultant values based upon the defaults in Table 4 above:

Table 5. Resulting Default Values $\sum_{0\%}^{100\%}(\%\text{FF x PLR})$ (Ref. 7)

Control Type	$\sum_{0\%}^{100\%}(\%FF \times PLR)$
No Control or Bypass Damper	1.00
Discharge Dampers	0.80
Outlet Damper, BI & Airfoil Fans	0.78
Inlet Damper Box	0.69
Inlet Guide Vane, BI & Airfoil Fans	0.63
Inlet Vane Dampers	0.53
Outlet Damper, FC Fans	0.53
Eddy Current Drives	0.49
Inlet Guide Vane, FC Fans	0.39
VFD with duct static pressure controls	0.30
VFD with low/no duct static pressure	0.27

Table 6. Default Load Factors by Application

Application	Load Factor
Other	75%
Pump	75%
ECM Fan	90%
Fan	65%

Notes

Speed or capacity control is required by the 2015 Minnesota energy code by size and application; for VAV fan units greater than or equal to 7.5 Hp without variable pitch fan blades and heat rejection fans greater than or equal to 7.5 HP. It is generally accepted that VSDs provide this capacity control for these sizes, and should be considered the baseline for New Construction

References

1. IL-TRM Technical Advisory Committee. IL Technical Reference Manual v10.0.
2. Efficiency Vermont TRM 2021 for HVAC VSD motors.
3. U.S. Department of Energy Fans and Blowers Working Group
4. Costs are based on the U.S. Department of Energy Fans and Blowers Working Group spreadsheet: EERE-2013-BT-STD-0006-0189_attachment_1.xlsx
5. Fan Energy Index Market Research: Final Report", prepared for ComEd by Slipstream, May 2021.
6. Hours per year are estimated using the eQuest or OpenStudio models as the total number of hours the fans are operating for heating, cooling and ventilation for each building type.
7. Methodology developed and tested in Del Balso, Ryan Joseph. "Investigation into the Reliability of Energy Efficiency/Demand Side Management Savings Estimates for Variable Frequency Drives in Commercial Applications". A project report submitted to the Faculty of the Graduate School of the University of Colorado, 2013.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Cadmus	11/01/2022

C/I HVAC – Pump Energy Index

Measure Detail	Measure Value
Measure ID	2.02.23
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC
Applicable To	Commercial and industrial pumps
Actions	Modify, Replace Working (Retrofit), New Construction
Required from Customer/Contractor	Horsepower, application type, motor efficiency, annual operating hours
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	0
Measure Lifetime (years)	Variable speed: 15 (Ref. 1) Constant speed: 20 (Ref. 1)
Unit Participant Incremental Cost	Actual if known preferred given variability. See Table 1 for default values (Ref. 1)

Measure Description

The Pump Energy Index (PEI) is a pump efficiency metric allowing for the comparison of different pumps at application specific operating conditions. The more traditional Pump Efficiency Grade metric is defined at a rated condition only. PEI is incorporated in ASHRAE 90.1-2019 and IECC-2021. The baseline PEI is 1.0 for constant speed, with more efficient pumps having a lower PEI value. PEI only applies to stand alone pumps, not to embedded pumps within a system. This measure should be used for evaluating pump efficiency of pumps with the same control system. The variable speed drive measure should be used to compare control systems. This measure has been largely adopted from the Pump Energy Index measure within the Regional Technical Forum, version 3.0 (Ref. 1).

Algorithms

Annual kWh Savings $= \left(\frac{\text{HP} * 0.746 * \text{AdjFactor}}{\text{Motor Efficiency}}\right) * (\text{PEI}_{\text{Base}} - \text{PEI}_{\text{New}})$ x Hours

kW Demand Savings = $\left(\frac{\text{Annual kWh Savings}}{\text{Hours}}\right) * \text{CF}$

Where:

HP = HP of pump motor, actual should be used.

0.746 = Conversion factor from horsepower to kW

Adj Factor = Adjustment factor for pump. Default values in Table 4.

Motor Efficiency = Efficiency of NEMA premium efficient motor as a percentage.

PEI_{Base} = Pump Energy Index of baseline pump. PEI_{BASE} is defined by the actual if known, 1.0 for constant speed. Variable speed values will vary depending on control and size. See Table 2 for defaults.

PEI_{New} = Pump Energy Index of new pump. Must meet or exceed efficiency standards in Table 3, and must be at least 0.02 PEI below baseline.

Hours = Annual operating hours for pump based on building type, see Table 3 for defaults, or use actuals.

CF = Coincidence factor, default of 0.9.

Example:

A 2 HP constant speed industrial pump (1.0 PEI Base) is replaced with a constant flow 92% efficiency pump of the same size (0.97 PEI New).

$$\text{Annual kWh Savings} = \left(\frac{2 * 0.746 * 0.85}{0.92}\right) \text{ x } (1.00 - 0.97) \text{ x } 5{,}000 = 206.8 \text{ kWH}$$

$$\text{kW Demand Savings} = \left(\frac{206.8 \text{ kWh}}{5{,}000 \text{ hours}}\right) \text{ x } 0.9 = 0.04 \text{ kW}$$

Deemed Input Tables

Table 1. Incremental Cost and Default Sizing of Pumps (Ref. 1)

Type	Motor HP Range	Representative Pump Size (HP accounting for average oversize %)	Cost Calculation ($/HP)
Constant	1 – 4.9	1.9	$20.43
	5 – 9.9	5.1	$10.02
	10 – 24.9	12.8	$5.24
	25 – 49.9	28.6	$2.98
	50 – 99.9	60.0	$1.76
	100 – 200	125.1	$1.05
Variable Speed	1 – 1.9	0.9	$33.75
	2 – 2.9	1.6	$23.29
	3 – 4.9	2.5	$16.62
	5 – 9.9	5.1	$10.02
	10 – 24.9	12.8	$5.24
	25 – 49.9	28.6	$2.98
	50 – 99.9	60.0	$1.76
	100 – 200	125.1	$1.05

Table 2. Default Values for PEI Baseline (Ref. 1)

Type	Size	
	1 – 5 HP	> 7.5 HP
All Constant Speed	1.00	1.00
Non- Vertical Turbine Variable Speed	0.54	0.50
Vertical Turbine Variable Speed	0.63	0.60

Table 3. Annual Operating Hours Based on Building Type (Ref. 1)

Building Type	Total Run Hours
Agricultural	2,400
Commercial HVAC and DHW	4,000
Industrial and Municipal	5,000

Table 4. Adjustment Factors for Pumps (Ref. 1)

Pump Type	Variable Speed Pumps			Constant Flow Pumps (all Segments)
	Agricultural Irrigation	Industrial and Municipal	Commercial HVAC and DHW	
Non- Vertical Turbine Pump	1.13	1.13	1.22	0.85
Vertical Turbine Pump	1.50	1.50	1.60	1.15

References

1 Regional Technical Forum, Technical Advisory Committee to NW Power and Conservation Council. UES Measure: Efficient Pumps. Version 3.0. Effective April 18, 2022. https://rtf.nwcouncil.org/measure/efficient-pumps/

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Cadmus	11/01/2022

C/I HVAC –Programmable Thermostat Adjustments

Measure Detail	Measure Value
Measure ID	2.02.24
Target Market Segments	Commercial
Target End Uses	HVAC
Applicable To	Commercial customers in businesses noted in Table 1 with commercial unitary type air-conditioning equipment controlled by thermostats. Gas must be the primary heating source to use this measure and building automation systems must not be incorporated.
Actions	Modify
Required from Customer/Contractor	Confirmation of gas or electric heating, business type (see Table 2), location (county), heating size (Btu/h Input) or (kW Input), cooling size (tons), existing hours of setback, existing degrees of setback, proposed hours of setback, proposed degrees of setback
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	8 (Ref. 1)
Unit Participant Incremental Cost	$181 (Ref. 2)

Measure Description

This measure includes adjustment of new or existing programmable thermostat schedules in existing small commercial businesses where the current HVAC operating schedule does not align with the building occupancy. An estimate is provided for cooling and heating energy consumption through temperature set-back during unoccupied times. Savings make no other assumptions regarding adjustments during occupied periods or sequence of operations incorporated into the programmable thermostat. Among sequence savings not considered are optimal start, outside air damper control, or other potential energy savings measures associated with occupancy.

Algorithms

Unit kWh Savings per Year = Ecc x CSP x ISR + Hcel x HSP X ISR

Unit Dth Savings per Year = Hcgas x HSP x ISR

Where:

Ecc	= Electrical consumption for cooling and ventilation, kWh
Ecc	= $EFLH_{COOL}$ x Size x (12/EffC_e)
$EFLH_{COOL}$	= Equivalent Full Load Hours of cooling, see Table 1 (Ref. 3)
Size	= Nominal cooling capacity in tons of the controlled equipment (1 ton = 12,000 btu/h), if unknown assume 5 tons (Ref.4)

EffC_e	= SEER or IEER rating of controlled equipment, provided by customer. If unknown, assume 12.1 (Ref.5).
CSP	= SFC x ((Hours_Ca x Degrees_Ca) – (Hours_Ce x Degrees_Ce)), Cooling Savings Percentage, %
SFC	= Savings Factor for cooling consumption, % per Degree-Hour, See Table 2 (Ref. 6)
Hours_Ce	= Existing hours per week of cooling setback, Hours, provided by customer
Hours_Ca	= New hours per week of cooling setback, Hours, provided by customer
Degrees_Ce	= SP_Ceo – SP_Ceu, existing cooling setback degrees (°F)
SP_Ceo	= Existing occupied temperature cooling set point, °F, provided by customer
SP_Ceu	= Existing unoccupied temperature cooling set point, °F, provided by customer
Degrees_Ca	= SP_Cao – SP_Cau, adjusted cooling setback degrees, °F
SP_Cao	= New occupied temperature set point, °F, provided by customer
SP_Cau	= New unoccupied temperature set point, °F, provided by custom
ISR	= In-Service Rate, the percentage of units installed and programmed effectively, Table 4. (Ref. 7)
Hcel	= Heating consumption for electrically heated businesses, kWh
Hcel	= $EFLH_{HEAT}$ x kW_H x Load_Factor_H
$EFLH_{HEAT}$	= Equivalent Full Load Hours heating, See Table 1. (Ref. 8)
kW_H	= Nominal Heating capacity in kW of the equipment. Capacity, kW, provided by customer/contractor or use = 23.9 kWh if unknown. (Ref. 9)
Load_Factor_H	= the heating load factor, assumed to be 0.5 (implies 50% oversizing) (Ref. 10)
HSP	= SFH x ((Hours_Ha x Degrees_Ha) – (Hours_He x Degrees_He)), Heating Savings Percentage, %
SFH	= Savings Factor for heating consumption, % per Degree-Hour, See Table 2 (Ref. 6)
Hours_He	= Existing hours per week of heating setback, Hours, provided by customer
Hours_Ha	= New hours per week of heating setback, Hours, provided by customer
Degrees_He	= Existing setback degrees, °F
Degees_He	= SP_Heo – SP_Heu
SP_Heo	= Existing occupied temperature set point, °F, provided by customer
SP_Heu	= Existing unoccupied temperature set point, °F, provided by customer
Degrees_Ha	= Adjusted setback degrees, °F
Degees_Ha	= SP_Hao – SP_Hau
SP_Hao	= Adjusted occupied temperature set point, °F, provided by customer

SP_Hau = Adjusted unoccupied temperature set point, °F, provided by customer

Ecgas = Heating consumption for gas heated businesses, Dth

Hcgas = $EFLH_{HEAT}$ x BTUH_IN x Load_Factor_H /Conversion_Factor

Btuh_In = Nominal Heating capacity in btu/h of the equipment. Capacity, btu/h, provided by customer/contractor or use = 100,000 if unknown. (Ref. 11)

Conversion_Factor = 1,000,000 Btu/Dth

Examples:

Adjust the schedule for a programmable thermostat in a gas heated strip mall retail store Climate Zone 1, via a direct installation program delivery.

Current Occupied Set Points: 70 Cooling /68 Heating

Current Unoccupied Set Points: 75 Cooling /65 Heating

Current Hours of Setback per week: 75

Proposed Occupied Set Points: 70 Cooling /68 Heating

Proposed Unoccupied Set Points: 80 Cooling /58 Heating

Proposed Hours of Setback per week: 80

Ecc = 307 x 5 x 12 / 12.1 = 1,522 kWh

CSP = 0.0040% x (80 x (80 -70) – 75 x (75 – 70)) = 1.5 %

Hcel = 0

Unit kWh Savings per Year = 1,522 kWh x 1.5% x 1.0 + 0 = 22.83 kWh

Hcgas = 1,701 x 100,000 x 0.5 / 1,000,000 = 85.05 Dth

HSP = 0.0139% x (80 x (68 – 58) – (75 x (68 – 65)) = 8%

Unit Dth Savings per Year = 85.05 x 8% x 1.0 = 6.8 Dth

Deemed Input Tables

Table 1. Equivalent Full Load Hours of cooling ($EFLH_{COOL}$) per zone in Minnesota by building type (Ref. 3)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	647	825	986
Office – Low Rise	257	359	446
Restaurant	347	535	652
Retail – Large Department Store	462	588	686
Retail – Strip Mall	307	441	574
Other/Miscellaneous	443	612	729

Table 2. Cooling and Heating Savings Factor per degree of setback per hour unoccupied per zone in Minnesota by building type (Ref. 6)

Building Type	SFC	SFH
Convenience Store	0.0054%	0.0072%
Office – Low Rise	0.0050%	0.0164%
Restaurant	0.0059%	0.0072%
Retail – Large Department Store	0.0040%	0.0072%
Retail – Strip Mall	0.0040%	0.0139%
Other/Miscellaneous	0.0040%	0.0072%

Table 3. Equivalent Full Load Hours of heating per zone in Minnesota by building type (Ref. 8)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	1,887	1,699	1,546
Office – Low Rise	1,966	1,770	1,610
Restaurant	1,868	1,681	1,530
Retail – Large Department Store	1,763	1,587	1,444
Retail – Strip Mall	1,701	1,531	1,393
Other/Miscellaneous	2,123	1,911	1,739

Table 4. In-Service Rates (Ref. 7)

Program Delivery	ISR
Direct Install	1.0
Other, or unknown	0.56

Methodology and Assumptions

EFLH_Cool data based on DOE2/eQuest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

$EFLH_{HEAT}$ were determined from based prototypes building models on the California DEER study prototypes modified Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3). Values were scaled as follows: $EFLH_{MN} = EFLH_{IL} \times HDD_{55,MN} / HDD_{55,IL} \times DTD_{IL} / DTD_{MN}$, where DTD is the design temperature difference.

Table 5. Heating Degree Days and Design Temperature Difference

Geography	HDD55	DTD
Chicago, IL	4,029	73.5
MN Zone 1	6,956	92
MN Zone 2	5,888	86.5
MN Zone 3	5,233	84.5

Demand savings are assumed to be minimal, as it is assumed that demand savings for HVAC measures are defined as summer peak hour savings. Savings are calculated based upon a constant speed baseline operation.

References

1. Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007.
2. Nicor Rider 30 Business EER Program Database, Paid Rebates with Programmable Thermostat Installation Costs, Program to Date as of January 11, 2013.
3. Calculated through energy modeling of California DEER study prototypes modified by Illinois field data with TMY3 Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3) by FES 2012.
4. Utilizing nominal square footage noted in DTE and CE C&I Programmable Thermostat Savings Analysis: Preliminary Findings, Navigant Energy, June 17, 2014 and assumption of 400 square feet per ton of cooling capacity results in 5-ton cooling unit.
5. Commercial and Industrial Programmable Thermostats, Navigant Energy, June 16, 2015, pg. 33.
6. Utilizing the savings results from the Table 4-1 MEMD Calibration Research – Commercial and Industrial Programmable Thermostats, Navigant Energy, June 16, 2015 and dividing these results from the nominal weighted setbacks recorded in Appendix E of the Commercial Rooftop Units in Minnesota Characteristics and Performance, Final Report, Minnesota Department of Commerce Department of Energy Resources, March 2017 and the prototype DEER modeling unoccupied hours for each building type.
7. "Programmable Thermostats. Report to KeySpan Energy Delivery on Energy and Cost Effectiveness," GDS Associates, Marietta, GA. 2002.
8. FES scaled EFLH from those provided in the Illinois Technical Reference Manual based on Minnesota weather data. EFLH for the Illinois Technical Reference Manual were based on California DEER study prototypes modified by Illinois field data to closely match EFLH from the modeling to those calculated from field data.
9. Utilizing nominal square footage noted in DTE and CE C&I Programmable Thermostat Savings Analysis: Preliminary Findings, Navigant Energy, June 17, 2014 and assumption of 400 square feet per ton of cooling capacity results in 5-ton cooling unit. This result was then utilized to determine the heating input for rooftop units in this size from the three largest manufacturers. This value was then converted to KW assuming electrical resistance heating and 100% efficiency.
10. Commercial Rooftop Units in Minnesota Characteristics and Performance, Final Report, Minnesota Department of Commerce Department of Energy Resources, March 2017, Pg. 85.
11. Utilizing nominal square footage noted in DTE and CE C&I Programmable Thermostat Savings Analysis: Preliminary Findings, Navigant Energy, June 17, 2014 and assumption of 400 square feet per ton of cooling capacity results in 5-ton cooling unit. This result was then utilized to determine the heating input for rooftop units in this size from the three largest manufacturers.

Revision History

Version	Description	Author	Date
1.0	New Measure	Franklin Energy Services	09/01/2017

C/I HVAC – Boilers, Space Heating Only

Measure Detail	Measure Value
Measure ID	2.02.25
Target Market Segments	Commercial
Target End Uses	HVAC
Applicable To	Commercial customers with HVAC boilers
Actions	New Construction, Replace on Fail, Replace Working
Required from Customer/Contractor	New boiler input Btu/h, new boiler efficiency at actual operating conditions, new boiler type (steam, steam except natural draft, hot water), existing boiler type (steam, steam except natural draft, hot water), project location (county), facility type
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	20 (Ref. 1)
Unit Participant Incremental Cost	See Table 2

Measure Description

This measure includes replacement of failed or working HVAC boilers in existing commercial buildings with high-efficiency steam or hot water boilers, as well as installation of high-efficiency steam or hot water boilers in new commercial buildings.

Algorithms

Unit Dth Savings per Year = BTUH_In x Load_Factor x $EFLH_{HEAT}$ x Eff_High x (1/Eff_Base – 1/Eff_High) / ConversionFactor

Where:

BTUH_In = the nominal rating of the input capacity of the boiler in Btu/h

Load_Factor = boiler load factor, assumed to be 77% (Ref. 2)

$EFLH_{HEAT}$ = the heating equivalent full load hours. See Table 1.

Eff_Base = Efficiency of the baseline boiler. See Table 2.

Eff_High = Efficiency of the new high-efficiency boiler

ConversionFactor = 1,000,000 Btu/Dth

Example:

A 1,000 kBtuh gas-fired hot water boiler is replaced with a 1,000 kBtuh 88% efficient hot water boiler in Zone 2 in Mid-Rise Office:

Unit Dth Saving Per Year = 1,000,000 x 0.77 x 1971 x 0.88 x (1/0.80 – 1/0.88) / 1,000,000 = 151.8 Dth/yr

Deemed Input Tables

Table 1. Equivalent Full Load Hours of heating per zone in Minnesota by building type (Ref. 3)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	1887	1699	1546
Education – Community College/University	1972	1776	1616
Education – Primary	2394	2156	1961
Education – Secondary	2561	2306	2098
Health/Medical – Clinic	2234	2012	1830
Health/Medical – Hospital	2508	2258	2054
Lodging	2361	2126	1934
Manufacturing	1397	1258	1144
Multifamily	2324	2092	1904
Office-Low Rise	1966	1770	1610
Office-Mid Rise	2189	1971	1793
Office-High Rise	2149	1935	1760
Restaurant	1868	1681	1530
Retail – Large Department Store	1763	1587	1444
Retail – Strip Mall	1701	1531	1393
Warehouse	1872	1685	1533
Other/Miscellaneous	2123	1911	1739

Table 2. Incremental Costs and Baseline Efficiency (Ref. 4, 5, 6, 7, 8, 9, 10)

High-efficiency Replacement Boiler Type	High-Efficiency Boiler Efficiency Range*	Baseline Boiler Efficiency*	Incremental Cost ($ / kBtuh)
Steam, < 300 kBtu/h	82+% AFUE	80% AFUE	$3.30
Steam except natural draft, 300-2500 kBtu/h	83-85% TE	79% TE	$1.44
Steam, natural draft, 300-2500 kBtu/h	83-85% TE	77% TE	$1.44
Steam except natural draft, > 2500 kBtu/h	83-85% CE	79% TE	$1.02
Steam, natural draft, > 2500 kBtu/h	83-85% CE	77% TE	$1.02
Mid-Efficiency Hot Water, < 300 kBtu/h	84.5-88%AFUE	82% AFUE	$5.88
Mid-Efficiency Hot Water, 300-2500 kBtu/h	85-88% TE	80% TE	$4.97
Mid-Efficiency Hot Water, > 2500 kBtu/h	85-88% CE	82% CE	$2.50
High-Efficiency Hot Water, < 300 kBtu/h	≥ 88% AFUE	82% AFUE	$9.14
High-Efficiency Hot Water, 300-2500 kBtu/h	≥ 88% TE	80% TE	$9.12
High-Efficiency Hot Water, > 2500 kBtu/h	≥ 88% CE	82% CE	$7.25

* AFUE = Annual Fuel Utilization Efficiency, CE = Combustion Efficiency, TE = Thermal Efficiency

Notes

Incremental material cost should be confirmed with manufacturer and project data.

$EFLH_{HEAT}$ were determined from based prototypes building models on the California DEER study prototypes modified Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3). Values were scaled as follows: $EFLH_{MN} = EFLH_{IL} \times HDD_{55,MN} / HDD_{55,IL} \times DTD_{IL} / DTD_{MN}$, where DTD is the design temperature difference.

Table 3. Heating Degree Days and Design Temperature Differences

Geography	HDD55	DTD
Chicago, IL	4,029	73.5
MN Zone 1	6,956	92
MN Zone 2	5,888	86.5
MN Zone 3	5,233	84.5

There are currently federal efficiency standards in place for HVAC boiler systems. They are as follows:

Table 4. Federal Efficiency Standards for Products Manufactured On Or After March 2, 2012 (Ref. 6)

Boiler Type	Size (Btu/hr)	Efficiency Requirement
Gas-fired, hot water	≥300,000 and ≤2,500,000	80% thermal efficiency
Gas-fired, hot water	>2,500,000	82% combustion efficiency
Oil-fired, hot water	≥300,000 and ≤2,500,000	82% thermal efficiency
Oil-fired, hot water	>2,500,000	84% combustion efficiency
Gas-fired except natural draft, steam	≥300,000 and ≤2,500,000	79% thermal efficiency
Gas-fired except natural draft, steam	>2,500,000	79% thermal efficiency
Gas-fired-natural draft, steam	≥300,000 and ≤2,500,000	77% thermal efficiency
Gas-fired-natural draft, steam	>2,500,000	77% thermal efficiency
Oil-fired, steam	≥300,000 and ≤2,500,000	81% thermal efficiency
Oil-fired, steam	>2,500,000	81% thermal efficiency

Table 5. Federal Efficiency Standards for Products Manufactured On or After March 2, 2022 (Ref. 6)

Boiler Type	Size (Btu/hr)	Efficiency Requirement
Gas-fired natural draft, steam	≥300,000 and ≤2,500,000	79% thermal efficiency
Gas-fired natural draft, steam	>2,500,000	79% thermal efficiency

References

1. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values, October 10, 2008
2. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010. This factor implies that non-condensing boilers are 30% oversized on average.

3. FES scaled EFLH from those provided in the Illinois Technical Reference Manual based on Minnesota weather data. EFLH for the Illinois Technical Reference Manual were based on California DEER study prototypes modified by Illinois field data to closely match EFLH from the modeling to those calculated from field data.
4. 2008 Database for Energy-Efficient Resources, Revised DEER Measure Cost Summary, June 2, 2008. All incremental cost values assume replacement on failure.
5. Xcel Energy, 2010/2011/2012 Triennial Plan, Minnesota Electric and Natural Gas Conservation Improvement Program, June 1, 2009
6. Title 10, Code of Federal Regulations, Part 431 - Energy Conservation Program: Energy Conservation Standards for Commercial Packaged Boilers; Final rule; technical amendment. https://www.regulations.gov/document/EERE-2013-BT-STD-0030-0103
7. Franklin Energy Services review of boiler manufacturer data and past projects – December, 2012.
8. ASHRAE Standard 90.1-2004 as adopted by MN Commercial Energy Code (MN Rules Ch. 1323)
9. Title 10, Code of Federal Regulations, Part 430 – Energy Conservation Program For Consumer Products, Subpart C – Energy and Water Conservation Standards. https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=06bb5275babde5c3b0d48497ae00764f&mc=true&n=sp10.3.430.c&r=SUBPART&ty=HTML. Title 10 has been amended on 9/28/2023resulting in modifications to steam commercial boilers (gas fired) baseline efficiency noted in Table 4. https://www.energy.gov/sites/default/files/2023-09/cpb-tech-amend.pdf?utm_medium=email&utm_source=govdelivery
10. Wisconsin Focus on Energy TRM Commercial Condensing Boiler. Historical project data obtained from SPECTRUM for average unit cost from 400 projects, 741 boilers, and 1,017,865 MBH from January 2018 through July 2020 showed $21.99. Efficient unit cost is 27.6% higher than baseline. Therefore, incremental cost was calculated as $21.99 x 27.6% = $6.07/MBh.

Revision History

Version	Description	Author	Date
4.0	Changed from Heating Degree Days to $EFLH_{HEAT}$. Updated Table 1 to include building types	Franklin Energy Services	11/12/2015
5.0	Updated baseline efficiencies to follow code, updated costs	Cadmus	10/2018
5.1	Updated efficiency standards	Cadmus	11/01/2022
5.2	Updated efficiency standards	Cadmus	12/14/2023

Industrial HVAC – Process Boilers

Measure Detail	Measure Value
Measure ID	2.02.26
Target Market Segments	Industrial
Target End Uses	Industrial Process
Applicable To	Industrial customers with boilers
Actions	New Construction, Replace on Fail, Replace Working
Required from Customer/Contractor	New boiler input Btu/h, new boiler efficiency at actual operating conditions, new boiler type (steam, steam except natural draft, hot water), existing boiler type (steam, steam except natural draft, hot water), project location (county), facility type
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	20 (Ref. 2)
Unit Participant Incremental Cost	See Table 2

Measure Description

This measure includes replacement of failed or working boilers in existing industrial facilities with high-efficiency steam or hot water boilers, as well as installation of high-efficiency steam or hot water boilers in new industrial facilities.

Algorithms

Unit Dth Savings per Year = BTUH_In x Load_Factor x HOU_t x Eff_High x (1/Eff_Base – 1/Eff_High) / Conversion Factor

Where:

BTUH_In = The nominal rating of the input capacity of the boiler in Btu/h

Load_Factor = boiler load factor, assumed to be 41.9% or installation-specific load factor provided by the customer (Ref. 1)

HOU = Hours of use. Table 1.

Eff_Base = Efficiency of the baseline boiler. See Table 2.

Eff_High = Efficiency of the new high-efficiency boiler.

Conversion Factor = 1,000,000 Btu/Dth

Example:

A 1,000 kBtuh natural draft steam boiler is replaced with a 1,000 kBtuh 85% efficient natural draft steam boiler in a two shift facility:

Unit Dth Saving Per Year = 1,000,000 x 0.419 x 5844 x 0.85 x (1/0.77 – 1/0.85) / 1,000,000

= 254.4 Dth/yr

Deemed Input Tables

Table 1. Hours of use

Schedule	HOU
One Shift	2922
Two Shift	5844
Three Shift	8766

Table 2. Incremental Costs and Baseline Efficiency (Ref. 3, 4, 5, 6, 7, 8, 10)

High-efficiency Replacement Boiler Type	High-Efficiency Boiler Efficiency Range*	Baseline Boiler Efficiency*	Incremental Cost ($ / kBtuh)
Steam, < 300 kBtu/h	82+% AFUE	80% AFUE	$3.30
Steam except natural draft, 300-2500 kBtu/h	83-85% TE	79% TE	$1.44
Steam, natural draft, 300-2500 kBtu/h	83-85% TE	77% TE	$1.44
Steam except natural draft, > 2500 kBtu/h	83-85% CE	79% TE	$1.02
Steam, natural draft, > 2500 kBtu/h	83-85% CE	77% TE	$1.02
Mid-Efficiency Hot Water, < 300 kBtu/h	84.5-88%AFUE	82% AFUE	$5.88
Mid-Efficiency Hot Water, 300-2500 kBtu/h	85-88% TE	80% TE	$4.97
Mid-Efficiency Hot Water, > 2500 kBtu/h	85-88% CE	82% CE	$2.50
High-Efficiency Hot Water, < 300 kBtu/h	≥ 88% AFUE	82% AFUE	$9.14
High-Efficiency Hot Water, 300-2500 kBtu/h	≥ 88% TE	80% TE	$9.12
High-Efficiency Hot Water, > 2500 kBtu/h	≥ 88% CE	82% CE	$7.25

* AFUE = Annual Fuel Utilization Efficiency, CE = Combustion Efficiency, TE = Thermal Efficiency

Notes

Incremental material cost should be confirmed with manufacturer and project data.

There are currently federal efficiency standards in place for Commercial boiler systems. They are illustrated in Table 3.

Table 3. Federal Efficiency Standards for Products Manufactured On Or After March 2, 2012 (Ref. 6)

Boiler Type	Size (Btu/hr)	Efficiency Requirement
Gas-fired, hot water	≥300,000 and ≤2,500,000	80% thermal efficiency
Gas-fired, hot water	>2,500,000	82% combustion efficiency
Oil-fired, hot water	≥300,000 and ≤2,500,000	82% thermal efficiency
Oil-fired, hot water	>2,500,000	84% combustion efficiency
Gas-fired except natural draft, steam	≥300,000 and ≤2,500,000	79% thermal efficiency
Gas-fired except natural draft, steam	>2,500,000	79% thermal efficiency
Gas-fired-natural draft, steam	≥300,000 and ≤2,500,000	79% thermal efficiency
Gas-fired-natural draft, steam	>2,500,000	79% thermal efficiency
Oil-fired, steam	≥300,000 and ≤2,500,000	81% thermal efficiency
Oil-fired, steam	>2,500,000	81% thermal efficiency

Table 4. Federal Efficiency Standards for Products Manufactured On or After March 2, 2022 (Ref. 6)

Boiler Type	Size (Btu/hr)	Efficiency Requirement
Gas-fired natural draft, steam	≥300,000 and ≤2,500,000	79% thermal efficiency
Gas-fired natural draft, steam	>2,500,000	79% thermal efficiency

References

1. Illinois Statewide Technical Reference Manual 8.0 Vol. 2, 4.43, September, 2022. This source used data from a work paper provided by Resource Solutions Group that is not available publicly.
2. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values, October 10, 2008
3. Title 10, Code of Federal Regulations, Part 430 – Energy Conservation Program For Consumer Products, Subpart C – Energy and Water Conservation Standards. https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=06bb5275babde5c3b0d48497ae00764f&mc=true&n=sp10.3.430.c&r=SUBPART&ty=HTML
4. 2008 Database for Energy-Efficient Resources, Revised DEER Measure Cost Summary, June 2, 2008. All incremental cost values assume replacement on failure.
5. Xcel Energy, 2010/2011/2012 Triennial Plan, Minnesota Electric and Natural Gas Conservation Improvement Program, June 1, 2009
6. Title 10, Code of Federal Regulations, Part 431 - Energy Conservation Program: Energy Conservation Standards for Commercial Packaged Boilers; Final rule; technical amendment.

   https://www.regulations.gov/document/EERE-2013-BT-STD-0030-0103
7. Franklin Energy Services review of boiler manufacturer data and past projects – December, 2012.
8. ASHRAE Standard 90.1-2004 as adopted by MN Commercial Energy Code (MN Rules Ch. 1323)

Revision History

Version	Description	Author	Date
1.0	Measure created	Cadmus	11/01/2022

C/I HVAC – Boiler Modifications, Space Heating Only

Measure Detail	Measure Value
Measure ID	2.02.27
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC, Industrial Process
Applicable To	Commercial and industrial customers with HVAC boilers
Actions	Operations & Maintenance, Modify
Required from Customer/Contractor	Modification type, nominal pre-modification Btu/h input, project location (county), facility type
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	See Table 2
Unit Participant Incremental Cost	Unit Participant Incremental Cost: Use actual cost of modification. Table 2 figures may be used for planning estimates

Measure Description

This measure describes retrofit opportunities to increase boiler efficiency. This includes cut-out controls, modulating burners, reset controls, oxygen controls, stack dampers, boiler tune-ups, and turbulators. Applies only to natural gas boilers in space heating applications.

To qualify for the boiler tune-up modification measure the facility must, as applicable, complete the tune-up requirements[5] listed below, by approved technician:

- Measure combustion efficiency using an electronic flue gas analyzer
- Adjust airflow and reduce excessive stack temperatures
- Adjust burner and gas input, manual or motorized draft control
- Check for proper venting
- Complete visual inspection of system piping and insulation
- Check safety controls
- Check adequacy of combustion air intake
- Clean fireside surfaces.
- Inspect all refractory. Patch and wash coat as required.
- Inspect gaskets on front and rear doors and replace as necessary.
- Seal and close front and rear doors properly.

[5] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up

- Clean low and auxiliary low water cut-off controls, then re-install using new gaskets.
- Clean plugs in control piping.
- Remove all hand hole and man hole plates. Flush boiler with water to remove loose scale and sediment.
- Replace all hand hole and man hole plates with new gaskets.
- Open feedwater tank manway, inspect and clean as required. Replace manway plate with new gasket.
- Clean burner and burner pilot.
- Check pilot electrode and adjust or replace.
- Clean air damper and blower assembly.
- Clean motor starter contacts and check operation.
- Make necessary adjustments to burner for proper combustion.
- Perform all flame safeguard and safety trip checks.
- Check all hand hole plates and man hole plates for leaks at normal operating pressures.
- Troubleshoot any boiler system problems as requested by on-site personnel

Algorithms

Unit Dth Savings per Year = (Percentage Savings) x (Pre-Annual Consumption)

Pre-Annual Consumption (Dth/yr) = BTUH_In x Load_Factor x $EFLH_{HEAT}$ / ConversionFactor

Where:

BTUH_In = the nominal rating of the input capacity of the boiler in Btu/h

Load_Factor = boiler load factor, assumed to be 77% (Ref. 1)

$EFLH_{HEAT}$ = the heating equivalent full load hours. See Table 1.

ConversionFactor = 1,000,000 Btu/Dth

Percentage Savings = percentage of the pre-modification annual consumption saved. See Table 2.

Example:

For a 1000 kBtuh boiler tune-up in Zone 2 in a Mid-Rise Office:

Pre-Annual Consumption (Dth/yr) = 0.77 x 1,000,000 x 1971 / 1,000,000 = 1517.7 Dth

Gas Energy Heating Savings (Dth/yr) = 0.022 x 1517.7 = 33.39 Dth

Deemed Input Tables

Table 1. Equivalent Full Load Hours of heating per zone in Minnesota by building type (Ref. 12)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	1887	1699	1546
Education – Community College/University	1972	1776	1616
Education – Primary	2394	2156	1961
Education – Secondary	2561	2306	2098
Health/Medical – Clinic	2234	2012	1830
Health/Medical – Hospital	2508	2258	2054
Lodging	2361	2126	1934
Manufacturing	1397	1258	1144
Multifamily	2324	2092	1904
Office-Low Rise	1966	1770	1610
Office-Mid Rise	2189	1971	1793
Office-High Rise	2149	1935	1760
Restaurant	1868	1681	1530
Retail – Large Department Store	1763	1587	1444
Retail – Strip Mall	1701	1531	1393
Warehouse	1872	1685	1533
Other/Miscellaneous	2123	1911	1739

Table 2. Modification Savings and Incremental Costs

Modification Type	Percentage Savings	Approximate Cost	Measure Life
Cut-out Control	1.7% (Ref. 2)	$141 per boiler (Ref. 2)	5 years (Ref. 7)
Fully Modulating Burner	3% (Ref. 3)	$2.53 per kBtu/h input (Ref. 4)	15 years (Ref. 4)
Outdoor Reset Control	3.8% (Ref. 2)	$600 per boiler (Ref. 2)	5 years (Ref. 7)
Oxygen Control	1.1% (Ref. 13)	$27,000 per boiler (Ref. 6)	5 years (Ref. 7)
Stack Damper	5% (Ref. 5)	$3.125 per nominal pre-modification kBtu/h input (Ref. 2)	5 years (Ref. 7)
Tune-up	2.2% (Ref. 8)	$0.83/kBtu/h input (Ref. 9)	2 years (Ref. 10)
Turbulators	3% (Ref. 11)	$1,375 per boiler (Ref. 2)	20 years (Ref. 2)

Notes

There are currently no existing Minnesota state-wide or federal efficiency standards for aftermarket boiler retrofit measures.

$EFLH_{HEAT}$ were determined from prototypes building models based on the California DEER study prototypes modified Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3). Values were scaled as follows: $EFLH_{MN} = EFLH_{IL} \times HDD_{55,MN} / HDD_{55,IL} \times DTD_{IL} / DTD_{MN}$, where DTD is the design temperature difference.

Table 3. Heating Degree Days and Design Temperature Difference

Geography	HDD55	DTD
Chicago, IL	4,029	73.5
MN Zone 1	6,956	92
MN Zone 2	5,888	86.5
MN Zone 3	5,233	84.5

References

1. PA Consulting, KEMA, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010. This factor implies that boilers are 30% oversized on average.
2. CenterPoint Energy, Triennial CIP/DSM Plan 2010-2012, June 1, 2009
3. Xcel Energy, 2010/2011/2012 Triennial Plan, Minnesota Electric and Natural Gas Conservation Improvement Program, E,G002/CIP-09-198
4. Franklin Energy Services review of PY2/PY3 costs for custom People's and Northshore high turndown burner projects, used in Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 3.0, February 14, 2014.
5. United States EPA, Climate Wise: Wise Rules for Industrial Efficiency, July 1998
6. California Utilities Statewide Codes and Standards Team, CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE): PROCESS BOILERS, October 2011
7. Focus on Energy Evaluation, Business Programs: Measure Life Study, August 25, 2009.
8. FES determined by collection of results from approximately 25 projects completed through a Midwest energy project.
9. Illinois Statewide Technical Reference Manual, Sections 6.4.3 and 6.4.4, July 18, 2012. This source used data from a work paper provided by Resource Solutions Group that is not available publicly.
10. How to Select, Prioritize, & Justify Economically Viable Energy Projects, Eileen Westervelt, U of I Business Innovation Services, 10-30-2012
11. United States DOE, Industrial Technologies Program, Steam Fact Sheet #25, January 2012
12. FES scaled EFLH from those provided in the Illinois Technical Reference Manual based on Minnesota weather data. EFLH for the Illinois Technical Reference Manual were based on California DEER study prototypes modified by Illinois field data to closely match EFLH from the modeling to those calculated from field data.
13. Wisconsin Focus on Energy Technical Reference Manual, v2022. Boiler Oxygen Trim Controls Measure. Accessed September 1, 2022.

Revision History

Version	Description	Author	Date
3.6	Changed to EFLH heating and revised boiler tune-up efficiency	FES	11/12/2015
4.1	Modified oxygen control percentage savings value	Cadmus	11/01/2022

Industrial HVAC – Process Boiler Modifications

Measure Detail	Measure Value
Measure ID	2.02.28
Target Market Segments	Industrial
Target End Uses	Industrial Process
Applicable To	Industrial customers with boilers
Actions	Operations & Maintenance, Modify
Required from Customer/Contractor	Modification type, nominal pre-modification Btu/h input, project location (county), facility type
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	See Table 2
Unit Participant Incremental Cost	Unit Participant Incremental Cost: Use actual cost of modification. Table 2 figures may be used for planning estimates

Measure Description

This measure describes retrofit opportunities to increase boiler efficiency. This includes cut-out controls, modulating burners, reset controls, oxygen controls, stack dampers, boiler tune-ups, and turbulators. Applies only to natural gas boilers in process applications.

To qualify for the boiler tune-up modification measure the facility must, as applicable, complete the tune-up requirements[6] listed below, by approved technician:

- Measure combustion efficiency using an electronic flue gas analyzer
- Adjust airflow and reduce excessive stack temperatures
- Adjust burner and gas input, manual or motorized draft control
- Check for proper venting
- Complete visual inspection of system piping and insulation
- Check safety controls
- Check adequacy of combustion air intake
- Clean fireside surfaces.
- Inspect all refractory. Patch and wash coat as required.
- Inspect gaskets on front and rear doors and replace as necessary.
- Seal and close front and rear doors properly.

[6] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up

- Clean low and auxiliary low water cut-off controls, then re-install using new gaskets.
- Clean plugs in control piping.
- Remove all hand hole and man hole plates. Flush boiler with water to remove loose scale and sediment.
- Replace all hand hole and man hole plates with new gaskets.
- Open feedwater tank manway, inspect and clean as required. Replace manway plate with new gasket.
- Clean burner and burner pilot.
- Check pilot electrode and adjust or replace.
- Clean air damper and blower assembly.
- Clean motor starter contacts and check operation.
- Make necessary adjustments to burner for proper combustion.
- Perform all flame safeguard and safety trip checks.
- Check all hand hole plates and man hole plates for leaks at normal operating temperatures and pressures.
- Troubleshoot any boiler system problems as requested by on-site personnel

Algorithms

Unit Dth Savings per Year = (Percentage Savings) x (Pre-Annual Consumption)

Pre-Annual Consumption (Dth/yr) = BTUH_In x Utilization_Factor x HOU / ConversionFactor

Where:

BTUH_In = the nominal rating of the input capacity of the boiler in Btu/h

Utilization_Factor = boiler utilization factor, assumed to be 41.9% or installation-specific utilization factor provided by the customer (Ref. 1)

HOU = 8,766hr/yr, or actual

ConversionFactor = 1,000,000 Btu/Dth

Percentage Savings = percentage of the pre-modification annual consumption saved. See Table 2.

Example:

For a 1000 kBtuh boiler tune-up:

Pre-Annual Consumption (Dth/yr) = 0.419 x 1,000,000 x 8766 / 1,000,000 = 3672.95 Dth

Gas Energy Heating Savings (Dth/yr) = 0.022 x 3672.95 = 80.81 Dth

Deemed Input Tables

Table 2. Modification Savings and Incremental Costs

Modification Type	Percentage Savings	Approximate Cost	Measure Life
Cut-out Control	1.7% (Ref. 2)	$141 per boiler (Ref. 2)	5 years (Ref. 7)
Fully Modulating Burner	3% (Ref. 3)	$2.53 per kBtu/h input (Ref. 4)	15 years (Ref. 4)
Outdoor Reset Control	3.8% (Ref. 2)	$600 per boiler (Ref. 2)	5 years (Ref. 7)
Oxygen Control	1.1% (Ref. 13)	$27,000 per boiler (Ref. 6)	5 years (Ref. 7)
Stack Damper	5% (Ref. 5)	$3.125 per nominal pre-modification kBtu/h input (Ref. 2)	5 years (Ref. 7)
Tune-up	2.2% (Ref. 8)	$0.83/kBtu/h input (Ref. 9)	2 years (Ref. 10)
Turbulators	3% (Ref. 11)	$1,375 per boiler (Ref. 2)	20 years (Ref. 2)

References

1. Illinois Statewide Technical Reference Manual 8.0 Vol. 2, 4.43, September, 2022. This source used data from a work paper provided by Resource Solutions Group that is not available publicly.
2. CenterPoint Energy, Triennial CIP/DSM Plan 2010-2012, June 1, 2009
3. Xcel Energy, 2010/2011/2012 Triennial Plan, Minnesota Electric and Natural Gas Conservation Improvement Program, E,G002/CIP-09-198
4. Franklin Energy Services review of PY2/PY3 costs for custom People's and Northshore high turndown burner projects, used in Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 3.0, February 14, 2014.
5. United States EPA, Climate Wise: Wise Rules for Industrial Efficiency, July 1998
6. California Utilities Statewide Codes and Standards Team, CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE): PROCESS BOILERS, October 2011
7. Focus on Energy Evaluation, Business Programs: Measure Life Study, August 25, 2009.
8. FES determined by collection of results from approximately 25 projects completed through a Midwest energy project.
9. Illinois Statewide Technical Reference Manual, Sections 6.4.3 and 6.4.4, July 18, 2012. This source used data from a work paper provided by Resource Solutions Group that is not available publicly.
10. How to Select, Prioritize, & Justify Economically Viable Energy Projects, Eileen Westervelt, U of I Business Innovation Services, 10-30-2012
11. United States DOE, Industrial Technologies Program, Steam Fact Sheet #25, January 2012
12. FES scaled EFLH from those provided in the Illinois Technical Reference Manual based on Minnesota weather data. EFLH for the Illinois Technical Reference Manual were based on California DEER study prototypes modified by Illinois field data to closely match EFLH from the modeling to those calculated from field data.

13. Wisconsin Focus on Energy Technical Reference Manual Boiler Oxygen Trim Controls, September 1, 2022.

Revision History

Version	Description	Author	Date
1.0	Measure created	Cadmus	11/01/2022

C/I HVAC - Boiler Blowdown Controls

Measure Detail	Measure Value
Measure ID	2.02.29
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC, Industrial Process
Applicable To	Commercial/industrial customers with natural gas-fired steam boilers
Actions	Modify, New Construction
Required from Customer/Contractor	Boiler hp or Input Btu/h, steam pressure in psig
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	5 (Ref. 1)
Unit Participant Incremental Cost	$4,250 (Ref. 2) or use actual

Measure Description

In a steam boiler, the water boiled within evaporates and leaves behind suspended solids. These suspended solids can form a sediment in the boiler and reduce the effectiveness of its heat transfer; also resulting are dissolved solids which create foaming and can encourage boiler water leaving with the steam. To reduce the number of suspended solids, the boiler periodically purges some of its contents from the bottom of the tank, which is called bottom blowdown. The dissolved solids are removed by skimming the surface of the boiler water, which is called surface blowdown. Surface blowdown is often a continual process. Excessive blowdown can waste energy by unnecessarily purging heated water.

Excessive blowdown can be reduced by automatic blowdown control systems. These systems measure the characteristics of the water (conductivity, total dissolved solids (TDS), alkalinity and silica and chloride concentrations) and allow the boiler to blowdown only when needed.

Algorithms

Unit Dth Savings per Year = (Feedwater_pre – Feedwater_post) x Hours x (h_bd – h_fw) / Eff / C

Where:

Feedwater_pre = (Delivery_rate) / (1 – BDR_pre), boiler feedwater consumption with no blowdown controls in pounds per hour.

Feedwater_post = (Delivery_rate) / (1 – BDR_post), boiler feedwater consumption with blowdown controls installed in pounds per hour.

Delivery_rate = 34.5 x Boiler_HP, boiler delivery rate in pounds of steam per hour.

Boiler_HP = boiler horsepower rating, 1 boiler HP = 33,475 Btu/h

BDR_pre = blowdown ratio with no controls. If unknown, assume 8% (Ref. 2).

BDR_post = blowdown ratio with controls. If unknown, assume BDR_pre – 2% (Ref. 3)

h_bd = enthalpy of blowdown water in Btu/lb., see Table 1.

h_fw	= enthalpy of feedwater in Btu/lb., see Table 2. If feedwater temperature is unknown, assume 49˚
EFLH	= effective full load hours of boiler operation per year. See Table 3 or use actual if available.
Eff	= boiler efficiency. If unknown, use typical value of 80%.
C	= 1,000,000 Btu/Dth, conversion factor.

Example:

Blowdown controls are installed on a 60HP steam boiler producing steam at 90 psig. The boiler is used for process heating and operates at full load 8,760 hours per year.

Delivery_rate = 34.5 x 60 = 2,070 lbs./hour

Feedwater_pre = 2,070/(1-0.08) = 2,250 lbs./hour

Feedwater_post = 2,070 (1-0.06) = 2,202 lbs./hour

From Table 1, using 90 psig steam, h_bd = 302 Btu/lb.

From Table 2, assuming 49˚F feedwater, h_fw = 17 Btu/lb.

Unit Dth Savings per Year = (2,250-2,202) x 8,760 x (302-17) / 0.80 / 1,000,000 = 149 Dth

Deemed Input Tables

Table 1. Steam Table

Gauge Pressure (psig)	Temperature (°F)	Enthalpy (Btu/lb.)
0	212	180
1	215	183
2	219	187
3	222	190
4	224	192
5	227	195
6	230	198
7	232	200
8	233	201
9	237	205
10	239	207
12	244	212
14	248	216
16	252	220
18	256	224
20	259	227
22	262	230
24	265	233
26	268	236

Gauge Pressure (psig)	Temperature (°F)	Enthalpy (Btu/lb.)
28	271	239
30	274	243
32	277	246
34	279	248
36	282	251
38	284	253
40	286	256
42	289	258
44	291	260
46	293	262
48	295	264
50	298	267
55	300	271
60	308	278
65	312	282
70	316	287
75	320	290
80	324	295
85	327	298
90	331	302
95	335	305
100	338	309
105	341	312
110	344	316
115	347	319
120	350	322
125	353	325
130	356	328
135	358	330
140	361	333
145	363	336
150	366	339
155	368	341
160	371	344
165	373	346
170	375	348
175	377	351
180	380	353
185	382	355
190	384	358
195	386	360
200	388	362

Gauge Pressure (psig)	Temperature (°F)	Enthalpy (Btu/lb.)
205	390	364
210	392	366
215	394	368
220	395	370
225	397	372
230	399	374
235	401	376

Table 2. Water Table

Temperature (°F)	Enthalpy (Btu/lb.)
45	13
46	14
47	15
48	16
49	17
50	18
51	19
52	20
53	21
54	22
55	23
56	24
57	25
58	26
59	27
60	28
61	29
62	30
63	31
64	32
65	33
66	34
67	35
68	36
69	37
70	38

Table 3. Effective Full Load Hours of Operation by Building Type (Ref. 4)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	1887	1699	1546
Education - Community College/University	1972	1776	1616
Education – Primary	2394	2156	1961
Education – Secondary	2561	2306	2098
Health/Medical – Clinic	2234	2012	1830
Health/Medical – Hospital	2508	2258	2054
Lodging	2361	2126	1934
Manufacturing	1397	1258	1144
Multifamily	2324	2092	1904
Office-Low Rise	1966	1770	1610
Office-Mid Rise	2189	1971	1793
Office-High Rise	2149	1935	1760
Restaurant	1868	1681	1530
Retail - Large Department Store	1763	1587	1444
Retail - Strip Mall	1701	1531	1393
Warehouse	1872	1685	1533
Other/Miscellaneous	2123	1911	1739

Methodology and Assumptions

With manual blowdown, blowdown ratio typically varies between 4% and 8% but can be as high as 20% if extremely poor-quality feedwater (Ref. 2 and Ref. 3). Blowdown controls typically reduce boiler energy usage by 2% and 5% (Ref. 2). Blowdown controls typically cost between $2,500 and $6,000 (Ref. 2). Measure life is assumed to be five years for consistency with other boiler control measures in Ref. 1.

References

1. KEMA, Focus on Energy Evaluation, Business Programs: Measure Life Study, August 25, 2009.
2. US Department of Energy, Steam Tip Sheet #23, “Install an Automatic Blowdown-Control System”, January 2012.
3. N.C. Division of Pollution Prevention and Environmental Assistance Fact Sheet: Boiler Blowdown, August 2004.
4. FES scaled EFLH from those provided in the Illinois Technical Reference Manual based on Minnesota weather data. EFLH for the Illinois Technical Reference Manual were based on California DEER study prototypes modified by Illinois field data to closely match EFLH from the modeling to those calculated from field data.).

Revision History

Version	Description	Author	Date
1.0	New measure	Franklin Energy Services	12/4/17

C/I HVAC – Condensing Unit Heaters

Measure Detail	Measure Value
Measure ID	2.02.30
Target Market Segments	Commercial
Target End Uses	HVAC
Applicable To	Commercial customers
Actions	New Construction, Replace on Fail, Replace Working
Required from Customer/Contractor	Input capacity of the new condensing unit heater, project location, thermal efficiency
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	12 (Ref. 1)
Unit Participant Incremental Cost	$676 (Ref. 2)

Measure Description

This measure applies to a gas fired condensing unit heater installed in a commercial application.

Algorithms

Unit Dth Savings per Year = BTUH_in x Load_Factor x $EFLH_{HEAT}$ x Eff_High x (1/Eff_Base – 1/Eff_High) / Conversion_Factor

Where:

Btuh Input = Nominal rating of the input capacity of the new condensing unit heater in Btu/h

Load_Factor = Load factor, assumed to be 0.77 (Ref. 3)

$EFLH_{HEAT}$ = the equivalent full load hours, see Table 1

Eff Base = Efficiency of the baseline, standard is 80% (Ref. 5)

Eff High = Thermal efficiency of the new condensing unit heater, supplied by customer/contractor, if unsure use 90% (Ref. 6)

Conversion_Factor = 1,000,000 Btuh/Dth

Example:

Replacing an 80% efficient 280,000 Btuh unit heater in an average Minneapolis building with a 280,000 Btuh condensing unit heater.

Unit Dth Savings per Year = 280,000 Btuh x .77 x 1739 EFLH x 80% x (1/80% - 1/90%) / 1,000,000 Btuh/Dth = 41.7 Dth

Deemed Input Tables

Table 1. Equivalent Full Load Hours of Heating per zone in Minnesota by building type (Ref. 4)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	1887	1699	1546
Education – Community College/University	1972	1776	1616
Education – Primary	2394	2156	1961
Education – Secondary	2561	2306	2098
Health/Medical – Clinic	2234	2012	1830
Health/Medical – Hospital	2508	2258	2054
Lodging	2361	2126	1934
Manufacturing	1397	1258	1144
Multifamily	2324	2092	1904
Office-Low Rise	1966	1770	1610
Office-Mid Rise	2189	1971	1793
Office-High Rise	2149	1935	1760
Restaurant	1868	1681	1530
Retail – Large Department Store	1763	1587	1444
Retail – Strip Mall	1701	1531	1393
Warehouse	1872	1685	1533
Other/Miscellaneous	2123	1911	1739

$EFLH_{HEAT}$ were determined from prototypes building models based on the California DEER study prototypes modified Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone 3). Values were scaled as follows: $EFLH_{MN} = EFLH_{IL} \times HDD_{55,MN} / HDD_{55,IL} \times DTD_{IL} / DTD_{MN}$, where DTD is the design temperature difference.

Table 2. Heating Degree Days and Design Temperature Difference

Geography	HDD55	DTD
Chicago, IL	4,029	73.5
MN Zone 1	6,956	92
MN Zone 2	5,888	86.5
MN Zone 3	5,233	84.5

References

1. Database for Energy Efficient Resources (DEER) 2008
2. ENERGY STAR and CEE do not currently provide calculators for this type of equipment therefore deemed values from Nicor Gas were used. Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

3. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010. This factor implies that heating systems are 30% oversized on average.
4. FES scaled EFLH from those provided in the Illinois Technical Reference Manual based on Minnesota weather data. EFLH for the Illinois Technical Reference Manual were based on the California DEER study prototypes modified by Illinois field data to closely match EFLH from the modeling to those calculated from field data.
5. ASHRAE 90.1 2007, Heating, Ventilating, and Air Conditioning, Table 6.8.1E
6. Illinois Statewide Technical Reference Manual for Energy Efficiency (Effective 6-1-15) Measure 4.4.5 Condensing Unit Heaters
7. National Climate Data Center – National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.
8. 2013 ASHRAE Handbook – Fundamentals, Table 1A Climate Design Information, Minnesota Heating DB 99.6%.

Revision History

Version	Description	Author	Date
1.0	Created standalone Specifications for Condensing Unit Heaters	Franklin Energy Services	11/10/2015

C/I HVAC – Demand Control Ventilation

Measure Detail	Measure Value
Measure ID	2.02.31
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC
Applicable To	Commercial and industrial customers where air unitary equipment has been/could be installed
Actions	Replace Working (addition on working equipment)
Required from Customer/Contractor	Existing equipment type, existing equipment nominal cooling capacity in tons, existing equipment EER/SEER, building type (refer to Table 1), project location (county)
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	See Table 2 (Ref. 2)

Measure Description

This measure includes the retrofit of existing constant volume equipment or the optional addition of demand control ventilation. This measure analyzes the heating and cooling savings potential of the installation of demand control ventilation on unitary equipment. This measure is applicable to DX and water cooled air systems with natural gas heating.

The incremental cost is associated with CO2 sensor equipment cost and programming, the incremental cost does not include any damper actuator installation costs.

Algorithms

Unit kWh Savings per Year = (4.5 x CFM_pre x Δh) x ($EFLH_{COOL}$ x 1 / SEER) x SF_C /1000

Unit Dth Savings per Year = [(1.08 x CFM_pre)/η x HDD65 x Hours] / 1,000,000 x SF_H

Where:

CFM_pre = Constant outside air flow in cubic feet per minute, for systems with supply and exhaust fans the supply fan flow shall be used, Provided by customer/contractor.

Δh = Difference in enthalpy (Btu/lbm) between the design day outside air conditions (Ref. 3) and the return air conditions (Ref.4) See Table 1.

$EFLH_{COOL}$ = Equivalent full load cooling hours based on the building type. See Table 2. (Ref. 5)

EER = Energy efficiency ratio of the existing equipment, provided by the customer (Ref. 6) Assume EER = 10.9 in unavailable. (Ref. 7)

Hours	= Average hours per day of operation. Provided by customer.
HDD65	= Heating Degree Days See Table 1. (Ref. 8)
SF_C	= Deemed cooling savings factor based upon building type. See Table 2. (Ref. 9)
SF_H	= Deemed Heating savings factor based upon building type. See Table 2. (Ref. 9)
η	= Efficiency of heating equipment. Assume 0.8 (Ref. 12) unless different efficiency is provided by owner.
1.08	= Conversion factor for flow rate and specific volume of air
4.5	= Conversion factor for BTU, flow rate and specific volume
1,000,000	= Conversion factor for BTU to Dth

Example:

Install a CO2 senor in the return duct for a 13 SEER packaged rooftop installed on a low rise office building open on average 12 hours per day in Climate Zone 3. OA supply existing is 1500 cfm.

Unit kWh Savings per Year = (4.5 x 1500 x (36.55 – 29.07)) x (446 x 1 / (13)) x 0.15 / 1000= 260 kWh

Unit Dth Savings per Year = ((1.08 x 1500) / 0.8 x 7651 x 12) / 1,000,000 x 0.28= 52 Dth

Deemed Input Tables

Table 1. Enthalpies, heating degree days and incremental costs

Zone	Design Cooling h (Btu/lbm) (Ref. 3)	Cooling Return h (Btu/lbm) (Ref. 4)	HDD65 (°F-days) (Ref. 8)	Incremental Cost ($/CFM) (Ref. 2)
Northern: #1	32.40	28.36	9,833	1.32
Central: #2	35.55	28.36	8,512	1.32
Southern: #3	36.55	28.36	7,651	1.32

Table 2. Cooling and Heating Savings Factors and Equivalent Full Load Hours of cooling per zone (Ref. 5) in Minnesota by building type

Building Type	SF_C (Ref. 9)	SF_H (Ref. 9, Ref. 13)	EFLH		
			Zone 1	Zone 2	Zone 3
Convenience Store	0.34	0.63	647	825	986
Education – Community College/University	0.34	0.63	682	782	785
Education – Primary	0.34	0.63	289	338	408
Education – Secondary	0.34	0.63	484	473	563
Health/Medical – Clinic	0.29	0.34	558	738	865
Health/Medical – Hospital	0.34	0.40	663	1,089	1,298
Lodging	0.15	0.18*	401	606	754
Manufacturing	0.29	0.53	347	472	589
Office-Low Rise	0.15	0.28	257	359	446

Building Type	SF_C (Ref. 9)	SF_H (Ref. 9, Ref. 13)	EFLH		
			Zone 1	Zone 2	Zone 3
Office-Mid Rise	0.15	0.28	373	529	651
Office-High Rise	0.15	0.28	669	1,061	1,263
Restaurant	0.34	0.62	347	535	652
Retail – Large Department Store	0.34	0.62	462	588	686
Retail – Strip Mall	0.34	0.62	307	441	574
Warehouse	0.31	0.36	164	343	409
Other/Miscellaneous	0.30	0.51	443	612	729

* Value is applicable to Common Areas and Conference Rooms and not to sleeping areas

Methodology and Assumptions

$EFLH_{COOL}$ were determined from based prototypes building models on the California DEER study prototypes modified Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Assumed ventilation rates complied with the requirements of ASHRAE standard 62.1 – 2004. Incremental costs include controls and programming and assume similar cost between dx and water cooled equipment.

Savings assume constant volume air system.

Assumes existing economizer operation and economizer operation is given preference over demand control ventilation strategy.

Assumes savings in hospitals and clinics is limited to those areas not having code required ACH of fresh air.

Gas savings algorithm is derived from the following:

Energy = Design Heating Load / η x $EFLH_{HEAT}$ x conversion

Where:

Design Heating Load = (1.08 x CFM x ΔT),

$EFLH_{HEAT}$ = HDD65 x 24 / ΔT x Hours/24

ΔT = Difference in temperature (°F) between the return air conditions (Ref. 5) and the design day outside air conditions

Unit Dth Savings per Year = [(1.08 x CFM x ΔT)/η x (HDD65 x Hours /ΔT)] / 1,000,000 x SF_H

Unit Dth Savings per Year = [(1.08 x CFM_pre)/η x HDD65 x Hours] / 1,000,000 x SF_H

Effective January 1, 2023, HVAC products will be subject to regional minimum efficiencies, according to Seasonal Energy Efficiency Ratio 2 (SEER2). The nomenclature of SEER2, EER2 and HSPF2 will be used to denote the new M1 ratings. Conversion between the new M1 ratings and original M ratings should be done using an AHRI approved method, using the multipliers in Table 2 and Table 3 below.

Table 2. M to M1 Forward Conversion (Ref. 14)

System Type	Multiplier to convert to SEER2	Multiplier to convert to EER2	Multiplier to convert to HSPF2
Ducted	0.95	0.95	0.85
Ductless	1.00	1.00	0.90
Packaged	0.95	0.95	0.84

Table 3. M1 to M Backward Conversion (Ref. 14)

System Type	Multiplier to convert to SEER	Multiplier to convert to EER	Multiplier to convert to HSPF2
Split System Air Conditioner	1.05	1.04	N/A
Split System Heat Pump	1.05	1.04	1.18
Packaged Air Conditioner	1.04	1.04	N/A
Packaged Heat Pump	1.04	1.04	1.18
Ductless Heat Pump	1.00	1.00	1.12
Space Constrained System	1.01	1.00	1.17
Small Duct High Velocity System	1.00	1.00	1.18

Notes

The 2015 Minnesota Energy Code generally requires Demand Controlled Ventilation be provided for spaces larger than 500 square feet (50 m2) and with an average occupant load of 25 people per 1000 square feet (93 m2) of floor area. Please reference Section C403.2.5.1 Demand controlled ventilation of the 2015 Minnesota Energy Code for specific requirements.

References

1. Assumed Service life limited by controls and control life referenced from “Demand Control Ventilation Using CO2 Sensors”, pg. 19, by US Department of Energy Efficiency and Renewable Energy
2. “Demand Control Ventilation Using CO2 Sensors”, pg. 2, by US Department of Energy Efficiency and Renewable Energy and with an assumed zone size of 1500 Outside Air CFM
3. Psychometric Calculator, by KW Engineering and from ASHRAE 2009. Cooling DB/MCWB @ 1.0% for each TRM weather zone.
4. Assumed cooling set point of 74°F and 50% relative humidity with a 2°F temperature rise in the return plenum, FES
5. Calculated through energy modeling of California DEER study prototypes modified by Illinois field data with TMY3 Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3) by FES 2012

6. "ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment"
7. "Small Commercial HVAC, Surveying the Frontier of Energy Efficiency", by Lee DeBallie, PE – Energy Center of Wisconsin
8. National Climate Data Center – National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.
9. Calculated through energy modeling by FES with certain building type SF modified based upon economizer operation hours. Savings where limited to 40% based upon professional experience due to concerns for negative building pressurization and minimum outside air requirements per sq. ft of occupied facility. Higher values may be obtained, but custom calculations would be required.
10. Assumed heating set point of 70°F, FES
11. 2009 ASHRAE Handbook HVAC Fundamentals
12. Assumed standard combustion efficiency of heating equipment, FES
13. Seventhwave. Energy Savings from Implementing and Commissioning Demand Control Ventilation. July 2015. http://mn.gov/commerce-stat/pdfs/card-report-energy-savings-demand-control-ventilation.pdf
    Indicates heating savings factors should be increased by 56%.
14. Consortium for Energy Efficiency. CEE Residential Electric HVAC Specification. Published October 18, 2023. https://cee1.my.site.com/s/resources?id=a0V2R00000sUQbyUAG

Revision History

Version	Description	Author	Date
2.0	Added 2015 Minnesota Energy Code Information. Updated $EFLH_{COOL}$ format and description and added Other category.	Franklin Energy Services	11/12/15
3.0	Updated equation, updated heating savings factors based on CARD study,	Cadmus	11/1/2018
4.1	Clarification to SEER2, EER2 and HSPF2 conversions	Cadmus	11/1/2023

C/I HVAC – Energy Recovery Ventilator (ERV)

Measure Detail	Measure Value
Measure ID	2.02.32
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC
Applicable To	Commercial and industrial customers where energy recovery equipment could be installed
Actions	Replace on Fail, Replace Working, Modify
Required from Customer/Contractor	ERV type, outside air cfm, building hours of operation, project location (county), cooling system type
Measure Energy Type	Electric (demand only), Gas
Unit kWh Savings per Year	0 (Ref. 11)
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	See Table 4 (Ref. 2)

Measure Description

This measure includes the optional addition of energy recovery on existing air side equipment, and also on new equipment where energy recovery is not required by current building codes. This measure analyzes the heating savings potential of an energy recovery ventilator on air side equipment. This measure is applicable to all gas-fired heated air systems (Dth and kW demand savings), and all electric ASHP heated air systems (kWh and kW demand savings). Current energy Minnesota Commercial Energy Code specifies energy recovery requirements by climate zone and percent outdoor air at design flow rate. The requirements for ERVs for Minnesota climate zones are shown in Table 5 (Ref 18). All large ERV systems (10,000 CFM+) installed should be fully commissioned and design flow rates should be validated against as operated flows. Control sequences should follow ERV manufacturer recommendations and any deviations should be justified by project engineers (Ref 18).

Algorithms

ASHP Electric Heating System:

Unit kWh Savings per Year = ((4.5 x CFM x Δh_heating) / η_ASHP x ((HDD65 x 24) / (T_indoor – T_design)) x (Hours / 24)) / 3,412 x ERV_E x 0.75

Unit Peak kW Savings = ((4.5 x CFM x Δh_cooling) x (1 / EER x ERV_E)/1000 – (CFM x PD / 6356 / Eff_Motor / Eff_Fan x 0.75) x CF

Gas Fired Heating System:

Unit Dth Savings per Year = ((4.5 x CFM x Δh_heating) / η_Furnace x ((HDD65 x 24) / (T_indoor – T_design)) x (Hours / 24)) / 1,000,000 x ERV_E x 0.75

Unit Peak kW Savings = ((4.5 x CFM x Δh_cooling) x (1 / EER x ERV_E)/1000 – (CFM x PD / 6346 / Eff_Motor / Eff_Fan x 0.75) x CF

Where:

CF	= Coincidence Factor = 0.9 (Ref. 8)
CFM	= Outside Air Flow in cubic feet per minute
EER	= Provided by customer. If SEER provided use EER = 1.12 x SEER – 0.02 x $SEER^2$ (Ref. 10). If value not provided use default values in Table 3. (Ref. 6).
Eff_Fan	= Efficiency of Fan. Provided by customer. If value not provided assume 0.705 (Ref. 13)
Eff_Motor	= Efficiency of Motor. Provided by customer. If value not provided assume 0.855 (Ref. 14)
ERV_E	= Total Energy Effectiveness of ERV. Provided by manufacturer/customer If values are not provided use default values in Table 4. (Ref. 7)
Hours	= Hours of ventilation operation, annual daily average run time during which heat/cooling is being recovered, based on the assumption that ERV is selected to provide adequate ventilation rate when operated continuously on the coldest day of the year. Provided by customer. If none provided, assume 12. (Ref. 15)
HDD65	= Heating Degree Days See Table 1. (Ref. 3)
PD	= Additional Pressure Drop through heat exchanger, inches of Water Column per CFM. Provided by customer. If value is not provided see values in Table 4. (Ref. 7)
T_indoor	= Customer provided indoor heating conditioned space temperature in °F. See Table 1 for default values if not provided.
T_design	= the equipment design heating temperature of the climate zone. See Table 1. (Ref. 4)
η_ASHP	= Efficiency of electric ASHP heating equipment. Assume 7.7 HSPF (Ref. 6) unless different efficiency is provided by customer.
η_Furnace	= Efficiency of gas fired heating equipment (furnace, boiler). Assume 0.8 (Ref. 9) unless different efficiency is provided by customer.
Δh_cooling	= Difference in enthalpies (btu/lb) between the design day cooling enthalpy and exhaust air heat exchanger inlet enthalpy. See Table 2 for default values if not provided.
Δh_heating	= Difference in enthalpies (btu/lb) between the exhaust air heat exchanger inlet enthalpy and design day heating enthalpy. See Table 1 for default values if not provided.

4.5	= Conversion factor for flow rate and specific volume of air at standard room conditions and minutes to hours (0.075 lb/cubic foot at 1 atm and 68 degrees F x 60 min/hr = 4.5)
6,346	= Conversion factor for ft-lb/min to horsepower, and psi to inches of water (33,013 ft-lb/min divided by 5.202 inches of water per pound/square foot = 6,346)
1,000	= Conversion factor of watts per kWh
1,000,000	= Conversion factor for BTU to Dth
3,412	= Conversion factor for BTU to kWh
0.75	= factor to account for prevention of freezing of condensate. Control strategies incorporate full air flow by-pass or other strategies that reduce the number of hours of operation at lower temperatures, multiply ERE_E by 0.75 if not adjusted by manufacturer or customer. (Ref. 15)
24	= Conversion factor, 24 hours per day

Example:

Install a rotary heat recovery wheel on a low-rise office building in Climate Zone 3. The outside air existing supply rate is 1500 cfm, and the building is open and conditioned on average 12 hours per day. The cooling system utilizes a 15 EER Air-Cooled Chiller.

Unit peak kW Savings = (((4.5 x 1500 x (36.55– 28.36)) x1 / 15 x 0.730)/1000 – (1,500 x 0.00012 / 6346 / 0.855 / 0.705 x 0.75)) x 0.9 = 2.7 kW

Unit Dth Savings per Year = ((4.5 x 1500 x (25.34 – (-3.29)) / 0.8) x (7,651 x 24) / (70.0 – (-14.5)) x 12 / 24) / 1,000,000 x 0.730 x 0.75 = 143.7 Dth

Deemed Input Tables

Table 1. Heating design temperatures, heating enthalpies and heating degree days base 65

Climate Zone	Design Day Heating Outside Air Conditions		Return Air Conditions Heating		ΔT_heating	Δh_heating	HDD65 (Ref. 9)
	T_Design Heating (°F) (Ref. 4)	Enthalpy (Btu/lb) (Ref. 12)	T_Indoor Temp.(°F) (Ref. 5)	Enthalpy (Btu/lb) (Ref. 12)	Temp.(°F)	Enthalpy (Btu/lb)	
Zone 1 (Northern)	-22.0	-5.16	70.0	25.34	92.0	30.5	9,833
Zone 2 (Central)2	-16.5	-3.79	70.0	25.34	86.5	29.1	8,512
Zone 3 (Southern/ Twin Cities)	-14.5	-3.29	70.0	25.34	84.5	28.6	7,651

Table 2. Cooling design temperatures and enthalpies

Climate Zone	Design Day Cooling Outside Air Properties	Return Air Conditions Cooling		Δh_cooling
	Enthalpy (Btu/lb) (Ref. 12)	T_Indoor Temp.(°F) (Ref. 5)	Enthalpy (Btu/lb) (Ref. 12)	Enthalpy (Btu/lb)
Zone 1 (Northern)	32.40	76.0*	28.36	4.04
Zone 2 (Central)	35.55	76.0*	28.36	7.19
Zone 3 (Southern/ Twin Cities)	36.55	76.0*	28.36	8.19

* Assuming 74F air at 50% RH with an additional 2F duct temperature rise

Table 3. EER values for various equipment (ref.6)

Equipment Type	Capacity	EER
Very Small ASHP or AC (Single Package)	< 65,000 Btu/h	12.5
Very Small ASHP or AC (Split System)	< 65,000 Btu/h	12.0
Small commercial ASHP or AC	≥ 65,000 Btu/h – < 135,000 Btu/h	11.6
Medium commercial ASHP	≥135,000 Btu/h <240,000 Btu/h	10.7
Large commercial ASHP	≥240,000 Btu/h	9.3
GSHP	Any	17.1
Air/Water Cooled Chiller	Any	15.0

Table 4. Energy Recovery Effectiveness Factor, Pressure Drop and Incremental Cost

Energy Recover Type	ERV-E Total Heating Effectiveness	PD Pressure Drop /CFM Inches WC/CFM	Incremental Cost** /CFM
	(Ref.7)	(Ref. 7)	(Ref. 2)
Fixed Plate – (Sensible Heat Only)	0.355	0.00035	$6
Fixed Plate – (Sensible and Latent Heat)	0.640	0.00074	$6
Fixed Plate – Unknown	0.498	0.00055	$6
Membrane Plate	0.660	0.00055	$6
Rotary Wheel	0.730	0.00012	$6
Heat Pipe	0.310	0.00011	$6

** Cost includes cabinet and controls incorporated into packaged and built up air handler units.

Methodology and Assumptions

Default efficiencies assume 1-to-1 ratio of fresh vs. exhaust/relief air. Savings do not include any savings from reduced energy for humidification.

Studies have shown that potential cooling savings (9-23% of load) are frequently offset by the increased fan energy in all Minnesota climate zones but could reduce peak demand load by up to 50% when operated in cooling season (Ref 18). For this reason, kWh cooling savings are not quantified in this measure, but peak kW demand savings have been quantified. Customers are encouraged to operate installed ERVs in both mechanical heating and mechanical cooling conditions, but particularly when OSA temperatures are between 0 – 45 degrees F, when 60-80% of potential savings can be realized (Ref 18).

Code requires Energy Recovery Ventilation for most applications based upon the table below. The "green code" ASHRAE Standard 189 further reduces outdoor air thresholds requiring ERV and increases minimum ERV effectiveness to 60%.

Table 5. Design Supply Fan Air Flow Rate (CFM)

CLIMATE ZONE	Percentage Outdoor Air at Full Design Air Flow Rate					
	≥ 30% and < 40%	≥ 40% and < 50%	≥ 50% and < 60%	≥ 60% and < 70%	≥ 70% and < 80%	≥ 80%
6A (MN)	≥ 5,500	≥ 4,500	≥ 3,500	≥ 2,000	≥ 1,000	> 0
7*	≥ 2,500	≥ 1,000	> 0	> 0	> 0	> 0

*ASHRAE Zone 7 MN counties include: Aitkin, Becker, Beltrami, Carlton, Cass, Clay, Clearwater, Cook, Crow Wing, Grant, Hubbard, Itasca, Kanabec, Kittson, Koochirching, Lake, Lake of the Woods, Mahnomen, Marshall, Mille Lacs, Norman, Otter Tail, Pennington, Pine, Polk, Red Lake, Roseau, St. Louis, Wadena, Wilkin

Effective January 1, 2023, HVAC products will be subject to regional minimum efficiencies, according to Seasonal Energy Efficiency Ratio 2 (SEER2). The nomenclature of SEER2, EER2 and HSPF2 will be used to denote the new M1 ratings. Conversion between the new M1 ratings and original M ratings should be done using an AHRI approved method, using the multipliers in Table 2 and Table 3 below.

Table 6. M to M1 Forward Conversion (Ref. 17)

System Type	Multiplier to convert to SEER2	Multiplier to convert to EER2	Multiplier to convert to HSPF2
Ducted	0.95	0.95	0.85
Ductless	1.00	1.00	0.90
Packaged	0.95	0.95	0.84

Table 7. M1 to M Backward Conversion (Ref. 17)

System Type	Multiplier to convert to SEER	Multiplier to convert to EER	Multiplier to convert to HSPF2
Split System Air Conditioner	1.05	1.04	N/A
Split System Heat Pump	1.05	1.04	1.18
Packaged Air Conditioner	1.04	1.04	N/A
Packaged Heat Pump	1.04	1.04	1.18
Ductless Heat Pump	1.00	1.00	1.12
Space Constrained System	1.01	1.00	1.17
Small Duct High Velocity System	1.00	1.00	1.18

References

1. Assumed service life limited by controls –" Demand Control Ventilation Using CO2 Sensors", pg. 19, by US Department of Energy Efficiency and Renewable Energy.
2. "Map to HVAC Solutions", by Michigan Air, Issue 3, 2006.
3. National Climate Data Center – National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.
4. 1997 ASHRAE Handbook HVAC Fundamentals.
5. Assumed heating set point of 70°F and cooling set point of 72° F with a 2F temperature rise in the return ducting and 50% relative humidity
6. 2024 Minnesota Energy Code with ANSI/ASHRAE/IES Standard 90.1-2019. Section 6.8.1 Minimum Efficiency Requirement Listed Equipment—Standard Rating and Operating Conditions Effective January 5, 2024. https://codes.iccsafe.org/content/MNEC2024P1/6-heating-ventilating-and-air-conditioning#MNEC2024P1_Ch06_Sec6.8
7. Analysis of AHRI listed devices available 1/1/2016.
8. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to with most being very close to 0.9, primary data has not been identified.

9. Title 10, Code of Federal Regulations, Part 431 – Energy Efficiency Program for Certain Commercial and Industrial Equipment. November 2023. https://www.energy.gov/femp/incorporate-minimum-efficiency-requirements-heating-and-cooling-products-federal-acquisition
10. ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment. This value is given as a SEER and is modified as EER = 1.12 x SEER – 0.02 x $SEER^2$ for single stage equipment.
11. It is assumed cooling savings are equal to the increased fan energy usage.
12. Psychometric Calculator, by kW Engineering and from ASHRAE 2009 Cooling DB/MCWB @ 1.0% for each TRM weather zone
13. Average Fan efficiency for centrifugal fans from the Energy Efficiency Guide Book (2004), Chapter 5, Bureau of Energy Efficiency, Government of India.
14. Assumed average 5 HP Nema EPAct Open Frame motor efficiency.
15. Franklin Energy Services estimate of operational hours.
16. Values calculated using psychrometric conditions at 1000ft and 50% relative humidity.
17. Consortium for Energy Efficiency. CEE Residential Electric HVAC Specification. Published October 18, 2023. https://cee1.my.site.com/s/resources?id=a0V2R00000sUQbyUAG
18. Center for Energy and Environment. MN CARD Final Report: *Energy Recovery in Minnesota Commercial and Institutional Buildings: Expectations and Performance*. April 28, 2017. https://mn.gov/commerce-stat/pdfs/card-report-cee-erv.pdf

Revision History

Version	Description	Author	Date
2.0	Added kW Peak savings. Removed gas algorithm derived from notes and added full equation to reduced equation algorithm. Updated code requirements.	Franklin Energy Services	1/1/16
2.1	Changed to total (sensible and latent) energy savings	Franklin Energy Services	1/1/16
2.2	Updated return-air enthalpy to reflect 70F, 50% relative humidity and sea-level altitude. Updated example calculation.	Franklin Energy Services	12/4/17
3.0	Updated equation, broadened measure definition, clarified baselines	Cadmus	11/2018
3.3	Updated and clarified equation inputs and units	Cadmus	10/2020
4.1	Clarification to SEER2, EER2 and HSPF2 conversions	Cadmus	11/1/2023
5.0	Added newer CARD study reference to support updates to metrics presented in measure. Added kWh heating savings from electric driven (ASHP) heating systems.	Cadmus	9/1/2025

C/I HVAC – Exhaust Energy Recovery

Measure Detail	Measure Value
Measure ID	2.02.33
Target Market Segments	Commercial, Industrial
Target End Uses	HVAC
Applicable To	Commercial and industrial customers where energy can be recovered from exhausted air
Actions	Replace Working, New Construction, Modify
Required from Customer/Contractor	Air to liquid or Air to Air heat exchanger type (fixed plate or runaround loop), exhaust air CFM, exhaust air temperature, hours per year of operation, temperature of media being heated
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	15 years (Ref. 1)
Unit Participant Incremental Cost	See Table 1 (Ref. 2)

Measure Description

This measure includes the addition of energy recovery on new and existing exhaust systems. This measure analyzes the heating savings potential of the heat energy recovery from exhausted air. This analysis assumes there is a requirement of heating capacity greater than the potential for recovery. This measure is applicable to HVAC and process exhaust air systems above 100° F.

Algorithms

Unit kWh Savings per Year = - (CFM x PD / 6356 / Eff_Motor / Eff_Fan x 0.746 x 2 x Hours)

Unit Peak kW Savings = - (CFM x PD / 6356 / Eff_Motor / Eff_Fan x 0.746 x 2)

Unit Dth Savings per Year = 1.08 x CFM x ΔT x Hours x ERV_E / (1,000,000 x η)

Where:

CFM	= Exhaust Air flow in cubic feet per minute
Eff_Fan	= Efficiency of Fan. Provided by customer. If value is not provided assume 0.69 (Ref. 10)
Eff_Motor	= Efficiency of Motor. Provided by customer. If value is not provided assume 0.855 (Ref. 11)
ERV_E	= Sensible Energy Effectiveness of ERV. Provided by manufacturer or customer. If value is not provided see Table 1.
Hours	= Hours of operation per year. Provided by customer.
PD	= Pressure Drop increase. Provided by customer. If value not provided assume 1” WC. (Ref. 12)

ΔT	= T_exhaust – T_media Difference in temperature (°F) between the exhaust air heat exchanger inlet and temperature of media being heated.
T_ exhaust	= Temperature of exhaust (°F). Provided by customer. If value not provided assume 131.4° F. (Ref. 3)
T_media	= Temperature of media being heated. Provided by customer. If value not provided see table 2 for possible applications.
η	= Efficiency of heating equipment of media gaining energy. Assume 0.8 (Ref. 4) unless different efficiency is provided by customer.
1.08	= Conversion factor for flow rate and specific volume of air and minutes to hours
6356	= Conversion factor for Flow and inches of water column to Horsepower
0.746	= Conversion Factor for Horsepower to KW
1,000,000	= Conversion facto for BTU to Dth
2	= Factor to account for similar power consumption for both sides of heat exchanger (Ref.12)

Example:

Install a runaround loop filters on a kitchen exhaust hood to pre-heat domestic hot water in zone 2. The kitchen hood operates 16 hours a day 360 days per year and exhausts and average of 1000 cfm.

Unit kW Savings = - (1,000 x 1 / 6356 / 0.69 / 0.85 x 0.746 x 2) = - 0.4 kW

Unit kWH Savings = - (1,000 x 1 / 6356 / 0.69 / 0.85 x 0.746 x 2 x 16 x 360) = - 2,292 kWh

Unit Dth Savings per Year = 1.08 x 1,000 x (131.4 – 49.1) x 16 x 360 x 0.60 / (1,000,000 x 0.8) = 384 Dth

Deemed Input Tables

Table 1. Air Heat Exchanger Sensible Effectiveness and Incremental Costs

Energy Recovery Type	Sensible Heating Effectiveness	Incremental Cost (Ref. 2)
Fixed Plate	0.54 (Ref. 5)	$3/CFM
Runaround Loop	0.60 (Ref. 6)	$3/CFM

Table 2. Air Heat Exchanger Application Media Temperatures

Heating Application	Zone 1 Media Temperature °F	Zone 2 Media Temperature °F	Zone 3 Media Temperature °F
Pre-Heat Incoming Domestic Water (Ref.7)	46.5	49.1	51.3
Re-Heat Ventilation Air (Ref.8)	55	55	55
Heat Water Source Heat Pump Loop (Ref.9)	60	60	60

Methodology and Assumptions

Runaround loop costs assume no special coatings and relatively short distance between coils.

References

1. Assumed service life limited by controls –" Demand Control Ventilation Using CO2 Sensors", pg. 19, by US Department of Energy Efficiency and Renewable Energy
2. "Map to HVAC Solutions", by Michigan Air, Issue 3, 2006
3. Kitchen exhaust temperature from picture 33 in article "Heat Load Based Design – Hood Studies", by Foodservice Society Consultants International
4. Assumed standard combustion efficiency of heating equipment, Franklin Energy Services Analysis of AHRI listed devices available 1/1/2016.
5. Laboratories for the 21st Century: Best Practices, Energy Recovery for Ventilation Air in Laboratories, Dept. of Energy, DOE/GO-102003-1774, October 2003.
6. Values are from DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Tables 8.2.13-14, 8.2.16 (http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch8.pdf). The values are interpreted with explanation in the "Cost Info" tab of this worksheet.
7. Responsible Energy, Reheat for Commercial Buildings, Madison Gas & Electric, GS1889, 10/28/2015
8. Trane Engineering Newsletter Volume 36-2, Energy Savings Strategies for Water Source Heat Pump Systems, ADM-APN024-EN (May 2007)
9. Average Fan efficiency from the Energy Efficiency Guide Book (2004), Chapter 5, Bureau of Energy Efficiency, Government of India.
10. Assumed average 5 HP Nema EPAct Open Frame motor efficiency.
11. Best design practice noted in Laboratories for the 21st Century: Best Practices, Energy Recovery for Ventilation Air in Laboratories, Dept. of Energy, DOE/GO-102003-1774, October 2003.

Revision History

Version	Description	Author	Date
1.0	New savings specification for retrofit/incorporation of energy recovery.	Franklin Energy Services	8/1/2012
1.1	Changed Table 2 footnote from "reduce efficiency by 75%" to "multiply efficiency by 0.75" to be clear, changed action to replace working, fixed example calculation, changed description from "applicable to all exhaust air systems" to "applicable to HVAC and kitchen hood exhaust air systems", changed days to year from 365 to 365.25 for consistency with other measures	Joe Plummer	3/13/2013
1.2	Added New Construction and Modify to Action Types	Joe Plummer	11/24/13

Version	Description	Author	Date
1.3	Modified equation to be HDD based, instead of temperature based to reflect savings for heating season only. Change exhaust air temperature reference to typical building occupied set point. Changed conversion factor from 1.08 to 4.5 to correct change in equation base. Added heating degree days and enthalpies definitions. Update example. Modified Table 2 to include return air temperature, enthalpies and HHD values. Changed notes. Added references.	Franklin Energy Services	7/18/2014
1.4	Corrected example and typos, added reference for efficiency derating factor.	Joe Plummer	8/1/2014
2.0	Corrected reference numbering. Changed equation format to be consistent with other measures.	Franklin Energy Services	11/12/2014
2.1	Changed to sensible only based equation. Removed EFLH. Added kW and kWH penalties, corresponding references and heating application table.	Franklin Energy Services	1/12/2016

C/I HVAC – Forced-Air Heating Maintenance

Measure Detail	Measure Value
Measure ID	2.02.34
Target Market Segments	Commercial
Target End Uses	HVAC
Applicable To	Commercial customers with natural gas-fired, forced-air heating systems
Actions	Operations & Maintenance
Required from Customer/Contractor	Nominal Btu/h input of heating system, project location (county), building type
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	2 (Ref. 1)
Unit Participant Incremental Cost	$0.83/Mbtuh (Ref. 2)

Measure Description

This measure includes the maintenance of forced-air space heating systems in commercial spaces. This includes furnaces, RTUs, unit heaters, and makeup air units, for example. This does not include boiler or infrared heater maintenance. This measure applies to heating equipment in space heating applications only.

Algorithms

Unit Dth Savings per Year = (Percentage Savings) x (Pre-Annual Consumption)

Where:

Pre-Annual Consumption (Dth/yr) = Btuh_In x Load_Factor x $EFLH_{HEAT}$ / Conversion_Factor

Percentage Savings = percentage of the pre-modification annual consumption saved. Assumed to be 1.6% on average. (Ref. 5)

Btuh_In = the nominal rating of the input capacity of the heating equipment in Btu/h

Load_Factor = oversizing factor, assumed to be 77% (Ref. 3)

$EFLH_{HEAT}$ = the heating equivalent full load hours of heating. See Table 1.

Conversion_Factor = 1,000,000 Btu/Dth

Example:

For maintenance performed on a 150 Mbtuh heating unit in Zone 2 on an unknown building type:

Pre-Annual Consumption (Dth/yr) = 150,000 x 0.77 x 1911 /1,000,000 = 221 Dth

Gas Energy Heating Savings (Dth/yr) = 0.016 x 221 = 3.5 Dth

Deemed Input Tables

Table 1. Equivalent Full Load Hours of heating per zone in Minnesota by building type (Ref. 4)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	1887	1699	1546
Education – Community College/University	1972	1776	1616
Education – Primary	2394	2156	1961
Education – Secondary	2561	2306	2098
Health/Medical – Clinic	2234	2012	1830
Health/Medical – Hospital	2508	2258	2054
Lodging	2361	2126	1934
Manufacturing	1397	1258	1144
Multifamily	2324	2092	1904
Office-Low Rise	1966	1770	1610
Office-Mid Rise	2189	1971	1793
Office-High Rise	2149	1935	1760
Restaurant	1868	1681	1530
Retail – Large Department Store	1763	1587	1444
Retail – Strip Mall	1701	1531	1393
Warehouse	1872	1685	1533
Other/Miscellaneous	2123	1911	1739

Notes

There are currently no existing Minnesota state-wide or federal efficiency standards for heating maintenance.

$EFLH_{HEAT}$ were determined from based prototypes building models on the California DEER study prototypes modified Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3). Values were scaled as follows: $EFLH_{MN} = EFLH_{IL} \times HDD_{55,MN} / HDD_{55,IL} \times DTD_{IL} / DTD_{MN}$, where DTD is the design temperature difference.

Table 2. Heating Degree Days and Design Temperature Difference

Geography	HDD55	DTD
Chicago, IL	4,029	73.5
MN Zone 1	6,956	92
MN Zone 2	5,888	86.5
MN Zone 3	5,233	84.5

References

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc. June 2007. http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf
2. Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012
3. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010. This factor implies that heating systems are 30% oversized on average.
4. FES scaled EFLH from those provided in the Illinois Technical Reference Manual based on Minnesota weather data. EFLH for the Illinois Technical Reference Manual were based on California DEER study prototypes modified by Illinois field data to closely match EFLH from the modeling to those calculated from field data.
5. Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0, March 22, 2010. Assuming the same savings percentage value as Boiler Tune-Ups.

Revision History

Version	Description	Author	Date
1.0	Original document	Franklin Energy Services	7/30/2012
1.1	Changed name	Joe Plummer	2/11/2013
2.0	Changed from Heating Degree Days to $EFLH_{HEAT}$. Updated Table 2 to include building types.	Franklin Energy Services	11/12/2015

Commercial HVAC – Guest Room Energy Management Controls

Measure Detail	Measure Value
Measure ID	2.02.35
Target Market Segments	Commercial
Target End Uses	HVAC
Applicable To	Commercial and Public Buildings that serve as a lodging facility and are heated and cooled with PTAC, PTHP, or fan coil HVAC systems
Actions	Modify, Replace Working (retrofit), New Construction
Required from Customer/Contractor	1. Cooling system type (PTAC, PTHP, or chilled water fan coil) 2. Heating type (PTAC/electric resistance, PHTP, hot water PTAC or fan coil) 3. Cooling system size in BTU/hr, heating system size in BTU/hr
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	$260 (Ref. 2)

Measure Description

This measure includes the addition of enhanced guest room heating and cooling controls. Controls are available to minimize energy costs for guestroom HVAC systems. These controls use sensors to determine when a room is occupied. If the room is empty, the controls adjust the room temperature to an “unoccupied” setting. Regular settings are resumed when the guests return to their rooms. These controls are available in multiple forms, two of which are keycard based occupancy sensors and passive infrared occupancy monitors.

Algorithms

Unit kWh Cooling Savings per Year = (Cooling_Size / 1,000) x EFLH_cool x (1 / Cooling_Eff) x GREM_Savings

Unit Peak kW Savings = (Cooling_Size / 1,000) x (1 / Cooling_Eff) x GREM_Savings x CF

If electric heat:

Unit kWh Heating Savings per Year = (Heating_Size / 3,412) x (1 / Heating_Eff) x EFLH_heat x GREM_Savings

If gas heat:

Unit Dth Heating Savings per Year = Heating_Size / 1,000,000 x (1 / Heating_Eff) x EFLH_heat x GREM_Savings

Where:

Cooling_Size = nominal cooling capacity of the cooling system in BTU/hr, use 9,000 Btu/hr if unknown

1,000 = unit conversion, BTU to kBTU

EFLH_cool = cooling equivalent full load hours per Table 1 (Ref. 3)

Table 1. Equivalent Full Load Hours of cooling per zone in Minnesota by building type (Ref. 3)

Building Type	Cooling Equivalent Full Load Hours		
	Zone 1	Zone 2	Zone 3
Lodging	401	606	754

EFLH_heat = heating equivalent full load hours per Table 2 (Ref. 4)

Table 2. Equivalent Full Load Hours of heating per zone in Minnesota by building type (Ref. 4)

Building Type	Heating Equivalent Full Load Hours		
	Zone 1	Zone 2	Zone 3
Lodging	2361	2126	1934

Cooling_Eff = cooling efficiency of the HVAC system in units of EER, use actual or select from Table 3

Table 3. Cooling System EER (PTAC/PTHP, Ref. 5; CW Unit, Ref. 6)

HVAC Cooling System	Standard Size	Non-Standard Size
PTAC, < 7,000 BTU	11.9	9.4
PTAC, 7,000-15,000 BTU	14.0 – (0.300 x Cap/1000)	10.9 – (0.213 x Cooling_Size / 1,000)
PTAC, > 15,000 BTU	9.5	7.7
PTHP, < 7,000 BTU	11.9	9.3
PTHP, 7,000-15,000 BTU	14.0 – (0.300 x Cap/1000)	10.8 – (0.213 x Cooling_Size / 1,000)
PTHP, > 15,000 BTU	9.5	7.6
Chilled Water Fan Coil Unit	12.5	N/A

Cap = unit size in BTU/hr

Heating_Size = nominal heating capacity of the heating system in BTU/hr, for PTAC and PTHP units Cooling_Size may be used if heating capacity is unknown

3,412 = unit conversion, BTU per kWh

Heating_Eff = heating efficiency of the HVAC system in units of COP, use actual or select from Table 4

Table 4. Heating System COP (PTAC, See Assumptions; PTHP, Ref. 5; HW Unit, Ref. 7)

HVAC Heating System	Standard Size	Non-Standard Size
PTAC, All Sizes	1.0	1.0
PTHP, < 7,000 BTU	3.3	2.7
PTHP, 7,000-15,000 BTU	3.7 – (0.052 x Cap/1000)	2.9 – (0.026 x Cap/1000)
PTHP, > 15,000 BTU	2.9	2.5
Hot Water PTAC or Fan Coil Unit	0.8	N/A

Cap = unit size in BTU/hr

GREM_Savings = 18.4%, savings fraction for using guest room energy management controls (Ref. 8)

1,000,000 = unit conversion, BTU per dekatherm

CF = 0.90, deemed coincidence factor (Ref. 9)

Example 1:

A hotel customer installed a guest room energy management system for a room with a 9,000 BTU cooling / 9,000 BTU heating standard sized PTHP in climate zone 3.

Cooling_Eff = 14.0 – (0.300 x Cap/1,000) = 14.0 – (0.300 x 9,000/1,000) = 11.3

Cooling Savings = (9,000 / 1,000) x 754 x (1 / 11.3) x 0.184 = 110.5 kWh

Demand Savings = (9,000 / 1,000) x (1 / 11.3) x 18.4% x 0.9 = 0.132 kW

Heating_Eff = 3.7 – (0.052 x Cap/1,000) = 3.7 – (0.052 x 9,000/1,000) = 3.23

Heating Savings = (9,000 / 3,412) x (1 /3.23) x 1934 x 0.184 = 290.6 kWh

Total kWh Savings: 401 kWh

Total Peak kW Savings: 0.132 kW

Example 2:

A hotel customer installed a guest room energy management system for a room with a 9,000 BTU cooling / 9,000 BTU heating PTAC in climate zone 2.

Cooling_Eff = 14.0 – (0.300 x Cap/1,000) = 14.0 – (0.300 x 9,000/1,000) = 11.3

Cooling Savings = (9,000 / 1,000) x 606 x (1 / 11.3) x 0.184 =88.8 kWh

Demand Savings = (9,000 / 1,000) x (1 / 11.3) x 18.4% x 0.9= 0.132 kW

Heating Savings = (9,000 / 3412) x (1 / 1.0) x 2126 x 0.184 = 1031.8 kWh

Total kWh Savings: 1120.6 kWh

Total Peak kW Savings: 0.132 kW

Notes

$EFLH_{COOL}$ were determined from based prototypes building models on the California DEER study prototypes modified Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

$EFLH_{HEAT}$ were determined from prototypes building models based on the California DEER study prototypes modified by using ASHRAE fundamentals weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3). Values were scaled as follows: $EFLH_{MN} = EFLH_{IL} \times HDD_{55,MN} / HDD_{55,IL} \times DTD_{IL} / DTD_{MN}$, where DTD is the design temperature difference.

Table 5. Heating Degree Days and Design Temperature Differences

Geography	HDD55	DTD
Chicago, IL	4,029	73.5
MN Zone 1	6,956	92
MN Zone 2	5,888	86.5
MN Zone 3	5,233	84.5

References

1. DEER 2008 value for energy management systems (used by 2015 Illinois TRM)
2. Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 4.0, February 13, 2015, page 195 (source in IL TRM is actual project data from ComEd Smart Ideas program in program year 1 and 2).
3. FES calculated EFLH from energy models based on California DEER study prototypes modified by Illinois field data with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3) 2012.
4. FES scaled EFLH from those provided in the Illinois Technical Reference Manual based on Minnesota weather data. EFLH for the Illinois Technical Reference Manual were based on the California DEER study prototypes modified by Illinois field data to closely match EFLH from the modeling to those calculated from field data.
5. 2024 Minnesota Energy Code with ANSI/ASHRAE/IES Standard 90.1-2019. Section 6.8.1 Minimum Efficiency Requirement Listed Equipment—Standard Rating and Operating Conditions Effective January 5, 2024. https://codes.iccsafe.org/content/MNEC2024P1/6-heating-ventilating-and-air-conditioning#MNEC2024P1_Ch06_Sec6.8
6. ASHRAE Standard 90.1-2010, Energy Standard for Buildings Except Low-Rise Residential Buildings, Table 6.8.1C, average of air cooled chiller (9.562 EER) and ≥75 to <150 ton water cooled chiller (0.775 kW or 15.48 EER).
7. Title 10, Code of Federal Regulations, Part 431 – Energy Efficiency Program for Certain Commercial and Industrial Equipment, Subpart E – Commercial Packaged Boilers. January 1, 2010. https://www.ecfr.gov/cgi-bin/text-idx?SID=0fc362824764c46ec3f6e2af2a4b1e0f&mc=true&node=sp10.3.431.e&rgn=div6

8. Guest Room HVAC Occupancy-Based Control Technology Demonstration, US DOE Pacific Northwest National Laboratory, September, 2012. http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/creea_guest_room_occupancy-based_controls_report.pdf
9. 0.9 is a typical value used for central HVAC equipment in many programs. The range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	7/30/2015
1.1	Updating NG savings method to EFLH method	Franklin Energy Services	11/16/2015
1.2	Updated cooling efficiencies for standard sized PTACs. Added Cooling and heating efficiencies for non-standard sized PTACs and PTHPs.	Cadmus	11/2018

C/I HVAC – Programmable Thermostats with Electric Heating

Measure Detail	Measure Value
Measure ID	2.02.36
Target Market Segments	Commercial
Target End Uses	HVAC
Applicable To	Commercial customers in businesses noted in Table 1 with commercial unitary type heat pump heating equipment controlled by thermostats. Electricity must be the primary heating source to use this measure and building automation systems must not be incorporated.
Actions	Replace on Fail, Replace Working
Required from Customer/Contractor	Confirmation of electric heating, business type (see Table 1), program delivery type (see Table 2), location (county), size (cooling tons), efficiency (HPSF or COP –Table 3)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	0
Measure Lifetime (years)	8 (Ref. 1)
Unit Participant Incremental Cost	$181 (Ref. 2)

Measure Description

This measure includes replacement of failed or working manual thermostats in existing commercial businesses with programmable or smart thermostats. New units must have the capability to adjust temperature setpoints according to a schedule without manual intervention. An estimate is provided for reduced energy consumption through temperature set-back during unoccupied or reduced demand times. Savings make no other assumptions regarding sequence of operations incorporated into the programmable thermostat. Among sequence savings not considered are optimal start, outside air damper control, or other potential energy savings measures associated with occupancy.

Algorithms

Unit kWh Savings per Year = Savings kWh_{HEAT} + Savings kWh_{COOL}

Unit Savings kWh_{HEAT} = Hcelec x HSF x ISR

HC_{ELEC} = $EFLH_{HEAT}$ x $Size_{HEAT}$ x Load_Factor x EFF

Unit Savings kWh_{COOL} = CC_{ELEC} x CSF x ISR CC_{ELEC} = $EFLH_{COOL}$ x $Size_{COOL}$ x EFF

Where:

HC_{ELEC} = Heating consumption for electrically heated businesses

CC_{ELEC} = Cooling consumption for electrically air conditioned businesses

$EFLH_{HEAT}$ = Equivalent Full Load Hours heating, See Table #1. (See Assumptions, Ref. 3)

$ELFH_{COOL}$ = Equivalent Full Load Hours heating, See Table #1. (See Assumptions, Ref. 3)

$Size_{HEAT}$	=	Nominal capacity in tons of the equipment (1 ton = 12,000 btu/h) Capacity in tons, provided by customer/contractor. Convert from btu/h (12,000 btu/h = 1 ton) = 5.0 if unknown. (Ref. 4).
$Size_{COOL}$	=	Nominal capacity in tons of the equipment (1 ton = 12,000 btu/h) Capacity in tons, provided by customer/contractor or use = 5.0 if unknown
Load_Factor	=	boiler load factor, assumed to be 77% (Ref. 5)
EFFHEAT	=	equipment heating efficiency:
		For less than 5.5 tons: EFFHEAT = 12 / HSPF, Where HSPF = Heating system performance factor of existing equipment, provided by customer/contractor or use = 8.5 if unknown, see Table 3 (Ref. 6)
		For 5.5 tons or greater: EFFHEAT = 3.52 / COP, Where COP = Heating system performance factor of baseline or existing ASHP, provided by customer/contractor or use = 3.4 COP if unknown, see Table 3 (Ref. 6)
		If size is unknown assume 5 tons (Ref. 7)
EFFCOOL	=	equipment cooling efficiency:
		For less than 5.5 tons: EFFCOOL= 12 / SEER, Where SEER= Seasonal energy efficiency ratio of existing equipment, provided by customer/contractor or use = 15 if unknown, see Table 3 (Ref. 6)
		For 5.5 tons or greater: EFFCOOL = 12 / IEER, Where IEER = Integrated energy efficiency ratio of baseline or existing ASHP, provided by customer/contractor or use = 12.8 if unknown, see Table 3 (Ref. 6)
		If size is unknown assume 5 tons (Ref. 7)
HSF	=	Heating Savings Factor, assumed fraction reduction in heating energy consumption due to programmable thermostat, HSF = 0.05 (Ref. 8)
CSF	=	Cooling Savings Factor, assumed fraction reduction in cooling energy consumption due to programmable thermostat, CSF = 0.09% (See Assumptions, Ref. 10)
ISR	=	In-Service Rate, the percentage of units installed and programmed effectively, Table 2. (Ref. 9)

Examples:

Retrofit of a manual thermostat with a programmable thermostat in an electrically heated and air conditioned strip mall retail store in Climate Zone 1, via a direct installation program delivery. ASHP size is 60,000 btu/hr (5 tons), 8.5 HSPF and 15 SEER.

HC_{Elec} = 1701 x 5 x 0.77 x 12 / 8.5 = 9,245 kWh

Unit Savings kWh_{HEAT} = 9,245 x 0.05 x 1.0 = 462 kWh

CC_{ELEC} = 307 x 5 x 12 / 15 = 1,228 kWh

Unit Savings kWh_{COOL} = 1,228 x 0.09 x 1.0 = 111 kWh

Unit kWh Savings per Year = 462 kWh + 111 kWh = 573 kWh

Deemed Input Tables

Table 1. Equivalent Full Load Hours per zone in Minnesota by building type (Ref. 3)

Building Type	Heating			Cooling		
	Zone 1	Zone 2	Zone 3	Zone 1	Zone 2	Zone 3
Convenience Store	1887	1699	1546	647	825	986
Education –	1972	1776	1616	682	782	785
Education – Primary	2394	2156	1961	289	338	408
Education –	2561	2306	2098	484	473	563
Health/Medical –	2234	2012	1830	558	738	865
Health/Medical –	2508	2258	2054	663	1089	1298
Lodging	2361	2126	1934	401	606	754
Manufacturing	1397	1258	1144	347	472	589
Office-Low Rise	1966	1770	1610	257	359	446
Office-Mid Rise	2189	1971	1793	373	529	651
Office-High Rise	2149	1935	1760	669	1061	1263
Restaurant	1868	1681	1530	347	535	652
Retail – Large	1763	1587	1444	462	588	686
Retail – Strip Mall	1701	1531	1393	307	441	574
Warehouse	1872	1685	1533	164	343	409
Other/Miscellaneous	2123	1911	1739	443	612	729

Table 2. In-Service Rates (Ref. 9)

Program Delivery	ISR
Direct Install	1.0
Other, or unknown	0.56

Table 3. Deemed baseline efficiency for heating and cooling (Ref 6, 11)

Equipment	Capacity (Btu/h)	Type	Federal 431.97 Effective 1/1/2016 (Ref 6)	MN 2024 Energy Code ASHRAE 90.1-2019 (Ref 11)
			M metrics (installed equipment predates 1/1/2023)	M1 metrics (Installed equipment predates 1/1/2023)
Air Conditioners, Air-Cooled (Cooling Mode)	<65,000 Btu/h	Split System	15.0 SEER; 12.5 EER (single phased) 13.0 SEER (three phased)	13.4 SEER2
		Single Package System	15.0 SEER; 12.0 EER; (single phased) 14.0 SEER (three phased)	13.4 SEER2
	≥65,000 Btu/h <135,000 Btu/h	Electric Resistance Heat	11.2 EER; 12.8 IEER; 3.4 COP at 47ºF	14.8 IEER
		All other heat	11.0 EER; 12.6 IEER; 3.4 COP at 47ºF	14.6 IEER
	≥135,000 Btu/h <240,000 Btu/h	Electric Resistance Heat	11.0 EER; 12.4 IEER; 3.3 COP at 47ºF	14.2 IEER
		All other heat	10.8 EER; 12.2 IEER; 3.3 COP at 47ºF	14.0 IEER
	≥240,000 Btu/h and<760,000 Btu/h	Electric Resistance Heat	10.0 EER; 11.6 IEER	13.2 IEER
		All other heat	9.8 EER 11.4 IEER	13.0 IEER
	≥760,000 Btu/h	Electric Resistance Heat	9.7 EER 11.2 IEER	12.5 IEER
		All other heat	9.5 EER 11.0 IEER	12.3 IEER

Heat Pumps, Air-Cooled	<65,000 Btu/h	Split System, all heating types	15.0 SEER; 12.5 EER; 8.5 HSPF (single phased) 14.0 SEER (three phased)	14.3 SEER2 7.5 HSPF2
		Single Package system, all heating types	15.0 SEER; 12.0 EER; 8.2 HSPF (single phased) 14.0 SEER (three phased)	13.4 SEER2 6.7 HSPF2
	≥65,000 Btu/h <135,000 Btu/h	Electric Resistance Heat	11.8 EER; 12.8 IEER; 3.4 COP at 47ºF	14.1 IEER 3.4 COP at 47ºF 2.25 COP at 17ºF
		All other heat	11.6 EER; 12.6 IEER; 3.4 COP at 47ºF	13.9 IEER 3.4 COP at 47ºF 2.25 COP at 17ºF
	≥135,000 Btu/h <240,000 Btu/h	Electric Resistance Heat	10.9 EER; 12.0 IEER; 3.3 COP at 47ºF	13.5 IEER 3.3 COP at 47ºF 2.05 COP at 17ºF
		All other heat	10.7 EER; 11.8 IEER; 3.3 COP at 47ºF	13.3 IEER 3.3 COP at 47ºF 2.05 COP at 17ºF
	≥240,000 Btu/h	Electric Resistance Heat	9.5 EER; 10.6 IEER 3.2 COP at 47ºF	12.5 IEER 3.2 COP at 47ºF 2.05 COP at 17ºF
		All other heat	9.3 EER; 10.4 IEER 3.2 COP at 47ºF	12.3 IEER 3.2 COP at 47ºF 2.05 COP at 17ºF

Table 4. Baseline Case Minimum Energy Efficiency Requirements (Ref. 11)

Table 2. Baseline Case Minimum Energy Efficiency Requirements	Single Stage		Multistage	
	EER*	COP**	EER	COP
Closed Loop Water-to-Air	14.1	3.2	EER= (highest rated capacity EER + lowest rated capacity EER) / 2	COP= (highest rated capacity COP + lowest rated capacity COP) / 2
Open Loop Water-to-Air	18.0	3.7		
Closed Loop Water-to-Water	12.1	2.5		
Open Loop Water-to-Water	16.3	3.1		
Direct Geoexchange DGX-to-Air	14.1	3.2		
Direct Geoexchange DGX-to-Water	12.1	2.5		

*EER values rated at entering water temperature of 77°F for closed loop systems, and 59°F for open loop systems.
**COP values rated at entering water temperature of 32°F for closed loop systems, and 50°F for open loop systems.

Methodology and Assumptions

$EFLH_{HEAT}$ were determined from based prototypes building models on the California DEER study prototypes modified Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3). Values were scaled as follows: $EFLH_{MN} = EFLH_{IL} \times HDD_{55,MN} / HDD_{55,IL} \times DTD_{IL} / DTD_{MN}$, where DTD is the design temperature difference.

Table 5. Heating degree days and design temperature difference

Geography	HDD55	DTD
Chicago, IL	4,029	73.5
MN Zone 1	6,956	92
MN Zone 2	5,888	86.5
MN Zone 3	5,233	84.5

Cooling Savings factor has been derived from the IL TRM v12 volume 2 Small Commercial Thermostats measure CSF value of 17.7% savings of total cooling kWh. The IL value has been scaled by using the ratio of $EFLH_{COOL}$ values from IL (existing building unknown space type, avg of all zones, 1,178 hrs) and MN (other space type, avg of zones, 595 hrs) = (17.7% * (595/1,178)) = 9%.

Demand savings are assumed to be minimal, as it is assumed that demand savings for HVAC measures are defined as summer peak hour savings.

Savings are calculated based upon a constant speed baseline operation.

References

1. Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007
2. Nicor Rider 30 Business EER Program Database, Paid Rebates with Programmable Thermostat Installation Costs, Program to Date as of January 11, 2013
3. FES scaled EFLH from those provided in the Illinois Technical Reference Manual based on Minnesota weather data. EFLH for the Illinois Technical Reference Manual were based on California DEER study prototypes modified by Illinois field data to closely match EFLH from the modeling to those calculated from field data.
4. Utilizing nominal square footage noted in DTE and CE C&I Programmable Thermostat Savings Analysis: Preliminary Findings, Navigant Energy, June 17, 2014 and assumption of 400 square feet per ton of cooling capacity.
5. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010. This factor implies that oversizing on average is 30%.
6. Title 10, Code of Federal Regulations, Part 431 – Energy Efficiency Program for Certain Commercial and Industrial Equipment. November 2023. https://www.ecfr.gov/current/title-

10/chapter-II/subchapter-D/part-431/subpart-F/subject-group-ECFR2640f6ad978e4e6/section-431.97

7. Utilizing nominal square footage noted in DTE and CE C&I Programmable Thermostat Savings Analysis: Preliminary Findings, Navigant Energy, June 17, 2014 and assumption of 400 square feet per ton of cooling capacity results in 5 ton cooling unit.
8. DTE and CE C&I Programmable Thermostat Savings Analysis: Preliminary Findings, Navigant Energy, June 17, 2014. https://www.michigan.gov/-/media/Project/Websites/mpsc/workgroups/EWR_Collaborative/2014/dte_ce_statsavings06_12_14final.pdf?rev=bebe2912988d4dd2b68450a2a036b5cc
9. "Programmable Thermostats. Report to KeySpan Energy Delivery on Energy and Cost Effectiveness," GDS Associates, Marietta, GA. 2002
10. IL Technical Reference Manual v12.0 Volume 2. Measure 4.4.48 Small Commercial Thermostats. https://www.ilsag.info/technical-reference-manual/
11. 2024 Minnesota Energy Code with ANSI/ASHRAE/IES Standard 90.1-2019. Effective January 5, 2024. https://codes.iccsafe.org/content/MNEC2024P1/6-heating-ventilating-and-air-conditioning#MNEC2024P1_Ch06_Sec6.8

Revision History

Version	Description	Author	Date
1.0	New Measure	Franklin Energy Services	11/12/2015
4.2	Added cooling savings, updated baseline efficiency to match C/I Heat Pump measure baseline efficiency	Cadmus	8/1/2024

C/I HVAC – Programmable Thermostats with Gas Heating

Measure Detail	Measure Value
Measure ID	2.02.37
Target Market Segments	Commercial
Target End Uses	HVAC
Applicable To	Commercial customers in business noted in Table 1 with commercial unitary type heating equipment controlled by thermostats. Gas must be the primary heating source to use this measure and building automation systems must not be incorporated
Actions	Replace on Fail, Replace Working
Required from Customer/Contractor	Confirmation of gas heating, business type (see Table 2), program delivery type (see Table 3), location (county), heating size (Btu/h Input)
Measure Energy Type	Electric and Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	8 (Ref. 1)
Unit Participant Incremental Cost	$181 (Ref. 2)

Measure Description

This measure includes replacement of failed or working manual thermostats in existing commercial businesses with programmable or smart thermostats. New units must have the capability to adjust temperature setpoints according to a schedule without manual intervention. An estimate is provided for reduced energy consumption through temperature set-back during unoccupied or reduced demand times. Savings make no other assumptions regarding sequence of operations incorporated into the programmable thermostat. Among sequence savings not considered are optimal start, outside air damper control, or other potential energy savings measures associated with occupancy.

Algorithms

Unit Dth Savings per Year = HC_{GAS} x HSF x ISR

HC_{GAS}= $EFLH_{HEAT}$ x btuh_In x Load_Factor / Conversion_Factor x EFF

Unit kWh Savings per Year = CC_{ELEC} x CSF x ISR

CC_{ELEC} = $EFLH_{COOL}$ x $Size_{COOL}$ x 1/SEER

Where:

HC_{GAS} = Heating consumption for gas heated businesses, see Table 1. (Ref. 3)

CC_{ELEC} = Cooling consumption for electrically air conditioned businesses

$EFLH_{HEAT}$ = Equivalent Full Load Hours heating, See Table #1. (See Assumptions, Ref. 3)

$ELFH_{Cool}$ = Equivalent Full Load Hours heating, See Table #1. (See Assumptions, Ref. 3)

Btuh_In = Nominal Heating capacity in btu/h of the equipment. Capacity, btu/h, provided by customer/contractor or use = 100,000 if unknown. (Ref. 4)

$Size_{COOL}$ = Nominal capacity in tons of the equipment (1 ton = 12,000 btu/h) Capacity in tons, provided by customer/contractor or use = 5.0 if unknown.

Load_Factor = the load factor, assumed to be 0.77 (implies 30% oversizing) (Ref. 5)

Conversion_Factor = 1,000,000 Btu/Dth

EFF = % efficiency of gas heating system, provided by customer/contractor, use 80% if unknown. (Ref 6)

SEER = Seasonal Energy Efficiency Ratio of the cooling equipment, actual provided by customer/contractor, use 15 SEER if unknown, see Table 3 (Ref 6).

HSF = Heating Savings Factor, assumed fraction reduction in heating energy consumption due to programmable thermostat, HSF = 0.05 (Ref. 6)

CSF = Cooling Savings Factor, assumed fraction reduction in cooling energy consumption due to programmable thermostat, CSF = 0.09% (See Assumptions, Ref. 8)

ISR = In-Service Rate, the percentage of units installed and programmed effectively, Table 2. (Ref. 7)

Example:

Retrofit of a manual thermostat with a programmable thermostat in a gas heated, air conditioned strip mall retail store Climate Zone 1, via a direct installation program delivery. Furnace size is 60,000 btu/hr input capacity. AC unit size is 3 ton capacity, 15 SEER.

HC_{GAS}= 1701 x 60,000 x 0.77 / 1,000,000 * 0.80= 62.9Dth

Unit Dth Savings per Year = 62.9 x 0.05 x 1.0 = 3.1Dth

CC_{ELEC} = 307 x 3 x 12/15 = 737 kWh

Unit kWh Savings per Year = 737 x 0.09 x 1.0 = 66 kWh

Deemed Input Tables

Table 1. Equivalent Full Load Hours per zone in Minnesota by building type (Ref. 3)

Building Type	Heating			Cooling		
	Zone 1	Zone 2	Zone 3	Zone 1	Zone 2	Zone 3
Convenience Store	1887	1699	1546	647	825	986
Education – Community	1972	1776	1616	682	782	785
Education – Primary	2394	2156	1961	289	338	408
Education – Secondary	2561	2306	2098	484	473	563
Health/Medical – Clinic	2234	2012	1830	558	738	865
Health/Medical – Hospital	2508	2258	2054	663	1089	1298
Lodging	2361	2126	1934	401	606	754
Manufacturing	1397	1258	1144	347	472	589
Office-Low Rise	1966	1770	1610	257	359	446
Office-Mid Rise	2189	1971	1793	373	529	651
Office-High Rise	2149	1935	1760	669	1061	1263
Restaurant	1868	1681	1530	347	535	652
Retail – Large Department Store	1763	1587	1444	462	588	686
Retail – Strip Mall	1701	1531	1393	307	441	574
Warehouse	1872	1685	1533	164	343	409
Other/Miscellaneous	2123	1911	1739	443	612	729

Table 2. In-Service Rates (Ref. 7)

Program Delivery	ISR
Direct Install	1.0
Other, or unknown	0.56

Table 3. Deemed baseline efficiency for heating and cooling (Ref 9,10)

Equipment	Capacity (Btu/h)	Type	Federal 431.97 Effective 1/1/2016 (Ref 6)	MN 2024 Energy Code ASHRAE 90.1-2019 (Ref 11)
			M metrics (installed equipment predates 1/1/2023)	M1 metrics (Installed equipment predates 1/1/2023)
Air Conditioners, Air-Cooled (Cooling Mode)	<65,000 Btu/h	Split System	15.0 SEER; 12.5 EER (single phased) 13.0 SEER (three phased)	13.4 SEER2
		Single Package System	15.0 SEER; 12.0 EER; (single phased) 14.0 SEER (three phased)	13.4 SEER2
	≥65,000 Btu/h <135,000 Btu/h	Electric Resistance Heat	11.2 EER; 12.8 IEER; 3.4 COP at 47ºF	14.8 IEER
		All other heat	11.0 EER; 12.6 IEER; 3.4 COP at 47ºF	14.6 IEER
	≥135,000 Btu/h <240,000 Btu/h	Electric Resistance Heat	11.0 EER; 12.4 IEER; 3.3 COP at 47ºF	14.2 IEER
		All other heat	10.8 EER; 12.2 IEER; 3.3 COP at 47ºF	14.0 IEER
	≥240,000 Btu/h and<760,000 Btu/h	Electric Resistance Heat	10.0 EER; 11.6 IEER	13.2 IEER
		All other heat	9.8 EER 11.4 IEER	13.0 IEER
	≥760,000 Btu/h	Electric Resistance Heat	9.7 EER 11.2 IEER	12.5 IEER
		All other heat	9.5 EER 11.0 IEER	12.3 IEER

Heat Pumps, Air-Cooled	<65,000 Btu/h	Split System, all heating types	15.0 SEER; 12.5 EER; 8.5 HSPF (single phased) 14.0 SEER (three phased)	14.3 SEER2 7.5 HSPF2
		Single Package system, all heating types	15.0 SEER; 12.0 EER; 8.2 HSPF (single phased) 14.0 SEER (three phased)	13.4 SEER2 6.7 HSPF2
	≥65,000 Btu/h <135,000 Btu/h	Electric Resistance Heat	11.8 EER; 12.8 IEER; 3.4 COP at 47ºF	14.1 IEER 3.4 COP at 47ºF 2.25 COP at 17ºF
		All other heat	11.6 EER; 12.6 IEER; 3.4 COP at 47ºF	13.9 IEER 3.4 COP at 47ºF 2.25 COP at 17ºF
	≥135,000 Btu/h <240,000 Btu/h	Electric Resistance Heat	10.9 EER; 12.0 IEER; 3.3 COP at 47ºF	13.5 IEER 3.3 COP at 47ºF 2.05 COP at 17ºF
		All other heat	10.7 EER; 11.8 IEER; 3.3 COP at 47ºF	13.3 IEER 3.3 COP at 47ºF 2.05 COP at 17ºF
	≥240,000 Btu/h	Electric Resistance Heat	9.5 EER; 10.6 IEER 3.2 COP at 47ºF	12.5 IEER 3.2 COP at 47ºF 2.05 COP at 17ºF
		All other heat	9.3 EER; 10.4 IEER 3.2 COP at 47ºF	12.3 IEER 3.2 COP at 47ºF 2.05 COP at 17ºF

Table 3. Baseline Case Minimum Energy Efficiency Requirements (Ref. 10)

Table 2. Baseline Case Minimum Energy Efficiency Requirements	Single Stage		Multistage	
	EER*	COP**	EER	COP
Closed Loop Water-to-Air	14.1	3.2	EER= (highest rated capacity EER + lowest rated capacity EER) / 2	COP= (highest rated capacity COP + lowest rated capacity COP) / 2
Open Loop Water-to-Air	18.0	3.7		
Closed Loop Water-to-Water	12.1	2.5		
Open Loop Water-to-Water	16.3	3.1		
Direct Geoexchange DGX-to-Air	14.1	3.2		
Direct Geoexchange DGX-to-Water	12.1	2.5		

*EER values rated at entering water temperature of 77°F for closed loop systems, and 59°F for open loop systems.
**COP values rated at entering water temperature of 32°F for closed loop systems, and 50°F for open loop systems.

Notes

$EFLH_{HEAT}$ were determined from based prototypes building models on the California DEER study prototypes modified Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3). Values were scaled as follows: $EFLH_{MN} = EFLH_{IL} \times HDD_{55,MN} / HDD_{55,IL} \times DTD_{IL} / DTD_{MN}$, where DTD is the design temperature difference.

Table 4. Heating degree days and design temperature difference

Geography	HDD55	DTD
Chicago, IL	4,029	73.5
MN Zone 1	6,956	92
MN Zone 2	5,888	86.5
MN Zone 3	5,233	84.5

Cooling Savings factor has been derived from the IL TRM v12 volume 2 Small Commercial Thermostats measure CSF value of 17.7% savings of total cooling kWh. The IL value has been scaled by using the ratio of $EFLH_{COOL}$ values from IL (existing building unknown space type, avg of all zones, 1,178 hrs) and MN (other space type, avg of zones, 595 hrs) = (17.7% * (595/1,178)) = 9%.

Demand savings are assumed to be minimal, as it is assumed that demand savings for HVAC measures are defined as summer peak hour savings. Savings are calculated based upon a constant speed baseline operation.

References

1. Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007
2. Nicor Rider 30 Business EER Program Database, Paid Rebates with Programmable Thermostat Installation Costs, Program to Date as of January 11, 2013
3. FES scaled EFLH from those provided in the Illinois Technical Reference Manual based on Minnesota weather data. EFLH for the Illinois Technical Reference Manual were based on California DEER study prototypes modified by Illinois field data to closely match EFLH from the modeling to those calculated from field data.
4. Utilizing nominal square footage noted in DTE and CE C&I Programmable Thermostat Savings Analysis: Preliminary Findings, Navigant Energy, June 17, 2014 and assumption of 400 square feet per ton of cooling capacity results in 5 ton cooling unit. This result was then utilized to determine the nominal heating input for rooftop units in this size from the 3 largest manufacturers.
5. PA Consulting, KEMA, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010. This factor implies that boilers are 30% oversized on average.

6. DTE and CE C&I Programmable Thermostat Savings Analysis: Preliminary Findings, Navigant Energy, June 17, 2014. https://www.michigan.gov/-/media/Project/Websites/mpsc/workgroups/EWR_Collaborative/2014/dte_ce_statsavings06_12_14final.pdf?rev=bebe2912988d4dd2b68450a2a036b5cc
7. "Programmable Thermostats. Report to KeySpan Energy Delivery on Energy and Cost Effectiveness," GDS Associates, Marietta, GA. 2002
8. IL Technical Reference Manual v12.0 Volume 2. Measure 4.4.48 Small Commercial Thermostats. https://www.ilsag.info/technical-reference-manual/
9. Title 10, Code of Federal Regulations, Part 431 – Energy Efficiency Program for Certain Commercial and Industrial Equipment, Subpart F – Commercial Air Conditioners and Heat Pumps. https://www.ecfr.gov/cgi-bin/text-idx?SID=ded1dbd4f1450bfd666ff67a75d7aba8&mc=true&node=pt10.3.431&rgn=div5
10. 2024 Minnesota Energy Code with ANSI/ASHRAE/IES Standard 90.1-2019. Effective January 5, 2024. https://codes.iccsafe.org/content/MNEC2024P1/6-heating-ventilating-and-air-conditioning#MNEC2024P1_Ch06_Sec6.8

Revision History

Version	Description	Author	Date
1.0	New measure	Franklin Energy Services	11/12/2015
4.2	Added cooling savings, updated baseline efficiency to match C/I AC measure baseline efficiency	Cadmus	8/1/2024

Envelope

C/I Envelope – Fast Acting Doors

Measure Detail	Measure Value
Measure ID	2.03.01
Target Market Segments	Commercial, Industrial
Target End Uses	Envelope, Refrigeration
Applicable To	Commercial and Industrial Refrigeration
Actions	New Construction, Modify
Required from Customer/Contractor	Baseline doorway barrier type, length and width of doorway in feet, average number of passages per hour, average minutes per hour door is held open, annual hours of operation
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	12 (Ref. 4)
Unit Participant Incremental Cost	Approximately $150/ft2 of automated door (Ref. 5)

Measure Description

High speed doors save energy by lowering infiltration by reducing the time that rooms at different air temperatures are exposed to each other. They also provide better insulation between divided spaces.

This measure characterizes the energy savings achieved by replacing open doorways, standard speed doors, or strip curtains with high speed doors through infiltration reduction. The methodology for estimating energy savings for this measure is well documented (2014 ASHRAE Refrigeration Handbook, Refrigerated-Facility Loads, Chapter 24).

Algorithms

$kWh_{SAVED} = 1/(3412 \times COP) \times t \times (qt_B - qt_E)$

$kW_{SAVED} = CF \times 1/(3412 \times COP) \times (qt_B - qt_E)$

Where:

3412	= conversion factor, Btu per kWh
qt_B	= $qt_{OPEN\ B} + qt_{CLOSED\ B}$, total sensible and latent load due to infiltration, baseline equipment (Btu/h)
qt_E	= $qt_{OPEN\ E} + qt_{CLOSED\ E}$, total sensible and latent load due to infiltration, efficient equipment (Btu/h)
$qt_{OPEN\ B}$	= $q \times Dt_B \times Df \times (1 - E_{OPEN\ B})$, sensible and latent load due to infiltration when door open, baseline equipment (Btu/h)

$qt_{OPEN\ E}$	= q x Dt_E x Df x (1 – $E_{OPEN\ E}$), sensible and latent load due to infiltration when door open, efficient equipment (Btu/h)
$qt_{CLOSED\ B}$	= q x (1 – Dt_B) x Df x (1 – $E_{CLOSED\ B}$), sensible and latent load due to infiltration when door closed, baseline equipment (Btu/h)
$qt_{CLOSED\ E}$	= q x (1 – Dt_E) x Df x (1 – $E_{CLOSED\ E}$), sensible and latent load due to infiltration when door closed, efficient equipment (Btu/h)
q	= 795.6 x A x (h_I – h_R) x ρ_R x (1 – ρ_I/ρ_R)$^{0.5}$ x (gH)$^{0.5}$ x F_M, sensible and latent load if unrestricted airflow between rooms (Btu/h) (Ref. 3) See Table 2 for typical loads.
A	= doorway area (ft2), provided by customer
h_I	= enthalpy of infiltration air (Btu/lb), see Table 1
h_R	= enthalpy of refrigerated air (Btu/lb), see Table 1
ρ_I	= density of infiltration air (lb/ft^3) , see Table 1
ρ_R	= density of refrigerated air (lb/ft^3) , see Table 1
g	= 32.174, gravitational constant (ft/s^2)
H	= doorway height in feet, provided by customer (typically 10 ft)
F_M	= (2 / (1 + (ρ_r/ρ_i)$^{1/3}$))$^{1.5}$, density factor (Ref. 3)
Dt_B	= (P x Θ_P_b + 60 x Θ_o) / 3600, decimal fraction per hour that door is open, baseline equipment (Ref. 3). If baseline equipment is open doorway or strip curtains, Dt_b = 1.
Dt_E	= (P x Θ_P_e + 60 x Θ_o) / 3600, decimal fraction per hour that door is open, efficient equipment (Ref. 3).
P	= average number of doorway passages per hour, provided by customer
Θ_P_b	= door open-close time, baseline equipment (seconds). Refer to Table 3, or customer-provided.
Θ_P_e	= door open-close time, efficient equipment (seconds). Refer to Table 3, or customer-provided.
Θ_o	= average minutes per hour door is held open, provided by customer
60	= conversion factor, minutes per hour
3600	= conversion factor, seconds per hour
Df	= Doorway flow factor, 0.8 if temperature differential > 20˚F, 1.1 if temperature differential < 20˚F (Ref. 3)
$E_{OPEN\ B}$	= effectiveness of doorway barrier during passage, baseline equipment. See Table 3.
$E_{CLOSED\ B}$	= effectiveness of doorway barrier when closed, baseline equipment. See Table 3.

$E_{OPEN\ E}$	= effectiveness of doorway barrier during passage, efficient equipment. See Table 3.
$E_{CLOSED\ E}$	= effectiveness of doorway barrier when closed, efficient equipment. See Table 3.
T	= annual hours of operation, provided by customer.
COP	= coefficient of performance, 1.3 for freezers, 2.5 for coolers (Ref. 2)
CF	= peak coincident factor, assumed to be 0.9 (Ref. 6)

Examples:

Fast-acting doors are proposed for an 8ft x 10ft doorway between an unconditioned loading dock and a cooler. The existing barrier is a manual door that is held open during business hours and closed during non-business hours. On average, a forklift passes through the doorway 6 times per hour during business hours. The facility operates two-shifts per day, five days per week (4,160 hours per year). The proposed fast-acting doors will be held open 3 minutes per hour on average during business hours.

From Table 2, q = 917 x 8 x 10 = 73,360 Btu/h, Df = 1.1

Dt_B = 1 (open doorway)

Dt_E = (6 x 5 + 60 x 3)/3600 = 0.058

From Table 3, $E_{OPEN\ B}$ = $E_{CLOSED\ B}$ = 0, $E_{OPEN\ E}$ = 0, $E_{CLOSED\ E}$ = 0.95

$qt_{OPEN\ B}$ = 73,360 x 1 x 1.1 x (1-0) = 80,696 Btu/h

$qt_{CLOSED\ B}$ = 73,360 x (1-1) x 1.1 x (1-0) = 0 Btu/h

$qt_{TOTAL\ B}$ = 80,696 + 0 = 80,696 Btu/h

$qt_{OPEN\ E}$ = 73,360 x 0.058 x 1.1 x (1-0) = 4,707 Btu/h

$qt_{CLOSED\ E}$ = 73,360 x (1-0.058) x 1.1 x (1-0.95) = 3,799 Btu/h

$qt_{TOTAL\ E}$ = 4,707 + 3,799 = 8,507 Btu/h

COP = 2.5 (cooler)

kWh_{SAVED} = 1/(3412 x 2.5) x 4,160 x (80,696 – 8,507) = 35,206

kW_{SAVED} = 0.9 x 1/(3412 x 2.5) x (80,696 – 8,507) = 7.62

Fast-acting doors are proposed for an 8ft x 10ft doorway between a cooler and a freezer. The existing barrier is a manual door with strip curtains that is held open during business hours and closed during non-business hours. On average, a forklift passes through the doorway 6 times per hour during business hours. The facility operates two-shifts per day, five days per week (4,160 hours per year). The proposed fast-acting doors will be held open 3 minutes per hour on average during business hours.

Note that this example requires two kWh calculations: one for the load on the cooler, one for the load on the freezer. The net kWh savings are the sum of the cooler and freezer loads.

Cooler Load:

From Table 2, q = -4580 x 8 x 10 = -366,400 Btu/h, Df = 0.8

Dt_B = 1 (strip curtains)

Dt_E = (6 x 5 + 60 x 3) / 3600 = 0.058

From Table 3, $E_{OPEN\ B} = E_{CLOSED\ B}$ = 0.58, $E_{OPEN\ E}$ = 0, $E_{CLOSED\ E}$ = 0.95

$qt_{OPEN\ B}$ = -366,400 x 1 x 0.8 x (1 – 0.58) = -123,110 Btu/h

$qt_{CLOSED\ B}$ = 73,360 x (1 – 1) x 0.8 x (1 – 0.58) = 0 Btu/h

$qt_{TOTAL\ B}$ = -123,110 + 0 = -123,110 Btu/h

$qt_{OPEN\ E}$ = -366,400 x 0.058 x 0.8 x (1-0) = -17,099 Btu/h

$qt_{CLOSED\ E}$ = 73,360 x (1-0.058) x 1.1 x (1-0.95) = -13,801 Btu/h

$qt_{TOTAL\ E}$ = -30,900 Btu/h

COP = 2.5 (cooler)

kWh_{SAVED} = 1/(3412 x 2.5) x 4,160 x (-123,110 – (-30,900)) = -44,970

kW_{SAVED} = 0.9 x 1/(3412 x 2.5) x (-123,110 – (-30,900)) = -9.73

Freezer Load:

$qt_{TOTAL\ B}$ = 123,110 Btu/h

$qt_{TOTAL\ E}$ = 30,900 Btu/h

COP = 1.3 (freezer)

kWh_{SAVED} = 1/(3412 x 1.3) x 4,160 x (123,110 – 30,900) = 86,481

kW_{SAVED} = 0.9 x 1/(3412 x 1.3) x (123,110 – 30,900) = 18.71

Net Savings:

kWh_{SAVED} = -44,970 + 86,481 = 41,511 kWh

kW_{SAVED} = -9.73 + 18.71 = 8.98 kW

Deemed Input Tables

Table 1. Assumed Air Conditions (Ref. 7)

Space Type	Dry bulb temp. (˚F)	Relative Humidity	Enthalpy, h (Btu/lb)	Density, ρ (lb/ft3)
Freezer	-10.0	40%	-2.21	0.0856
Cooler	35.0	40%	10.24	0.0777
Outside (avg)	45.9	66%	15.71	0.0759

Table 2. Typical Sensible and Latent Refrigeration Loads, Unrestricted Flow; Flow Factor (Ref. 3)

Doorway location	Load per Unit Area, q/A (Btu/h)/ft^2	Flow Factor, Df
Cooler-Unconditioned Space	917	1.1
Freezer-Unconditioned Space	7132	0.8
Cooler-Freezer (cooler load)	-4580	0.8
Cooler-Freezer (freezer load)	4580	0.8

Table 3. Assumed Effectiveness and Typical Open-Close Time of Doorway Barrier Types

Doorway Barrier	Effectiveness	Open-Close Time, Θ_P (sec)	Reference
Open Doorway	0	n/a	3
Strip Curtains (existing)	0.58	n/a	1
Standard door (existing)	0.90	20	3
High speed door	0.95	5	3

Methodology and Assumptions

Conductive heat transfer through barrier devices is not included in the savings algorithms. Also, the waste heat generated by standard or fast-acting automated door motors, which is typically small compared to infiltration heat losses, is not included in the savings algorithm.

In new construction, the baseline equipment is assumed to be a standard speed door.

Per Ref. 3, the typical open-close time *Θ_P* for conventional pull-cord-operated doors ranges from 15 to 25 s per passage. The time for high-speed doors ranges from 5 to 10 s, although it can be as low as 3 s. The fact that steady-state flow becomes established 3 s after the cold-room door is opened may be used as a basis to reduce *Θ_P* for high-speed doors.

References

1. Pennsylvania Technical Reference Manual 2015, Table 3-115, p.418
2. US DOE Publication #46230-00, "Energy Savings Potential for Commercial Refrigeration Equipment", 1996, Arthur C. Little, Inc, Table 4-4 p.12, http://www.scribd.com/doc/13260953/Energy-Savings-Potential-for-Commercial-Refrigeration-Equipment
3. 2014 ASHRAE Handbook – Refrigeration, Chapter 24. Refrigerated-Facility Loads, Infiltration Air Load; Eqns. 15, 17.
4. DEER 2008; based on similar refrigeration measures, anti-sweat heaters, and case doors.
5. Approximated from Rite Hite – Industrial High Speed Door pricing.

6. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified.
7. Enthalpies and densities calculated from 2013 ASHRAE Handbook – Fundamentals, Chapter 1, Eqns. 11, 28, 32; and Table 2 – Thermodynamic Properties of Moist Air at Standard Atmospheric Pressure, 14.696 psia. Outside air average temperature, relative humidity, and enthalpy was calculated from TMY3 data for Minneapolis.

Revision History

Version	Description	Author	Date
1.0	Created specification for Commercial and Industrial Fast Acting Doors	Franklin Energy Services	11/01/15
1.1	Updated algorithm, assumptions, and example calculations	Franklin Energy Services	11/28/17
1.2	Corrected equations for infiltration loads	Cadmus	11/2020

C/I Envelope – Loading Dock Door and Pit Seals

Measure Detail	Measure Value
Measure ID	2.03.02
Target Market Segments	Commercial, Industrial, Public
Target End Uses	Envelope
Applicable To	Commercial and industrial customer facilities with loading docks
Actions	New Construction (pit seals only), Modify
Required from Customer/Contractor	Leak area of existing dock doors and pits, climate zone, temperature setpoint
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	10
Unit Participant Incremental Cost	$2,857 Dock Door Seals, $780 for Pit/Ramp Seals

Measure Description

Loading dock seals, sometimes called shelters, stop unconditioned air from leaking into a building when trucks are loading or being unloaded. Typically, there will be a four to six-inch gap between a semi and the dock door opening. Installing seals can remove this potentially large source of infiltration.

Commonly, facilities will also have a built-in pit ramp that elevates to the level of a semi-trailer floor. The pits below these ramps typically remain open, creating year-round infiltration of outside air. Ramp pit seals can be installed to fill these gaps.

Algorithms

Unit Dth Savings per Year = C_1 x Average Infiltration CFM x HDD x C_2 x t_{week} / C_3 / Eff / C_4

Where:

Average Infiltration CFM = LA x $\sqrt{(C_{stack} \times (T_{set} - T_{ave}) + C_{wind} \times (V_{wind}^2))}$

LA = Effective Leakage Area, measured area of openings, in²

C_{stack} = Stack Coefficient, 0.0225 Assuming a 1.5 story building (Ref. 1)

T_{set} = Temperature Setpoint, typically 68°F or 55˚F

T_{ave} = Average Winter Temperature, see Table 1 for average temperature for the given climate zone

C_{wind} = Wind Coefficient, 0.0138 Assuming a 1.5 story building average with no obstructions or local shielding (Ref. 1)

V_{wind} = Average Winter Wind Speed, see Table 1 for average wind speed for the given climate zone

HDD	= Heating Degree Days, see Table 1 for heating degree-days base 65˚F or 55˚F depending on heating setpoint, for the climate zone
t_{week}	= 10 hours, per week, for dock doors;168 hours, per week, for pit rampsEff = Heating System Efficiency, 80% for a typical heating system
C_1	= 1.08 Btu/h/CFM/˚F
C_2	= 24 hours/day
C_3	= 168 hours/week
C_4	= 1,000,000 Btu/Dth

Example:

Door Seals: A single loading dock with leaks along the door measuring 20in² for a warehouse in Minneapolis is installing seals. The temperature setpoint is 68˚F.

Average Infiltration CFM = 20 in² x √(0.0225 x (68 °F – 36.0 °F) + 0.0138 x ((11.5 mph)²)) = 31.9 CFM

Unit Dth Savings per Year = 1.08 Btu/CFM x 31.9 CFM x 8,512 HDD x 24 hr/day x 10 hours/week / 168 hours/week / 80% Efficiency / 1,000,000 Btu/Dth = 0.52 Dth

Deemed Input Tables

Table 1. Heating Degree Days (HDD), Heating Design Temperatures and Average Wind Speed by Zone

	Zone 1	Zone 2	Zone 3
	Northern MN	Central MN	Southern MN/Twin Cities
HDD Base 65˚F (for setpoints approx. 68˚F) (Ref. 2)	9,833	8,512	7,651
HDD Base 55˚F (for setpoints approx. 55˚F) (Ref. 2)	6,956	5,888	5,233
Average heating season temperature (°F) (Ref. 3)	33.3 °F	35.5 °F	36.0 °F
Average wind speed, winter (mph) (Ref. 5)	9.4	10.3	11.6

Notes

The 2015 Minnesota Commercial Energy Code requires weather seals for cargo doors and loading dock doors to restrict infiltration when vehicles are parked in the doorway (Ref. 4).

References

1. 2013 ASHRAE Handbook – Fundamentals, Chapter 16: Ventilation and Infiltration, page 16.23-24.
2. National Climate Data Center – National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.
3. Typical Meteorological Year 3 data from the National Solar Radiation Data Base http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#M. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and

Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3. Average winter temperature equal to weighted average temperature below 65°F.

4. Minnesota Rules 1323.0402, Section C402.4.6.
5. NOAA-National Centers for Environmental Information-Comparative Climate Data, 1981-2015, Wind – Average Speed (MPH) http://www1.ncdc.noaa.gov/pub/data/ccd-data/wndspd15.dat, accessed December 4, 2017. Average wind speeds for October-April. Monthly wind speeds for Duluth and International Falls were averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.

Revision History

Version	Description	Author	Date
1.0	Created standalone Specification Loading Dock Door and Pit Seals	Franklin Energy Services	11/12/15
1.1	Updated algorithm to use average winter temperature, updated example calculation.	Franklin Energy Services	12/4/17

Hot Water

Commercial Hot Water – Heat Pump Water Heater

Measure Detail	Measure Value
Measure ID	2.04.01
Target Market Segments	Commercial
Target End Uses	Water Heating
Applicable To	Commercial customers with gas or electric storage or instantaneous water heaters upgrading to heat pump water heaters installed in commercial applications
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Baseline water heater type (gas storage or gas instantaneous), Baseline and Efficient input Btu/h or input power kW, uniform energy factor (UEF) or thermal efficiency (TE), UEF usage bin (High or Medium) if applicable, tank size in gallons, building type, square footage, project location (county)
Measure Energy Type	Gas, Electric, EFS
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	10 (Ref. 3)
Unit Participant Incremental Cost	$784 (Ref. 3)

Measure Description

This measure includes replacement of failed or working storage-type and instantaneous electric resistance and gas water heaters in commercial facilities with more efficient storage-type heat pump water heaters. Qualifying efficient equipment must meet the performance criteria outlined in ENERGY STAR v2 (Ref 12) for commercial water heaters, but do not need to be ENERGY STAR certified to be eligible. See Table 4 for the current ENERGY STAR performance criteria.

The Minnesota Energy Conservation and Optimization Act (Ref. 11, 12) allows for efficient fuel switching (EFS) improvements where electricity or natural gas replaces another fuel used by the customer (i.e. natural gas, fuel oil, propane, etc) provided that the following criteria are met for each measure pursued:

1. The proposed efficient fuel switching measure results in a net reduction in the amount of source energy consumed for a particular use, measured on a fuel-neutral basis, using the utility's annual system average efficiency, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.
2. The proposed efficient fuel switching measure results in a net reduction of statewide greenhouse gas emissions (Ref 13), over the lifetime of the improvement. For an efficient fuel-switching improvement installed by an electric utility, the reduction in emissions must be

measured using the utility's annual average emissions factor, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.

3. The project is cost-effective, considering the costs and benefits from the perspective of the utility, participants, and society.
4. The proposed efficient fuel switching measure should produce a similar or higher level of quality, service, or output as the technical assumptions identified in the baseline technology to be eligible (Ref. 14).

This measure potentially includes the efficient fuel switching energy savings resulting conversion of non-electric heating energy of the baseline equipment to electric heating energy in the proposed HPWH equipment.

Baseline equipment for this measure is assumed to include commercial sized storage and instant hot water heaters driven by electric resistance, or gas. The proposed efficient technology is a commercial sized heat pump hot water heater. To meet the same quality of service the baseline provides, the HPWH should be sized to meet the demand served by the baseline equipment.

Algorithms

Electric Water Heater Replacement, Non EFS

Unit kWh Savings per Year = $(Energy_{HeatWater} \times (1/UEF_{BASE} - 1/UEF_{EFF}) / CF_1$

Unit Peak kW Savings = (Unit kWh Savings per Year) / 8,760

Gas Water Heater Replacement, EFS

Unit Dth Savings per Year = $(Energy_{HeatWater} \times (1/UEF_{BASE}) + (SL_{BASE} \text{ x } 8760)) / CF_3$

Unit kWh Added per Year = $(Energy_{HEATWATER} \text{ x } (1/UEF_{EFF})) / CF_1$

Net MMBtu savings per Year = Unit Dth Savings – (Unit kWh Added x CF_2)

Where:

$Energy_{HeatWater}$ = SpecificHeat × Density × (Gallons / 1,000 SF per year) × Area / 1,000 / Yr × $(T_{set} - T_{cold})$

SpecificHeat =1.0 btu／lb ·°F

Density = 8.34 lbs／gal

Gallons / 1,000 SF per Year = See Table 2; gallons per 1,000 ft^2/Year based on building type.

Area = Square footage (SF) of facility served by hot water heater, provided by customer/contractor.

Days = See Table 2; days per year of operation

T_{set} = 130˚F default (Ref. 7), or actual

T_{cold} = See Table 1; average groundwater temperature. Default to average MN temperature of 49.0˚F.

UEF_{BASE}	= See Table 3; base water heater efficiency based on tank size, or TE of baseline instead of UEF. V = rated volume of DHW tank in gallons
UEF_{EFF}	= Uniform Energy Factor (UEF) of new water heater, actual, see Table 4 for minimum efficiency requirement. V = rated volume of DHW tank in gallons
CF_1	= 3,412 Btu⁄kWh
CF2	= 0.003412 Dth⁄kWh
CF3	= 1,000,000 Btu / Dth
SLBASE GAS	= Standby loss of gas baseline unit in Btu/h. Used when tank is equal to or greater than 75,000 Btu/h. For units <75,000 Btu/h, any size electric, and/or for instantaneous/tankless units of any size, SL = 0 or has already been incorporated into the UEF. (Ref. 4, 8). SL Base Gas = (input Btu/h) / 800 + 110 x (tank size in gallons)^0.5, or use default of 872 Btu/h based on an input of 75,000 Btu/hr and volume of 50 gal.

Example 1: Electric Resistance to Electric ASHP

A 10,000 ft^2 general commercial space installed a new 100-gallon, heat pump medium draw water heater with an UEF of 3.0 and input power of 6 kW. The average MN ground temperature, and the 'other commercial' space type will be used in the calculation. The existing water heater is electric, 6 kW, medium draw pattern, but unknown actual UEF.

UEF_{BASE} = 0.9307 – (0.0002 x 100) = 0.9107
EnergyHeatWater = 1 x 8.34 x 3,941 x 10,000 /1,000 x (130 – 49.0) = 26,623,031 Btu
Unit kWh Savings per Year = (26,623,031 x (1 / 0.9107 – 1/3.0) / 3412 = 5,967 kWh
Unit Peak kW Savings = 5,967 / 8,760 = 0.68 kW

Example 2: Gas storage to Electric ASHP

A 10,000 ft^2 general commercial space installed a new 100-gallon, heat pump medium draw water heater with an UEF of 3.0 and input power of 6 kW. The average MN ground temperature, and the 'other commercial' space type will be used in the calculation. The existing water heater is gas storage, 100,000 btu/h, medium draw pattern, but unknown actual UEF.

UEF_{BASE} = 0.80 TE
EnergyHeatWater = 1 x 8.34 x 3,941 x 10,000 /1,000 x (130 – 49.0) = 26,623,031 Btu
$SL_{BASE\ GAS}$ = 100,000 (Btu/h) / 800 + 110 x (100 gallons)^0.5 = 1,225 Btu/h
Unit Dth Savings per Year = (26,623,031 Btu × (1/0.80) + (1,225 x 8760)) / 1,000,000 = 44.0 Dth
Unit kWh Added per Year = (26,623,031 Btu x (1/3.0)) / 3412 = 2,601 kWh
Net MMBtu savings = 44.0 Dth – (2,601 kWh x 0.003412 Dth/kWh) = 35.1 Dth

Deemed Input Tables

Table 1. Average groundwater temperatures (Ref. 1)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3
MN statewide average, or if location unknown	**49.0**

Table 2. Deemed Annual Hot Water Use by Building Type (Ref. 2)

Building Type	Gal per 1,000 sq. ft. per Year
Small Office	1,540
Large Office	1,818
Restaurant	44,439
Convenience	4,594
Retail	1,354
Grocery	697
School	7,285
Health	24,540
Nursing	30,503
Lodging	29,548
Warehouse	1,239
Other Commercial	3,941

Table 3. Minimum Uniform Energy Factor (UEF), for Electric Commercial Water Heaters (Ref. 4)

Product Class	Rated Storage Volume	Draw Patten	Uniform Energy Factor V = rated volume of DHW tank in gallons
Electric Storage Water Heaters	≥ 20 gallons and ≤ 55 gallons	Very Small	0.8808 – (0.0008 × V)
		Low	0.9254 – (0.0003 × V)
		Medium	0.9307 – (0.0002 × V)
		High	0.9349 – (0.0001 × V)
	> 55 gallons and ≤ 120 gallons	Very Small	1.9236 – (0.0011 × V)
		Low	2.0440 – (0.0011 × V)
		Medium	2.1171 – (0.0011 × V)
		High	2.2418 – (0.0011 × V)
Electric Instant Water Heaters	≤12kW and ≤2 gal	All	0.92
	> 12kW and ≤58.6 kW and ≤2 gal	All	0.80

Table 4. Minimum Thermal Efficiency (TE) for Gas Commercial Water Heaters (Ref. 4)

Product Class	Rated Storage Volume and Input Rating	Minimum Thermal Efficiency
Gas-fired Storage Water Heaters	>120 gallon tanks >75,000 Btu/h	80%
Gas-fired Instantaneous Water Heaters	Any size > 200,000 Btu/h	80%

Table 5. ENERGY STAR Equipment Standards (Ref. 10)

Type of Equipment	Energy Factor *(Denoted as COP_h in ENERGY STAR criteria)*
Commercial Heat Pump Water Heater	UEF ≥ 3.0 or COP_h ≥ 3.0

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3. 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.
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Revision History

Version	Description	Author	Date
1.0	Created standalone measure	Franklin Energy Services	11/10/15
1.1	Removed Table 4, added ENERGY STAR criteria	Franklin Energy Services	9/27/16
1.2	Updated EF efficiency value to UEF value	Franklin Energy Services	12/5/17
4.2	EFS algorithm adjustments and expansion, added gas baseline, updates to ENERGY STAR criteria and references.	Cadmus	8/1/2024

Commercial Hot Water – Gas Water Heater

Measure Detail	Measure Value
Measure ID	2.04.02
Target Market Segments	Commercial
Target End Uses	Water Heating
Applicable To	Storage or instantaneous gas water heaters installed in commercial applications
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Water heater type (gas storage or gas instantaneous), input Btu/h, uniform energy factor (UEF) or thermal efficiency (TE), UEF usage bin (High or Medium) if applicable, tank size in gallons, building type, square footage, project location (county)
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	See Table 5
Unit Participant Incremental Cost	See Table 6

Measure Description

This measure includes replacement of failed or working gas water heaters in existing commercial facilities with high-efficiency gas units, as well as installation of high-efficiency gas water heaters in new commercial facilities. Includes installation of high-efficiency instantaneous gas water heaters.

Algorithms

Residential and residential-duty commercial water heaters (≤ 75,000 Btu/h, see Notes):

Unit Dth Savings per Year = $Energy_{HEATWATER}$ x $(1/UEF_{BASE} – 1/UEF_{EFF})$ / CF

Non-residential storage and tankless water heaters (> 75,000 Btu/h, see Notes):

Unit Dth Savings per Year = ($Energy_{HEATWATER}$ x $(1/TE_{BASE} – 1/TE_{EFF})$ + $((SL_{BASE} – SL_{EFF})$ x 8,760)) / CF

Where:

$Energy_{HEATWATER}$ = SpecificHeat × Density × (Gallons /1,000 SF per year) × Area / 1,000 × (T_{SET} - T_{COLD})

SpecificHeat = 1.0 btu / (lb·°F)

Density = 8.34 lbs / gal

Gallons/1,000 SF per yr = See Table 2; gallons per 1,000 ft^2/year based on building type.

Area = Square footage (SF) of facility served by hot water heater, provided by customer/contractor.

T_{SET} = 130˚F (Ref. 9)

T_{COLD}	=	See Table 1; average groundwater temperature, default to MN average of 49.0˚F
UEF_{BASE}	=	See Table 3; uniform energy factor of standard minimum efficiency consumer or residential-duty commercial water heater. V = rated volume of DHW tank in gallons
TE_{BASE}	=	See Table 4; thermal efficiency of standard minimum efficiency commercial water heater
UEF_{EFF}	=	Uniform Energy Factor (UEF) of new commercial or residential-duty commercial water heater. V = rated volume of DHW tank in gallons
TE_{EFF}	=	Thermal efficiency of new commercial water heater
CF	=	1,000,000 Btu⁄Dth
SL_{BASE}	=	Standby loss of baseline unit in Btu/h. Used when tank is equal to or greater than 75,000 Btu/h. For units <75,000 Btu/h, and/or for instantaneous/tankless units of any size, SL = 0 (Ref 4, 14) SL Base = (input Btu/h) / 800 + 110 x (tank size in gallons)^0.5, or use default of 872 Btu/h based on an input of 75,000 Btu/hr and volume of 50 gal.
SL_{EFF}	=	Nameplate standby loss of new water in Btu/h. Used when tank is equal to or greater than 75,000 Btu/h. For units <75,000 Btu/h, and/or for instantaneous/tankless units of any size, SL = 0 (Ref 4, 14)Use actual if possible, otherwise for storage units use SL = 0.84 * [(input Btu/h) / 800 + 110 x (tank size in gallons)^0.5] or 0.84 * (SL Base) = Default of 732 Btu/h based on an input of 75,000 Btu/hr and volume of 50 gal.

Example:

A 3,000 ft^2 sit-down restaurant installed a new 100-gallon, 200,000 Btu/h gas storage water heater with TE of 94%. The standby loss values of baseline and efficient units are not known. The average MN ground temperature of 49.0 will be used in the calculation instead of zone 2 specific temperature. The equivalent TE base is 80% in this example.

$Energy_{HEATWATER}$ = 1 (Btu/lb·°F) × 8.34 (lbs/gal) × 44,439 (gal/1,000ft^2) × 3,000 (ft^2) / 1,000 (ft^2) × (130°F – 49.0°F) = 90,060,966 Btu⁄yr

TE_{BASE} = 80%

SL_{BASE} = 200,000 (Btu/h) / 800 + 110 x (100 gallons)^0.5 = 1,350 Btu/h

SL_{EFF} = 0.84 * [200,000 (Btu/h) / 800 + 110 x (100 gallons)^0.5] = 1,134 Btu/h

Unit Dth Savings per Year = 90,060,966 x (1/0.80 – 1/0.94) / 1,000,000 + (1,350 – 1,134) x 8,760 / 1,000,000 = 16.8 Dth

Deemed Input Tables

Table 1. Average groundwater temperatures (Ref. 1)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3
MN statewide average, or if location unknown	**49.0**

Table 2. Deemed Annual Hot Water Use by Building Type (Ref. 2)

Building Type	Annual Hot Water Load (Gal per 1,000 sq. ft. Per Year)
Small Office	1,540
Large Office	1,818
Restaurant	44,439
Convenience	4,594
Retail	1,354
Grocery	697
Warehouse	1,239
School	7,285
Health	24,540
Nursing	30,503
Lodging	29,548
Warehouse	1,239
Other Commercial	3,941

Table 3. Minimum Uniform Energy Factor (UEF) for Residential Water Heaters (Ref. 3)

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	Uniform Energy Factor (V = rated volume of DHW tank in gallons)
Gas-fired Storage Water Heater	≥ 20 gallons and ≤ 55 gallons ≤75,000 Btu/h	Medium	0.6483 – (0.0017 × V)
		High	0.6920 – (0.0013 × V)
	> 55 gallons and ≤ 100 gallons ≤75,000 Btu/h	Medium	0.7897 – (0.0004 × V)
		High	0.8072 – (0.0003 × V)
High Capacity Gas-Fired Storage Water Heater	≤120 gallon tanks > 75,000 Btu/h	Medium	0.6002 – (0.0011 * V)
		High	0.6597 – (0.0009 * V)
Gas-fired Instantaneous Water Heater	≤ 2 gallons and ≤ 200,000 Btu/h	Medium	0.81
		High	0.81

Table 4. Minimum Thermal Efficiency (TE) for Commercial Water Heaters (Ref. 4)

Product Class	Rated Storage Volume and Input Rating	Minimum Thermal Efficiency
Gas-fired Storage Water Heaters	>120 gallon tanks >75,000 Btu/h	80%
Gas-fired Instantaneous Water Heaters	Any size > 200,000 Btu/h	80%

Table 5. Equipment Lifetime by Type (Ref. 5)

Equipment Type	Lifetime (years)
Gas Storage Water Heaters	11
Gas Instantaneous Water Heaters	20

Table 6. Incremental Cost by Type (Ref. 6 and Ref. 7)

Equipment Type	Input Btu/h	Incremental Cost
Gas Storage Water Heaters	≤75,000 Btu/h	$577.00
	>75,000 Btu/h	$1,350.00
Gas Instantaneous Water Heaters	>50,000 Btu/h and <200,000 Btu/h	$1,096.60
	≥ 200,000 Btu/h	$1,800.00

Notes

In its July 2014 Final Rule (Ref. 11), the US Department of Energy (DOE) amended its test procedure for residential water heaters and certain commercial water heaters to establish a uniform efficiency descriptor. This rule also established a new equipment class of commercial waters termed "residential-duty commercial water heaters" that are required to be tested using the procedure for the uniform efficiency descriptor.

The July 2014 Final Rule also propagated the following criteria for defining non-residential water heaters, which are not subject to the uniform efficiency test procedures:

- Non-residential Gas-fired Storage: rated input > 105 kBtu/h, rated storage volume > 120 gallons
- Non-residential Gas-fired Instantaneous: rated input > 200 kBtu/h, rated storage volume > 2 gallons

Residential-duty Gas Commercial Water Heaters were defined as not meeting the above criteria, and not designed to provide outlet hot water at temperatures greater than 180 ˚F. This class of water heaters is subject to the 2014 amended test procedures.

ENERGY STAR definitions include the following criteria:

- Residential Gas-fired Storage: hot water temperature < 180˚F, rated input ≤ 75 kBtu/h and rated storage volume ≥ 20 gallons and < 100 gallons (Ref. 10)
- Residential Gas-fired Instantaneous: initiate heating upon sensing water flow, hot water temperature < 180˚F, ≥ 4 (kBtu/h)/gal, rated input > 50 kBtu/h and < 200 kBtu/h (Ref. 10)

- Commercial Gas-fired Storage: rated input > 75 kBtu/h (Ref. 12)
- Commercial Gas-fired Storage: rated input ≥ 4 (kBtu/h)/gal (Ref. 12)

Table 7. ENERGY STAR Residential Gas Water Heater Standards (Ref. 10)

Type	Size	ENERGY STAR Requirements	
Gas Storage Water Heaters	≤75,000 Btu/h and ≤ 55 gallons	Medium Draw Pattern	UEF ≥ 0.81
		High Draw Pattern	UEF ≥ 0.86
	≤75,000 Btu/h and >55 gallons	Medium Draw Pattern	UEF ≥ 0.86
		High Draw Pattern	UEF ≥ 0.86
Gas Instantaneous Water Heaters	Any	Any	UEF ≥ 0.95

Table 8. ENERGY STAR Commercial Gas Water Heater Standards (Ref. 12)

Criteria	Type	ENERGY STAR Requirements
Thermal Efficiency (TE)	Storage (> 75,000 Btu/h); Instantaneous (> 200,000 Btu/h)	TE ≥ 0.94
Maximum Standby Loss (Btu/h)	Storage (> 75,000 Btu/h)	≤ 0.84 x [(Input Btu/h / 800) + 110(tank volume in gallons)^0.5]
	Instantaneous (> 200,000 Btu/h)	N/A

The curve fitting equations for ENERGY STAR qualified gas water heaters is based on data from the ENERGY STAR Certified Products List (Ref. 13). Data from 405 gas storage and 94 gas instantons models is used. The fit is poor, but SL is often difficult to obtain so the approximation is made here.

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Revision History

Version	Description	Author	Date
1.0	Corrected instantaneous water heater efficiency requirement	Franklin Energy Services	11/11/15
2.0	Updated EF efficiency value to UEF value for residential-sized water heaters. Updated incremental costs for gas storage water heaters ≤ 75,000 Btu/h and instantaneous water heaters >50,000 Btu/h and <200,000 Btu/h	Franklin Energy Services	9/28/17
3.2	Updated to account for standby losses, changed example, updated T_{OUT}	Cadmus	10/2018
4.2	Minor clarifications to input variable definitions and defaults, and clarification to baseline criteria table.	Cadmus	8/1/2024

Commercial Hot Water – Faucet Aerator with Electric Water Heater

Measure Detail	Measure Value
Measure ID	2.04.03
Target Market Segments	Commercial
Target End Uses	DHW
Applicable To	Commercial facilities with electric water heaters.
Actions	Replace Working
Required from Customer/Contractor	Confirmation of electric water heater, project location (county), number of people, number of faucets, bath or kitchen faucets
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	10 (Ref. 1)
Unit Participant Incremental Cost	$6.70 (Ref. 5)

Measure Description

This measure includes replacing an existing faucet aerator with low-flow aerator.

Algorithms

Unit kWh Savings per Year = $[(GPM_{BASE} \times TF_{BASE} - GPM_{LOW} \times TF_{LOW}) \times FLU \times (People / Faucets) \times Days \times DF \times Density \times C_P \times (T_{OUT} - T_{IN}) / (ReEff \times 3{,}412)$

Unit Peak kW Savings = Unit kWh Savings per Year x CF / Hours

Where:

GPM_{BASE} = Actual or 2.2 gallons per minute (Ref. 4)

TF_{BASE} = Throttling factor for base use = 0.83 (Ref. 9)

GPM_{LOW} = Actual

TF_{LOW} = Throttling factor for installed use = 0.95 (Ref. 9)

FLU = Fixture length of use = 3 min/person/day (Ref. 8)

People = Number of people in facility = Actual or, If unknown, assume 10 people.

Faucets = Number of faucets in facility = Actual or, If unknown, assume 3 faucets. (Ref. 7)

Days = Days of operation per Table 3 (Ref. 6)

DF = Drain factor per Table 2 (See Assumptions). Drain factor accounts for the fact that a portion of faucet use is dictated by volume, not time (generally filling vessels, as opposed to washing items).

Density = 8.34 lb / gal

C_P = 1.0 Btu / (lb x °F)

T_{OUT}	=	Temperature of faucet usage per Table 2 (Ref. 10)
T_{IN}	=	Average groundwater temperature per Table 1 (Ref. 3)
ReEff	=	Recovery Efficiency = 98% (electric water heater) (Ref. 2)
3,412	=	Conversion from Btu to kWh
CF	=	Coincidence factor per Table 2 (Ref. 11)
Hours	=	Hours of use per year = (People x FLU / Faucets) x Days / 60

Example:

Direct installation of a 1.5 GPM faucet aerator in a location with electric water heat. The type of business, zone, number of people, number of faucets, and flow rate of existing aerator is unknown.

Unit kWh Savings per Year = (2.2 x 0.83 – 1.5 x 0.95) x 3 x 10 / 3 x 304.4 x 0.95 x 8.34 x 1 x (90 – 49) / (0.98 x 3,412) = 119 kWh

Hours = (10 x 3 / 3) x 304.4 / 60 = 50.7 hours

Unit Peak kW Savings = 119 x 0.0023 / 50.7 = 0.005 kW

Deemed Input Tables

Table 1. Average groundwater temperatures (Ref. 3)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3
MN statewide average, or if location unknown	**49.0**

Table 2. Faucet Drain Factor (See Assumptions), T_{OUT} (Ref. 10), and Coincidence Factor (Ref. 11)

Application	DF	T_{OUT}	CF
Kitchen	90%	93°F	0.0033
Bath	100%	86°F	0.0012
If application is unknown	95%	90°F	0.0023

Table 3. Deemed Annual Hot Water Use by Building Type (Ref. 6)

Building Type	Days Per Year
Small Office	250
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Retail	365
Grocery	365
Warehouse	250
Elementary School	200
Jr. High/High School/College	200
Health	365
Motel	365
Hotel	365
Other Commercial	250
If building type is unknown	304.4

Methodology and Assumptions

The IL TRM (Ref. 2) assumes drain factors of 75% for kitchen and 90% for bathroom aerators. These are agreed-upon values based on engineering judgement as determined by the Illinois Stakeholder Advisory Group. However, while these seem appropriate for residential settings, here commercial sites are deemed to have 90% kitchen and 100% bathroom drain factors.

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10. Cadmus and Opinion Dynamics. Showerhead and Faucet Aerator Meter Study. Memo to Michigan Evaluation Working Group. June 2013.
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Revision History

Version	Description	Author	Date
1.0	Created standalone spec from ResidentialElectricDHW_v03.2	Joe Plummer	
2.0	Revised formatting and algorithms	Franklin Energy Services	7/27/2012
2.1	Update the measure life and measure cost	Franklin Energy Services	7/27/2012
3.0	Update the algorithm to IL TRM	Franklin Energy Services	8/27/2012
3.1	Update the Peak kW algorithm	Franklin Energy Services	8/28/2012
3.2	Changed Action from Direct Install to Replace Working, changed from 8,760 to 8,766 hours per year to be consistent with other measures, minor edits	Joe Plummer	3/13/2013
3.3	Changed “electric or gas water heater” to “confirmation of gas water heater” in Required Inputs	Joe Plummer	11/25/2013
4.0	Changed “L” from 9.85 minutes to 3 minutes to more accurately reflect commercial faucet usage patterns	Franklin Energy Services	1/6/2016
5.0	Updated algorithm for kWh and kW savings, splitting out savings for kitchen and bathroom aerators, and using actual installed GPM and drain and throttling factors	Cadmus	10/2018

Commercial Hot Water – Faucet Aerator with Gas Water Heater

Measure Detail	Measure Value
Measure ID	2.04.04
Target Market Segments	Commercial
Target End Uses	DHW
Applicable To	Commercial facilities with gas water heaters.
Actions	Replace Working
Required from Customer/Contractor	Confirmation of gas water heater, project location (county), number of people, number of faucets, bath or kitchen faucets
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	10 (Ref. 1)
Unit Participant Incremental Cost	$6.70 (Ref. 5)

Measure Description

This measure includes replacing an existing faucet aerator with low-flow aerator.

Algorithms

Unit Dth Savings per Year = $[(GPM_{BASE} \times TF_{BASE} - GPM_{LOW} \times TF_{LOW}) \times FLU \times (People / Faucets) \times Days \times DF \times Density \times C_P \times (T_{OUT} - T_{IN}) / (ReEff \times 1{,}000{,}000)$

Where:

GPM_{BASE} = Actual or 2.2 gallons per minute (Ref. 4)

TF_{BASE} = Throttling factor for base use = 0.83 (Ref. 9)

GPM_{LOW} = Actual

TF_{LOW} = Throttling factor for installed use = 0.95 (Ref. 9)

FLU = Fixture length of use = 3 min/person/day (Ref. 8)

People = Number of people in facility = Actual or, If unknown, assume 10 people.

Faucets = Number of faucets in facility = Actual or, If unknown, assume 3 faucets. (Ref. 7)

Days = Days of operation per Table 3 (Ref. 6)

DF = Drain factor per Table 2 (See Assumptions). Drain factor accounts for the fact that a portion of faucet use is dictated by volume, not time (generally filling vessels, as opposed to washing items).

Density = 8.34 lb / gal

C_P = 1.0 Btu / (lb x °F)

T_{OUT} = Temperature of faucet usage per Table 2 (Ref. 10)

T_{IN} = Average groundwater temperature per Table 1 (Ref. 3)

ReEff = Recovery Efficiency = 67% (gas water heater) (Ref. 2)

1,000,000 = Conversion from Btu to kWh

Example:

Direct installation of a 1.5 GPM faucet aerator in a location with gas water heat. The type of business, zone, number of people, number of faucets, and flow rate of existing aerator is unknown.

Unit Dth Savings per Year = (2.2 x 0.83 – 1.5 x 0.95) x 3 x 10 / 3 x 304.4 x 0.95 x 8.34 x 1 x (90 – 49) / (0.67 x 1,000,000) = 0.59 Dth

Deemed Input Tables

Table 1. Average groundwater temperatures (Ref. 3)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3
MN statewide average, or if location unknown	**49.0**

Table 2. Faucet Drain Factor (See Assumptions) and T_{OUT} (Ref. 10)

Application	DF	T_{OUT}
Kitchen	90%	93°F
Bath	100%	86°F
If application is unknown	95%	90°F

Table 3. Deemed Annual Hot Water Use by Building Type (Ref. 6)

Building Type	Days Per Year
Small Office	250
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Retail	365
Grocery	365
Warehouse	250
Elementary School	200
Jr. High/High School/College	200
Health	365
Motel	365
Hotel	365
Other Commercial	250
If building type is unknown	304.4

Methodology and Assumptions

The IL TRM (Ref. 2) assumes drain factors of 75% for kitchen and 90% for bathroom aerators. These are agreed-upon values based on engineering judgement as determined by the Illinois Stakeholder Advisory Group. However, while these seem appropriate for residential settings, here commercial sites are deemed to have 90% kitchen and 100% bathroom drain factors.

References

1. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values. http://www.deeresources.com/deer2008exante/downloads/DEER%200607%20Measure%20Update%20Report.pdf. Accessed on 7/31/12.
2. Illinois Stakeholder Advisory Group. State of Illinois Energy Efficiency Technical Reference Manual, Version 6.0, Volume 2: Residential Measures. February 8th, 2017. Page 90. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_2_C_and_I_020817_Final.pdf
3. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules* https://www.energy.gov/eere/buildings/building-america-analysis-spreadsheets
4. Title 10, Code of Federal Regulations, Part 430 – Energy Conservation Program for Consumer Products, Subpart C – Energy and Water Conservation Standards and Their Effective Dates. https://www.ecfr.gov/cgi-bin/text-idx?SID=45151ba12ebfbba8afbf95d31bcd2ace&mc=true&node=pt10.3.430&rgn=div5#sp10.3.430.c
5. 2008 Database for Energy-Efficient Resources, Cost Values and Summary Documentation http://www.deeresources.com/deer2008exante/downloads/DEER%200607%20Measure%20Update%20Report.pdf. Accessed on 7/31/12.
6. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.
7. Assumes one kitchen faucet and two restroom faucets. Franklin Energy Services.
8. Connecticut UI and CLP Program Savings Documentation. September 29, 2009.
9. M. Schuldt and D. Tachibana. *Energy-Related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes*. August 2008. Page 1-265. http://www.seattle.gov/light/Conserve/Reports/paper_10.pdf
10. Cadmus and Opinion Dynamics. Showerhead and Faucet Aerator Meter Study. Memo to Michigan Evaluation Working Group. June 2013.

Revision History

Version	Description	Author	Date
1.0	Created standalone spec from ResidentialElectricDHW_v03.2	Joe Plummer	
2.0	Revised formatting and algorithms	Franklin Energy Services	7/27/2012
2.1	Update the measure life and measure cost	Franklin Energy Services	7/27/2012
3.0	Update the algorithm to IL TRM	Franklin Energy Services	8/27/2012
3.1	Update the Peak kW algorithm	Franklin Energy Services	8/28/2012
3.2	Changed Action from Direct Install to Replace Working, changed from 8,760 to 8,766 hours per year to be consistent with other measures, minor edits	Joe Plummer	3/13/2013
3.3	Changed “electric or gas water heater” to “confirmation of gas water heater” in Required Inputs	Joe Plummer	11/25/2013
4.0	Changed “L” from 9.85 minutes to 3 minutes to more accurately reflect commercial faucet usage patterns	Franklin Energy Services	1/6/2016
5.0	Updated algorithm for Dth savings, splitting out savings for kitchen and bathroom aerators, and using actual installed GPM and drain and throttling factors	Cadmus	10/2018

Commercial Hot Water – Pre-Rinse Sprayers w/ Electric Water Heater

Measure Detail	Measure Value
Measure ID	2.04.05
Target Market Segments	Commercial
Target End Uses	DHW
Applicable To	Commercial facilities with kitchens: restaurants, large office buildings, etc., with gas water heaters
Actions	Replace Working
Required from Customer/Contractor	Confirmation of electric water heater, building type, project location (county)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	5 (Ref. 1)
Unit Participant Incremental Cost	Actual cost should be used; if unknown use $92.90 (Ref. 3)

Measure Description

This measure includes retrofit of working standard pre-rinse sprayers with low-flow pre-rinse sprayers in commercial kitchen applications.

Algorithms

Unit kWh Savings per Year = C_P x Density x (T_{OUT} – T_{IN}) x (GPM_{BASE} x $Hours_{BASE}$ – GPM_{EFF} x $Hours_{EFF}$) / (Eff x 3,412)

Unit Peak kW Savings = (Unit kWh Savings per Year) / 8,760 hours

Where:

C_P	=	1.0 Btu / (lb x °F); specific heat of water
Density	=	8.34 lbs / gal
GPM_{BASE}	=	2.23 gal/min (Ref. 1)
GPM_{EFF}	=	Actual or 1.12 gal/min (Ref.1)
$Hours_{BASE}$	=	0.44 hr/day (Ref. 1)
$Hours_{EFF}$	=	0.60 hr/day (Ref. 1)
Days	=	See Table 2
T_{OUT}	=	110 °F; spray water temperature (Ref. 7)
T_{IN}	=	Average groundwater temperature per Table 1 (Ref. 2)
Eff	=	0.97; electric water heater efficiency (Ref. 3)
3,412	=	Conversion from Btu to kWh

Example:

A direct install crew has installed a low-flow pre-rinse spray valve (rated flow unknown) in a local sit-down restaurant kitchen. The existing water heater is electric and the location is unknown.

WaterSaved = (2.23 gal/min x 0.44 hr/day – 1.12 gal/min x 0.60 hr/day) x 60 min/day x 365 day/yr = 6,776 gal/yr

EPG = (1 Btu/lb°F) x (8.34 lbs/gal) x (110°F – 49.0°F) = 508.7 Btu/gal

Unit kWh Savings per Year = 508.7 Btu/gal x 6,776 gal/yr / 0.97 / (3,412 Btu/kWh) = 1,020 kWh/yr

Unit Peak kW Savings = 1,020 kWh / 8,760 hours = 0.116 kW

Deemed Input Tables

Table 1. Average groundwater temperatures (Ref. 2)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3
MN statewide average, or if location unknown	**49.0**

Table 2. Deemed Days of Hot Water Use by Building Type (Ref. 5)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250
Senior Living	365

Methodology and Assumptions

The following building types were considered not to apply to this measure: Small Office, Retail, Warehouse and Motel.

Notes

The federal maximum flow standard for pre-rinse spray valves manufactured on or after January 1, 2006 is 1.6 GPM (Ref. 4). Pre-rinse spray valves manufactured on or after January 28, 2019 shall have a flow rate that does not exceed the following:

Table 3. Pre-rinse Spray Valve Flow Rate by Product Class (Ref. 4)

Effective January 28, 2019

Product Class (Spray Force in Ounce-Force, ozf)	Flow Rate (Gallons Per Minute, gpm)
Product Class 1 (≤5.0 ozf)	1.00
Product Class 2 (>5.0 ozf and ≤8.0 ozf)	1.20
Product Class 3 (>8.0 ozf)	1.28

Federal agencies are required to purchase US EPA WaterSense-labeled products where applicable. Version 1 of the WaterSense Specification for Commercial Pre-Rinse Spray Valves went into effect in September 2013 and requires a maximum flow rate value equal to 1.28 GPM or less (Ref. 6, 8).

References

1. SBW Consulting. *Impact and Process Evaluation Final Report for California Urban Water Conservation Council 2004-5 Pre-Rinse Spray Valve Installation Program (Phase 2).* February 21, 2007. http://infohouse.p2ric.org/ref/50/49026.pdf
2. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules* http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html
3. Illinois Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 6.0, Volume 2.* Page 60. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_2_C_and_I_020817_Final.pdf
4. Title 10, Code of Federal Regulations, Part 431 – Energy Efficiency Program for Certain Commercial and Industrial Equipment, Subpart O – Commercial Prerinse Spray Valves. January 1, 2010. https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=314b19ef2b3eab0c89f644fe6f841fe2&mc=true&n=pt10.3.431&r=PART&ty=HTML#sp10.3.431.o
5. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.
6. Purchasing Water-Efficient Faucets, Pre-Rinse Spray Valves, Showerheads, Toilets, and Urinals. http://www.energy.gov/eere/femp/purchasing-water-efficient-faucets-pre-rinse-spray-valves-showerheads-toilets-and-urinals. Accessed 09/24/16.
7. 110°F is an average of surveyed results in *Pre-Rinse Spray Valves Field Study Report*, EPA WaterSense. March 31, 2011. http://www3.epa.gov/watersense/docs/final_epa_prsv_study_report_033111v2_508.pdf.
8. WaterSense® Specification for Commercial Pre-Rinse Spray Valves, Version 1.0, September 19, 2013. https://www3.epa.gov/watersense/docs/prsv-finalspec-091913-final-508.pdf. Accessed 09/24/16.

Revision History

Version	Description	Author	Date
3.0	Added Senior Living building type and unknown location to Table 1. The average hot water temperature has been increased from 105˚F to 110˚F based on the results of a 2011 EPA study.	Franklin Energy Services	12/1/2015
3.1	Added 2019 federal standard to Notes, updated purchasing requirements for federal agencies.	Franklin Energy Services	8/22/2016
3.2	Algorithm reworked, permitting actual installed flowrate	Cadmus	10/2018

Commercial Hot Water – Pre-Rinse Sprayers with Gas Water Heater

Measure Detail	Measure Value
Measure ID	2.04.06
Target Market Segments	Commercial
Target End Uses	DHW
Applicable To	Commercial facilities with kitchens: restaurants, large office buildings, etc., with gas water heaters
Actions	Replace Working
Required from Customer/Contractor	Confirmation of gas water heater, building type, project location (county)
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	5 (Ref. 1)
Unit Participant Incremental Cost	Actual cost should be used; if unknown use $92.90 (Ref. 3)

Measure Description

This measure includes retrofit of working standard pre-rinse sprayers with low-flow, 1.6 gpm pre-rinse sprayers in commercial kitchen applications.

Algorithms

Unit Dth Savings per Year = C_P x Density x (T_{OUT} – T_{IN}) x (GPM_{BASE} x $Hours_{BASE}$ – GPM_{EFF} x $Hours_{EFF}$) / (Eff x 1,000,000)

Where:

C_P	=	1.0 Btu / (lb x °F); specific heat of water
Density	=	8.34 lbs / gal
GPM_{BASE}	=	2.23 gal/min (Ref. 1)
GPM_{EFF}	=	Actual or 1.12 gal/min (Ref.1)
$Hours_{BASE}$	=	0.44 hr/day (Ref. 1)
$Hours_{EFF}$	=	0.60 hr/day (Ref. 1)
Days	=	See Table 2
T_{OUT}	=	110 °F; spray water temperature (Ref. 7)
T_{IN}	=	Average groundwater temperature per Table 1 (Ref. 2)
Eff	=	0.80; gas water heater efficiency (Ref. 3)
1,000,000	=	Conversion from Btu to Dth

Example:

A direct install crew has installed a low-flow pre-rinse spray valve (rated flow unknown) in a local sit-down restaurant kitchen. The existing water heater is gas and the location is unknown.

WaterSaved = (2.23 gal/min x 0.44 hr/day – 1.12 gal/min x 0.60 hr/day) x 60 min/day x 365 day/yr = 6,776 gal/yr

EPG = (1 Btu/lb°F) x (8.34 lbs/gal) x (110°F – 49.0°F) = 508.7 Btu/gal

Unit Dth Savings per Year = 508.7 Btu/gal x 6,776 gal/yr / 0.80 / (1,000,000 Btu/Dth) = 4.3 Dth/yr

Deemed Input Tables

Table 1. Average groundwater temperatures (Ref. 2)

Location	Temperature (°F)
Zone 1 (Northern MN)	46.5
Zone 2 (Central MN)	49.1
Zone 3 (Twin Cities/Southern MN)	51.3
MN statewide average, or if location unknown	**49.0**

Table 2. Deemed Days of Hot Water Use by Building Type (Ref. 5)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250
Senior Living	365

Methodology and Assumptions

The following building types were considered not to apply to this measure: Small Office, Retail, Warehouse and Motel.

Notes

The federal maximum flow standard for pre-rinse spray valves manufactured on or after January 1, 2006 is 1.6 GPM (Ref. 4). Pre-rinse spray valves manufactured on or after January 28, 2019 shall have a flow rate that does not exceed the following:

Table 3. Pre-rinse Spray Valve Flow Rate by Product Class (Ref. 4)

Effective January 28, 2019

Product Class (Spray Force in Ounce-Force, ozf)	Flow Rate (Gallons Per Minute, gpm)
Product Class 1 (≤5.0 ozf)	1.00
Product Class 2 (>5.0 ozf and ≤8.0 ozf)	1.20
Product Class 3 (>8.0 ozf)	1.28

Federal agencies are required to purchase U.S. EPA WaterSense-labeled products where applicable. Version 1 of the WaterSense Specification for Commercial Pre-Rinse Spray Valves went into effect in September 2013 and requires a maximum flow rate value equal to 1.28 GPM or less (Ref. 6, 8).

References

1. SBW Consulting. *Impact and Process Evaluation Final Report for California Urban Water Conservation Council 2004-5 Pre-Rinse Spray Valve Installation Program (Phase 2).* February 21, 2007. http://infohouse.p2ric.org/ref/50/49026.pdf
2. US DOE Building America Program. Building America Analysis Spreadsheet, *Standard Benchmark DHW Schedules* http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html
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7. 110°F is an average of surveyed results in *Pre-Rinse Spray Valves Field Study Report*, EPA WaterSense. March 31, 2011. http://www3.epa.gov/watersense/docs/final_epa_prsv_study_report_033111v2_508.pdf.
8. WaterSense® Specification for Commercial Pre-Rinse Spray Valves, Version 1.0, September 19, 2013. https://www3.epa.gov/watersense/docs/prsv-finalspec-091913-final-508.pdf. Accessed 09/24/16.

Revision History

Version	Description	Author	Date
3.0	Added Senior Living building type and unknown location to Table 1. The average hot water temperature has been increased from 105˚F to 110˚F based on the results of a 2011 EPA study.	Franklin Energy Services	12/1/2015
3.1	Added 2019 federal standard to Notes, updated purchasing requirements for federal agencies.	Franklin Energy Services	8/22/2016
3.2	Algorithm reworked, permitting actual installed flowrate	Cadmus	10/2018

Refrigeration

C/I Refrigeration – Add Doors to Open Multideck Case

Measure Detail	Measure Value
Measure ID	2.05.01
Target Market Segments	Commercial, Industrial
Target End Uses	Refrigeration
Applicable To	Commercial and Industrial Refrigeration
Actions	Modify
Required from Customer/Contractor	Length of case in feet, refrigeration type (cooler or freezer), climate zone Optional inputs: Refrigerated case total load, HVAC COP (cooling), HVAC heating efficiency
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	12 (Ref. 1)
Unit Participant Incremental Cost	$126.53/linear ft. (Ref. 2)

Measure Description

Existing open multi-deck style cases can be retrofitted with doors. The doors are designed to fit right onto the open multi-deck style cases with minimal case modification. The measure savings are based on a per-foot-of-case enclosed.

Algorithms

Unit kWh Savings per Year = P_c x F_I x (1 – F_{CR}) / 3412 x (LF x 8,760 / COP_R – HRS_C / COP_H) x LEN

Unit Peak kW Savings = (Unit kWh Savings per Year)/8,760

Unit Dth Savings per Year = (P_c x F_I x (1 – F_{CR}) / Eff_{heat} / 1,000,000 x HRS_H) x LEN

Where:

LEN	= case length in feet, provided by customer
P_C	= Total case load in Btu/h per linear foot. If unknown see Table 1.
F_I	= 68%; Amount of case load associated with infiltration reduction (Ref. 3)
F_{CR}	= 13%; Amount of case load associated with conduction and radiation (Ref. 5)
3412	= Conversion factor, Btu/h per kW
LF	= Case load factor, the compressor duty cycle needed to maintain case temperatures. Refer to Table 1.
8,760	= Annual operating hours for case (Ref. 9)

COP_R	= Coefficient of performance of refrigeration system. Refer to Table 1.
HRS_C	= Annual cooling hours, equal to annual hours above an assumed balance point of 60˚F. Refer to Table 2.
HRS_H	= Annual heating hours, equal to annual hours below an assumed balance point of 60˚F.
COP_H	= Cooling coefficient of performance of HVAC system, assume 3.2 if unknown (Ref. 7)
Eff	= Heating system efficiency, assume 80% if unknown (Ref. 7)
1,000,000	= Conversion factor, Btu per Dth

Example:

Adding doors to a multideck cooler case that is six-feet wide, Zone 2.

Unit kWh Savings per Year = 1,500 x 0.68 x (1-0.13),/,3,412 x (0.62 x 8,760 / 2.5 – 2424 / 3.2) x 6 = 2,208

Unit Peak kW Savings = 2,208 / 8,760 = 0.252 kW

Unit Dth Savings per Year = 1,500 x 0.68 x (1-0.13) / 0.8 / 1,000,000 x 6,336 x 6 = 42.2 Dth

Deemed Input Tables

Table 1. Cooler and Freezer calculation values

Multideck Case Type	P_C (Btuh/ft.)	LF (Ref. 9)	COP_R (Ref. 8)
Cooler	1,500 (Ref. 8)	62%	2.5
Freezer	1,850 (Ref. 4)	80%	1.3

Table 2. Annual Cooling (HRSC) and Heating (HRSH) Hours by Climate Zone with Balance Point of 60˚F (Ref. 6)

Climate Zone	HRS_C	HRS_H
Zone 1 (Northern MN)	2,025	6,735
Zone 2 (Central MN)	2,424	6,336
Zone 3 (Southern MN/Twin Cities)	2,809	5,951

References

1. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” June 2, 2008. Available online: http://www.deeresources.com/.
2. Historic Focus on Energy project data, 2013. Two projects, average cost is $126.53 per foot.
3. Investigation of Energy-Efficient Supermarket Display Cases California Edison Research and Thermal Test Center. December 2004.
4. Manufacturer’s specification sheet for open multideck style freezer case. Hussmann Excel F6L. December 2015.

5. Comparison of Vertical Display Cases: Energy and Productivity Impacts of Glass Doors Versus Open Vertical Display Cases. ASHRAE RP-1402. 2009.
6. Cooling degree data and heating degree data derived from Typical Meteorological Year 3 (TMY3) weather data for the following cities in Minnesota: averaged of International Falls and Duluth (Zone 1), average of Duluth and Minneapolis/St. Paul (Zone 2), and average of Minneapolis/St. Paul and Rochester (Zone 3).
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8. Arthur D. Little, Inc. Energy Savings Potential for Commercial Refrigeration Equipment – Final Report. 1996.
9. PA Consulting Group Inc. *State of Wisconsin Public Service Commission, Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.* Updated March 22, 2010.

Revision History

Version	Description	Author	Date
1.0	Original issue for adding doors to multideck cases	Franklin Energy Services	12/5/17

C/I Refrigeration – Anti-Sweat Heat Control

Measure Detail	Measure Value
Measure ID	2.05.02
Target Market Segments	Commercial, Industrial
Target End Uses	Refrigeration
Applicable To	Commercial reach-in coolers and freezers with standard, low, or no-heat doors
Actions	Modify, New Construction
Required from Customer/Contractor	Equipment type (cooler or freezer), door type (standard/low/no heat), number of doors, temperature (high/medium/low), humidity or conductivity-based control
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	0
Measure Lifetime (years)	12 (Ref. 1)
Unit Participant Incremental Cost	$200 (Ref. 2)

Measure Description

Glass doors on refrigerator and freezer cases can have anti-sweat or anti-condensate heaters in the frames and mullions of the case. These heaters operate continuously in order to prevent condensation/frosting on the glass and frame that occurs when the surface temperature is below the dew point of the surrounding air. Anti-sweat heater controls control the operation of these heaters so that they do not run continuously when not needed (lower dew point in the air as typically occurs in winter). Anti-sweat heaters are only required to operate at full capacity when the space humidity is 55%. This results in energy savings due to reduced operation of the heater elements.

Algorithms

Unit kWh Savings per Year = kW_base x n_door x ESF x BF x Hours

Where:

kW_base = Connected load kW for reach-in cooler or freezer door and frame with a heater. Refer to Table 1 for typical loads.

N_door = number of doors controlled by sensor, actual installed

Hours = 8,760 operating hours over the course of a year

ESF = Energy Savings Factor; represents the percentage of hours annually that the door heater is powered off due to the controls. Assumed to be 55% for humidity based controls, 70% for conductivity based control (Ref. 4)

BF = Bonus Factor; represents the increased savings due to reduction in cooling load inside the cases, and the increase in cooling load in the building space to cool the additional

heat generated by the door heaters. Assumed to be 1.36 for low temp, 1.22 for medium temp, and 1.15 for high temp application (Ref. 4)
Low Temperature: Freezers, -35F to 0F evaporator temp., frozen foods, ice cream, etc.
Medium Temperature: Coolers, 0F to 20F evaporator temp., meat, milk, dairy, etc.
High Temperature: Coolers, 20F to 45F evaporator temp., floral, produce, etc.

Example:

Install anti-sweat humidity-based heat control on 2-door low-temperature freezer with standard door.

Unit kWh Savings per Year = 0.195 x 2 x 0.55 x 1.36 x 8,760 = 2,557 kWh

Deemed Input Tables

Table 1. Typical Anti-Sweat Heater kW for Reach-in Case Doors

Application Type and Door Type	Heater kW	Ref. #
Freezer Door, Standard	0.195	(Ref. 3)
Freezer Door, Low-Heat	0.132	(Ref. 5)
Freezer Door, No-Heat	0.054	(Ref. 5)
Cooler Door, Low-Heat	0.092	(Ref. 3)
Cooler Door, No-Heat	0.052	(Ref. 5)

References

1. 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, December 16, 2008.
2. Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010, Pg. 208-210
3. Based on a range of wattages from two manufacturers and metered data
4. Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010
5. PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, p. 4-100 to 4-102.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	FES	8/20/2012
1.1	Corrected required inputs, defined temperature ranges, corrected example calculation, changed measure name, removed erroneous 0.9 factor in example calculation, removed Reference 5 referring to 0.9 factor, changed annual hours from 8,760 to 8,766	Joe Plummer	11/22/2013
1.2	Eliminated option to provide connected load and removed connected load from required inputs to simply the Smart Measure design, added equipment type to Required Inputs.	Joe Plummer	3/2/2014
1.3	Added low-heat and no-heat door options	FES	9/24/2016

C/I Refrigeration – Case Night Covers

Measure Detail	Measure Value
Measure ID	2.05.03
Target Market Segments	Commercial, Industrial
Target End Uses	Refrigeration
Applicable To	Commercial and Industrial Refrigeration
Actions	Modify, New Construction
Required from Customer/Contractor	Equipment use, cooler temperature, length Optional inputs: Unoccupied hours/hours of night cover use
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0 (no expectation to utilize night covers during peak loads)
Unit Dth Savings per Year	0
Measure Lifetime (years)	5 (Ref. 2)
Unit Participant Incremental Cost	$40.20/linear foot (Ref. 3)

Measure Description

Refrigeration thermal blinds, or night covers, are utilized to create a protective thermal barrier between ambient air and the cooled, conditioned air in open refrigerated cases. Deployed when grocery centers close, night covers insulate cold refrigeration cases while maintaining the desired displayed food temperature. Night covers are typically constructed of a flexible, woven fabric. Night covers differ from case strip curtains, because night covers can be designed with no gaps and are stowed during unoccupied store hours. The thermal barrier results in energy savings due to reduced refrigeration load from the loss of chilled air and the thermal gain from ambient air.

Algorithms

Unit kWh Savings per Year = CL x SF x Hours (Ref. 1)

Where:

CL	= Case length, feet
SF	= Savings factor per unit length based on a cooler case temperature in Table 1 (Ref. 1).
Hours	= Unoccupied grocery hours over the course of a year (Default of 2190 hours assumes 6 hours per day)

Example

Adding an aluminum fabric night cover to a dairy case that is thermostatically set at 34°F (1°C). The 3-deck dairy case is eight (8) feet in length.

Unit kWh Savings per Year = 8 ft x 0.01 kW/ft x 2190 hrs = 175 kWh

Deemed Input Tables

Table 1. Savings factor for thermal night covers.

Refrigerated Case Temperature, °F (°C)	SF – Savings Factor, kW/ft
-35 to -5 °F (-37 to -21 °C)	0.03
0 to 30 °F (-17 to -1 °C)	0.02
35 to 55 °F (2 to 13 °C)	0.01

References

1. "Effects of low emissive shields on performance and power use of a refrigerated display case", Southern California Edison, 1997. http://www.econofrost.com/acrobat/sce_report_long.pdf. Accessed 08/23/16.
2. DEER Effective Useful Life (EUL) Summary Update, April 5, 2014. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx. Accessed 08/23/16.
3. Workpaper PGECOREF101 Night Covers for Display Cases, Pacific Gas & Electric Company, May 29, 2009.

Revision History

Version	Description	Author	Date
1.0	Original issue for C&I Night Covers	Franklin Energy Services	07/19/16

C/I Refrigeration – Strip Curtains for Walk in Freezers and Coolers

Measure Detail	Measure Value
Measure ID	2.05.04
Target Market Segments	Commercial, Industrial
Target End Uses	Refrigeration
Applicable To	Commercial and Industrial Refrigeration
Actions	New
Required from Customer/Contractor	Length of door(s) in linear feet, refrigeration type (cooler or freezer), climate zone
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	4 (Ref. 1)
Unit Participant Incremental Cost	$10.22/ sq ft of door opening (Ref. 2)

Measure Description

This measure pertains to the installation of infiltration barriers (strip curtains) on walk-in coolers or freezers. Strip curtains impede heat transfer from adjacent warm and humid spaces into walk-ins when the main door is opened, thereby reducing the refrigeration load. As a result, compressor run time and energy consumption are reduced. The most likely areas of application are grocery stores, supermarkets, restaurants, and refrigerated warehouse. Strip curtains must be at least 0.06 inches thick. Low temperature strip curtains must be used for low temperature applications.

Algorithms

Unit kWh Savings per Year = ΔkWh/SqFt x A

Unit Peak kW Savings = ΔkW/SqFt x A

Where:

ΔkWh/SqFt = Savings per square foot of door, as shown in Table 1

A = Doorway area (length x width) in square feet. If the actual doorway area in square feet is unknown, use the square footage value for the facility type and cooler type in Table 1. The default doorway area values assume that walk-in unit doors are 7 feet tall.

Example:

A grocery store adds a new strip curtain on a walk-in cooler that does not currently have one installed. The door width of the walk-in cooler is 4 feet and the height is 7 feet. The square footage of this doorway is 28 square feet.

Unit kWh Savings per Year = 37 kWh/SqFt x 28 SqFt = 1,036 kWh

Unit Peak kW Savings = 0.0042 kW/SqFt x 28 SqFt = 0.1176 kW

Deemed Input Tables

Table 1. Equivalent Full Load Hours of heating per zone in Minnesota by building type (Ref. 3)

Facility Type	Pre-Existing Curtain Condition	Energy Savings (kWh/SqFt)	Demand Reduction (kW/SqFt)	Default Doorway Area (square feet)
Supermarket – Cooler	Existing curtain	37	0.0042	35
	No curtain	108	0.0123	
	Unknown	108	0.0123	
Supermarket – Freezer	Existing curtain	119	0.0136	35
	No curtain	349	0.0398	
	Unknown	349	0.0398	
Convenience Store – Cooler	Existing curtain	5	0.0006	21
	No curtain	20	0.0023	
	Unknown	11	0.0013	
Convenience Store – Freezer	Existing curtain	8	0.0009	21
	No curtain	27	0.0031	
	Unknown	17	0.0020	
Restaurant – Cooler	Existing curtain	8	0.0009	21
	No curtain	30	0.0034	
	Unknown	18	0.0020	
Restaurant – Freezer	Existing curtain	34	0.0039	21
	No curtain	119	0.0136	
	Unknown	81	0.0092	
Refrigerated Warehouse	Existing curtain	254	0.0290	80
	No curtain	729	0.0832	
	Unknown	287	0.0327	

Notes

This algorithm and savings values are currently used by the Wisconsin,[5] Arkansas,[6] and Illinois[7] TRMs, adapted from the 2016 Pennsylvania TRM,[4] and its earlier versions. Details on its derivation can be found in the Pennsylvania and Arkansas TRMs.

References

1. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." EUL Table. 2014. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx
2. 2008 Database for Energy-Efficiency Resources (DEER). Revised DEER Measure Cost Summary, revised 6/2/2008. http://www.deeresources.com/files/deer0911planning/downloads/DEER2008_Costs_ValuesAndDocumentation_080530Rev1.zip

3. Default Energy Savings and Demand Reductions for Strip Curtains in Pennsylvania Public Utility Commission TRM, chapter 3.5.9 Strip Curtains for Walk-in Freezers and Coolers. The source algorithm from which the savings per square foot values are determined is based the ASHRAE handbook (*American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE). 2010. ASHRAE Handbook, Refrigeration: 13.4, 13.6*).
4. Assumed Doorway area for four different facility types including supermarket, convenience store, restaurant and refrigerated warehouse. Pennsylvania Public Utility Commission 2016 TRM, chapter 3.5.9 Strip Curtains for Walk-in Freezers and Coolers. http://www.puc.pa.gov/pcdocs/1370278.docx
5. Cadmus. *Wisconsin Focus on Energy 2020 Technical Reference Manual*. Page 820. https://focusonenergy.com/sites/default/files/Focus_on_Energy_2020_TRM.pdf
6. Arkansas Public Service Commission. *Arkansas Technical Reference Manual*, Version 7.0. August 31, 2017. Page 443. http://www.apscservices.info/EEInfo/TRMv7.0.pdf
7. Illinois Stakeholder Advisory Group. *State of Illinois Energy Efficiency Technical Reference Manual, Version 6.0, Volume 3: Residential Measures*. October 17th, 2019. Page 541. https://ilsag.s3.amazonaws.com/IL-TRM_Effective_0-10-120_v8.0_Vol_2_C_and_I_10-17-19_Final.pdf

Revision History

Version	Description	Author	Date
01	Initial Submittal	Cadmus	9/2020

C/I Refrigeration – ECM Compressor/Condenser Fan Motors

Measure Detail	Measure Value
Measure ID	2.05.05
Target Market Segments	Commercial, Industrial
Target End Uses	Refrigeration
Applicable To	Commercial and Industrial Refrigeration
Actions	Replace on Fail, Replace Working, New Construction, Modify
Required from Customer/Contractor	Type of motor that was replaced (shaded pole or permanent split capacitor) and size of the motor installed
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	$80 (Ref. 2)

Measure Description

This measure includes replacing an existing shaded pole and permanent split capacitor motors with higher efficiency electronically commutated motors (ECM) in a commercial refrigeration system compressor or condensing unit.

Algorithms

Unit kWh Savings per Year = Motor_HP x LF x Conversion_Factor x (1/Baseline_Motor_Eff – 1/Proposed_Motor_Eff) x Hrs x Duty_Cycle

Unit Peak kW Savings = Motor_HP x LF x Conversion_Factor x (1/Baseline_Motor_Eff – 1/Proposed_Motor_Eff) x CF

Where:

Motor_HP = horsepower of the motor per Table 1

LF = load factor for the motor. Assumed to be 0.9 (Ref. 3)

Baseline_Motor_Eff = baseline motor efficiency per Table 2

Proposed_Motor_Eff = 76.35% (Ref. 4)

Hrs = hours per year = 8,760

Duty_Cycle = percent of time the compressor or condensing unit is actually running = 85% for freezers and 55% for coolers (Ref. 5)

CF = coincidence factor = 0.90 (Ref. 6)

Conversion_Factor = 0.746 kW per horsepower

Example:

Replacement of a 1/15 hp shaded pole condensing unit fan motor for a freezer application with an ECM motor.

Motor_HP = 0.0667

Baseline_Motor_Eff = 24.40%

Unit kWh Savings per Year = 0.0667 hp x 0.9 x 0.746 watts per hp x (1/24.40% - 1/76.35%) x 8,760 x 0.85
= 930 kWh Saved

Unit Peak kW Savings = 0.0667 hp x 0.9 x 0.746 kW per hp x (1/24.40% - 1/76.35%) x 0.90 = 0.112 kW

Deemed Input Tables

Table 1. Typical Motor Horsepower (Ref. 4)

Motor Size (Fraction)	Motor Size (Decimal)
1/20 hp	0.050
1/15 hp	0.067
1/10 hp	0.100
1/6 hp	0.167
1/3 hp	0.333
If unknown, use average of sizes above	0.143

Table 2. Baseline Motor Efficiency (Ref. 4)

Motor Type	Motor Efficiency (%)
Shaded Pole Motor	24.40%
Permanent Split Capacitor Motor (baseline for New Cons.)	53.29%
If motor type is unknown	38.85%

Methodology and Assumptions

Assumes that power output of the baseline and proposed motors are the same.

For new construction projects, the baseline motor efficiency should be the permanent split capacitor motor efficiency.

Notes

This measure does not cover the use of ECM fan motors in walk-in or reach-in cooler or freezer evaporators; refer to separate measure for ECM fan motors for those applications.

References

1. State of Wisconsin Public Service Commission of Wisconsin: Focus on Energy Evaluation, Business Programs: Measure Life Study. PA Consulting Group. October 28, 2009.
2. Public Service Commission of Wisconsin, Wisconsin Focus on Energy Technical Reference Manual, October 22, 2015, pages 435-436 and 686.

3. PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, p. 4-103 to 4-106.
4. Calculated efficiencies are from data in Table 5-3. 2009 of: US DOE Publication ID 6180. "Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration." Navigant Consulting, Inc. Available online: http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/commercial_refrig_report_10-09.pdf
5. Arthur D. Little Inc. Global Comparative Analysis of HFC and Alternative Technologies for Refrigeration, Air Conditioning, Foam, Solvent, Aerosol Propellant, and Fire Protection Applications, Section 8.2. Final Report to the Alliance for Responsible Atmospheric Policy. March 21, 2002.
6. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	8/26/16

C/I Refrigeration – Demand Defrost Controls

Measure Detail	Measure Value
Measure ID	2.05.06
Target Market Segments	Commercial, Industrial
Target End Uses	Refrigeration
Applicable To	Commercial and Industrial Refrigeration
Actions	Replace Working, Replace on Fail, Modify
Required from Customer/Contractor	Wattage of defrost controlled
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	10 (Ref. 1)
Unit Participant Incremental Cost	$619 per controller (Ref. 2, Ref. 3, see Methodology and Assumptions)

Measure Description

Evaporator coils in walk-in freezers will accumulate ice if not intermittently defrosted. This defrosting occurs by introducing heat to the coils, which does not allow for proper heat exchange. Demand defrost controls incorporate sensors and software that statistically model the defrost cycle and only initiate defrost cycles when deemed necessary by the sensors. This measure includes replacement of an existing walk-in freezer system without electronic Demand Defrost Controls which defrosts on a timed cycle, assumed to be a 20-minute cycle occurring every 4 hours. The efficient condition of this measure is a walk-in freezer system that triggers the defrost cycle only when the software, triggered by the array of sensors, determines that defrosting must occur. This measure applies to high-efficiency small walk-ins, not reach-ins.

Algorithms

Unit kWh Savings per Year = $kW_{DEFROST}$ x HOU_{BASE} x SF x (1 + 1 / COP)

Unit Peak kW Savings = (Unit kWh Savings per Year) / 8,760

Where:

$kW_{DEFROST}$ = Kilowatts of electric defrost; provided by customer/contractor

HOU_{BASE} = Annual hours defrost occurs without defrost controls, default of 573 hours (Ref 5,6,7, see Methodology and Assumptions)

SF = Savings Factor or defrost reduction factor, default of 47% (Ref 7,8,9, see Methodology and Assumptions)

COP = Coefficient of Performance, actual if known, unknown default of 1.3 (Ref. 4). If efficiency of refrigeration system is given in kW/ton, convert to COP = (12 / (3.412 * kW/ton).

8,760 = Annual hours of freezer operation, 24/7 assumption.

Example 1:

Retrofit an existing, standard walk-in freezer with Demand Defrost Control Sensors and Software using 1,500 W of electric defrost. Defaults for HOU, SF and COP are used.

Unit kWh Savings per Year = 1.5 kW x 573 hours x 47% savings factor x [1 + (1 / 1.3 COP)] = 714.7 kWh

Unit Peak kW Savings = 714.7 / 8,760 = 0.082 kW

Methodology and Assumptions

The incremental cost is the difference between the cost for timer controls ($146, Ref. 2) and demand defrost controls ($765, Ref. 3). $765 - $146 = $619.

Baseline run hours

Estimates of baseline defrost hours vary by source. Baseline hours of use (HOU_{BASE}) has been derived from the following three sources. The average of these five reference values results in 573 hours per year, which is the default deemed value used in this measure algorithm.

- An Oak Ridge National Laboratory paper (Ref. 5) states "Defrosts are typically scheduled to occur every six or eight hours, with a duration of 20 to 30 minutes." This indicates HOU ranging from 365 to 730 hours a year, or **548 hours** on average.
- The Wisconsin TRM (Ref. 6) uses the Oak Ridge National Laboratory reference and assumes every six hours for 20 minutes, producing **487 hours** a year (= 80 minutes per day * 365 days / 60 min per hour = 487 hours per year of active defrost cycle).
- A Minnesota CARD study (Ref. 7) examined two installations of KE2 brand controllers for 7 to 14 days before and after installation. The study observed the equivalent of 973 hours a year of baseline defrost in a cafeteria and 681 hours a year in a convenience store, or **827 hours** on average. The study states "Typically the defrost heaters on walk-in freezers run on a timer that turns on the heaters for 15
  minutes 3 times per day," which would project to **274 hours** a year. The study also showcases a KE2 fact sheet reading "The defrost coil is controlled by a time-clock, typically set to run for 30 minutes four times a day," which is **730 hours** a year.

Savings factor

- Estimates of percentage reduction in hours vary by source. Savings Factor (SF) has been derived from the following three sources. The average of these three reference values results in 47% savings factor, which is the default deemed value used in this measure algorithm. A National Renewable Energy Laboratory paper (Ref. 8) states "In one field study, a manufacturer of these controls found that smart defrost controls reduced the number of defrost cycles by **30%** (Criscione 2006)" although their 2006 reference, titled "New Energy Saving Opportunity For Walk-In Freezers" from E Source Tech News in November 2006, is not available.

- The Massachusetts TRM (Ref. 9) deems **35%**, citing "Supported by 3rd party evaluation: Independent Testing was performed by Intertek Testing Service on a Walk-in Freezer that was retrofitted with Smart Electric Defrost capability"
- The Minnesota CARD study (Ref. 7) observed equivalent reduced hours of 164 hours a year in the cafeteria, an 83% reduction, and 209 hours in the convenience store, a 69% reduction, or a **76%** average reduction for the two sites.

References

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Grainger, Inc. *Average Cost of Defrost Timer Controls (= $146; average of 23 relevant products).* Baseline cost. Accessed September 2018. https://www.grainger.com/category/defrost-timer-control/
3. Heatcraft Refrigeration Products, LLC. *Cost of Smart Defrost Controls (= $765).* Efficient cost. Accessed September 2018. *https://www.heatcraftrpd.com/PDF/Archived/SDK_CutSheetGen1*
4. Arthur D. Little, Inc. Energy Savings Potential for Commercial Refrigeration Equipment – Final Report. 1996.
5. Fricke, Brian A., and Sharma, Vishal. Oak Ridge National Laboratory. "Demand Defrost Strategies in Supermarket Refrigeration Systems." October 2011. https://info.ornl.gov/sites/publications/files/pub31296.pdf
6. Cadmus. *Wisconsin Focus on Energy Technical Reference Manual*. 2021. Page 954. https://focusonenergy.com/sites/default/files/inline-files/Focus%20on%20Energy%202021%20TRM.pdf
7. Michaels Energy. *Cost-effective Recommissioning of Restaurants*. October 2015. Page 93, Appendix A, Appendix N. https://www.cards.commerce.state.mn.us/CARDS/security/search.do?method=showPoup&documentId=%7B44ECFDC5-283A-455F-A4E1-6122450D6E43%7D&documentTitle=384566&documentType=6
8. National Renewable Energy Laboratory. *Advanced Energy Retrofit Guide—Grocery Stores.* Appendix F.2.9: Detailed Retrofit Measure Description. Page 168. June 2013. https://www.osti.gov/biblio/1045045
9. Mass Save. *Massachusetts Technical Reference Manual*. May 2020. Page 649. https://fileservice.eea.comacloud.net/FileService.Api/file/FileRoom/12190505

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Cadmus	9/2021

5.0	Corrected the conflicting default values between variable input list and Methodology write up. Corrected algorithm discrepancy between primary algorithm and example algorithm. Added missing variable definitions. Checked reference notations. Aligned referenced COP value to other C&I Refrigeration measures.	Cadmus	7/2025

C/I Refrigeration – Door Gasket Replacements

Measure Detail	Measure Value
Measure ID	2.05.07
Target Market Segments	Commercial
Target End Uses	Refrigeration
Applicable To	Commercial customers with existing refrigerated cases and walk-in units where the existing gasket is worn and no longer provides an effective seal.
Actions	Replace on Fail
Required from Customer/Contractor	Confirmation existing gasket is visibly damaged and the number of doors receiving new door gasket
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	3[1]
Unit Participant Incremental Cost	See Table 3[2,3]

Measure Description

This measure includes replacement of door gaskets on existing refrigerated cases and walk-in units where the existing gasket no longer provides an effective seal. Worn gaskets replaced with tight fitting gaskets inhibit infiltration of warm, moist air into refrigerated spaces, reducing refrigeration energy consumption. Tight fitting gaskets prevent frost build-up on evaporator coils, reduce compressor run time and improve overall effectiveness of heat removal from refrigerated space. The baseline is assumed to be a worn and visibly damaged refrigeration gasket which allows air to enter the unit with the door closed.

Algorithms

Unit kWh Savings per Year =ΔkWhDoor x Doors

Unit Peak kW Savings = ΔkWDoor x Doors

Unit Dth Savings per Year =0

Algorithm Inputs:

Variable	Definition	Units	Ref
Doors	Number of doors receiving new door gaskets	doors	
ΔkWhDoor	Annual kWh savings per door	kWh	3
ΔkWDoor	Annual kW savings per door	kWh	3

Example:

A bank of 8 reach-in freezer doors have their old gaskets replaced with properly sealed and tight-fitting new gaskets. These new gaskets will generate annual savings shown in the calculation below.

Unit kWh Savings per Year = 243 x 8 = 1944 kWh

Unit Peak kW Savings = 0.032 x 8 = 0.256 kW

Unit Dth Savings per Year = 0

Deemed Input Tables

Table 1: Average annual kWh and kW savings per door based on refrigeration space type, incremental cost by refrigeration type (Ref 2,3)

Refrigeration Space Type	ΔkWhDoor	ΔkWDoor	Cost/Door
Reach-in Cooler	248	0.032	$126.00
Reach-in Freezer	243	0.032	$156.00
Walk-in Cooler	204	0.027	$118.00
Walk-in Freezer	347	0.045	$177.00

Methodology and Assumptions

Deemed kWh and kW savings values are based on values from a door gasket replacement measure maintained by the Regional Technical Forum (Ref 3).

References

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) CPUC Support Table (2020) – Effective Useful Life and Remaining Useful Life. https://www.caetrm.com/cpuc/table/effusefullife/

2. U.S. Bureau of Labor Statistics - CPI Inflation Calculator https://data.bls.gov/cgi-bin/cpicalc.pl

3. Database for UES measures, Regional Technical Forum. Door Gasket Replacement, Version 1.5. December 2016 https://rtf.nwcouncil.org/measure/door-gasket-replacement/

Revision History

Version	Description	Author	Date
5.0	New measure created	Cadmus	8/1/2025

C/I Refrigeration – Ice Machines

Measure Detail	Measure Value
Measure ID	2.05.08
Target Market Segments	Commercial
Target End Uses	Refrigeration
Applicable To	Commercial air-cooled ice making head (IMH), remote condensing unit (RCU) and self-contained unit (SCU) batch and continuous-type ice making machines
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Equipment type (ICH, RCU, SCU), Harvest Type (Batch, Continuous) Ice Daily Harvest Rate (H)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	12 (Ref. 2)
Unit Participant Incremental Cost	$200 (Ref. 3)

Measure Description

Commercial ice machines are used in restaurants, hospitals, hotels, schools, offices and grocery stores. ENERGY STAR rates air-cooled ice machines. ENERGY STAR ice machines are designed with higher efficiency compressors and use less water than standard ice machines. Compliant efficient products do not need to be ENERGY STAR qualfied through the EPA program but would need to meet the ENERGY STAR performance criteria specified within this measure.

Algorithms

Unit kWh Savings per Year = DC x H/C x Days x (kWh_base – kWh_proposed) (Ref. 1)

Unit Peak kW Savings = CF x (Unit kWh Savings per Year)/(Days x 24) (Ref. 1)

Where:

kWh_base = baseline unit daily consumption per 100 lbs. of ice produced

kWh_proposed = proposed unit daily consumption per 100 lbs. of ice produced

DC = Duty cycle. Assumed to be 57%(Ref. 4)

H = Average ice machine harvest rate, lbs. of ice/day

C = Conversion factor, from lbs. of ice/day to 100 lbs. of ice/day

Days = Annual days of operation, 365

CF = Deemed coincidence factor, equal to 0.937 Ref. 1)

Example:

Install ENERGY STAR Ice Making Head with a batch harvest rate of 1,219 lbs. of ice/day

Unit kWh Savings per Year = 0.57 x 1,219/100 x 365 x ((6.89 – 0.0011 x 1,219) – (37.72x1219^(-0.298)) = 2,562 kWh

Unit Peak kW Savings = 0.937 x 2,562/(365x24) = 0.274 kW

Deemed Input Tables

Table 1. Air-Cooled Batch-Type Ice Makers (Ref. 5 and Ref. 6).

Ice Machine Type H = rated ice harvest rate (lbs per 24 hours)	kWh_base (kWh/100 lbs ice)	kWh_proposed (kWh/100 lbs ice)
Ice Making Head (300 ≤ H < 850)	7.05 – 0.0025 x H	$37.72 \times H^{-0.298}$
Ice Making Head (1,500 ≤ H < 1,600)	4.61	$37.72 \times H^{-0.298}$
Remote Condensing Unit, without remote compressor (400 ≤ H < 988)	7.97 – 0.00342 x H	$22.95 \times H^{-0.258} + 1.00$
Remote Condensing Unit, without remote compressor (988 ≤ H < 1,600)	4.59	
Remote Condensing Unit, without remote compressor (1,600 ≤ H < 4,000)	4.59	-0.00011 x H + 4.60
Remote Condensing Unit, with remote compressor (200 < H < 930)	7.97 – 0.00342 x H	$22.95 \times H^{-0.258} + 1.00$
Remote Condensing Unit, with remote compressor (1,600 ≤ H < 4,000)	4.79	-0.00011 x H + 4.60

Table 2. Air-Cooled Continuous-Type Ice Makers (Ref. 5 and Ref.6).

Ice Machine Type H = rated ice harvest rate (lbs per 24 hours)	kWh_base (kWh/100 lbs ice)	kWh_proposed (kWh/100 lbs ice)
Ice Making Head (H < 310)	9.19 – 0.00629 x H	$9.18 \times H^{-0.057}$
Ice Making Head (310 ≤ H < 820)	8.23 – 0.0032 x H	
Remote Condensing Unit, without remote compressor (400 < H < 800)	9.7 – 0.0058 x H	$6.00 \times H^{-0.162} + 3.50$
Remote Condensing Unit, with remote compressor (400 ≤ H < 800)	9.9 – 0.0058 x H	$6.00 \times H^{-0.162} + 3.50$
Remote Condensing Unit, without remote compressor (800 ≤ H < 4,000)	5.26	
Self-Contained Unit (700 ≤ H < 4,000)	5.1	$59.45 \times H^{-0.349} + 0.08$

Methodology and Assumptions

In Tables 1 and 2, base kWh represents federal standard maximum energy consumption for units manufactured on or after January 28, 2018 per Ref. 5. Proposed kWh represents maximum energy consumption for ENERGY STAR-labeled units per Automatic Commercial Ice Makers specification, Version 2.0. H = rated ice harvest rate in pounds per 24 hours.

Ice machine types where the ENERGY STAR maximum energy consumption exceeds the federal standard maximum energy consumption are not included in this measure.

References

1. The State of Illinois, Illinois Statewide Technical Reference Manual for Energy Efficiency DEER 2014, Version 5.0, page 59.
2. DEER 2014, http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx, Accessed 8/8/17.
3. San Diego Gas & Electric, Work Paper WPSDGENRCC0004, Revision 2, pages i-ii.
4. Fisher-Nickel Inc., Ice Machine Field Study: Energy and Water Saving with Ice Machine Upgrade and Load Shifting, https://fishnick.com/publications/fieldstudies/Ice_Machine_Upgrade_Load_Shifting_Field_Study.pdf, Accessed 8/8/17.
5. US Department of Energy, EERE-2010-BT-STD-0037-0137, https://www.regulations.gov/document?D=EERE-2010-BT-STD-0037-0137, Accessed 8/8/17.
6. US Environmental Protection Agency, ENERGY STAR® Program Requirements for Automatic commercial ice makers, https://www.energystar.gov/sites/default/files/specs//private/ENERGY_STAR_ACIM_V_2_Specification.pdf, Accessed 8/8/17.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	12/5/17

C/I Refrigeration – Refrigerator and Freezer

Measure Detail	Measure Value
Measure ID	2.05.09
Target Market Segments	Commercial, Industrial
Target End Uses	Refrigeration
Applicable To	Vertical closed and horizontal closed commercial refrigerators with transparent or solid doors and self-contained condensing units
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Actual installed frozen compartment volume in cubic feet, solid or glass door, refrigerator or freezer
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	12 (Ref. 1)
Unit Participant Incremental Cost	See Table 1

Measure Description

This measure relates to the installation of a new reach-in commercial refrigerator or freezer meeting ENERGY STAR efficiency standards. In order for this characterization to apply, the efficient equipment is assumed to be a new vertical glass door refrigerator or freezer or vertical chest freezer meeting the minimum ENERGY STAR efficiency level standards. Compliant efficient products do not need to be ENERGY STAR qualified through the EPA program but would need to meet the ENERGY STAR performance criteria specified within this measure.

Algorithms

Unit kWh Savings per Year = (kWh_base – kWh_EE) x 365

Unit Peak kW Savings = kWh Savings / 8,760

Where:

kWh_base	= baseline maximum daily energy consumption in kWh, calculated using actual chilled or frozen compartment volume (V) of the efficient unit as shown in Table 2
kWh_EE	= efficient maximum daily energy consumption in kWh, calculated using actual chilled or frozen compartment volume (V) of the efficient unit as shown in the Table 3
V	= the chilled or frozen compartment volume (ft.^{3}) (as defined in the Association of Home Appliance Manufacturers Standard HRF1–1979), actual installed
8,760	= operating hours over the course of a year
365	= days per year

Example

Install an ENERGY STAR vertical glass door refrigerator with a volume of 15 ft3 (see Notes).

Unit kWh Savings per Year = [(0.1 x 15+0.86) – (0.066 x 15 + 0.31)] x 365 = 387 kWh

Unit Peak kW Savings = 387 / 8,760 x 0.9 = 0.040 kW

Deemed Input Tables

Table 1. Incremental capital costs for commercial ENERGY STAR refrigerators (Ref. 2)

	Refrigerator	Freezer
Vertical Closed		
Solid Door(s)		
All volumes	$86	$113
Transparent Door(s)		
All volumes	TBD*	TBD*
Horizontal Closed		
Solid Door(s)		
All volumes	TBD*	$30
Transparent Door(s)		
All volumes	$84	TBD*

*TBD means there were no product options meeting the ENERGY STAR 4.0 standard in the Technical Support Document (Ref. 2)

Table 2. Baseline maximum daily energy consumption in kWh (Ref. 3)

Product Volume (in cubic feet)	Refrigerator	Freezer
Vertical Closed		
Solid Door(s)		
All volumes	0.05V + 1.36	0.22V + 1.38
Transparent Door(s)		
All volumes	0.1V + 0.86	0.29V + 2.95
Horizontal Closed		
Solid Door(s)		
All volumes	0.05V + 0.91	0.06V + 1.12
Transparent Door(s)		
All volumes	0.06V + 0.37	0.08V + 1.23

Table 3. ENERGY STAR maximum daily energy consumption in kWh (Ref.4) Product Volume (in cubic feet)

	Refrigerator	Freezer
Vertical Closed		
Solid Door(s)		
0 < V < 15	0.022V + 0.97	0.21V + 0.9
15 ≤ V < 30	0.066V + 0.31	0.12V + 2.248
30 ≤ V < 50	0.04V + 1.09	0.285V – 2.703
V ≥ 50	0.024V + 1.89	0.142V + 4.445
Transparent Door(s)		
0 < V < 15	0.095V + 0.445	0.232V + 2.36
15 ≤ V < 30	0.05V + 1.12	
30 ≤ V < 50	0.076V + 0.34	
V ≥ 50	0.105V – 1.111	
Horizontal Closed		
Solid or Transparent		
All volumes	0.05V + 0.28	0.057V + 0.55

Notes

ENERGY STAR Program Requirements for Commercial Refrigerators and Freezers, Version 4.0, was finalized on September 20, 2016 and will take effect on March 27, 2017 (Ref. 4). Table 1 should be revised as more products are produced that meet the new ENERGY STAR standard.

References

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc. June 2007. http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf.
2. Derived from Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Refrigeration Equipment. US DOE, February 2014. Tables 8.2.4 and 8.2.5. Determined incremental costs from mapping maximum daily energy consumption per ENERGY STAR 4.0 and Federal minimum standards to Efficiency Levels (EL) in Table 8.2.5.
3. Electronic Code of Federal Regulations; Commercial Refrigerators, Freezers and Refrigerator-Freezers. http://www.ecfr.gov/cgi-bin/text-idx?SID=ea9937006535237ca30dfd3e03ebaff2&mc=true&node=se10.3.431_166&rgn=div8. Accessed 08/18/16.
4. Commercial Refrigerators and Freezers Specification 4.0. https://www.energystar.gov/products/spec/commercial_refrigerators_freezers_specification_version_4_0_pd. Accessed 12/1/16.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	8/20/2012
2.0	Corrected example, changed 365 days/yr. to 365.25, changed 8,760 h/yr. to 8,766, changed name	Joe Plummer	2/11/2013
2.1	Corrected example	Joe Plummer	5/8/2014
2.2	Updated to new standard	Franklin Energy Services	12/18/2014
2.3	Changed example description	Joe Plummer	1/5/2015
3.0	Updated federal standards, added notes section with comment about ENERGY STAR versions, updated references and example	Franklin Energy Services	12/2/2016

C/I Refrigeration – Evaporator Fan Motor Retrofit

Measure Detail	Measure Value
Measure ID	2.05.10
Target Market Segments	Commercial, Industrial
Target End Uses	Refrigeration
Applicable To	Commercial and Industrial Refrigeration
Actions	Motors > 1 hp or > 460 volts, or in walk-ins manufactured before 1/1/2009: Replace Working, Replace on Fail, Modify Motors < 1 hp and < 460 volts in walk-ins manufactured on or after 1/1/2009: Replace Working
Required from Customer/Contractor	Equipment type (refrig or freezer, reach-in or walk-in), motor category (1-14W, 16-23W, 1/20 HP, 1/15 HP, 1/10 HP) Optional inputs: wattages of existing and new evaporator fan motors
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	$100 (Ref. 1)

Measure Description

This measure includes replacement of an existing, working standard-efficiency shaded-pole evaporator fan motor in refrigerated/freezer display cases or walk-in coolers with a high-efficiency electronically commutated motor (ECM).

Note that Federal code requires that motors less than 1 horsepower and less than 460 volts in walk-in coolers manufactured on or after January 1, 2009 shall use ECM or 3-phase evaporator fan motors (Ref. 7). For such scenarios, this measure shall be replace working only.

Algorithms

Unit kWh Savings per Year = (W_base – W_EE) / 1000 x LF x DC_evap x (1 + 1/(DG x COP)) x 8,760

Unit Peak kW Savings = (W_base – W_EE) / 1000 x LF x DC_evap x (1 + 1/(DG x COP)) x CF

Where:

W_base = Input wattage of existing/baseline evaporator fan motor. See Table 1 for reach-ins and Table 2 for walk-ins.

W_EE = Input wattage of new energy efficient evaporator fan motor. See Table 1 for reach-ins and Table 2 for walk-ins.

LF = Load Factor of evaporator fan motor. Assumed to be 0.9 (Ref. 2)

DC_evap	=	Duty cycle of evaporator fan motor for refrigerator/freezer. DC_evap = 100% for refrigerator, DC_evap = 94.4% for freezer (Ref. 2)
DG	=	Degradation factor of compressor COP. Assumed to be 0.98 (Ref. 5)
COP	=	Coefficient of performance of compressor in the refrigerator/freezer. COP = 2.5 for refrigerator, COP = 1.3 for freezer (Ref. 1, 2)
8,760	=	Operating hours over the course of a year
CF	=	Coincidence factor = 0.9 (Ref. 4)

Example 1:

Replace working 19.5 Watt SP evaporator fan motor with ECM fan motor for a reach-in cooler

Unit kWh Savings per Year = (93 – 30) / 1,000 x 0.9 x 1 x (1 + 1/(0.98 x 2.5)) x 8,760 = 700.0

Example 2:

Retrofit 1/15 HP ECM fan motor in walk-in freezer. The existing motor type is unknown.

Unit kWh Savings per Year = (193.9 – 65.1) / 1,000 x 0.9 x 0.944 x (1 + 1/(0.98 x 1.3)) x 8,760 = 1,712.2

Deemed Input Tables

Table 1. Reach-in Display Case Evaporator Fan Motor Wattages (Ref. 3, 7)

Motor Category	% of All Units[1]	Motor Output Watts	SP Eff	SP Input Watts	PSC Eff	PSC Input Watts	SP/PSC Wtd Avg Base Watts	ECM Eff	ECM Input Watts
1-14 watts (9 watt as industry average)	91%	9	18%	50	41%	22	43	66%	14
16-23 watts (19.5 watt as industry average)	3%	19.5	21%	93	41%	48	82	66%	30
1/20 HP (~37 watts)	6%	37	26%	142	41%	90	129	66%	56

Table 2. Walk-in Cooler and Freezer Evaporator Fan Motor Wattages (Ref. 6, 7)

Motor Type	Input Watts, Full Speed
1/20 hp Shaded pole	152.8
1/15 hp Shaded pole	203.8
1/10 hp Shaded Pole	305.7
1/20 hp PSC	70.0
1/15 hp PSC	93.3
1/10 hp PSC	140.0
1/20 hp ECM	48.9
1/15 hp ECM	65.1
1/10 hp ECM	97.7

Motor Type	Input Watts, Full Speed
1/20 hp Weighted Average of SP/PSC	145.3
1/15 hp Weighted Average of SP/PSC	193.9
1/10 hp Weighted Average of SP/PSC	290.8

Table 3. Split between shaded pole and permanent split capacitor motors for walk-in and reach-in units (Ref. 6)

Unit Type	SP %	PSC %
Walk In	91%	9%
Reach In	75%	25%

References

1. US DOE Publication #46230-00, "Energy Savings Potential for Commercial Refrigeration Equipment", 1996, Arthur C. Little, Inc http://www.scribd.com/doc/13260953/Energy-Savings-Potential-for-Commercial-Refrigeration-Equipment
2. PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, p. 4-103 to 4-106.
3. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Grocery Display Case ECM, FY2010, V2. Accessed from RTF website: http://www.nwcouncil.org/rtf/measures/Default.asp on July 30, 2010
4. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified.
5. Regional Technical Forum. Evaporator Fan Controls and Evaporator Fan Uniform Energy Savings Measures Calculations. 2010. Available online: http://rtf.nwcouncil.org/meetings/2010/09/leds%20open%20display%20cases%20and%20ecmotor%20evap%20fan%20controllers_rev.ppt
6. Walk-in motor split is based on a random sampling of Focus on Energy projects from 2012 through August 2016; reach-in motor split is estimated based on Franklin Energy program experience.
7. Motor input watts are calculated from data in Table 5-3. 2009 of: US DOE Publication ID 6180. "Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration." Navigant Consulting, Inc. Available online: http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/commercial_refrig_report_10-09.pdf
8. Code of Federal Regulations. Title 10, Chapter II, Subchapter D, part 431.306. https://www.ecfr.gov/cgi-bin/text-idx?SID=06bb5275babde5c3b0d48497ae00764f&mc=true&node=pt10.3.431&rgn=div5#se10.3.431_1306

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	8/20/2012
1.1	Minor revisions, changed name, corrected required inputs, removed qty from algorithms, changed hours from 8,760 to 8,766 to be consistent with other measures, removed New Construction and Replace on Fail from action types since as of 2009 federal standard requires ECM motors for evaporator fan motors < 1 HP and < 460V, changed measure description, replaced “cooler” with “refrigerator”, removed reference 5 (applied to new construction)	Joe Plummer	2/8/2013
1.2	Corrected Required Inputs	Joe Plummer	3/29/2014
1.3	Added weighted-average watts for baseline motors, added Table 2 for walk-in coolers and freezers, added example	Franklin Energy Services	9/6/16
2.0	Clarified that many motor types are required to be ECM	Cadmus	10/2020

C/I Refrigeration – Evaporator Fan Speed Controls

Measure Detail	Measure Value
Measure ID	2.05.11
Target Market Segments	Commercial, Industrial
Target End Uses	Refrigeration
Applicable To	Commercial and Industrial Refrigeration; Single Phase Permanent Split Capacitor (PSC), Shaded Pole (SP), or Electronically Commutated (EC) Evaporator Fan Motors in Walk-in Coolers and Freezers
Actions	New Construction, Modify
Required from Customer/Contractor	Where controls were installed (cooler or freezer), number of motors controlled by each controller, type of motor used in the evaporator (shaded pole, permanent split capacitor, or ECM), and size of the motor
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	16 (Ref. 1)
Unit Participant Incremental Cost	$161.74 per motor controlled (Ref. 2)

Measure Description

This measure adds controls to vary the speed of evaporator fan motors in walk-in coolers and freezers. The evaporator fans are used to both provide cooling when the compressor is running and to provide air circulation when the compressor is off. The controls provide a lower fan speed during periods when the compressor is off.

Algorithms

Unit kWh Savings per Year = N_motors x (Watts_Full_Speed x (1-Percent_Low_Speed) + Watts_Low_Speed x Percent_Low_Speed) / Conversion_Factor x (1 + 1/(DG x COP)) x (Hrs x (1 – Percent_Defrost))

Unit Peak kW Savings = N_motors x (Watts_Full_Speed x (1-Percent_Low_Speed) + Watts_Low_Speed x Percent_Low_Speed) / Conversion_Factor x (1 + 1/(DG x COP)) x CF

Where:

N_motors = number of motors controlled

Watts_Full_Speed = wattage of fan motor at full speed, selected from Table 1 or use 138.7 watts if fan motor type and hp are unknown

Watts_Low_Speed = wattage of fan motor at low speed setting, selected from Table 1 or use 10.4 watts if fan motor type and hp are unknown

Percent_Low_Speed = percentage of time the fan runs at the low speed setting = 32% for freezers and 42% for coolers (Ref. 3)

DG = Degradation factor of compressor COP. Assumed to be 0.98 (Ref. 3)

COP = Coefficient of Performance, = 2.5 for coolers, 1. 3 for freezers. (Ref. 4, Ref. 5)

Hrs = hours per year = 8,760

Percent_Defrost = percentage of hours the fan is off for defrost cycle = 0% for coolers and 4% for freezers (Ref. 3)

CF = coincidence factor = 0.90 (Ref. 6)

Conversion_Factor = 1,000 watts per kW

Example:

Add evaporator fan controls to an evaporator with one 1/10 hp PSC fan motor for a walk-in freezer.

Watts_Full_Speed = 140.0

Watts_Low_Speed = 10.5

Percent_Low_Speed = 32%

COP = 1.3

Percent_Defrost = 4%

Unit kWh Savings per Year = (140.0 watts x (1-32%) + 10.5 watts x 32%) / 1,000 watts per kW x (1 + 1/(0.98 x 1.3)) x (8,760 x (1 – 4%)) = 1,480 kWh

Unit Peak kW Savings = (140.0 watts x (1-32%) + 10.5 watts x 32%) / 1,000 watts per kW x (1 + 1/(0.98 x 1.3)) x 0.90 = 0.158 kW

Deemed Input Tables

Table 1. Typical Evaporator Fan Motor Watts

Motor Type	Input Watts, Full Speed (Ref. 7)	Input Watts, Low Speed (Ref. 3)
1/20 hp Shaded pole	152.8	11.5
1/15 hp Shaded pole	203.8	15.3
1/10 hp Shaded Pole	305.7	22.9
1/20 hp PSC	70.0	5.2
1/15 hp PSC	93.3	7.0
1/10 hp PSC	140.0	10.5
1/20 hp ECM	48.9	3.7
1/15 hp ECM	65.1	4.9
1/10 hp ECM	97.7	7.3
1/20 hp Type Unknown	90.6	6.8

Motor Type	Input Watts, Full Speed (Ref. 7)	Input Watts, Low Speed (Ref. 3)
1/15 hp Type Unknown	120.7	9.1
1/10 hp Type Unknown	181.1	13.6
If neither motor type or size is known, use average of the 3 "Type Unknown" wattages:	130.8	9.8

Methodology and Assumptions

Assumes that in both the baseline and proposed cases the evaporator fan motor is off during the defrost cycle for freezer applications. Evaporator must use single phase shaded pole, permanent split capacitor, or ECM motors. Larger systems with three phase and/or induction motors are excluded from this measure.

Input watts at low speed are based on adjusting full speed input watts using fan law, using reported typical RPM from (Ref. 3), which is 1550 RPM for full speed and 550 RPM for low speed. A fan law exponent of 2.5 was used to be conservative.

Notes

This measure only covers evaporator fan controls for walk-in coolers and freezers. It does not cover reach-in coolers and freezers.

References

1. California Energy Commission and California Public Utilities Commission. Database for Efficient Resources (DEER) 2008, Effective/Remaining Useful Life Values. Available online: http://www.deeresources.com/files/deer2008exante/downloads/EUL_Summary_10-1-08.xls
2. California Energy Commission and California Public Utilities Commission. Database for Efficient Resources (DEER) 2008, Measure Cost Summary.
3. Regional Technical Forum. Evaporator Fan Controls and Evaporator Fan Uniform Energy Savings Measures Calculations. 2010. Available online: *http://rtf.nwcouncil.org/meetings/2010/09/leds%20open%20display%20cases%20and%20ecmotor%20evap%20fan%20controllers_rev.ppt*
4. US DOE Publication #46230-00, "Energy Savings Potential for Commercial Refrigeration Equipment", 1996, Arthur C. Little, Inc. Available Online: http://www.scribd.com/doc/13260953/Energy-Savings-Potential-for-Commercial-Refrigeration-Equipment
5. PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, p. 4-103 to 4-106.
6. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified.
7. Motor input watts are calculated from data in Table 5-3. 2009 of: US DOE Publication ID 6180. "Energy Savings Potential and Research & Development Opportunities for Commercial

Refrigeration." Navigant Consulting, Inc. Available online: http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/commercial_refrig_report_10-09.pdf

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	8/26/16

C/I Refrigeration – Loading Dock Pit Seals

Measure Detail	Measure Value
Measure ID	2.05.12
Target Market Segments	Commercial, Industrial
Target End Uses	Envelope
Applicable To	Cold storage facilities
Actions	Modify, New Construction
Required from Customer/Contractor	Climate zone
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	10
Unit Participant Incremental Cost	$780 for Pit/Ramp Seals (Ref. 7)

Measure Description

Many loading dock pits include a leveler ramp that has an area underneath that is exposed to the outside, and gaps that allow infiltration of outside air, causing sensible and latent heat loads that must be removed by the refrigeration system in a cold storage facility. This measure characterizes the savings from installing pit seals and/or thermal blankets to reduce these heat gains.

Algorithms

Unit kWh Savings per Year = $(\Delta Q_{infil,ave} + \Delta Q_{cond,ave}) / 3412 / COP \times Hours$

Unit Peak kW Savings = $(\Delta Q_{infil,max} + \Delta Q_{cond,max}) / 3412 / COP$

Where:

$\Delta Q_{infil,ave}$	= $4.5 \times CFM_{infil.ave} \times (h_{OA,ave} - h_0)$, average reduction in heat loss due to infiltration in Btu/hr
$\Delta Q_{cond,ave}$	= $F_1 \times A_{ramp} \times (T_{OA,ave} - T_O) \times (1/R_1 - 1/R_2)$, average reduction in heat loss due to conduction in Btu/hr
$\Delta Q_{infil,max}$	= $4.5 \times CFM_{infil.max} \times (h_{OA,max} - h_0)$, maximum reduction in heat loss due to infiltration in Btu/hr
$\Delta Q_{cond,max}$	= $F_1 \times A_{ramp} \times (T_{OA,,max} - T_O) \times (1/R_1 - 1/R_2)$, maximum reduction in heat loss due to conduction in Btu/hr
3412	= conversion factor, Btu per kWh
COP	= typical coefficient of performance for refrigeration system, 2.5 for coolers (Ref. 4)
Hours	= 8,760, average hours per year
$CFM_{infil,ave}$	= $F_2 \times LA \times \sqrt{(C_{stack} \times (T_{OA,ave} - T_0) + C_{wind} \times V_{wind,ave}^2)}$, average outside air infiltration rate in cubic feet per minute. (Ref. 1)

$CFM_{infil,max}$	= F_2 x LA x √(C_{stack} x ($T_{OA,max}$ – T_0) + C_{wind} x $V_{wind,max}^2$), maximum outside air infiltration rate in cubic feet per minute. (Ref. 1)
LA	= Effective Leakage Area in square inches. If unknown, assume 16.8 in^2 (assumes a 0.05-inch gap around perimeter of 84" x 78" ramp) (Ref. 6).
C_{stack}	= Stack Coefficient, 0.0225 Assuming a 1.5 story building (Ref. 1)
T_O	= Indoor Temperature Setpoint. If unknown, assume 35˚F.
$T_{OA,ave}$	= Average Outside Air Temperature, see Table 1
C_{wind}	= Wind Coefficient, 0.0138 Assuming a 1.5 story building average with no obstructions or local shielding (Ref. 1)
$V_{wind,Ave}$	= Average Wind Speed, see Table 1
$h_{OA,ave}$	= Average Outside Air Enthalpy, see Table 1
h_o	= Indoor enthalpy in Btu/lb. If unknown assume 10.24 Btu/lb. (Ref. 5)
A_{ramp}	= Area of leveler ramp in square feet. Assume 45.5 ft^2 if unknown (84" x 78").
R_1	= 1.36, R-value of uninsulated ramp, approximately equal to R-value of air films (R-0.68) above and below ramp
R_2	= R_{ins} + 1.36, R-value of insulated ramp, approximately equal to R-value of insulating material plus air films.
R_{ins}	= R-value of ramp insulation. Assume R-1 if unknown.
F_1	= 0.75, adjustment factor accounting for possibility of positive pressure within the building, which will reduce the rate of heat transfer due to conduction (Ref. 6).
F_2	= 0.75, adjustment factor accounting for orientation of the dock door relative to the direction of prevailing winds (Ref. 6).

Example:

A refrigerated warehouse in Minneapolis installs a pit seal and an R-2 ramp leveler blanket. The indoor temperature setpoint is 35°F.

Energy savings calculation:

$CFM_{infil,ave}$ = 0.75 x 16.8 x √(0.0225 x (44.8 – 35) + 0.0138 x 11.5^2) = 18.0 CFM

$\Delta Q_{infil,ave}$ =4.5 x 18.0 x (17.0 – 10.24) = 547.6 Btu/h

$\Delta Q_{cond,ave}$ =0.75 x 45.5 x (44.8 – 35) x (1/1.36 – 1/3.36) = 146.4 Btu/h

Unit kWh Savings per Year = (547.6 + 146.4)/3412/2.5 x 8,760 = 713.2 kWh

Peak demand savings calculation:

$CFM_{infil,max}$ = 0.75 x 16.8 x √(0.0225 x (94.4 – 35) + 0.0138 x 40.4^2) = 61.5 CFM

$\Delta Q_{infil,max}$ =4.5 x 61.5 x (49.5 – 10.24) =10,873.6 Btu/h

$\Delta Q_{cond,max}$ =0.75 x 45.5 x (94.4 – 35) x (1/1.36 – 1/3.36) = 887.2 Btu/h

Unit Peak kW Savings = 0.9 x (10,873.6 + 887.2)/3412/2.5 = 1.38 kW

Deemed Input Tables

Table 1. Outside air conditions (Ref. 2 and Ref. 3)

Climate Zone	$h_{OA,ave}$ Btu/lb.	$h_{OA,max}$ Btu/lb.	$T_{OA,ave}$ °F	$T_{OA,max}$ °F	$V_{wind,ave}$ miles/hr.	$V_{wind,max}$ miles/hr.
Zone 1 (Northern MN)	14.6	45.3	38.6	90.4	9.5	33.5
Zone 2 (Central MN)	16.0	46.8	42.6	92.8	10.4	37.5
Zone 3 (Southern MN/Twin Cities)	17.0	49.5	44.8	94.4	11.5	40.4

References

1. 2013 ASHRAE Handbook – Fundamentals, Chapter 16: Ventilation and Infiltration, page 16.23-24. Infiltration rate formula includes a 0.75 factor to account for wind orientation relative to dock door (engineering judgement).
2. National Climate Data Center – National Oceanic and Atmospheric Administration 1981-2010 Normals. Weather data for Duluth and International Falls was averaged for Zone 1, Duluth and Minneapolis for Zone 2, and Minneapolis and Rochester for Zone 3.
3. 2013 ASHRAE Handbook – Fundamentals, Climate Design Information Appendix Table, Minnesota Heating DB 99.6%.
4. US DOE Publication #46230-00, "Energy Savings Potential for Commercial Refrigeration Equipment", 1996, Arthur C. Little, Inc.
5. Assumes 40% relative humidity at 35˚F dry bulb.
6. *Energy Efficiency Evaluation: Warehouse Dock Leveler Improvements.* Prepared for Minnesota Department of Commerce by Franklin Energy, April 2011.
7. "Deemed savings estimate – Dock Pit-Door systems-v2.xls". Prepared for Minnesota Department of Commerce by Franklin Energy, April 2011.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	9/14/17

C/I Refrigeration – Low-Heat and No-Heat Doors

Measure Detail	Measure Value
Measure ID	2.05.13
Target Market Segments	Commercial, Industrial
Target End Uses	Refrigeration
Applicable To	Commercial and Industrial Refrigeration
Actions	New Construction, Modify
Required from Customer/Contractor	Where doors were installed (cooler or freezer), number of doors installed, type of door installed (low heat or no heat), temperature range (low, medium, or high)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	12 (Ref. 1)
Unit Participant Incremental Cost	See Table 1

Measure Description

This measure replaces standard refrigerated case doors which incorporate electric resistance heaters in the door to prevent condensation from forming on the glass and frost from forming on the door frames with more efficient doors that have a smaller electric resistance heater (low heat) or no heater at all (no heat). Low heat and no heat doors are more efficient due to having three panes of glass, a low conductivity filler gas (such as argon), and/or a low-E coating on the glass.

Algorithms

Unit kWh Savings per Year = (kW_base – kW_new) x n_door x BF x Hrs

Unit Peak kW Savings = (kW_base – kW_new) x n_door x BF x CF

Where:

kW_base = connected load kW for baseline reach-in cooler or freezer door and frame with a heater per Table 2

kW_new = connected load kW for new reach-in cooler or freezer door and frame with a either a low wattage heater or no heater per Table 2

n_door = number of doors replaced

BF = Bonus Factor; represents the increased savings due to reduction in cooling load inside the cases, and the decrease in cooling load in the building space to cool the additional heat generated by the door heaters. Assumed to be 1.36 for low temp (roughly -10 to +10°F), 1.22 for medium temp (roughly 30-45°F), and 1.15 for high temp (> 50°F) application (Ref. 2)

Hrs = operating hours over the course of a year = 8,760

CF = coincidence factor = 0.90 (Ref. 3)

Example:

Retrofit a 4-door freezer from standard doors to no-heat doors.

kW_base = 0.195

kW_new = 0.054

n_door = 4

BF = 1.36 for freezers

Unit kWh Savings per Year = (0.195 – 0.054) x 4 doors x 1.36 x 8,760 = 6,724 kWh

Unit Peak kW Savings = (0.195 – 0.054) x 4 doors x 1.36 x 0.90 = 0.690 kW

Deemed Input Tables

Table 1. Incremental Cost for Low-Heat and No-Heat Doors (Ref. 4)

Application Type and Door Type	Incremental Cost per Door
Freezer Door, Low-Heat	$145.00
Freezer Door, No-Heat	$290.00
Cooler Door, No-Heat	$72.50

Table 2. Typical Anti-Sweat Heater kW for Reach-in Case Doors

Application Type and Door Type	Heater kW	Ref. #
Freezer Door, Standard	0.195	(Ref. 5)
Freezer Door, Low-Heat	0.132	(Ref. 6)
Freezer Door, No-Heat	0.054	(Ref. 6)
Cooler Door, Low-Heat	0.092	(Ref. 5)
Cooler Door, No-Heat	0.052	(Ref. 6)

Methodology and Assumptions

This measure assumes that the doors being retrofitted / upgraded have anti-sweat heaters without controls.

Cooler doors are only available in low- and no-heat options, as the smaller temperature difference across the glass results in less condensation forming. Low-heat is therefore considered the standard option for cooler doors.

Heater kW in Table 2 accounts for the door heater wattage and mullion heater wattage. No-heat doors will still have a heater in the mullion, which may be a smaller or larger wattage depending on the manufacturer. The mullion heater wattage is why the no-heat doors don't show 0 kW for the heater kW in Table 2.

Notes

Uses methodology from anti-sweat heater controls measure in MN TRM V2.0, but adapted to have a base kW and new door kW. It is also similar to methodology used in 2015 Efficiency Vermont TRM for zero-energy doors and frames.

For cooler doors, there are only two efficiency levels available: low-heat (which is the baseline) and no-heat.

References

1. California Energy Commission and California Public Utilities Commission. Database for Efficient Resources (DEER) 2008, Effective/Remaining Useful Life Values. Available online: http://www.deeresources.com/files/deer2008exante/downloads/EUL_Summary_10-1-08.xls
2. Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010
3. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified.
4. Public Service Commission of Wisconsin, Wisconsin Focus on Energy Technical Reference Manual, October 22, 2015, page 682.
5. Standard door kW based on a range of wattages from two manufacturers and metered data
6. PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, p. 4-100 to 4-102.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	8/26/16

C/I Refrigeration – Floating Head Pressure Controls

Measure Detail	Measure Value
Measure ID	2.05.14
Target Market Segments	Commercial, Industrial
Target End Uses	Refrigeration
Applicable To	Refrigeration systems without floating head pressure controls
Actions	Modify, New Construction
Required from Customer/Contractor	Equipment type (refrigerator or freezer), Condenser type (condensing unit or remote condenser), project location (county)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	0
Measure Lifetime (years)	10 (Ref. 1)
Unit Participant Incremental Cost	See Table 1

Measure Description

Reducing the compressor discharge pressure reduces the pressure ratio across the compressor and improves the operating efficiency. Many systems have controls that maintain a minimum condensing pressure to ensure proper operation of all components. By letting the condensing pressure drop down at lower ambient temperatures with head pressure controls, energy savings can be achieved. The typical design target for refrigeration systems for head pressure is the equivalent of approximately 95°F saturated condensing temperature.

Algorithms

$kWh_{SAVED} = HP_{COMPRESSOR} \times (kWh / HP)$

Where:

$HP_{COMPRESSOR}$ = Actual rated horsepower of compressor

kWh / HP = Annual savings per horsepower per Table 2

Example:

A customer in climate zone 1 installed floating head pressure controls on a freezer with a five horsepower compressor and a remote condenser.

$kWh_{SAVED} = 5 \times 852 = 4{,}260$ kWh

Deemed Input Tables

Table 3. Incremental Cost by Equipment Type (Ref. 2, Ref. 3, See Assumptions)

Equipment Type	Incremental Cost ($/HP)
Refrigerator (Condensing)	$451
Refrigerator (Remote)	$239
Freezer (Condensing)	$343
Freezer (Remote)	$182

Table 4. Annual Savings (kWh/HP) by Location and Equipment Type (Ref. 2, Ref. 4, Ref. 5, See Assumptions)

Equipment Type	Zone 1 (Northern MN)	Zone 2 (Central MN)	Zone 3 (Southern MN/Twin Cities)
Refrigerator (Condensing)	887	829	736
Refrigerator (Remote)	617	577	511
Freezer (Condensing)	1,057	988	876
Freezer (Remote)	852	797	707
Unknown (Condensing)	942	880	780
Unknown (Remote)	692	647	574

Methodology and Assumptions

Incremental costs from RTF (Ref. 2) include adjustable pressure control (flood back) valve, bypass valve, filter drier, and balance port valves. Values adjusted to 2018 dollars using US inflation calculator (Ref. 3).

Billings, MT was chosen as the closest representation of a MN climate that was modeled by RTF (Ref. 2). The RTF algorithm uses eQUEST models to derive savings for several northwest cities. Billings, MT savings were adapted to the state of MN by using TMY3 data (Ref. 4) to interpolate savings as a function of temperature and applying this to MN temperature bins.

Separate savings and interpolations were used for medium and low temp, unitary and remote units. Each interpolation produced a linear fit based on two points from which slope and intercept was calculated. The first point assumes zero savings at 75°F. The second point is based on the average temperature below 75°F and the average annual savings modeled by RTF. This savings per temp interpolation is applied across temperature bins for each of the three MN TRM climate zones.

Savings for the unknown equipment type are a weighted average of refrigerators and freezers where the weights were determined using the ASHRAE Refrigeration Handbook (Ref. 5).

References

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study. Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Regional Technical Forum. "Commercial: Grocery – Floating Head Pressure Controls for Single Compressor Systems." UES Measure Workbook 1.6. Floating Head Pressure Controls for Single Compressor Systems measures. December 5, 2016. https://rtf.nwcouncil.org/measure/floating-head-pressure-controls-single-compressor-systems
3. US Inflation Calculator. https://www.usinflationcalculator.com/
4. National Solar Radiation Data Base TMY3 weather files. https://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html
5. 2010 ASHRAE Refrigeration Handbook, page 15.1 "Medium- and low-temperature display refrigerator line-ups account for roughly 68% and 32%, respectively, of a typical supermarket's total display refrigerators."

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Cadmus	10/2018

Compressed Air

Industrial Compressed Air – Compressed Air Leak Detection

Measure Detail	Measure Value
Measure ID	2.06.01
Target Market Segments	Industrial
Target End Uses	Industrial Process
Applicable To	Industrial customers who have medium-to-large compressed air systems used in their manufacturing plant
Actions	Operation and Maintenance
Required from Customer/Contractor	Number of leaks repaired, leak size (CFM), air compressor type, air compressor control strategy, and annual operating hours of compressor. The customer must also maintain a 2 or 3-tag leak detection, repair, and monitoring system to receive incentives. Incentives can only be paid after the detected leaks have been repaired, and tested to ensure the repairs were actually performed.
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	1 year (Ref. 1)
Unit Participant Incremental Cost	$8 per horsepower (Ref. 2)

Measure Description

This measure shows the energy savings potential associated with reducing compressed air losses through ultrasonic leak detection, and the repair of compressed air leaks. Compressed air leaks can be responsible for as much as 20% to 30% of the total air compressor output in a facility. This measure is applicable for compressed air systems in manufacturing environments where they are used for blow off, pneumatic tools, and manufacturing processes of many varieties.

Algorithms

Unit kWh Savings per Year = N_leaks x CFM_leaks x C_aircomp x t x Control_factor

Unit Peak kW Savings = (unit kWh Savings per Year x CF)/t

Where:

N_leaks = Number of leaks repaired

CFM_leaks = CFM loss per leak (review Table 1)

C_aircomp = See Table 2. If unknown compressor type, use 0.19 kW/CFM (Ref. 3)

Control_factor = See Table 3. If unknown control type, use 0.3 %kW/%load (Ref. 4)

t	=	Hours of operation per year for an average manufacturing plant 6240 (Ref. 5)
CF	=	Coincidence Factor (0.845) (Ref. 6)

Example:

An ultrasonic leak detection service is performed at the facility, and identifies 10 small leaks, of 1/64th inch diameter. Assumptions:

- Facility operates at 100 PSIG
- Facility operates three shifts (6240 hours per year)
- Single-acting Reciprocating Air Compressor
- Inlet Valve Modulated Compressor Controls

Using the cfm value from Table 1 for a very small leak

Unit kWh Savings per Year = 10 x 0.41 x .23 x 6,240 x .31 = 1,824 kWh/year

Unit Peak KW Savings per Year = (1,824 x 0.845)/6,240 = 0.247 KW

Deemed Input Tables

Table 1. CFM per Leak Size for Compressed Air Leaks (Ref. 7)

Pressure (psig)	Orifice Diameter (inches)					
	1/64	1/32	1/16	1/8	1/4	3/8
70	0.3	1.2	4.8	19.2	76.7	173
80	0.33	1.3	5.4	21.4	85.7	193
90	0.37	1.5	5.9	23.8	94.8	213
100	0.41	1.6	6.5	26	104	234
125	0.49	2	7.9	31.6	126	284

Table 2. kW/CFM Efficiencies for Several Compressor Types (Ref. 3)*

Type	Efficiency
Single-acting Reciprocating Air Compressor	0.23 kW/CFM
Double-acting Reciprocating Air Compressor	0.155 kW/CFM
Lubricant-injected Rotary Screw Compressor	0.185 kW/CFM
Lubricant-free Rotary Screw Compressor	0.2 kW/CFM
Centrifugal Compressor	0.18 kW/CFM
AVERAGE:	**0.19 kW/CFM**

*Data from Compressed Air Challenge "Fundamentals of Compressed Air Systems" Pgs. 28-32

Table 3. Efficiency Factors per control type for air compressors (Ref. 4)*

Control Type	Percentage kW/Percentage Load
Inlet Valve Modulated	0.31
Variable Displacement	0.69
Variable Speed Drive	0.85

*Data extrapolated from Compressed Air Challenge "Fundamentals of Compressed Air Systems" Pg. 90-91

Methodology and Assumptions

Assumptions were made based on average data for several different types of air compressors from Fundamentals of Compressed Air. Averages were assumed for compressor type to make calculations simpler.

Notes

Savings are based on a load-unload control style compressor. Load-unload style compressors will have much less savings than their VSD or Variable Displacement counterparts. There are limited studies available on the market saturation of VSD air compressors, and therefore estimates based on the load-unload model are more conservative, and more likely.

References

1. One year measure life is based on typical recommendation of annual leak survey.
2. Engineering estimate: estimated from previous project cost data review and engineering judgment.
3. Compressed Air Challenge "Fundamentals of Compressed Air Systems" Pgs. 28-32.
4. Compressed Air Challenge "Fundamentals of Compressed Air Systems" Pgs. 90-91.
5. This is based on 3 shifts per day, 5 days per week. This figure is supported by a survey of previous compressed air projects within Michigan and Ohio energy efficiency programs.
6. KEMA, New Jersey's Clean Energy Program Energy Impact Evaluation and Protocol Review, July 10, 2009.
7. "Energy Tips: Minimize Compressed Air Leaks" http://www.energystar.gov/ia/business/industry/compressed_air3.pdf.

Revision History

Version	Description	Author	Date
1.0	New measure	Franklin Energy Services	11/12/2015

Industrial Compressed Air – Cycling Air Dryers

Measure Detail	Measure Value
Measure ID	2.06.02
Target Market Segments	Industrial
Target End Uses	Process
Applicable To	Compressed air systems. Existing air dryers must run exclusively in non-cycling mode and cannot be equipped with a feature allowing operation in a cycling mode.
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Capacity of cycling dryer (CFM), Annual Operating Hours
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	$11 per CFM (Ref. 2)

Measure Description

This measure includes replacing existing standard non-cycling refrigerated air dryers with new cycling air dryers. Cycling compressed air dryers are able to better match air drying with demand. Due to a significant degree of variability in types of compressed air dryers, the savings algorithms reflect average savings from switching from non-cycling to cycling implementations.

Algorithms

Unit kWh Savings per Year = (ΔkW/CFM) x CFM_Capacity x hours

Unit Peak kW Savings = CF x (ΔkW/CFM) x CFM_Capacity

Where:

CF = 0.865; electrical peak coincidence factor (Ref. 6)

ΔkW/CFM = kW_base x (EC_{nc}-$EC_{cycling}$) = 0.00238 kW/CFM; demand savings per CFM of dryer capacity

kW_base = 0.007 kW/CFM (Ref. 3); typical power draw of a fully loaded non-cycling air dryer.

EC_{nc} = 95% (Ref. 4); average % kW for non-cycling dryer

EC_c = 61% (Ref. 4); average % kW for cycling dryer

Hours = Annual operating hours, provided by customer/contractor or use 6,240 hours per year if unknown (Ref. 5).

CFM_capacity = Capacity of cycling dryer in cubic feet per minute (CFM), provided by customer/contractor.

Example:

Replacement of a non-cycling air dryer with a capacity of 300 CFM with a cycling air dryer with a capacity of 300 CFM. In this case customer does not specifically provide operating hours.

Unit kWh Savings per Year = 0.00238 x 300 x 6240 = 4,455

Unit Peak kW Savings = 0.865 x 0.00238 x 300 = 0.618

Methodology and Assumptions

The calculation in this TRM reflects average savings moving from a non-cycling dryer to a cycling dryer. If more accuracy is required, a custom calculation should be used.

References

1. *Measure Life Study* prepared for the Massachusetts Joint Utilities. Energy and Resource Solutions, 2005. http://rtf.nwcouncil.org/subcommittees/nonreslighting/Measure%20Life%20Study_MA%20Joint%20Utilities_2005_ERS-1.pdf, accessed 9/25/16.
2. Analysis of material cost between cycling and non-cycling dryers according to prices from Grainger (September 2016). Cost provided is the average incremental cost when comparing non-cycling dryers and cycling dryers of the same CFM capacity.
3. Based on a survey of available CAGI data sheets on non-cycling units from Gardner Denver, Hankison, Ingersoll Rand, Sullair and Zeks.
4. 95% and 61% represent the average percentage of power at 50% capacity for a non-cycling and cycling dryer, respectively. These figures were determined by all available CAGI data for refrigerated dryers manufactured by Atlas Copco, Gardner Denver, Hankison, Ingersoll Rand, Sullair and Zeks.
5. Annual operating hours assume 3 shifts per day, 5 days per week. This figure is supported by a survey of previous compressed air projects within Michigan and Ohio energy efficiency programs.
6. New Jersey's Clean Energy Program Energy Impact Evaluation and Protocol Review. KEMA, July 2009. Page 3-73. http://www.njcleanenergy.com/files/file/Library/SmartStart%20Protocol%20Review%20-%20Final%20July%2010%202009.pdf, accessed 9/25/16.

Revision History

Version	Description	Author	Date
1.0	New workpaper	Franklin Energy Services	9/25/2016

Industrial Compressed Air – Engineered Nozzles

Measure Detail	Measure Value
Measure ID	2.06.03
Target Market Segments	Industrial
Target End Uses	Industrial Process
Applicable To	Primarily manufacturing facilities with compressed air systems
Actions	Replace Working, Replace on Fail, New Construction
Required from Customer/Contractor	Operating pressure at nozzle inlet; nozzle diameter; compressed air system pressurized hours per year
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	$77 (Ref. 2)

Measure Description

This measure includes replacement of standard air nozzles with engineered nozzles, also referred to as Venturi or air amplification nozzles. Engineered nozzles use compressed air to entrain and amplify atmospheric air into a stream, thus increasing pressure while reducing compressed air use by up to 70%. The velocity of the resulting air stream is lower than an open jet, but the mass flow of the air is increased, thus increasing the cooling and drying effect. Engineered nozzles have the added benefits of noise reduction and improved safety in systems with pressures greater than 30 psig.

Algorithms

Unit kWh Savings per Year = (kW_base – kW_EE) x %USE x Hours

Unit Peak kW Savings = (kW_base – kW_EE) x CF

Where:

kW_base = SCFM_base x (ΔkW/CFM); standard nozzle demand (kW)

kW_EE = SCFM_EE x (ΔkW/CFM); engineered nozzle demand (kW)

SCFM_base = rated flow of standard air nozzle at operating pressure. If unknown, estimate from SCFM_base=C_flow x 14.5 x (14.7 + P) x Dia^2 (Ref. 3)

SCFM_EE = rated flow of engineered air nozzle at operating pressure. If unknown, estimate from SCFM_EE=SCFM_base x %ΔSCFM

C_flow = 0.79 (Ref. 3); coefficient of flow

P = gauge pressure at orifice or nozzle. 80 psig is a reasonable estimate if unknown (Ref. 4)

Dia = diameter of orifice or nozzle in inches.

%ΔSCFM = percentage reduction in air loss per nozzle, estimated at 50% (Ref. 4).

ΔkW/CFM	=	system power reduction per air demand (kW per CFM). If unknown, assume 0.20 kW/SCFM (Ref. 7).
Hours	=	provided by customer/contractor; compressed air system pressurized hours per year. If unknown, assume 6240 (Ref. 8).
%USE	=	5%; percentage of the compressor total operating hours that the nozzle is in use. (Ref. 5)
CF	=	0.865 (Ref. 6); peak electrical coincidence factor

Example:

A plant that produces plastic packaging has installed an engineered nozzle to replace an existing ¼" diameter nozzle on an injection molding machine. The packaging plant operates on a two-shift schedule, at 3,952 hours annually. The operating pressure and air compressor/control type are unknown.

SCFM_base = 0.79 x 14.5 x (14.7 + 80) x 0.25^2 = 67.80 CFM

SCFM_EE = 67.80 x 0.5 = 33.90 CFM

kW_base = 67.80 x 0.20 = 13.56 kW

kW_EE = 33.90 x 0.20 = 6.78 kW

Unit kWh Savings per Year = (13.56 - 6.78) x 0.05 x 3952 = 1,440 kWh

Unit Peak kW Savings = (13.56 – 6.78) x 0.865 = 5.86 kW

Table 1. Calculated Annual Energy Savings by Nozzle Diameter

Nozzle Diameter	kWh Savings per Year	Peak kW Savings
1/8"	397	0.055
3/16"	892	0.124
1/4"	1587	0.220
5/16"	2479	0.344
3/8"	3570	0.495
7/16"	4859	0.674
1/2"	6346	0.880

Assumptions: 6,240 hours/yr, 80 psig, %ΔSCFM = 50%, Screw Compressor/Load-Unload Control or Variable Displacement.

Methodology and Assumptions

Compressor is assumed to be between 40% and 100% capacity before and after changes to system demand.

Notes

Savings are sensitive to inlet pressure. It is best to obtain inlet pressure from customer, although estimates using 80 psig are reasonable if unknown.

References

1. *Business Programs: Measure Life Study.* PA Consulting Group, 2009. Prepared for the State of Wisconsin Public Service Commission.
2. Average of incremental measure costs, Illinois Technical Reference Manual, v5.0, February 2016. Costs are from EXAIR's website, accessed March 20, 2014.
3. Adapted from Air Flow Through Orifices; Air Compressor Works, Inc. CFM = 14.5 x P x D^2, where P is in absolute pressure. Because gauge pressure is provided for this measure, a factor of 14.7 psi (1 atm.) must be added to ensure absolute pressure. http://www.aircompressorworks.com/airflowthroughorifices.html. Accessed 08/24/16.
4. Illinois Technical Reference Manual, v5.0, February 2016. Conservative estimate based on average values provided by the Compressed Air Challenge Handbook.
5. Ohio Technical Reference Manual, August 2010. Assumes 50% handheld air guns and 50% stationary air nozzles. Manual air guns tend to be used less than stationary air nozzles, and a conservative estimate of 1 second of blow-off per minute of compressor run time is assumed. Stationary air nozzles are commonly more wasteful as they are often mounted on machine tools and can be manually operated resulting in the possibility of a long term open blow situation. An assumption of 5 seconds of blow-off per minute of compressor run time is used.
6. New Jersey's Clean Energy Program Energy Impact Evaluation and Protocol Review. KEMA, July 2009. Page 3-73.
7. The default value of 20 kW/100 cfm is from a market survey of 5 yr old model air compressor systems manufactured by Kaeser, Sullair, and Ingersoll Rand and is typical of older systems found in the field.

Revision History

Version	Description	Author	Date
1.0	Measure created	Franklin Energy Services	12/5/16

Industrial Compressed Air – Low Pressure Drop Filters

Measure Detail	Measure Value
Measure ID	2.06.04
Target Market Segments	Industrial
Target End Uses	Process
Applicable To	Compressed air systems ≥ 50 HP. Low pressure drop filter must have an initial pressure drop of 1 psid or less, and must replace a standard coalescing filter.
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Compressor nominal HP, nominal inlet flow of filter in SCFM. If SCFM is rated for both upstream and downstream of dryer are given, use the lower upstream value. Optional: Motor efficiency, compressed air system annual operating hours, pressure drop reduction in psi.
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	5 years (Replace on Fail, New Construction) or 3 years (Replace Working) (Ref. 1)
Unit Participant Incremental Cost	$1,740 + $2 per SCFM (Ref. 2)

Measure Description

This measure includes replacing standard coalescing filters with low pressure drop filters (aka Mist Eliminators). Oil filters will have pressure drops associated with their presence in a compressed air system, and generally low pressure filters will reduce the average required pressure by 5 psi. Lowering the pressure requirements of the system enable the compressor pressure setpoint to be lowered, reducing the energy input required by the system.

Algorithms

Unit kWh Savings per Year = C x HP / Eff x LF x Hours x Δpsid x SF / 100

Unit Peak kW Savings = (Unit kWh Savings per Year) / Hours x CF

Where:

C	=	0.746 kW/HP; conversion factor from HP to kW.
HP	=	compressor nominal horsepower
Eff	=	provided by customer/contractor; compressor motor efficiency. If unknown, assume 90% (Ref. 3).
LF	=	75% (Ref. 4); typical compressor load factor
Hours	=	provided by customer/contractor; annual operating hours. If unknown, use 6240 hours (Ref. 5)

SF	=	0.5; Savings Factor (for every 2 psi reduced, annual consumption is reduced by 1%) (Ref. 6)
Δpsid	=	Provided by customer/contractor; initial pressure drop reduction from switching from standard coalescing to mist eliminator filter. If unknown, assume 5 psig (Ref. 7).
CF	=	0.865 (Ref. 8); peak electrical coincidence factor.

Example:

A manufacturer installs a 435 SCFM mist eliminator filter to replace a working standard coalescing filter on a 100 HP compressed air system.

Unit kWh Savings per Year = 0.746 x 100 / 0.90 x 0.75 x 6240 x 5 x 0.5 / 100 = 9,698 kWh

Unit Peak kW Savings = 9,698/6240 x 0.865 = 1.3 kW

Methodology and Assumptions

The kWh savings algorithm reflects average savings based on typical load factors for compressed air systems and pressure drop reductions, and uses a standard savings per unit of pressure reduction (1% reduction in compressor drive energy versus 2 psi in pressure drop reduction).

References

1. Massachusetts Technical Reference Manual, 2013-2015 Program Years – Plan Version, October 2012. Page 266. Based on typical replacement schedules for low pressure filters (NSTAR staff estimates).
2. Estimated by regressing cost vs. rated SCFM over a range of products manufactured by Pneumatech, Aircel, Deltech, and Donaldson.
3. Franklin Energy Services default value for compressor motor efficiency.
4. Twelve custom compressed air projects (within MI and OH programs) were surveyed, where older, traditional controlled air compressors were replaced with similar-sized VSD air compressors. On average, these compressors were loaded to 47% (approx. 50%) of their full-load CFM. For load-unload control as typically found on older systems, this translates to approximately 75% of full-load kW.
5. Annual operating hours assume 3 shifts per day, 5 days per week. This figure is supported by a survey of previous compressed air projects within Michigan and Ohio energy efficiency programs.
6. *Improving Compressed Air System Performance: A Sourcebook for Industry.* US Department of Energy, November 2003.

7. Conservative estimate based on a review of datasheets from AirTak, Van Air, ZEKS, Motivair, Aircel and Deltech.
8. New Jersey's Clean Energy Program Energy Impact Evaluation and Protocol Review. KEMA, July 2009. Page 3-73.

Revision History

Version	Description	Author	Date
1.0	New workpaper	Franklin Energy Services	9/6/2016

Industrial Compressed Air – No Loss Drains

Measure Detail	Measure Value
Measure ID	2.06.05
Target Market Segments	Industrial
Target End Uses	Industrial Process
Applicable To	Industrial and commercial customers
Actions	Replace Working, Replace on Fail
Required from Customer/Contractor	CAGI Data Sheet for Air Compressor, Annual Hours of Operation
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	13 (Ref. 5)
Unit Participant Incremental Cost	$450/drain (Ref. 4)

Measure Description

This measure includes replacement of a failed or working open tube, timed, or manual condensate drain in a compressed air system with a qualified electronic, pneumatic, or hybrid "no loss drain" that is designed to automatically adjust with system demand and completely eliminate condensate with zero compressed air loss.

Algorithms

Unit kWh Savings per Year = kW_100_CFM x Hours x Drain_CFM / 100

Unit Peak kW Savings = kW_100_CFM x Drain_CFM x CF / 100

Where:

kW_100_CFM = Compressor efficiency, kW/100 CFM as listed on Compressed Air and Gas Institute (CAGI) datasheet. 20 kW/100 CFM is default value

Hours = Annual hours of operation. 3,528 hr default value. (reference 2)

Drain_CFM = Average CFM of existing drain, 3 CFM (reference 3)

CF = Coincidence Factor = 0.80

Example:

Install a no loss drain on a 40 hp compressed air system, with a CAGI efficiency of 16 kW/100CFM and running 2,000 hr/yr

Unit kWh Savings per Year = 16 x 3 x 2000 / 10 = 960

Unit kW Savings per Year = 16 x 3 x 0.8 / 100 = 0.39

Notes

The default value of 20 kW/100 cfm is from a market survey of 5 yr old model air compressor systems. Kaeser, Sullair, Ingersoll Rand

The average drain loss (cfm) assumes a timed drain system operating approximately 5% of the time. Average size is 1/4" orifice.

Focus on Energy (WI) and New York Standard Approach uses a CF = 0.80.

Consider updating default hours in future update.

References

1. US Department of Energy. Improving Compressed Air System Performance - A Sourcebook for Industry. November 2003.
2. US Department of Energy. United States Electric Motor Systems Market Opportunities Assessment. Appendix B. Dec 2002.
3. Orr, Ross. The Importance of Condensate Drains on Air System Efficiency. airbestpractices.com. May 2012.
4. Pliske, Jim. Compressed Air System Survey and Consultation. Brabazon Engineered Systems & Technology. Sept 2010.
5. Measure Life Study. Energy & Resource Solutions. Prepared for the Massachusetts Joint Utilities; Table 1-1. 2005.

Revision History

Version	Description	Author	Date
1.0	Original issue	Franklin Energy Services	8/28/2012
1.1	Added Replace on Fail to Action Types, changed measure name, added note to consider updating default hours in future update	Joe Plummer	9/12/2013

Industrial Compressed Air – Pressure/Flow Controller

Measure Detail	Measure Value
Measure ID	2.06.06
Target Market Segments	Industrial
Target End Uses	Industrial Process
Applicable To	Compressed air systems
Actions	Modify, New Construction
Required from Customer/Contractor	Compressor nominal HP Optional: Motor efficiency, compressed air system annual operating hours, pressure drop reduction in psi.
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	15 years (Ref. 1)
Unit Participant Incremental Cost	$27.15 per hp (Ref. 2)

Measure Description

This measure includes the installation of a pressure/flow controller on the downstream side of an air storage receiver in a compressed air system, allows the creation of a pressure differential entering and leaving the vessel. This pressure differential creates stored energy in the form of "squished air," which can be used to supply the peak air demand in situations where the event is short in duration, instead of having to use more compressor horsepower to feed this peak demand. Benefits include:

- Shaving kW of peak demand, especially with multiple-compressor configurations.
- Saving kWh by allowing compressor to run at most efficient loads, and turning itself off in low/no demand periods
- Saving kWh by reducing plant air pressure to minimum allowable. This leads to reduced loads on the electric motors and greater efficiency of the system. Rule of Thumb: for every 2-psi reduced in the system, 1% of energy is saved.
- Maintaining a reduced, constant pressure in the plant also means less wasted air due to leakage, and less volume required by the compressor.
- Constant pressure to process ensures quality control of the process. Machines can produce differences in the product quality when pressure is allowed to fluctuate.

Algorithms

Unit kWh Savings per Year = C x HP/Eff x LF x Hours x Δpsid x SF/100

Unit Peak kW Savings = (Unit kWh Savings per Year) / Hours x CF

Where:

C	=	0.746 kW/HP; conversion factor from HP to kW
HP	=	compressor nominal horsepower
Eff	=	provided by customer/contractor; compressor motor efficiency. If unknown, assume 90% (Ref. 3)
LF	=	75% (Ref. 4); typical compressor load factor
Hours	=	provided by customer/contractor; annual operating hours. If unknown, use 6,240 hours (Ref. 5)
SF	=	0.5; Savings Factor (for every 2-psi reduced, annual consumption is reduced by 1%) (Ref. 6)
Δpsid	=	Provided by customer/contractor; initial pressure reduction from installing pressure/flow controller. If unknown, assume 5 psig (Ref. 7)
CF	=	0.865 (Ref. 8); peak electrical coincidence factor

Example:

A manufacturer installs a pressure/flow controller on a 100 HP compressed air system.

Unit kWh Savings per Year = 0.746 x 100 / 0.90 x 0.75 x 6,240 x 5 x 0.5/100 = 9,698 kWh

Unit Peak kW Savings = 9,698/6,240 x 0.865 = 1.3 kW

Methodology and Assumptions

The kWh savings algorithm reflects average savings based on typical load factors for compressed air systems and pressure drop reductions, and uses a standard savings per unit of pressure reduction (1% reduction in compressor drive energy versus 2-psi in pressure drop reduction).

References

1. Wisconsin Focus on Energy Technical Reference Manual. 2017 version. Page 37. Based on estimate from product representative.
2. Wisconsin Focus on Energy Technical Reference Manual. 2017 version. Page 37. Based on the average cost of 71 past projects since 2012.
3. Franklin Energy Services default value for compressor motor efficiency.
4. Twelve custom compressed air projects (within MI and OH programs) were surveyed, where older, traditional controlled air compressors were replaced with similar-sized VSD air compressors. On average, these compressors were loaded to 47% (approximately 50%) of their full-load CFM. For load-unload control as typically found on older systems, this translates to approximately 75% of full-load kW.
5. Annual operating hours assume three shifts per day, five days per week. This figure is supported by a survey of previous compressed air projects within Michigan and Ohio energy efficiency programs.

6. Improving Compressed Air System Performance: A Sourcebook for Industry. US Department of Energy, November 2003.
7. Michigan Energy Measures Database. 2017 version.
8. New Jersey's Clean Energy Program Energy Impact Evaluation and Protocol Review. KEMA, July 2009. Page 3-73.

Revision History

Version	Description	Author	Date
1.0	New measure	Franklin Energy Services	8/30/2017

Industrial Compressed Air – Storage Tank

Measure Detail	Measure Value
Measure ID	2.06.07
Target Market Segments	Industrial
Target End Uses	Industrial Process
Applicable To	Compressed air systems with load/unload control
Actions	Modify, New Construction
Required from Customer/Contractor	Compressor nominal HP, existing storage volume (gal/cfm), proposed storage volume (gal/cfm). Optional: Motor efficiency, compressed air system annual operating hours.
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	20 years (Ref. 1)
Unit Participant Incremental Cost	$36 per hp (Ref. 2)

Measure Description

This measure includes the installation of an extra storage tank for compressed air system. Storage tanks provide extra capacity for a compressed air system. The energy savings associated with this measure is obtained by preventing the compressor from reacting to every demand event. For example, a load/no-load compressor without adequate storage tends to short-cycle which causes system inefficiency. Also, for compressors with other types of controls, having a storage tank in the system prevents the compressor from potentially ramping up to meet a very short demand event. Having a receiver tank in an air system also has the benefits of preventing oil from being deposited downstream if there is an issue.

Algorithms

Unit kWh Savings per Year = C x HP/Eff x Hours x (PPD_x - PPD_p)

Unit Peak kW Savings = (Unit kWh Savings per Year) / Hours x CF

Where:

C	=	0.746 kW/HP; conversion factor from HP to kW.
HP	=	compressor nominal horsepower
Eff	=	provided by customer/contractor; compressor motor efficiency. If unknown, assume 90% (Ref. 3).
Hours	=	provided by customer/contractor; annual operating hours. If unknown, use 6,240 hours (Ref. 4)
PPD_x	=	percent power draw of the system with existing storage volume (Table 1)

PPD_p = percent power draw of the system with added storage (Table 1)

CF = 0.865 (Ref. 5); peak electrical coincidence factor.

Deemed Input Tables

Table 1. Percentage Power Draw by Storage Volume for Load/Unload-Controlled Compressors (Ref. 6)

	1 gal/cfm	3 gal/cfm	5 gal/cfm	10 gal/cfm
50% load factor	87%	76%	71%	67%

Example:

A manufacturer increases the storage volume from 3gal/cfm to 5gal/cfm on a 100 HP compressed air system.

Unit kWh Savings per Year = 0.746 x 100 / 0.90 x 6,240 x (76%-71%) = 25,861 kWh

Unit Peak kW Savings = 25,861/6,240 x 0.865 = 3.58kW

Methodology and Assumptions

The kWh savings algorithm reflects average savings based on typical load factors for load/unload controlled compressed air systems. The savings from the other control types was assumed to be similar with that of load/unload.

References

1. Michigan Energy Measures Database, 2017 version, reduced from 25 to 20 years in accordance with maximum lifetimes in Minnesota Conservation Improvement Program.
2. Michigan Energy Measures Database. 2017 version. Based on survey of compressor vendors, the cost of air tank is about $4 per gallon; therefore, 2 gal/cfm x 4.5cfm/hp x $4/gal=$36/hp.
3. Franklin Energy Services default value for compressor motor efficiency.
4. Annual operating hours assume three shifts per day, five days per week. This is supported by a survey of previous compressed air projects within Michigan and Ohio energy efficiency programs.
5. New Jersey's Clean Energy Program Energy Impact Evaluation and Protocol Review. KEMA, July 2009. Page 3-73.
6. The percentage power draw is based on an average load factor of 50% for load/unload controlled air compressor. Plant Services "Special Report on Compressed Air System Efficiency." http://www.hollandindustrial.com/wp-content/uploads/sites/197/2015/12/compressed-air-ebook.pdf, accessed August 25, 2017.

Revision History

Version	Description	Author	Date
1.0	New workpaper	Franklin Energy Services	8/25/17

Industrial Compressed Air – VSD Air Compressors

Measure Detail	Measure Value
Measure ID	2.06.08
Target Market Segments	Industrial
Target End Uses	Industrial Process
Applicable To	Industrial and commercial customers
Actions	Replace Working, Replace on Fail, New Construction
Required from Customer/Contractor	CAGI Data sheet (new), CAGI Data sheet (existing) or nameplate data Optional: Annual facility hours where compressed air is required
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	$428/hp (Replace Working) or $100/hp (Replace on Fail or New Construction)

Measure Description

This measure includes replacement of an inlet modulated, variable displacement, or load/no load controlled air compressor units < 200 hp with variable speed drive (VSD) controlled units. Base load units do not qualify. Only one compressor per compressed air distribution system is eligible.

Algorithms

Unit kWh Savings per Year = hp x SF x C x Hours

Unit Peak kW Savings = hp x SF x C x CF

Where:

hp	=	Nominal horsepower of VSD air compressor motor, provided by customer
SF	=	Savings Factor: reference Table 1
Hours	=	Annual facility hours where compressed air is required, default 4,024 hours (reference 2)
C	=	Conversion constant = 0.746 kW/hp
CF	=	Coincidence factor, Default = 0.95

Example:

Replace an inlet modulated 25 hp air compressor with a 25 hp VSD air compressor. Hours are unknown, default used.

Unit kWh Savings per Year = 25 x 18% x 0.746 x 4,024 = 13,509 kWh

Unit kW Savings per Year = 25 x 18% x 0.746 x 0.95 = 3.2 kW

Deemed Input Tables

Table 1. Savings factor for VSD replacing existing control strategy (reference 3)

	Existing Control		
	Inlet Modulating	Load/No Load	Variable Displacement
% Savings Factor	18%	15%	6%

Notes

$428/hp from surveyed cost from MI and Ohio implemented projects. Full install cost for "replace working"

$100/hp is the incremental cost for replace upon fail or new construction

Focus on Energy (WI) and New York Standard Approach uses a CF = 0.80. The Illinois TRM lists CF = 0.95 and Vectren lists it at 1.0.

Savings factor assumes 75% loaded and the savings factor was interpolated from the part load curves of reference 3 (pages 43-45)

References

1. Measure Life Study. Energy & Resource Solutions. Prepared for the Massachusetts Joint Utilities; Table 1-1. 2005.
2. US Department of Energy. United States Electric Motor Systems Market Opportunities Assessment. Appendix B. Dec 2002.
3. US Department of Energy. Improving Compressed Air System Performance – A Sourcebook for Industry. Pages 43-45. November 2003.

Revision History

Version	Description	Author	Date
1.0	Original issue	Franklin Energy Services	8/28/2012
1.1	Specified that hp corresponds to VSD compressor, added optional input for facility hours, minor fixes	Joe Plummer	8/1/2013
5.0	Modified upper limit HP to 200 from 50 HP	Cadmus	7/1/2025

Food Service

Commercial Food Service – Dishwasher

Measure Detail	Measure Value
Measure ID	2.07.01
Target Market Segments	Commercial, Restaurants, Schools
Target End Uses	Other
Applicable To	Commercial kitchens
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Dishwasher type (see Table 2), building water heater fuel, booster water heater fuel
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	See Table 4
Unit Participant Incremental Cost	See Table 3

Measure Description

This measure involves the installation of a commercial dishwasher meeting current ENERGY STAR performance criteria. Compliant efficient appliances do not need to be ENERGY STAR qualified through the EPA program but would need to meet the ENERGY STAR performance criteria specified within this measure.

Algorithms

Unit kWh Savings per Year = kWh_dhw + kWh_boost + kWh_idle

Unit Peak kW Savings = Unit kWh Savings per Year / t_annual

Unit Dth Savings per Year = therms_dhw + therms_boost

Where:

kWh_dhw = (Cp x ρH2O x ΔT_dhw / η_electric / C1) x (RPD x (GPR_base - GPR_ee) x Days) if electric water heater, otherwise 0.

kWh_boost = (Cp x ρH2O x ΔT_boost / η_electric / C1) x (RPD x (GPR_base - GPR_ee) x Days) if electric booster heater, otherwise 0.

kW_idle = (kW_idle_base - kW_idle_ee) x (t_annual - (Days x RPD x t_rack / C2)

therms_dhw = (Cp x ρH2O x ΔT_dhw / η_gas / C1) x (RPD x (GPR_base - GPR_ee) x Days) if gas water heater, otherwise 0.

therms_boost = (Cp x ρH2O x ΔT_boost / η_gas / C1) x (RPD x (GPR_base - GPR_ee) x Days) if gas booster heater, otherwise 0.

Cp = 1 Btu/lb-°F. Specific heat of water.

ρ	=	8.34 lb/gallon. Density of water.
ΔT_dhw	=	70°F. Inlet water temperature rise for building water heater. (Ref. 1).
ΔT_boost	=	40°F. Inlet water temperature rise for booster heater. (Ref. 1).
η_gas	=	80%. Gas water heater efficiency. (Ref. 1).
η_electric	=	98%. Electric water heater efficiency. (Ref. 1).
RPD	=	Racks per day. See Tables 1 and 2.
t_rack	=	Typical wash time per rack. See Tables 1 and 2.
GPR_base	=	Gallons per rack of baseline dishwasher. See Table 1.
GPR_ee	=	Gallons per rack of ENERGY STAR dishwasher. See Table 2.
kW_idle_base	=	Idle power draw of baseline dishwasher. See Table 1.
kW_idle_ee	=	Idle power draw of ENERGY STAR dishwasher. See Table 2.
Days	=	360 days/year. Annual days of operation. (Ref. 2).
t_annual	=	6,480 hours. Annual hours of dishwasher operation. (Ref. 1).
C1_electric	=	3,413 Btu/kWh. Btu to kWh conversion factor.
C1_gas	=	100,000 Btu/therm. Btu to therm conversion factor.
C2	=	60 minutes/hour. Minutes per hour conversion factor.

Example:

A customer installed a new high-temp ENERGY STAR single tank door style dishwasher. The hot water is provided by an electric water heater and electric booster.

kWh_dhw = (1 Btu/lb-°F x 8.34 lb/gal x 70°F / 98% / 3,413 Btu/kWh) x (280 racks/day x (1.29 gal/rack - 0.89 gal/rack) x 360 day/yr) = 7,038 kWh

kWh_boost = (1 Btu/lb-°F x 8.34 lb/gal x 40°F / 98% / 3,413 Btu/kWh) x (280 racks/day x (1.29 gal/rack - 0.89 gal/rack) x 360 day/yr) = 4,021 kWh

kWh_idle = (0.87 kW - 0.70 kW) x (6,480 hrs - (360 day/yr x 280 rack/day x 1.0 min/rack / 60 min/hr)) = 816 kWh

Unit kWh Savings per Year = 7,038 kWh + 4,021 kWh + 816 kWh = 11,875 kWh

Unit Peak kW Savings = 11,875 kWh / 6,480 hrs x 1.0 = 1.83 kW

Deemed Input Tables

Table 1. Conventional Dishwasher Characteristics (Ref. 1, 3)

Dishwasher Type	Racks per Day (RPD)	Time per Rack (t_rack) (minutes)	Gallons per Rack (GPR)	Idle Power (kW_Idle)
Low Temperature				
Under Counter	75	2.0	1.73	0.50
Stationary Single Tank Door	280	1.5	2.10	0.60
Single Tank Conveyor	400	0.3	1.31	1.60
Multi Tank Conveyor	600	0.3	1.04	2.00
High Temperature				
Under Counter	75	2.0	1.09	0.76
Stationary Single Tank Door	280	1.0	1.29	0.87
Pot, Pan, and Utensil	280	3.0	0.70	1.20
Single Tank Conveyor	400	0.3	0.87	1.93
Multi Tank Conveyor	600	0.2	0.97	2.59

Table 2. ENERGY STAR Dishwasher Characteristics (Ref. 1, 3)

Dishwasher Type	Racks per Day (RPD)	Time per Rack (t_rack) (minutes)	Gallons per Rack** (GPR)	Idle Power* (kW_Idle)
Low Temperature				
Under Counter	75	2.0	1.19	0.25
Stationary Single Tank Door	280	1.5	1.18	0.30
Single Tank Conveyor	400	0.3	0.79	0.85
Multi Tank Conveyor	600	0.3	0.54	1.00
High Temperature				
Under Counter	75	2.0	0.86	0.30
Stationary Single Tank Door	280	1.0	0.89	0.55
Pot, Pan, and Utensil	280	3.0	0.58	0.90
Single Tank Conveyor	400	0.3	0.70	1.20
Multi Tank Conveyor	600	0.2	0.54	1.85

*Idle results should be measured with the door closed and represent the total idle energy consumed by the machine including all tank heater(s) and controls. Booster heater (internal or external) energy consumption should not be part of this measurement unless it cannot be separately monitored per the ENERGY STAR Test Method.
**GPR = gallons per rack; GPSF = gallons per square foot of rack; GPH = gallons per hour; x = maximum conveyor speed (feet/min as verified through NSF 3 certification) x conveyor belt width (feet).

Table 3. Incremental Costs (Ref. 1)

Dishwasher Type	Incremental Cost
Low Temperature	
Under Counter	$234
Door Type	$662
Single Tank Conveyor	$0
Multi Tank Conveyor	$970

Dishwasher Type	Incremental Cost
High Temperature	
Under Counter	$2,025
Door Type	$995
Pot, Pan, and Utensil	$1,710
Single Tank Conveyor	$2,050
Multi Tank Conveyor	$970

Table 4. Equipment Lifetime (Ref. 1)

Dishwasher Type	Lifetime (Years)
Under Counter	10
Door Type	15
Pot, Pan, and Utensil	10
Single Tank Conveyor	20
Multi Tank Conveyor	20

Table 6. Calculated Savings Values (Ref. 1)

Dishwasher System Description	Annual Savings		
	kW	kWh	Therms
High Temp Unit with Electric Booster Heater, Electric Water Heater			
Under Counter	0.49	3,154	-
Stationary Single Tank Door	1.83	11,875	-
Single Tank Conveyor	1.42	9,191	-
Multi Tank Conveyor	4.23	27,434	-
Pot, Pan, and Utensil	0.51	3,318	-
High Temp Unit with Electric Booster Heater, Gas Water Heater			
Under Counter	0.32	2,070	45
Stationary Single Tank Door	0.75	4,837	294
Pot, Pan, and Utensil	0.19	1,206	88
Single Tank Conveyor	0.76	4,918	179
Multi Tank Conveyor	1.73	11,222	678
High Temp Unit with Gas Booster Heater, Gas Water Heater			
Under Counter	0.22	1,451	71
Stationary Single Tank Door	0.13	816	462
Pot, Pan, and Utensil	-	-	139
Single Tank Conveyor	0.38	2,477	281
Multi Tank Conveyor	0.30	1,958	1,065
Low Temp Unit, Electric Water Heater			
Under Counter	0.39	2,545	-
Stationary Single Tank Door	2.50	16,186	-
Single Tank Conveyor	2.11	13,646	-
Multi Tank Conveyor	2.91	18,851	-

Dishwasher System Description	Annual Savings		
	kW	kWh	Therms
Low Temp Unit, Gas Water Heater			
Under Counter	-	-	106
Stationary Single Tank Door	-	-	677
Single Tank Conveyor	0.09	576	546
Multi Tank Conveyor	-	-	788

Notes

A high temp machine is defined as a machine that applies hot water to the surfaces of dishes to achieve sanitization. A low temp machine is defined as a machine that applies a chemical sanitizing solution to the surfaces of dishes to achieve sanitization. (Ref. 4)

References

1. Commercial Kitchen Equipment Savings Calculator, ENERGY STAR. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx. Published July 2017, Revised May 2021. Direct link: https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.energystar.gov%2Fsites%2Fdefault%2Ffiles%2Fasset%2Fdocument%2Fcommercial_kitchen_equipment_calculator.xlsx&wdOrigin=BROWSELINK. Webpage location link (CFS Equipment Calculator excel): https://www.energystar.gov/partner_resources/energy_star_training_center/commercial_food_service
2. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, PA Consulting Group Inc., March 22, 2010. Page 4-69. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
3. ENERGY STAR. ENERGY STAR Program Requirements for Commercial Dishwashers. Version 3, Published May 2021. https://www.energystar.gov/sites/default/files/asset/document/Commercial%20Dishwashers%20Version%203.0%20Specification%20%28Rev.%20-%20May%202021%29_0.pdfEnergy

Revision History

Version	Description	Author	Date
1.0	New Measure	Franklin Energy Services	7/15/2015
1.2	Updated standards to include “Pot, Pan, and Utensil” measure. Updated references, annual hours of operation, savings values and example.	Franklin Energy Services	8/19/2016
1.3	Updated performance criteria to ENERGY STAR standard v3.0. Updated reference links where needed. Reorganized table references to match ENERGY STAR criteria sequential order. Updated deemed savings values based on v3.0 ENERGY STAR criteria calculator.	Cadmus	11/1/2022

Commercial Food Service – Electric Cooktops, Ovens and Ranges

Measure Detail	Measure Value
Measure ID	2.07.02
Target Market Segments	Commercial
Target End Uses	Food Service
Applicable To	Commercial kitchens
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Building type, heating only or heating and cooling, and new equipment type
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	12 (Ref. 4)
Unit Participant Incremental Cost	See Table 1

Measure Description

This measure includes replacement of failed or working electric ovens and ranges with new high-efficiency cooktops, ovens and ranges. May also include new construction if facility does not have gas service. Eligible products must meet the current ENERGY STAR performance criteria for Electric Cooktops and Ranges (Ref. 7), but do not need to be qualified through the program.

Algorithms

Unit kWh Savings per Year = (kW_Base – kW_EE) x Hrs x Days x Rapid_Cook_Factor

Unit Peak kW Savings = (kW_Base – kW_EE) x CF x Rapid_Cook_Factor

Where:

kW_EE = Deemed wattage (kW per unit) for high-efficiency cooking equipment meeting minimum efficiency standards

kW_Base = Deemed corresponding wattage (kW per unit) of baseline cooking technology calculated as kW_EE x New_Tech_Eff÷Base_Tech_Eff from Table 1 below

Rapid_Cook_Factor = Deemed increased savings resulting from increased throughput or reduced cooking times associated with advanced cooking technology, if applicable. If absent or not applicable, RCF = 1.0.

Hrs = Deemed daily cooking hours by building type per Table 2 (Ref 8)

Days = Deemed annual days of operation by building type per Table 2 (Ref 2).

CF = Deemed coincident demand factor, 0.9 (Ref 1)

Example:

A high school cafeteria installed a new high-efficiency flashbake oven.

Unit kWh Savings per Year = (1.24 kW - 0.91 kW) x 5 hrs x 200 days 1.67 = 551.1 kWh

Unit Peak kW Savings = (1.24 kW - 0.91 kW) x 0.9 x 1.67 = 0.50 kW

Deemed Input Tables

Table 1. Pre- and Post-retrofit Equipment Parameters (Ref. 3, 5, 6)

Baseline Equipment	Efficient Equipment	kW_Base	kW_EE	Baseline Product Efficiency	Efficient Product Efficiency	Rapid Cook Factor	Incremental Cost (Ref. 5)
Full-size Range w/Std. Oven	Efficient Range w/Convection Oven	11.10	8.14	55.0%	75.0%	1.25	$3,000
Standard Oven	Flashbake Oven	1.24	0.91	55.0%	75.0%	1.67	$3,600
Standard Oven	Convection / Microwave Oven	1.28	0.80	50.0%	80.0%	1.25	$2,200
Standard Range	Induction Cooktop	5.10	4.14	65.0%	80.0%	1.00	$2,800

Table 2. Operation Days and Cooking Hours by Building Type (Ref. 2, 8)

Building Type	Days Per Year	Cooking Hours Per Day
Large Office	250	5
Fast Food Restaurant	365	5
Sit-Down Restaurant	365	5
Grocery	365	5
Elementary School	200	5
Jr. High/High School/College	200	5
Health	365	5
Hotel	365	5
Other Commercial	250	5

Notes

The following technologies have been removed from Table 1 because they now have their own measure: *Fryer, Griddle, Convection Oven and Steamer*

References

1. 2004-05 Database for Energy Efficiency Resources (DEER) Update Study Final Report, pp. 3-15 to 3-18. http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf

2. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.
3. Food Service Technology Assessment Report, Fisher-Nickel, kW_EE is productivity enhancement adjusted
4. Measure life for similar food service equipment, 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.
5. Incremental costs adopted from utility assumptions based on reasonable comparison against information in reference 3, above, and manufacturer Web sites
6. MN Utility Product Technical Assumption sheets provided for 2008 MN Deemed Savings project
7. ENERGY STAR Electric Cooktop Product Specification, Version 1.0. August 31, 2023. https://www.energystar.gov/products/commercial_cooktops/partners
8. ENERGY STAR. Savings Calculator for ENERGY STAR Commercial Food Service (CFS) Products. Updated March 2024. https://www.energystar.gov/partner-resources/energy-star-training-center/commercial-food-service.

Revision History

Version	Description	Author	Date
2.0	Original from Nexant with extraneous tabs hidden	Nexant	
2.1	Added some clarifying notes. Modified Hrs description to reflect that operating hours will be deemed. Removed food warmers because baseline and efficient product efficiencies were identical. Original specs also did not show any savings. Removed measures per note above and reformatted. Changed measure name, changed description	Joe Plummer	
3.0	Hours of use changed to 365.25	Franklin Energy Services	1/13/2016
4.1	ENERGY STAR specification update	Cadmus	11/1/2023
5.0	Simplified algorithm inputs, removed HVAC interactive effects and aligned building type metrics with other commercial food service measures.	Cadmus	7/1/2025

Commercial Food Service – Electric Combination Oven

Measure Detail	Measure Value
Measure ID	2.07.03
Target Market Segments	Commercial
Target End Uses	Food Service
Applicable To	Commercial kitchens
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Building type
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	12 (Ref. 4)
Unit Participant Incremental Cost	$3,824 (Ref. 2)

Measure Description

This measure includes the replacement of an electric combination oven with an electric combination oven meeting current ENERGY STAR performance criteria, or installation of an electric combination oven meeting current ENERGY STAR performance criteria in new construction. ENERGY STAR combination ovens incorporate timesaving features via sophisticated control packages. Compliant efficient appliances do not need to be ENERGY STAR qualfied through the EPA program but would need to meet the ENERGY STAR performance criteria specified within this measure.

Algorithms

Unit kWh Savings per Year = (Eday_base – Eday_EE) x Days

Unit Peak kW Savings = Unit kWh Savings per Year / (OpHrs x Days) x CF

Where:

Eday_base (kWh/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs – LBFood / PC_base – T_pre / 60] + E_pre_base

Eday_EE (kWh/day) = LBFood x Efood / Eff_EE + IdleRate_EE x [OpHrs – LBFood / PC_EE – T_pre / 60] + E_pre_EE

LBFood = 200 lbs/day; Pounds of food cooked per day (Ref. 2)

Efood = 0.0732 kWh/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 44%; Heavy load cooking energy efficiency baseline (Ref. 4)

Eff_EE = 66.5% Heavy load cooking energy efficiency efficient (Ref. 6)

IdleRate_base = 7.5 kW; Idle Energy Rate baseline (Ref. 2)

IdleRate_EE = 2.4 kW; Idle Energy Rate efficient (Ref. 7)

OpHrs = 8 hrs/day; Daily operating hours (Ref. 5)

PC_base = 80 lbs/hr; Production Capacity baseline (Ref. 2)

PC_EE = 100 lbs/hr; Production Capacity efficient (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = 3.00 kWh; Preheat energy baseline (Ref. 2)

E_pre_EE = 1.50 kWh; Preheat energy efficient (Ref. 2)

Days = Days of operation per year, See Table 1

CF = 0.9 (Ref. 2)

Example

A cafeteria in a large office building installed a new ENERGY STAR electric combination oven. Note that the metrics from the average mode of an average unit from Table 1 has been used in the default values of this algorithm.

Eday_base (kWh/day) = (200 lbs/day) x (0. 0732 kWh/lb) / (44%) + [7.5 kW x (8 hrs/day – (200 lbs/day / 80 lbs/hr) – (15 min / 60 min/hr))] + 3.00 kWh/day = 75.65 kWh/day

Eday_prop (kWh/day) = (200 lbs/day) x (0. 0732 kWh/lb) / (66.5%) + [2.29 kW x (8 hrs/day – (200 lbs/day / 100 lbs/hr) – (15 min / 60 min/hr))] + 1.50 kWh/day = 36.68 kWh/day

Unit kWh Savings per Year = (75.6 kWh/day – 36.68 kWh/day) x 250 days/yr = 9,741.3 kWh

Unit Peak kW Savings = 9,741.3 kWh / (8 hr/day x 250 days/yr) x 0.9 = 4.38 kW

Deemed Input Tables

Table 1. Operation Days by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Table 2. ENERGY STAR Electric Combination Oven Criteria (Ref. 6,7)

Size	Operation	Idle Rate, kW	Cooking-Energy Efficiency, %
3-4 Pan Capacity	Steam Mode	≤ 0.60P*	≥ 51
	Convection Mode	≤ 0.05P+0.55	≥ 70
5-40 Pan Capacity	Steam Mode	≤ 0.133P+0.6400	≥ 55
	Convection Mode	≤ 0.083P+0.35	≥ 78
Average (assuming 6-pan)	Combination of both modes	2.29	66.5

*P defined as number of pans. The average value derived from steam and convection oven idle rates, assuming 6-pans

Note

There is no code requirement for this technology.

References

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.
2. Commercial Combination Ovens, Food Service Equipment Workpaper PGECOFST100 R1, PG&E. June 1, 2009.
3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.
4. 2008 Database for Energy-Efficient Resources Version 2008.2.05 December 16, 2008; www.deeresources.com/DEER 2005/DEER 2005 Version Reports and Notifications/DEER 2005 Version 2.01 Enhancements and Notifications
5. Technology Assessment: Ovens, Food Service Technology Center, 2002. Page 7-23. http://www.fishnick.com/equipment/techassessment/7_ovens.pdf
6. ENERGY STAR Commercial Ovens Key Product Criteria, Version 3.0. Effective 1/12/2023. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%203.0%20Commercial%20Ovens%20Final%20Specification_0.pdf

Revision History

Version	Description	Author	Date
1.0	Put together algorithm	Franklin Energy Services	8/27/2012
2.0	Updated to include ENERGY STAR version 2.1 specification	Franklin Energy Services	7/31/2014
2.1	Updated description to include NC, changed 365 to 365.25 for consistency with other measures	Joe Plummer	7/31/2014
4.2	Updated ENERGY STAR version 3.0 criteria	Cadmus	8/1/2024

Commercial Food Service – Electric Convection Oven

Measure Detail	Measure Value
Measure ID	2.07.04
Target Market Segments	Commercial
Target End Uses	Food Service
Applicable To	Commercial kitchens
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Building type
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	12 (Ref. 1)
Unit Participant Incremental Cost	$1,682 (Ref. 2)

Measure Description

This measure includes installation of high-efficiency electric convection ovens meeting current ENERGY STAR performance criteria instead of standard efficiency units. Energy efficient commercial electric ovens reduce energy consumption primarily through sophisticated control packages. Compliant efficient appliances do not need to be ENERGY STAR qualified through the EPA program but would need to meet the ENERGY STAR performance criteria specified within this measure.

Algorithms

Unit kWh Savings per Year = (Eday_base – Eday_EE) x Days

Unit Peak kW Savings = Unit kWh Savings per Year / (OpHrs x Days) x CF

Where:

Eday_base (kWh/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs – LBFood / PC_base – T_pre / 60] + E_pre_base

Eday_EE (kWh/day) = LBFood x Efood / Eff_EE + IdleRate_EE x [OpHrs – LBFood / PC_EE – T_pre / 60] + E_pre_EE

LBFood = 100 lbs/day; Pounds of food cooked per day (Ref. 2)

Efood = 0.0732 kWh/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 65%; Heavy load cooking energy efficiency (Ref. 2)

Eff_EE = 76% (Ref. 4)

IdleRate_base = 2.00 kW; Idle Energy Rate (Ref. 2)

IdleRate_EE = 1.00 kW; (Ref. 4)

OpHrs = 8 hrs/day; Daily operating hours (Ref. 5)

PC_base = 70 lbs/hr; Production Capacity (Ref. 2)

PC_EE = 80 lbs/hr (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = 1.50 kWh; Preheat energy (Ref. 2)

E_pre_EE = 1.00 kWh (Ref. 2)

Days = See Table 1

CF = 0.9 (Ref. 6)

Example:

A fast food restaurant installed a new ENERGY STAR Electric Convection Oven

Eday_base (kWh/day) = (100 lbs/day) x (0. 0732 kWh/lb) / (65%) + [2.00 kW x (8 hrs/day – (100 lbs/day / 70 lbs/hr) – (15 min / 60 min/hr))] + 1.50 kWh/day = 25.4 kWh/day

Eday_prop (kWh/day) = (100 lbs/day) x (0. 0732 kWh/lb) / (76%) + [1.00 kW x (8 hrs/day – (100 lbs/day / 80 lbs/hr) – (15 min / 60 min/hr))] + 1.00 kWh/day = 17.13 kWh/day

Unit kWh Savings per Year = (25.4 kWh/day – 17.13 kWh/day) x 365 days/yr = 3.020 kWh

Unit Peak kW Savings = 3,020 kWh / (8 hr/day x 365 days/yr) x 0.9 = 0.93 kW

Deemed Input Tables

Table 1. Operation Days by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Table 2. ENERGY STAR Convection Oven Requirements (Ref. 4)

Capacity Size	Idle Rate, kW	Cooking-Energy Efficiency, %
Half Size	≤ 1.00	≥ 71
Full Size ≥ 5 Pans	≤ 1.40	≥ 76
Full Size < 5 Pans	≤ 1.00	≥ 76

Notes

There is no code requirement for this technology.

Default efficient equipment efficiency values within the algorithm have been based on a full size convection oven with capacity smaller than 5 pans.

References

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.
2. Commercial Convection Ovens, Food Service Equipment Workpaper PGEOFST101 R1, PG&E. June 1, 2009.
3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.
4. ENERGY STAR Commercial Ovens Key Product Criteria, version 3.0. Effective 1/12/2023. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%203.0%20Commercial%20Ovens%20Final%20Specification_0.pdf Technology Assessment: Ovens, Food Service Technology Center, 2002. Page 7-22. http://www.fishnick.com/equipment/techassessment/7_ovens.pdf
5. 2004-05 Database for Energy Efficiency Resources (DEER) Update Study Final Report, pp. 3-15 to 3-18. http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf

Revision History

Version	Description	Author	Date
1.0	Put together algorithm	Franklin Energy Services	8/14/2012
1.1	Renamed measure	Joe Plummer	2/8/2013
1.2	Corrected preheat energy labels	Joe Plummer	10/29/13
2.0	Updated ENERGY STAR requirements	Franklin Energy Services	11/11/2015
2.1	Hours of use changed to 365.25	Franklin Energy Services	1/13/2016
4.2	Updated ENERGY STAR version 3.0 criteria	Cadmus	8/1/2024

Commercial Food Service – Electric Fryer

Measure Detail	Measure Value
Measure ID	2.07.05
Target Market Segments	Commercial
Target End Uses	Food Service
Applicable To	Commercial kitchens
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Building type, fryer type (Standard or Large Vat)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	12 (Ref. 1)
Unit Participant Incremental Cost	$2,126 for Large Vat Fryers (Ref. 6), $1,344 for Standard Fryers (Ref. 2)

Measure Description

This measure includes installation of high-efficiency Standard and Large Vat electric fryers meeting current ENERGY STAR performance criteria instead of standard efficiency units. Energy efficient commercial electric fryers reduce energy consumption primarily through the application of advanced controls and insulation. Compliant efficient appliances do not need to be ENERGY STAR qualified through the EPA program but would need to meet the ENERGY STAR performance criteria specified within this measure.

Algorithms

Unit kWh Savings per Year = (Eday_base – Eday_ee) x Days

Unit Peak kW Savings = Unit kWh Savings per Year / (OpHrs x Days) x CF

Where:

Eday_base (kWh/day) = LBFood x Efood / Eff_base + IdleRate_base x (OpHrs – LBFood / PC_base – T_pre / 60) + E_pre_base

Eday_ee (kWh/day) = LBFood x Efood / Eff_ee + IdleRate_ee x (OpHrs – LBFood / PC_ee – T_pre / 60) + E_pre_ee

LBFood = 150 lbs/day; Pounds of food cooked per day (Ref. 2)

Efood = 0.167 kWh/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 75% for Large Vat Fryers (Ref. 6), 75% for Standard Fryers (Ref. 2); Heavy load cooking efficiency for standard efficiency equipment

Eff_ee = 80% for Large Vat Fryers, 83% for Standard Fryers (Ref. 4); Heavy load cooking efficiency for ENERGY STAR equipment

IdleRate_base =1.35 kW for Large Vat Fryers (Ref. 6), 1.05 kW for Standard Fryers (Ref. 2); Idle Energy Rate for standard efficiency equipment

IdleRate_ee	=	1.1 kW for Large Vat Fryers, 0.8 kW for Standard Fryers (Ref. 4); Idle Energy Rate for ENERGY STAR equipment
OpHrs	=	12 hrs/day for Large Vat Fryers (Ref. 6), 16 hrs/day for Standard Fryers (Ref. 2); Daily operating hours
PC_base	=	100 lbs/hr for Large Vat Fryers (Ref. 6), 65 lbs/hr for Standard Fryers (Ref. 2); Production capacity for standard efficiency equipment
PC_ee	=	110 lbs/hr for Large Vat Fryers (Ref. 6), 70 lbs/hr for Standard Fryers (Ref. 2); Production capacity for ENERGY STAR equipment (Ref. 2)
T_pre	=	15 min/day; Preheat Time (Ref. 2, 6)
E_pre_base	=	2.5 kWh/day for Large Vat Fryers (Ref. 6), 2.3 kWh/day for Standard Fryers (Ref. 2); Preheat energy for standard efficiency equipment
E_pre_ee	=	2.1 kWh/day for Large Vat Fryers (Ref. 6), 1.7 kWh/day for Standard Fryers (Ref. 2); Preheat energy for ENERGY STAR equipment
Days	=	See Table 1; Annual operating days
CF	=	0.9 (Ref. 5); Electrical peak coincidence factor

Example:

A fast food restaurant installed a new Standard-sized ENERGY STAR Electric Fryer:

Eday_base (kWh/day) = (150 lbs/day) x (0.167 kWh/lb) / (75%) + [1.05 kW x (16 hr/day – (150 lbs/day / 65 lb/hr) – (15 min / 60 min/hr))] + 2.3 kWh/day = 49.8 kWh/day

Eday_ee (kWh/day) = (150 lbs/day) x (0.167 kWh/lb) / (83%) + [0.8 kW x (16 hr/day – (150 lbs/day / 70 lb/hr) – (15 min / 60 min/hr))] + 1.7 kWh/day = 42.8 kWh/day

Unit kWh Savings per Year = (49.8 kWh/day – 42.8 kWh/day) x 365 days/yr = 2,574 kWh

Unit Peak kW Savings = 2,574 kWh / (16 hr/day x 365 days/yr) x 0.9 = 0.396 kW

Deemed Input Tables

Table 1. Operating Days per Year by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Notes

There is no code requirement for this technology.

ENERGY STAR defines a Standard Fryer as a fryer with a vat that measures ≥ 12 inches and < 18 inches wide, and a shortening capacity ≥ 25 pounds and ≤ 65 pounds (Ref. 4).

ENERGY STAR defines a Large Vat Fryer as a fryer with a vat that measures ≥ 18 inches and ≤ 24 inches wide, and a shortening capacity > 50 pounds (Ref. 4).

ENERGY STAR requires Standard Open Deep-Fat Electric Fryers have a heavy-load cooking efficiency ≥ 83% and an idle energy rate ≤ 800 Watts (Ref. 4).

ENERGY STAR requires Large Vat Open Deep-Fat Electric Fryers have a heavy-load cooking efficiency ≥ 80% and an idle energy rate ≤ 1,100 Watts (Ref. 4).

References

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.
2. *Commercial Fryer,* Food Service Equipment Workpaper PGEOFST102 R1, PG&E. June 1, 2009.
3. Data from Table 1 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.
4. *ENERGY STAR Program Requirements: Product Specification for Commercial Fryers: Eligibility Criteria, Version 3.0,* https://www.energystar.gov/sites/default/files/Commercial%20Fryers%20Program%20Requirements.pdf, accessed August, 19, 2016.

5. 2004-05 Database for Energy Efficiency Resources (DEER) Update Study Final Report, pp. 3-15 to 3-18. http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf
6. *Commercial Large Vat Fryer,* Food Service Equipment Workpaper PGECOFST114 R1, PG&E. June 1, 2009.

Revision History

Version	Description	Author	Date
1.0	Put together algorithm	Franklin Energy Services	8/24/2012
1.1	Changed measure name	Joe Plummer	2/8/2013
1.2	Corrected preheat energy labels	Joe Plummer	10/30/13
1.3	Hours of use changed to 365.25	Franklin Energy Services	1/13/2016
1.4	Updated to new ES Standard in algorithms and notes, added Large Vat fryers, updated example	Franklin Energy Services	8/19/2016

Commercial Food Service – Electric Griddle

Measure Detail	Measure Value
Measure ID	2.07.06
Target Market Segments	Commercial
Target End Uses	Food Service
Applicable To	Commercial kitchens
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Building type
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	12 (Ref. 1)
Unit Participant Incremental Cost	$2,162 (Ref. 2)

Measure Description

This measure includes installation of high-efficiency electric griddles meeting current ENERGY STAR performance criteria instead of standard efficiency units. Energy efficient commercial electric griddles reduce energy consumption primarily through application of advanced controls and improved temperature uniformity. Compliant efficient appliances do not need to be ENERGY STAR qualfied through the EPA program but would need to meet the ENERGY STAR performance criteria specified within this measure.

Algorithms

Unit kWh Savings per Year = (Eday_base – Eday_EE) x Days

Unit Peak kW Savings = Unit kWh Savings per Year / (OpHrs x Days) x CF

Where:

Eday_base (kWh/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs – LBFood / PC_base – T_pre / 60] + E_pre_base

Eday_EE (kWh/day) = LBFood x Efood / Eff_EE + IdleRate_EE x [OpHrs – LBFood / PC_EE – T_pre / 60] + E_pre_EE

LBFood = 100 lbs/day; Pounds of food cooked per day (Ref. 2)

Efood = 0.139 kWh/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 65%; Heavy load cooking energy efficiency (Ref. 2)

Eff_EE = 70% (Ref. 2)

IdleRate_base =2.50 kW; Idle Energy Rate (Ref. 2)

IdleRate_EE= 2.13 kW (Ref. 4); Assumes a 3’ x 2’ griddle size and a Tier 1 idle rate

OpHrs = 12 hrs/day; Daily operating hours (Ref. 5)

PC_base = 35 lbs/hr; Production Capacity (Ref. 2)

PC_EE = 40 lbs/hr (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = 4.00 kWh; Preheat energy (Ref. 2)

E_pre_EE = 2.00 kWh; (Ref. 2)

Days = See Table 1

CF = 0.9 (Ref. 6)

Example:

A hospital installed a new ENERGY STAR Electric Griddle in its kitchen

Eday_base (kWh/day) = (100 lbs/day) x (0.139 kWh/lb) / (65%) + [2.5 kW x (12 hr/day – (100 lbs/day / 35 lb/hr) – (15 min / 60 min/hr))] + 4.00 kWh = 47.6 kWh/day

Eday_EE (kWh/day) = (100 lbs/day) x (0.139 kWh/lb) / (70%) + [2.13 kW x (12 hr/day – (100 lbs/day / 40 lb/hr) – (15 min / 60 min/hr))] + 2.00 kWh = 41.6 kWh/day

Unit kWh Savings per Year = (47.6 kWh/day – 41.6 kWh/day) x 365 days/yr = 2,212 kWh

Unit Peak kW Savings = 2,212 kWh / (12 hrs/day x 365 days/yr) x 0.90 = 0.454 kW

Deemed Input Tables

Table 1. Operation Days by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Methodology and Assumptions

Savings assumes a 3’ x 2’ griddle size and a Tier 1 idle rate.

Notes

There is no code requirement for this technology.

ENERGY STAR requires that Tier 1 Electric Griddles have a cooking energy efficiency ≥ 70% and a normalized idle energy rate ≤ 355 Watts per ft^2 (Ref. 4)

ENERGY STAR requires that Tier 2 Electric Griddles have a cooking energy efficiency ≥ 70% and a normalized idle energy rate ≤ 320 Watts per ft^2 (Ref. 4)

References

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.
2. *Commercial Griddles,* Food Service Equipment Workpaper PGECOFST103 R1, PG&E. June 1, 2009.
3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.
4. *ENERGY STAR Commercial Griddles Key Product Criteria,* Accessed August, 15, 2012. http://www.energystar.gov/index.cfm?c=griddles.pr_crit_comm_griddles.
5. *Technology Assessment: Griddles,* Food Service Technology Center, 2002. Page 3-22. http://www.fishnick.com/equipment/techassessment/3_griddles.pdf
6. 2004-05 Database for Energy Efficiency Resources (DEER) Update Study Final Report, pp. 3-15 to 3-18. http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf

Revision History

Version	Description	Author	Date
1.0	Put together algorithm	Franklin Energy Services	8/24/2012
1.1	Renamed measure	Joe Plummer	2/8/2013
1.2	Fixed preheat energy labels	Joe Plummer	10/30/13
1.3	Hours of use changed to 365.25	Franklin Energy Services	1/13/2016

Commercial Food Service – Electric Hot Food Holding Cabinet

Measure Detail	Measure Value
Measure ID	2.07.07
Target Market Segments	Commercial
Target End Uses	Food Service
Applicable To	Commercial kitchens
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Building type, cabinet volume
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	12 (Ref. 1)
Unit Participant Incremental Cost	See Table 1 (Ref. 2)

Measure Description

This measure includes installation of high-efficiency electric hot food holding cabinets (HFHCs) meeting current ENERGY STAR performance criteria instead of standard efficiency units. Energy efficient commercial HFHCs reduce energy consumption primarily through better insulation, magnetic door electric gaskets, auto-door closures, or Dutch doors. Compliant efficient appliances do not need to be ENERGY STAR qualified through the EPA program but would need to meet the ENERGY STAR performance criteria specified within this measure.

Algorithms

Unit kWh Savings per Year = (kW_base – kW_ee) x Hours x Days

Unit Peak kW Savings = (kW_base – kW_ee) x CF

Where:

kW_base	=	Wattage of baseline unit. See Table 1. (Ref. 6)
kW_ee	=	Wattage of ENERGY STAR unit. See Table 1 (Ref. 4)
Hours	=	15 hrs/day (Ref. 7)
Days	=	See Table 2
CF	=	0.9 (Ref. 5)

Example:

A sit-down food restaurant installed a new full-size ENERGY STAR Electric HFHC:

Unit kWh Savings per Year = (2.0 kW – 0.294 kW) x 15 hrs/day x 365 days/yr = 9,347 kWh

Unit Peak kW Savings = (2.0 kW – 0.294 kW) x 0.9 = 1.54 kW

Deemed Input Tables

Table 1. Hot Food Holding Cabinet Performance Characteristics

Size	Volume (ft^3)	kW_base	kW_ee	Incremental Cost
Full-Size	20	2.000	0.294	$1,891
¾-Size	12	1.200	0.258	$707
Half-Size	8	0.800	0.172	$1,497

Table 2. Operation Days by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Methodology and Assumptions

The baseline energy usage is assumed to be 100 W/ft^2 based on the FSTC Life Cycle Cost Calculator

Notes

There is no code requirement for this technology.

The ENERGY STAR Version 3.0 specification revision for commercial HFHCs is under development as of August 2016. The previous version's standards are listed below, italicized.

> *ENERGY STAR requires that Electric HFHCs (28 $ft^3 \leq$ Volume) have an idle rate defined by: Watts $\leq$ 3.8 x Volume (ft^3) + 203.5*
>
> *ENERGY STAR requires that Electric HFHCs (13 $ft^3 \leq$ Volume < 28 ft^3) have an idle rate defined by: Watts $\leq$ 2.0 x Volume (ft^3) + 254.0*
>
> *ENERGY STAR requires that Electric HFHCs (Volume $\leq$ 13 ft^3) have an idle rate defined by: Watts $\leq$ 21.5 x Volume (ft^3)*

References

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.
2. *Insulated Holding Cabinet,* Food Service Equipment Workpaper PGECOFST105 R1, PG&E. June 1, 2009.

3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.
4. *ENERGY STAR Commercial Hot Food Holding Cabinets Key Product Criteria,* http://www.energystar.gov/index.cfm?c=hfhc.pr_crit_hfhc. Accessed 8/24/12.
5. 2004-2005 Database for Energy Efficiency Resources (DEER) Update Study Final Report, pp. 3-15 to 3-18. http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf
6. *Hot-Food Holding Cabinet Life-Cycle Cost Calculator*, Food Service Technology Center, http://www.fishnick.com/saveenergy/tools/calculators/holdcabcalc.php. Accessed on 8/27/12.

Revision History

Version	Description	Author	Date
1.0	Put together algorithm	Franklin Energy Services	8/24/2012
1.1	Update sizes	Franklin Energy Services	8/27/2012
1.2	Hours of use changed to 365.25	Franklin Energy Services	1/13/2016
1.3	Updated notes regarding ES Version 3.0	Franklin Energy Services	8/19/2016

Commercial Food Service – Electric Steamer

Measure Detail	Measure Value
Measure ID	2.07.08
Target Market Segments	Commercial
Target End Uses	Food Service
Applicable To	Commercial kitchens
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Building type, number of pans
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	12 (Ref. 1)
Unit Participant Incremental Cost	$2,490 (Ref. 2)

Measure Description

This measure includes replacement of commercial electric steamers with new 5 or 6-pan electric steamers meeting current ENERGY STAR performance criteria. Compliant efficient appliances do not need to be ENERGY STAR qualified through the EPA program but would need to meet the ENERGY STAR performance criteria specified within this measure.

Algorithms

Unit kWh Savings per Year = (Eday_base – Eday_EE) x Days

Unit Peak kW Savings = Unit kWh Savings per Year / (OpHrs x Days) x CF

Where:

Eday_base (kWh/day) = LBFood x Efood / Eff_base + (IdleRate_base + Res_Rate_base) x (OpHrs – LBFood / PC_base – T_pre / 60) + E_pre

Eday_EE (kWh/day) = LBFood x Efood / Eff_EE + (IdleRate_EE + Res_Rate_EE) x (OpHrs – LBFood / PC_EE – T_pre / 60) + E_pre

LBFood = See Table 1; Pounds of food cooked per day (Ref. 2)

Efood = 0.0308 kWh/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 26%; Heavy load cooking energy efficiency (Ref. 2)

Eff_EE = 50% (Ref. 2)

IdleRate_base = See Table 1; Idle Energy Rate (Ref. 2)

IdleRate_EE = See Table 1; (Ref. 2)

OpHrs = 12 hrs/day; Daily operating hours (Ref. 2)

PC_base = See Table 1; Production Capacity (Ref. 2)

PC_EE = See Table 1 (Ref. 2)

Res_Rate_base = 1.910 kW; Residual Energy Rate (Ref. 2)

Res_Rate_EE = 0.120 kW; Residual Energy Rate (Ref. 2)

T_pre = 15 min/day; Pyreheat Time (Ref. 2)

E_pre = 1.50 kWh; Preheat energy (Ref. 2)

Days = See Table 2

CF = 0.9 (Ref. 1)

Example:

A health clinic cafeteria installed a new 6-pan ENERGY STAR Electric Steam Cooker

Eday_base (kWh/day) = (192 lbs/day) x (0. 0308 kWh/lb) / (26%) + (2.00 kW + 1.91 kW) x (12 hrs/day – (192 lbs/day / 120 lbs/hr) – (15 min / 60 min/hr)) + 1.50 kWh/day = 63.9 kWh/day

Eday_EE (kWh/day) = (192 lbs/day) x (0. 0308 kWh/lb) / (50%) + (0.80 kW + 0.120 kW) x (12 hrs/day – (192 lbs/day / 100 lbs/hr) – (15 min / 60 min/hr)) + 1.50 kWh/day = 22.4 kWh/day

Unit kWh Savings per Year = (63.9 kWh/day – 22.4 kWh/day) x 365 days/yr = 15,158 kWh

Unit Peak kW Savings = 15,147 kWh / (12 hr/day x 365 days/yr) x 0.9 = 3.113 kW

Deemed Input Tables

Table 1. Steamer Characteristics

	3-Pan Steamer	4-Pan Steamer	5-Pan Steamer	6-Pan Steamer
LBFood (lbs/day)	100	128	160	192
Efood (kWh/lb)	0.0308	0.0308	0.0308	0.0308
Eff_base (%)	26%	26%	26%	26%
Eff_EE (%)	50%	50%	50%	50%
IdleRate_base (kW)	1.000	1.325	1.675	2.000
IdleRate_EE (kW)	0.400	0.530	0.670	0.800
OpHrs (hrs/day)	12	12	12	12
PC_base (lbs/hr)	70	87	103	120
PC_EE (lbs/hr)	50	67	83	100
Res_Rate_base (kW)	1.910	1.910	1.910	1.910
Res_Rate_EE (kW)	0.120	0.120	0.120	0.120
T_pre (minutes)	15	15	15	15
E_pre	1.5	1.5	1.5	1.5

Table 2. Operation Days by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Notes

There is no code requirement for this technology.

Table 3. ENERGY STAR requires that Electric Steam Cookers have the following efficiencies (Ref. 4):

Pan Capacity	Cooking Energy Efficiency	Idle Rate (Watts)
3-Pan	50%	400
4-Pan	50%	530
5-Pan	50%	670
6-Pan	50%	800

References

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.
2. *ENERGY STAR Commercial Steam Cookers,* Food Service Equipment Workpaper PGECOFST104 R1, PG&E. June 1, 2009.
3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.
4. *Commercial Steam Cookers Key Product Criteria,* http://www.energystar.gov/index.cfm?c=steamcookers.pr_crit_steamcookers. Accessed August, 27, 2012.

Revision History

Version	Description	Author	Date
1.0	Put together algorithm	Franklin Energy Services	8/27/2012
2.0	Updated OpHrs in table	Franklin Energy Services	11/11/2015
3.0	Updated the Energy-to-Food value to 0.0308 kWh/lb	Franklin Energy Services	11/11/2015

Commercial Food Service – Gas Combination Oven

Measure Detail	Measure Value
Measure ID	2.07.09
Target Market Segments	Commercial
Target End Uses	Food Service
Applicable To	Commercial kitchens
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Building type
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	12 (Ref. 1)
Unit Participant Incremental Cost	$5,717 (Ref. 2)

Measure Description

This measure includes the replacement of a gas combination oven with a gas combination oven meeting current ENERGY STAR performance criteria, or installation of a combination oven meeting current ENERGY STAR performance criteria in new construction. ENERGY STAR combination ovens incorporate timesaving features via sophisticated control packages. Compliant efficient appliances do not need to be ENERGY STAR qualified through the EPA program but would need to meet the ENERGY STAR performance criteria specified within this measure.

Algorithms

Unit Dth Savings per Year = (Eday_base – Eday_EE) / Conversion Factor x Day

Where:

Eday_base (Btu/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs – LBFood / PC_base – T_pre / 60] + E_pre_base

Eday_EE (Btu/day) = LBFood x Efood / Eff_EE + IdleRate_EE x [OpHrs – LBFood / PC_EE – T_pre / 60] + E_pre_EE

LBFood = 200 lbs/day; Pounds of food cooked per day (Ref. 2)

Efood = 250 Btu/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 35%; Heavy load cooking energy efficiency baseline (Ref. 6)

Eff_EE = 49.0%, Heavy load cooking energy efficiency efficient (Ref. 6)

IdleRate_base = 28,000 Btu/hr; Idle Energy Rate baseline (Ref. 2)

IdleRate_EE= 12,351 Btu/hr; Idle Energy Rate baseline (Ref. 6)

OpHrs = 8 hrs/day; Daily operating hours (Ref. 5)

PC_base = 80 lbs/hr; Production Capacity baseline (Ref. 2)

PC_EE = 120 lbs/hr; Production Capacity efficient (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = 18,000 Btu/day; Preheat energy baseline (Ref. 2)

E_pre_EE = 13,000 Btu/day; Preheat energy baseline(Ref. 2)

Days = See Table 1

ConversionFactor = 1,000,000 Btu/Dth

Example:

A hospital cafeteria installed a new ENERGY STAR gas combination oven.

Eday_base (Btu/day) = (200 lbs/day) x (250 Btu/lb) / (35%) + [28,000 Btu/hr x (8 hrs/day – (200 lbs/day / 80 lb/hr) – (15 min / 60 min/hr))] + 18,000 Btu/day = 307,857 Btu/day

Eday_prop (Btu/day) = (200 lbs/day) x (250 Btu/lb) / (49%) + [12,351 Btu/hr x (8 hrs/day – (200 lbs/day / 120 lb/hr) – (15 min / 60 min/hr))] + 13,000 Btu/day = 190,176.07 Btu/day

Unit Dth Savings per Year = (307,857 Btu/day – 190,176.07 Btu/day) / 1,000,000 Btu/Dth x 365 days/yr = 42.95 Dth

Deemed Input Tables

Table 1. Operation Days by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Methodology and Assumptions

Table 2. ENERGY STAR Gas Combination Oven Criteria (Ref. 6, 7)

Operation (Full size 5-40 Pan Capacity)	Idle Rate, Btu/h	Cooking-Energy Efficiency, %
Steam Mode	≤ 200P+6,511	≥ 41
Convection Mode	≤ 140P+3,800	≥ 57
Combination of both modes (assuming 6-pan unit)	12,351	49

*P defined as number of pans. Default idle rate and energy efficiency of efficient unit derived from the sum of steam and convection oven idle rates (summed because they can be used simultaneously), assuming 6-pans to be conservative.

Notes

There is no code requirement for this technology.

References

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.
2. Commercial Combination Ovens, Food Service Equipment Workpaper PGECOFST100 R1, PG&E. June 1, 2009.
3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.
4. 2008 Database for Energy-Efficient Resources Version 2008.2.05 December 16, 2008; www.deeresources.com / DEER 2005 / DEER 2005 Version Reports and Notifications/ DEER 2005 Version 2.01 Enhancements and Notifications
5. Technology Assessment: Ovens, Food Service Technology Center, 2002. Page 7-22. http://www.fishnick.com/equipment/techassessment/7_ovens.pdf
6. ENERGY STAR Commercial Ovens Key Product Criteria, Version 3.0. Effective 1/12/2023. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%203.0%20Commercial%20Ovens%20Final%20Specification_0.pdf

Revision History

Version	Description	Author	Date
1.0	Put together algorithm	Franklin Energy Services	8/27/2012
1.1	Renamed measure	Joe Plummer	2/8/2013
1.2	Updated to include ENERGY STAR version 2.1 specification	Franklin Energy Services	7/31/2014
1.3	Updated description to include new construction, changed 365 to 365.25 for consistency with other measures, put Table 2 in Methodology & Assumptions section	Joe Plummer	7/31/2014
4.2	Updated ENERGY STAR version 3.0 criteria	Cadmus	8/1/2024

Commercial Food Service – Gas Convection Oven

Measure Detail	Measure Value
Measure ID	2.07.10
Target Market Segments	Commercial
Target End Uses	Food Service
Applicable To	Commercial kitchens
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Building type
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	12 (Ref. 1)
Unit Participant Incremental Cost	$1,886 (Ref. 2)

Measure Description

This measure includes installation of high-efficiency gas convection ovens meeting current ENERGY STAR performance criteria instead of standard efficiency units. Energy efficient commercial gas ovens reduce energy consumption primarily through sophisticated control package. Compliant efficient appliances do not need to be ENERGY STAR qualified through the EPA program but would need to meet the ENERGY STAR performance criteria specified within this measure.

Algorithms

Unit Dth Savings per Year = (Eday_base – Eday_EE) / Conversion Factor x Days

Where:

Eday_base (Btu/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs – LBFood / PC_base – T_pre / 60] + E_pre_base

Eday_EE (Btu/day) = LBFood x Efood / Eff_EE + IdleRate_EE x [OpHrs – LBFood / PC_EE – T_pre / 60] + E_pre_EE

LBFood = 100 lbs/day; Pounds of food cooked per day (Ref. 2)

Efood = 250 Btu/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 30%; Heavy load cooking efficiency, standard efficiency equipment (Ref. 2)

Eff_EE = 49%; Heavy load cooking efficiency, ENERGY STAR equipment (Ref. 4)

IdleRate_base = 18,000 Btu/hr; Idle energy rate, standard efficiency equipment (Ref. 2)

IdleRate_EE= 9,500 Btu/hr; Idle energy rate, ENERGY STAR equipment (Ref. 4)

OpHrs = 8 hrs/day; Daily operating hours (Ref. 5)

PC_base = 70 lbs/hr; Production capacity, standard efficiency equipment (Ref. 2)

PC_EE = 80 lbs/hr; Production capacity, ENERGY STAR equipment (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = 19,000 Btu/day; Preheat energy (Ref. 2)

E_pre_EE = 11,000 Btu/day (Ref. 2)

Days = See Table 1

ConversionFactor = 1,000,000 Btu/Dth

Example:

A sit-down restaurant installed a new ENERGY STAR Gas Convection Oven

Eday_base (Btu/day) = (100 lbs/day) x (250 Btu/lb) / (30%) + [18,000 Btu/hr x (8 hrs/day – (100 lbs/day / 70 lb/hr) – (15 min / 60 min/hr))] + 19,000 Btu/day = 216,119 Btu/day

Eday_EE (Btu/day) = (100 lbs/day) x (250 Btu/lb) / (49%) + [9,500 Btu/hr x (8 hrs/day – (100 lbs/day / 80 lb/hr) – (15 min / 60 min/hr))] + 11,000 Btu/day = 123,770Btu/day

Unit Dth Savings per Year = (216,119 Btu/day – 123,770Btu/day) / 1,000,000 Btu/Dth x 365 days/yr = 33.7 Dth

Deemed Input Tables

Table 1. Operation Days by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Table 2. ENERGY STAR Convection Oven Requirements (Ref. 4)

Capacity Size	Idle Rate, Btu/hr	Cooking-Energy Efficiency, %
Full Size	≤ 9,500	≥ 49

Notes

There is no code requirement for this technology.

References

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.
2. Commercial Convection Ovens, Food Service Equipment Workpaper PGEOFST101 R1, PG&E. June 1, 2009.

3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.
4. ENERGY STAR Commercial Ovens Key Product Criteria. Effective 1/12/2023. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%203.0%20Commercial%20Ovens%20Final%20Specification_0.pdf
5. Technology Assessment: Ovens, Food Service Technology Center, 2002. Page 7-22. http://www.fishnick.com/equipment/techassessment/7_ovens.pdf

Revision History

Version	Description	Author	Date
2.0	Updated ENERGY STAR efficiency requirements	Franklin Energy Services	11/11/2015
2.1	Updated values to new ES requirements, updated example	Franklin Energy Services	8/19/2016
4.2	Updated ENERGY STAR version 3.0 criteria	Cadmus	8/1/2024

Commercial Food Service – Gas Fryer

Measure Detail	Measure Value
Measure ID	2.07.11
Target Market Segments	Commercial
Target End Uses	Food Service
Applicable To	Commercial kitchens
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Building type, fryer type (standard or large vat)
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	12 (Ref. 1)
Unit Participant Incremental Cost	$1,873 for Large Vat Fryers (Ref. 5), $1,219 for Standard Fryers (Ref. 2)

Measure Description

This measure includes installation of high-efficiency Standard and Large Vat gas fryers that meet current ENERGY STAR performance criteria instead of standard efficiency units. Energy efficient commercial gas fryers reduce energy consumption primarily through advanced burner and heat exchanger design and the application of advanced controls and insulation. Compliant efficient appliances do not need to be ENERGY STAR qualified through the EPA program but would need to meet the ENERGY STAR performance criteria specified within this measure.

Algorithms

Unit Dth Savings per Year = (Eday_base – Eday_EE) / ConversionFactor x Days

Where:

Eday_base (Btu/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs – LBFood / PC_base – T_pre / 60] + E_pre_base

Eday_EE (Btu/day) = LBFood x Efood / Eff_EE + IdleRate_EE x [OpHrs – LBFood / PC_EE – T_pre / 60] + E_pre_EE

LBFood = 150 lbs/day; Pounds of food cooked per day (Ref. 2)

Efood = 570 Btu/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 35% for Large Vat Fryers (Ref. 5), 35% for Standard Fryers (Ref. 2); Heavy load cooking efficiency for standard efficiency equipment

Eff_EE = 50% for Large Vat Fryers, 50% for Standard Fryers (Ref. 4); Heavy load cooking efficiency for ENERGY STAR equipment

IdleRate_base = 20,000 Btu/hr for Large Vat Fryers (Ref. 5), 14,000 Btu/hr for Standard Fryers (Ref. 2); Idle Energy Rate for standard efficiency equipment

IdleRate_EE = 12,000 Btu/hr for Large Vat Fryers, 9,000 Btu/hr for Standard Fryers (Ref. 4); Idle Energy Rate for ENERGY STAR equipment

OpHrs = 12 hrs/day for Large Vat Fryers (Ref. 5), 16 hrs/day for Standard Fryers (Ref. 2); Daily operating hours

PC_base = 100 lbs/hr for Large Vat Fryers (Ref. 5), 60 lbs/hr for Standard Fryers (Ref. 4); Production capacity for standard efficiency equipment

PC_EE = 110 lbs/hr for Large Vat Fryers (Ref. 5), 65 lbs/hr for Standard Fryers (Ref. 4); Production capacity for ENERGY STAR equipment

T_pre = 15 min/day; Preheat Time (Ref. 2, 5)

E_pre_base = 21,000 Btu/day for Large Vat Fryers (Ref. 5), 16,000 Btu/day for Standard Fryers (Ref. 2); Preheat energy for standard efficiency equipment

E_pre_EE = 16,500 Btu/day for Large Vat Fryers (Ref. 5), 15,500 Btu/day for Standard Fryers (Ref. 2); Preheat energy for ENERGY STAR equipment

Days = See Table 1; Annual operating days

ConversionFactor = 1,000,000 Btu/Dth

Example:

A grocery store installed a new Standard-sized ENERGY STAR Gas Fryer

Eday_base (Btu/day) = (150 lbs/day) x (570 Btu/lb) / (35%) + [14,000 Btu/hr x (16 hr/day – (150 lbs/day / 60 lb/hr) – (15 min / 60 min/hr))] + 16,000 Btu/day = 445,786Btu/day

Eday_EE (Btu/day) = (150 lbs/day) x (570 Btu/lb) / (50%) + [9,000 Btu/hr x (16 hr/day – (150 lbs/day / 65 lb/hr) – (15 min / 60 min/hr))] + 15,500 Btu/day = 307,481 Btu/day

Unit Dth Savings per Year = (445,786 Btu/day – 307,481 Btu/day) / 1,000,000 Btu/Dth x 365 days/yr = 50.5 Dth

Deemed Input Tables

Table 1. Operation Days by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Notes

There is no code requirement for this technology.

ENERGY STAR defines a Standard Fryer as a fryer with a vat that measures ≥ 12 inches and < 18 inches wide, and a shortening capacity ≥ 25 pounds and ≤ 65 pounds (Ref. 4).

ENERGY STAR defines a Large Vat Fryer as a fryer with a vat that measures ≥ 18 inches and ≤ 24 inches wide, and a shortening capacity > 50 pounds (Ref. 4).

ENERGY STAR requires Standard Open Deep-Fat Gas Fryers have a heavy-load cooking efficiency ≥ 50% and an idle energy rate ≤ 9,000 Btu/h (Ref. 4)

ENERGY STAR requires Large Vat Open Deep-Fat Gas Fryers have a heavy-load cooking efficiency ≥ 50% and an idle energy rate ≤ 12,000 Btu/h (Ref. 4)

References

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.
2. Commercial Fryer, Food Service Equipment Workpaper PGEOFST102 R1, PG&E. June 1, 2009.
3. Data from Table 1 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.
4. ENERGY STAR Program Requirements: Product Specification for Commercial Fryers: Eligibility Criteria, Version 3.0, https://www.energystar.gov/sites/default/files/Commercial%20Fryers%20Program%20Requirements.pdf, accessed August, 19, 2016.
5. Commercial Large Vat Fryer, Food Service Equipment Workpaper PGECOFST114 R1, PG&E. June 1, 2009.

Revision History

Version	Description	Author	Date
1.0	Put together algorithm	Franklin Energy Services	8/14/2012
1.1	Changed measure name	Joe Plummer	2/8/2013
1.2	Added Large Vat Fryers	Franklin Energy Services	8/19/2016

Commercial Food Service – Gas Griddle

Measure Detail	Measure Value
Measure ID	2.07.12
Target Market Segments	Commercial
Target End Uses	Food Service
Applicable To	Commercial kitchens
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Building type
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	12 (Ref. 1)
Unit Participant Incremental Cost	$1,912 (Ref. 6)

Measure Description

This measure includes installation of high-efficiency gas griddles that meet current ENERGY STAR performance criteria instead of standard efficiency units. Energy efficient commercial gas griddles reduce energy consumption primarily through advanced burner design and controls. Compliant efficient appliances do not need to be ENERGY STAR qualfied through the EPA program but would need to meet the ENERGY STAR performance criteria specified within this measure.

Algorithms

Unit Dth Savings per Year = (Eday_base – Eday_EE) / Conversion Factor x Days

Where:

Eday_base (Btu/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs – LBFood / PC_base – T_pre / 60] + E_pre_base

Eday_EE (Btu/day) = LBFood x Efood / Eff_EE + IdleRate_EE x [OpHrs – LBFood / PC_EE – T_pre / 60] + E_pre_EE

LBFood = 100 lbs/day; Pounds of food cooked per day (Ref. 2)

Efood = 475 Btu/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 32%; Heavy load cooking energy efficiency (Ref. 2)

Eff_EE = 38% (Ref. 4)

IdleRate_base = 19,000 Btu/hr; Idle Energy Rate (Ref. 2)

IdleRate_EE = 16,000 Btu/hr (Ref. 2)

OpHrs = 12 hrs/day; Daily operating hours (Ref. 5)

PC_base = 25 lbs/hr; Production Capacity (Ref. 2)

PC_EE = 45 lbs/hr (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = 21,000 Btu/day; Preheat energy (Ref. 2)

E_pre_EE = 15,000 Btu/day (Ref. 2)

Days = See Table 1

ConversionFactor = 1,000,000 Btu/Dth

Example:

A sit-down restaurant installed a new ENERGY STAR Gas Griddle

Eday_base (Btu/day) = (100 lbs/day) x (475 Btu/lb) / (32%) + [19,000 Btu/hr x (12 hr/day – (100 lbs/day / 25 lb/hr) – (15 min / 60 min/hr))] + 21,000 Btu/day = 316,688 Btu/day

Eday_EE (Btu/day) = (100 lbs/day) x (475 Btu/lb) / (38%) + [16,000 Btu/hr x (12 hr/day – (100 lbs/day / 45 lb/hr) – (15 min / 60 min/hr))] + 15,000 Btu/day = 292,444 Btu/day

Unit Dth Savings per Year = (316,688 Btu/day – 292,444 Btu/day) / 1,000,000 Btu/Dth x 365 days/yr = 8.9 Dth

Deemed Input Tables

Table 1. Operation Days by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Methodology and Assumptions

Savings assumes a 3’ x 2’ griddle size and a Tier 1 idle rate.

Notes

There is no code requirement for this technology.

ENERGY STAR requires that Gas Griddles have a cooking energy efficiency ≥ 38% and a normalized idle energy rate ≤ 2,650 Btu/h per ft^2 (Ref. 4).

References

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.
2. *Commercial Griddles,* Food Service Equipment Workpaper PGECOFST103 R1, PG&E. June 1, 2009.
3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.
4. *Commercial Griddles Key Product Criteria,* http://www.energystar.gov/index.cfm?c=griddles.pr_crit_comm_griddles. Accessed August, 15, 2012.
5. *Technology Assessment: Griddles,* Food Service Technology Center, 2002. Page 3-22. http://www.fishnick.com/equipment/techassessment/3_griddles.pdf
6. Based on Vulcan-Hart pricing from KaTom.com, see Costs tab.

Revision History

Version	Description	Author	Date
1.0	New measure	Franklin Energy Services	8/14/2012
1.1	Renamed measure	Joe Plummer	2/8/2013

Commercial Food Service – Gas Steamer

Measure Detail	Measure Value
Measure ID	2.07.13
Target Market Segments	Commercial
Target End Uses	Food Service
Applicable To	Commercial kitchens
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Building type, number of pans (5 or 6)
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	12 (Ref. 1)
Unit Participant Incremental Cost	$3,732 (Ref. 2)

Measure Description

This measure includes replacement of commercial gas steamers with new 5 or 6-pan gas steamers that meet current ENERGY STAR performance criteria. Compliant efficient appliances do not need to be ENERGY STAR qualified through the EPA program but would need to meet the ENERGY STAR performance criteria specified within this measure..

Algorithms

Unit Dth Savings per Year = (Eday_base – Eday_EE) / Conversion Factor x Days

Where:

Eday_base (Btu/day) = LBFood x Efood / Eff_base + (IdleRate_base + Res_Rate_base) x (OpHrs – LBFood / PC_base – T_pre / 60) + E_pre_base

Eday_EE (Btu/day) = LBFood x Efood / Eff_EE + (IdleRate_EE + Res_Rate_EE) x (OpHrs – LBFood / PC_prop – T_pre / 60) + E_pre_EE

LBFood = See Table 1; Pounds of food cooked per day (Ref. 2)

Efood = 105 Btu/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 15%; Heavy load cooking energy efficiency (Ref. 2)

Eff_EE = 38% (Ref. 2)

IdleRate_base = See Table 1; Idle Energy Rate (Ref. 2)

IdleRate_EE = See Table 1 (Ref. 2)

OpHrs = 12 hrs/day; Daily operating hours (Ref. 2)

PC_base = See Table 1; Production Capacity (Ref. 2)

PC_EE = See Table 1 (Ref. 2)

Res_Rate_base = 45,080 Btu/h; Residual Energy Rate (Ref. 2)

Res_Rate_EE = 1,658 Btu/h; Residual Energy Rate (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = 18,000 Btu/day; Preheat energy (Ref. 2)

E_pre_EE = 9,000 Btu/day (Ref. 2)

Days = See Table 2

ConversionFactor = 1,000,000 Btu/Dth

Example:

A fast-food restaurant installed a new 5-pan ENERGY STAR Gas Steamer

Eday_base (Btu/day) = (100 lbs/day) x (105 Btu/lb) / (15%) + (16,000 Btu/hr + 45,080 Btu/h) x (12 hrs/day – (100 lbs/day / 117 lb/hr) – (15 min / 60 min/hr)) + 18,000 Btu/day = 721,014 Btu/day

Eday_EE (Btu/day) = (100 lbs/day) x (105 Btu/lb) / (38%) + (12,500 Btu/hr + 1,658 Btu/h) x (12 hrs/day – (100 lbs/day / 100 lb/hr) – (15 min / 60 min/hr)) + 9,000 Btu/day = 163,608 Btu/day

Unit Dth Savings per Year = (721,014 Btu/day – 163608 Btu/day) / 1,000,000 Btu/Dth x 365 days/yr = 203.6 Dth

Deemed Input Tables

Table 1. Steamer Characteristics

Metric	5-Pan Steamer	6-Pan Steamer
LBFood (lbs/day)	83	100
Efood (Btu/lb)	105	105
Eff_base (%)	15%	15%
Eff_EE (%)	38%	38%
IdleRate_base (Btu/hr)	13,333	16,000
IdleRate_EE (Btu/hr)	10,400	12,500
OpHrs (hrs/day)	12	12
PC_base (lbs/hr)	117	140
PC_EE (lbs/hr)	100	120
Res_Rate_base (Btu/h)	45,080	45,080
Res_Rate_EE (Btu/h)	1,658	1,658
T_pre (minutes)	15	15
E_pre_base (Btu)	18,000	18,000
E_pre_EE (Btu)	9,000	9,000

Table 2. Operation Days by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Notes

There is no code requirement for this technology.

ENERGY STAR requires that Gas Steam Cookers have the following efficiencies (Ref. 4):

Table 3. Cooking Efficiency and Idle Rate by Pan Capacity

Pan Capacity	Cooking Energy Efficiency	Idle Rate (Btu/h)
3-Pan	38%	6,250
4-Pan	38%	8,350
5-Pan	38%	10,400
6-Pan	38%	12,500

References

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.
2. Commercial Steam Cookers, Food Service Equipment Workpaper PGECOFST104 R1, PG&E. June 1, 2009.
3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.
4. Commercial Steam Cookers Key Product Criteria, http://www.energystar.gov/index.cfm?c=steamcookers.pr_crit_steamcookers. Accessed August 27, 2012.

Revision History

Version	Description	Author	Date
1.0	Put together algorithm	Franklin Energy Services	8/27/2012

Commercial Food Service – Gas Conveyor Oven

Measure Detail	Measure Value
Measure ID	2.07.14
Target Market Segments	Commercial
Target End Uses	Food Service
Applicable To	Commercial kitchens
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Building type, width of conveyor (≤ 25”or > 25”)
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	12 (Ref. 1)
Unit Participant Incremental Cost	$1,751 for small; $4,731 for large (Ref. 2)

Measure Description

This measure includes the replacement of a standard efficiency gas conveyor oven with a high-efficiency model. High-efficiency conveyor ovens can achieve higher efficiencies through use of independently controlled temperature zones and air curtains at the ends of the oven.

Algorithms

Unit Dth Savings per Year = (Eday_base – Eday_EE) / Conversion Factor x Days

Where:

Eday_base (Btu/day) = nPizza x Efood / Eff_base + IdleRate_base x [OpHrs – nPizza / PC_base – T_pre / 60] + E_pre_base

Eday_EE (Btu/day) = nPizza x Efood / Eff_EE + IdleRate_EE x [OpHrs – nPizza / PC_EE – T_pre / 60] + E_pre_EE

nPizza = See Table 1; Pizzas cooked per day (Ref. 2)

Efood = 190 Btu/pizza; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 20%; Heavy load cooking energy efficiency (Ref. 2)

Eff_EE = 42% (Ref. 2)

IdleRate_base = See Table 1; Idle Energy Rate (Ref. 2)

IdleRate_EE = See Table 1 (Ref. 2)

OpHrs = 10 hrs/day; Daily operating hours (Ref. 4)

PC_base = See Table 1; Production Capacity (Ref. 2)

PC_EE = See Table 1 (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = See Table 1; Preheat energy (Ref. 2)

E_pre_EE = See Table 1 (Ref. 2)

Days = See Table 2

ConversionFactor = 1,000,000 Btu/Dth

Example:

A fast-food pizzeria installed a new 25-in. high-efficiency gas conveyor oven.

Eday_base (Btu/day) = (75 pizzas/day) x (190 Btu/pizza) / (20%) + [45,000 Btu/hr x (10 hrs/day – (75 pizzas/day / 55 pizzas/hr) – (15 min / 60 min/hr))] + 16,000 Btu/day = 464,636 Btu/day

Eday_EE (Btu/day) = (75 pizzas/day) x (190 Btu/pizza) / (42%) + [29,000 Btu/hr x (10 hrs/day – (75 pizzas/day / 75 pizzas/hr) – (15 min / 60 min/hr))] + 8,000 Btu/day = 295,679 Btu/day

Unit Dth Savings per Year = (464,636 Btu/day – 295,679 Btu/day) / 1,000,000 Btu/Dth x 365 days/yr = 61.7 Dth

Deemed Input Tables

Table 1. Conveyor Characteristics

Metric	Small Conveyor (≤ 25-in. width)	Large Conveyor Oven (> 25-in. width)
nPizza (pizzas/day)	75	150
Efood (Btu/pizza)	190	190
Eff_base (%)	20%	20%
Eff_EE (%)	42%	42%
IdleRate_base (Btu/hr)	45,000	70,000
IdleRate_EE (Btu/hr)	29,000	57,000
OpHrs (hrs/day)	10	10
PC_base (pizzas/hr)	55	150
PC_EE (pizzas/hr)	75	225
T_pre (minutes)	15	15
E_pre_base (Btu)	16,000	35,000
E_pre_EE (Btu)	8,000	18,000

Table 2. Operation Days by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Notes

There is no code requirement for this technology.

Small conveyor ovens are defined as having a conveyor width of 25-in. or less

Large conveyor ovens are defined as having a conveyor width of greater than 25-in.

References

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.
2. *Commercial Conveyor Ovens,* Food Service Equipment Workpaper PGECOFST117 R1, PG&E. June 1, 2009.
3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.
4. *Technology Assessment: Ovens,* Food Service Technology Center, 2002. Page 7-22. http://www.fishnick.com/equipment/techassessment/7_ovens.pdf

Revision History

Version	Description	Author	Date
1.0	Put together algorithm	Franklin Energy Services	8/27/2012
1.1	Replaced LBFood in algorithms with nPizza, changed measure name	Joe Plummer	2/8/2013

Commercial Food Service – Gas Oven, Broiler, Pasta Cooker

Measure Detail	Measure Value
Measure ID	2.07.15
Target Market Segments	Commercial
Target End Uses	Food Service
Applicable To	Commercial kitchens
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Input Btu/h of new equipment, new equipment type
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	12 (Ref. 1)
Unit Participant Incremental Cost	See Table 1

Measure Description

This measure includes replacement of failed or working gas food service equipment with new high-efficiency food service equipment.

Algorithms

Unit kWh Savings per Year = HVAC_Savings_Factor x BTUH_In / 1,000 kWh/Wh

Unit Dth Savings per Year = BTUH_In x BTU_Savings_Factor / 1,000,000

Where:

BTUH_In = Nameplate input Btu/h of equipment meeting installation standard (provided by the customer/contractor)

BTU_Savings_Factor = Deemed annual Btu savings per nameplate Btu/h input rating

HVAC_Savings_Factor = Deemed annual electricity savings from HVAC interactive effects (Watt-hours per installed Btu/h input)

Example:

A fast-food restaurant installed a new high-efficiency 48,000 Btu/h Pasta Cooker

Unit Dth Savings per Year = 48,000 Btu/h x (1,689 Btu/ (Btu/h x yr)) / 1,000,000 Btu/Dth = 81.0 Dth

Deemed Input Tables

Table 1. Pre- and Post-retrofit Equipment, Savings Factors, and Incremental Costs

Baseline Equipment	Efficient Equipment	BTU Savings Factor (Btu / ((Btu/h)-yr)) (Ref. 1)	HVAC Savings Factor (Watt-hours / ((Btu/h)-yr) (Ref. 1)	Incremental Cost ($/unit) (Ref. 3)
Open Flame Rotisserie Oven	Efficient Rotisserie Oven	554	15	$2,665
Range	Pasta Cooker	1,689	46	$2,413
Standard Charbroiler	Efficient Charbroiler	1,078	29	$2,173
Standard Radiant Broiler	Efficient Upright Broiler	1,041	30	$4,413
Standard Salamander Broiler	Efficient Salamander Broiler	885	28	$1,006

Notes

The following technologies have been removed from Table 1 because they now have their own measure:

- Convection Oven, Rack Oven, Conveyor Oven, Fryer, Griddle and Combination Oven

References

1. Savings per installed BTU derived from the Arkansas Food Service Deemed Savings table
2. Measure life for similar food service equipment, 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.
3. Incremental costs confirmed using "Commercial Cooking Appliance Technology Assessment, FSTC Report #5011.02.2, Food Service Technology Center, 2002" and product manufacturer Web sites

Revision History

Version	Description	Author	Date
1.0	Original from Nexant with extraneous tabs hidden	Nexant	
2.0	Cleaned up; removed extraneous fields, clarified that BTUH_In is specified by customer, added incremental costs, corrected HVAC effects formula to convert to kWh, added lifetime	Joe Plummer	
2.1	Corrected algorithm to add conversion factor from Btu to MMBtu	Joe Plummer	
2.2	Corrected algorithm to add conversion factor from Btu to kWh/yr (multiply by 1e-3 to divide by 1,000)	SK	
3.0	Removed measures per note above and reformatted	Franklin Energy Services	8/29/2012
3.1	Renamed measure	Joe Plummer	2/8/2013

Commercial Food Service – Gas Rack Oven

Measure Detail	Measure Value
Measure ID	2.07.16
Target Market Segments	Commercial
Target End Uses	Food Service
Applicable To	Commercial kitchens
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Building type, single or double rack
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	12 (Ref. 1)
Unit Participant Incremental Cost	$4,933 for single-rack; $5,187 for double-rack (Ref. 2)

Measure Description

This measure includes replacement of commercial gas rack ovens with new high-efficiency rack ovens. High-efficiency rack ovens achieve higher efficiencies by incorporating timesaving features via sophisticated control packages.

Algorithms

Unit Dth Savings per Year = (Eday_base - Eday_EE) / Conversion Factor x Days

Where:

Eday_base (Btu/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs - LBFood / PC_base - T_pre / 60] + E_pre_base

Eday_EE (Btu/day) = LBFood x Efood / Eff_EE + IdleRate_EE x [OpHrs - LBFood / PC_EE - T_pre / 60] + E_pre_EE

LBFood = See Table 1; Pounds of food cooked per day (Ref. 2)

Efood = 235 Btu/lb; ASTM Energy-to-Food value (Ref. 2)

Eff_base = 30%; Heavy load cooking energy efficiency (Ref. 2)

Eff_EE = 50% (Ref. 2)

IdleRate_base = See Table 1; Idle Energy Rate (Ref. 2)

IdleRate_EE = See Table 1 (Ref. 2)

OpHrs = 8 hrs/day; Daily operating hours (Ref. 4)

PC_base = See Table 1; Production Capacity (Ref. 2)

PC_EE = See Table 1 (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = See Table 1; Preheat energy (Ref. 2)

E_pre_EE = See Table 1 (Ref. 2)

Days = See Table 2

ConversionFactor = 1,000,000 Btu/Dth

Example:

A high school cafeteria installed a new high-efficiency double-rack oven.

Eday_base (Btu/day) = (1,200 lbs/day) x (235 Btu/lb) / (30%) + [65,000 Btu/hr x (8 hrs/day - (1,200 lbs/day / 250 lb/hr) - (15 min / 60 min/hr))] + 100,000 Btu/day = 1,231,750 Btu/day

Eday_EE (Btu/day) = (1,200 lbs/day) x (235 Btu/lb) / (50%) + [35,000 Btu/hr x (8 hrs/day - (1,200 lbs/day / 280 lb/hr) - (15 min / 60 min/hr))] + 85,000 Btu/day = 770,250 Btu/day

Unit Dth Savings per Year = (1,231,750 Btu/day - 770,250 Btu/day) / 1,000,000 Btu/Dth x 200 days/yr = 92.3 Dth

Deemed Input Tables

Table 1. Oven Characteristics

	Single-Rack Oven	Double-Rack Oven
LBFood (lbs/day)	600	1200
Efood (Btu/lb)	235	235
Eff_base (%)	30%	30%
Eff_EE (%)	50%	50%
IdleRate_base (Btu/hr)	43,000	65,000
IdleRate_EE (Btu/hr)	29,000	35,000
OpHrs (hrs/day)	8	8
PC_base (lbs/hr)	130	250
PC_EE (lbs/hr)	140	280
T_pre (minutes)	20	20
E_pre_base (Btu)	50,000	100,000
E_pre_EE (Btu)	44,000	85,000

Table 2. Operation Days by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365
Sit-Down Restaurant	365
Grocery	365
Elementary School	200
Jr. High/High School/College	200
Health	365
Hotel	365
Other Commercial	250

Notes

There is no code requirement for this technology.

References

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.
2. *Commercial Rack Ovens,* Food Service Equipment Workpaper PGECOFST109 R1, PG&E. June 1, 2009.
3. Data from Table 2 in Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995.
4. *Technology Assessment: Ovens,* Food Service Technology Center, 2002. Page 7-22. http://www.fishnick.com/equipment/techassessment/7_ovens.pdf

Revision History

Version	Description	Author	Date
1.0	New measure	Franklin Energy Services	8/27/2012
1.1	Changed measure name, added single or double rack as required input from customer/contractor	Joe Plummer	9/12/2013

Commercial Food Service – Kitchen Demand Control Ventilation

Measure Detail	Measure Value
Measure ID	2.07.17
Target Market Segments	Commercial
Target End Uses	HVAC
Applicable To	Commercial kitchens
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Confirmation of gas heat for make-up air, project location (county), fan hp, and hours of operation for the kitchen
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	$1,988 per fan for retrofit applications or $1,000 per fan for new construction applications (Ref. 1)

Measure Description

This measure includes installing controls for commercial kitchen hoods to vary the ventilation rate based upon cooling load, which varies throughout the day. By reducing the kitchen exhaust rate, fan energy savings are possible, and less make-up air is needed which results in heating savings.

Algorithms

Unit kWh Savings per Year = Usage_Save_Per_HP x HP x Actual_Hours / Tested_Hours

Unit Peak kW Savings = Demand_Save_Per_HP x HP

Unit Dth Savings per Year = CFM_Reduction x HP x Annual_Heating_Load x Actual_Hours / (Heat_Eff x Conversion_Factor)

Where:

Usage_Save_Per_HP = kWh savings per exhaust fan HP = 4,486 (Ref. 1)

Demand_Save_Per_HP = kW demand savings per exhaust fan HP = 0.76 (Ref. 1)

Actual_Hours = hours of operation. If unknown, use 4,745, which is 7 AM to 8 PM (per Appendix D) for 365 days per year.

Tested_Hours = annual hours of operation from PGE Workpaper, which was based on measured data. Average operation was 17.8 hours per day for 330 days per year, or 5,874 hours (Ref. 1)

CFM_Reduction = Average airflow reduction per exhaust fan HP with demand control ventilation = 611 CFM / HP (Ref. 2)

HP = horsepower of the exhaust fan for the ventilation system

Annual_Heating_Load = Annual Btu / CFM of outside air per hour needed as make-up for exhaust fan, value depends on location, see Table 1 below

Heat_Eff = heating efficiency of the make-up air unit, if unknown use typical value of 80%

Conversion_Factor = 1,000,000 Btu per Dth

Example:

Retrofit of a 3 HP kitchen exhaust fan with kitchen demand control ventilation in Climate Zone 2. The heating efficiency of the make-up air unit is unknown.

HP = 3.0

Annual_Heating_Load = 135,000 Btu per CFM

Heat_Eff = 80%

Unit kWh Savings per Year = 4,486 kWh per HP x 3.0 HP x 4,745 Hours / 5,874 Hours = 10,871 kWh

Unit Peak kW Savings = 0.76 kW per HP x 3.0 HP = 2.28 kW

Unit Dth Savings per Year = 611 CFM per HP x 3.0 HP x 135,000 Btu per CFM / (80% efficiency x 1,000,000 Btu per Dth) = 309.3 Dth

Deemed Input Tables

Table 1. Annual Heating Load by Location (Ref. 3)

Location	Annual Heating Load (Btu/CFM per hour of Operation)
Zone 1 (Northern MN)	32.23
Zone 2 (Central MN)	28.63
Zone 3 (Twin Cities/Southern MN)	25.66

Zone 1 is the average of data for International Falls and Duluth

Zone 2 is the average of data for Duluth and Minneapolis

Zone 3 is the average of data for Minneapolis and Rochester

Hours of operation included in the calculator were 7 AM to 8 PM, consistent with energy model inputs listed in Appendix D. Two additional hours of operation (5 AM to 10 PM and 10 AM to 8 PM) were also used, representing shorter and longer hours of operation than Appendix D, to confirm that normalizing Btu/CFM by hours of operation would be consistent for a variety of start and end times.

Methodology and Assumptions

Uses algorithms from IL TRM (Ref. 2) for gas savings.

Uses algorithms from PGE Workpaper (Ref. 1) for electric savings. Note that IL TRM appears to incorrectly list the 4,486 kWh/hp and 0.76 kW/hp electric savings from the PGE Workpaper as 4,486 kWh/fan and 0.76 kW.

Notes

This measure requires installation of a VFD to provide the variable speed capability of the exhaust fan. Savings associated with the VFD are included in the kitchen demand control ventilation measure. Projects should not be eligible for both kitchen demand control ventilation and VFD measures for the same equipment.

References

1. PGE Workpaper PGECOFST116, Commercial Kitchen Demand Ventilation Controls, December 21, 2007.
2. State of Illinois Energy Efficiency Technical Reference Manual, Version 5.0, Volume 2: Commercial and Industrial Measures, Page 74-76. February 11, 2016. www.ilsag.info/il_trm_version_5.html
3. Food Service Technology Center Outside Air Load Calculator, with inputs of 1 CFM and hours of operation from 7 AM to 8 PM. No inputs in calculator for days/week or days/year, so this is for 365 days/year. www.fishnick.com/ventilation/oalc/oac.php

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	8/26/16

Plug Load and Demand Management

Commercial Plug Load – Beverage Machine Controls

Measure Detail	Measure Value
Measure ID	2.08.01
Target Market Segments	Commercial
Target End Uses	Plug Loads
Applicable To	Commercial facilities with vending machines
Actions	Replace Working (addition to working equipment)
Required from Customer/Contractor	n/a
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm (Ref. 1)
Unit Peak kW Savings	See algorithm (Ref. 1)
Unit Dth Savings per Year	0
Measure Lifetime (years)	5 (Ref. 3)
Unit Participant Incremental Cost	$180 (Ref. 4)

Measure Description

Installation of automatic shutoff control on refrigerated vending machines. Controls must include a passive infrared sensor to shut off lighting and compressor. Controls must be capable of periodically powering up the machine to maintain product temperature and provide compressor protection.

Algorithms

Unit kWh Savings per Year = Wbase / 1000 x Hours x SavingsFactor

Unit Peak kW Savings = Unit kWh Savings per Year / Hours x CF

Where:

Wbase = 400 W; connected Wattage of the controlled equipment (Ref. 2)

Hours = 8,760 (average hours per year)

SavingsFactor = 46% (Ref. 2)

CF = 0.27 (Ref. 5)

Example:

A customer installed Vending Miser controls on their cold beverage vending machine.

Unit kWh Savings per Year = 400W / 1000 x (8,760 hours) x 46% = 1,613 kWh

Unit Peak kW Savings = 1,613 kWh / 8,760 hours x 0.27 = 0.050 kW

Notes

There are no energy code requirements for this technology

References

1. Energy and demand savings from Illinois Statewide Technical Resource Manual, pages 279-281.
2. USA Technologies Energy Management Product Sheets, July 2006; cited September 2009. http://www.usatech.com/energy_management/energy_productsheets.php
   *The SavingsFactor value is supported by the Focus on Energy's Deemed Savings Evaluation Report 2010, which references several studies in their defense of the figure.
3. 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008
4. 2005 Database for Energy Efficiency Resources (DEER) Update Study Final Report - Residential and Commercial Non-Weather Sensitive Measures
5. Northwest Power and Conservation Council, 2001. Accessed 1/4/13. www.nwcouncil.org/rtf/supportingdata/VendingMiser.XLS

Revision History

Version	Description	Author	Date
.1.0	Original from Nexant with extraneous tabs hidden	Nexant	
2.0	Reformatted	Joe Plummer	
3.0	Added algorithm per the IL TRM	Franklin Energy Services	7/23/2012
3.1	Adjusted savings; increased kWh and eliminated kW savings	Franklin Energy Services	7/23/2012
3.2	Added example	Franklin Energy Services	7/23/2012
3.3	Revised Product Description	Franklin Energy Services	7/23/2012
4.0	Updated the CF to 0.27 per Reference 5	Franklin Energy Services	1/4/2013
4.1	Changed Action from Retrofit to Replace Working; Changed Target End Use from Specialty to Plug loads; Changed annual hours from 8,760 to 8,760 for consistency with other measures	Joe Plummer	4/3/2013

Commercial Plug Load – Computer Power Management

Measure Detail	Measure Value
Measure ID	2.08.02
Target Market Segments	Commercial
Target End Uses	Electric
Applicable To	Commercial office and computer lab workstations; direct install/energy audit programs
Actions	Modify
Required from Customer/Contractor	Computer type (desktop or laptop), monitors per workstation
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	5 (Ref. 1)
Unit Participant Incremental Cost	$0 (does not include labor costs)

Measure Description

This measure characterizes average savings from adjustment of computer power management settings by a direct install technician. Computer power management settings, when properly enabled, automatically put the computer and monitor in a low power state when no activity is detected for a certain period of time.

Average per unit savings are provided in Table 5.

Algorithms

Annual Unit kWh savings = $((UEC_{CompBase} - UEC_{CompEff}) + (UEC_{MonBase} - UEC_{MonEff}))$ x HVAC_cooling_factor

Unit Peak kW Savings = (Unit kWh Savings per Year)/8,760 x HVAC_cooling_factor

Unit Dth Savings per Year= $((UEC_{CompBase} - UEC_{CompEff}) + (UEC_{MonBase} - UEC_{MonEff}))$ x HVAC_heating_factor

Where:

Unit = One Workstation

$UEC_{ComBase}$ = $(\sum_{State} Power_{State} \times Hours_{Base,State}) / 1{,}000$, energy consumption of computer before adjusting power settings

UEC_{ComEff} = $(\sum_{State} Power_{State} \times Hours_{Eff,State}) / 1{,}000$,energy consumption of computer after adjusting power settings

$UEC_{MonBase}$ = $(\sum_{State} MpW \times Power_{State} \times Hours_{Base,State}) / 1{,}000$, energy consumption of monitor before adjusting power settings

UEC_{MonEff} = $(\sum_{State} MpW \times Power_{State} \times Hours_{Eff,State}) / 1{,}000$, energy consumption of monitor after adjusting power settings

$Hours_{Base,State}$ = 8,760 x BaseDutyCycle(%), annual hours in each power state, see Table 1 for computers and Table 2 for monitors

$Hours_{Eff,State}$ = 8,760 x EfficientDutyCycle(%), annual hours in each power state, see Table 1 for duty cycle, see Table 1 for computers and Table 2 for monitors

MpW = Monitors per Workstation

$Power_{State}$ = Power (W) consumption in each power state, See Table 2

HVAC_cooling_factor = 1.095 (Ref. 4)

HVAC_heating_factor = -0.0023 Dth/kWh (Ref. 4)

Example:

A direct install technician adjusts power management settings in a desktop computer workstation with two monitors.

Computer savings:

Computer kWh savings = ($UEC_{CompBase}$ -$UEC_{CompEff}$)

kWh savings = ($UEC_{CompBase}$ -$UEC_{CompEff}$)

UECCompBase = 0 x 5% x 8,760 + 0.9 x 55% x 8,760 + 2.1 x 2% x 8,760 + 39.9 x 35% x 8,760 + 72.2 x 3% x 8,760 = 146.2 kWh

UECCompEff = 0 x 5% x 8,760 + 0.9 x 77% x 8,760 + 2.1 x 2% x 8,760 + 39.9 x 13% x 8,760 + 72.2 x 3% x 8,760 = 70.5 kWh

Computer kWh savings = (146.2-70.5) = 75.7 kWh

Computer peak kW savings = 75.7 / 8,760 = 0.009 kW

Monitor savings:

Monitor kWh savings = ($UEC_{MonBase}$ - UEC_{MonEff})

$UEC_{MonBase}$ = (2 x 0 x 22% x 8,760 + 2 x 0.23 x 50% x 8,760 +2 x 0.32 x 2% x 8,760 +2 x 14.43 x 26% x 8,760) / 1,000 = 67.9 kWh

UEC_{MonEff} = (2 x 0 x 22% x 8,760 + 2 x 0.23 x 57% x 8,760 + 2 x 0.32 x 2% x 8,760 + 2 x 14.43 x 19% x 8,760) / 1,000 = 50.5 kWh

Monitor kWh savings = (67.9-50.5) = 17.4 kWh

Monitor peak kW savings=17.4/8,760 = 0.002 kW

Total kWh Savings = (75.7+17.4) x 1.095 = 101.9 kWh

Total kW Savings = (0.009 + 0.002) x 1.095 = 0.012 kW

Deemed Input Tables

Table 1. Average baseline and efficient duty cycle for computers by power state (Ref. 2)

Computer Power State	Duty Cycle, as %	
	Base	Efficient
Unplugged	5%	5%
Off	55%	77%
Sleep	2%	2%
Idle	35%	13%
Active	3%	3%
Total	**100%**	**100%**

Table 2. Average baseline and efficient duty cycle for monitors by power state (Ref. 2)

Monitor Power State	Duty Cycle, as %	
	Base	Efficient
Unplugged	22%	22%
Off	50%	57%
Sleep	2%	2%
On	26%	19%
Total	**100%**	**100%**

Table 3. Average power draw by state for desktop and laptop computers (Ref. 3)

Power Draw, W		
Power State	Desktop Computer	Laptop Computer
Unplugged	0.0	0.0
Off	0.9	0.5
Sleep	2.1	0.9
Idle	39.9	8.9
Active	72.2	60.0

Table 4. Average power draw by state for monitors (Ref. 3)

Monitor Power State	Power Draw, W	
	Base	Measure
Unplugged	0.00	0.00
Off	0.23	0.23
Sleep	0.32	0.32
On	14.43	14.43

Table 5. Average Savings per Unit

Average Savings per unit		
Device	**kWh**	**kW**
Desktop Computer	75.7	0.009
Laptop* Computer	16.4	0.002
Monitor	8.7	0.001

* Laptop savings includes built in display

Methodology and Assumptions

Adapted from Northwest Regional Technical Forum Non-Res Network Computer Power Management measure.

Incremental cost does not include labor costs.

References

1. Measure life of a computer, 2016 IRS Publication 946, Page 30
2. RTF NonResNetCompPwrMgt_v4_1.xlsm which analyzed data from several sources
3. Updated RTF NonResNetCompPwrMgt_v4_1.xlsm with new values for Desktop, Laptop and Monitor power consumption per current ENERGY STAR information and market penetration
4. HVAC cooling and heating interactive factor data based on DOE2/eQuest building simulation. The prototypes building models are based on the California DEER study prototypes (see http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf), and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Revision History

Version	Description	Author	Date
1.0	Created document	Franklin Energy Services	12/5/17

Commercial Plug Load – Snack Machine Controls

Measure Detail	Measure Value
Measure ID	2.08.03
Target Market Segments	Commercial
Target End Uses	Plug Loads
Applicable To	Commercial facilities with vending machines
Actions	Plug-in addition to working equipment (or replace working machine)
Required from Customer/Contractor	n/a
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm (Ref. 1)
Unit Peak kW Savings	See algorithm (Ref. 1)
Unit Dth Savings per Year	0
Measure Lifetime (years)	5 (Ref. 3)
Unit Participant Incremental Cost	$80 (Ref. 4)

Measure Description

Installation of automatic shutoff control on non-refrigerated snack vending machines. Controls must include a passive infrared sensor to shut off lighting when the area surrounding the vending machine is unoccupied for fifteen (15) minutes. Controls must be capable of powering up the machine on IR activation to highlight the product offerings.

Algorithms

Unit kWh Savings per Year = W_{base} / 1000 x Hours x SavingsFactor

Unit Peak kW Savings = Unit kWh Savings per Year / Hours x CF

Where:

W_{base} = 85 W; connected Wattage of the controlled equipment (Ref. 2)

Hours = 8,760 (average hours per year)

Savings Factor = 46% (Ref. 2)

CF = 0.27 (Ref. 5)

Example:

A customer installed Vending Miser controls on their non-refrigerated vending machine.

Unit kWh Savings per Year = 85W / 1000 x (8,760 hours) x 46% = 343 kWh

Unit Peak kW Savings = 343 kWh / 8,760 hours x 0.27 = 0.01 kW

Notes

There are no energy code requirements for this technology

References

1. Energy and demand savings from Illinois Statewide Technical Resource Manual, pages 279-281. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_4/2-13-15_Final/Updated/Illinois_Statewide_TRM_Effective_060115_Final_02-24-15_Clean.pdf. Accessed 08/24/16.
2. State of Wisconsin Focus on Energy Evaluation Deemed Savings Manual V1.0, cited April 2007, pages 106-107. https://www.focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf. Accessed 08/24/16.
3. 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008. http://www.deeresources.com/files/deer0911planning/downloads/EUL_Summary_10-1-08.xls. Accessed 08/24/16.
4. Regional Technical Forum, Vending System Controls. http://rtf.nwcouncil.org/supportingdata/VendingMiser.XLS. Accessed 08/24/16.

Revision History

Version	Description	Author	Date
1.0	Original issue (based from Commercial Beverage)	Franklin Energy Services	7/19/2016

Commercial Plug Load – Tier 1 Advanced Power Strips

Measure Detail	Measure Value
Measure ID	2.08.04
Target Market Segments	Commercial
Target End Uses	Misc. Electric Loads
Applicable To	Commercial office and computer lab workstations
Actions	Modify, New Construction
Required from Customer/Contractor	n/a
Measure Energy Type	Electric
Unit kWh Savings per Year	134.1 kWh (see Methodology and Assumptions)
Unit Peak kW Savings	0 (Ref. 2)
Unit Dth Savings per Year	0
Measure Lifetime (years)	5 (Ref. 3)
Unit Participant Incremental Cost	$40 or use actual cost per unit (Ref. 1)

Measure Description

This measure relates to Advanced Power Strips – Tier 1 which are multi-plug power strips with the ability to automatically disconnect specific connected loads depending upon the power draw of a control load, also plugged into the strip. Power is disconnected from the switched (controlled) outlets when the control load power draw is reduced below a certain adjustable threshold, thus turning off the appliances plugged into the switched outlets. By disconnecting, the standby load of the controlled devices, the overall load of a centralized group of equipment (e.g. a desk workstation) can be reduced. In a commercial office space, savings generally occur during off-hours, when connected equipment continues to consume electricity while in standby mode or when off. Uncontrolled outlets are also provided that are not affected by the control device and so are always providing power to any device plugged into it.

Algorithms

Unit kWh Savings per Year = Unit kWh Savings x Install Rate

Where:

Unit kWh Savings = (145.6 kWh + 134 kWh) / 2 = 139.8 kWh (Ref. 4, 5)

Install Rate = The percentage of rebated equipment that is assumed to be installed

Example:

Advanced Tier 1 Power Strips are directly installed in ten workstations in a small commercial office site.

kWh Savings per Year = 139.8 kWh x 10 units x 100% = 1,398 kWh

Deemed Input Tables

Table 1. Install Rate based on Delivery Method (Ref 6)

Delivery Method	Install Rate
Retail	NA
Direct Install	100%
Virtual Assessment + Unverified Self-Install	71%
Requested Efficiency Kit	71%
Distributed Efficiency Kit	71%
Distributed School Efficiency Kit	NA

Methodology and Assumptions

The estimated electric energy savings for this measure represent typical savings per workstation calculated from an average of savings from two studies (Ref. 4, 5).

Unit kWh Savings = (145.6 kWh + 134 kWh) / 2 = 139.8 kWh (Ref. 4, 5)

The BPA Ross Complex study (Ref. 4) compiled energy savings data from a total of 45 tier 1 APS units installed in office cubicles in three separate facilities, finding an average of 145 kWh of annual savings per power strip. The ACEEE and University of Idaho study (Ref. 5) surveyed the energy savings from 88 tier 1 APS units controlling 77 separate devices in an office facility and found an average of 134 kWh of annual savings per power strip.

References

1. MEMD attachment FES-C18 Advanced Power Strips Michigan.xls
2. IL TRM V6.0 page 498 – No coincidence factor due to no savings attributable to standby losses between 1:00 p.m. and 5:00 p.m.
3. Ohio Technical Reference Manual: Technical Reference Manual (TRM) for Ohio Senate Bill 221" Energy Efficiency and Conservation Program" and 09-512-GE-UNC, October 15, 2009, Pages 149-150
4. Bonneville Power Administration. *Smart Power Strip Energy Savings Evaluation (Ross Complex)*. 2011. https://studylib.net/doc/8460015/smart-strip-energy-savings-evaluation-%E2%80%93-ross-complex--van
5. Acker, B., C. Duarte, K. Van Den Wymelenberg. *Office Space Plug Load Profiles and Energy Saving Interventions*. 2012. https://aceee.org/files/proceedings/2012/data/papers/0193-000277.pdf
6. Illinois Statewide Technical Reference Manual v12.0 Vol. 2 – Commercial and Industrial Measures, 4.8.7 Advanced Power Strip – Tier 1 Commercial. September 22, 2023.

Revision History

Version	Description	Author	Date
1.0	Document Created	Franklin Energy Services	9/7/17
2.0	Updated savings based on more recent data	Cadmus	10/30/2018
5.0	Included Install Rates	MN Department of Commerce	2025

Commercial Plug Load – Tier 2 Advanced Power Strips

Measure Detail	Measure Value
Measure ID	2.08.05
Target Market Segments	Commercial
Target End Uses	Misc. Electric Loads
Applicable To	Commercial office and computer lab workstations; compatibility with the host site's IT protocols should be considered
Actions	Modify, New Construction
Required from Customer/Contractor	n/a
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	125 (Ref. 4)
Unit Peak kW Savings	0.011 (Ref. 4)
Unit Dth Savings per Year	-0.0023 x (Unit kWh Savings per Year) = -0.29 (Ref. 3)
Measure Lifetime (years)	8 years (Ref. 2)
Unit Participant Incremental Cost	$65 or use actual cost per unit (Ref. 1)

Measure Description

Tier 2 Advanced Power Strips (APS) used in commercial workstation applications manage both active and standby power loads for controlled devices in a complete system. Tier 2 APS may operate either with or without a software installation on the workstation computer. Those without a software installation use localized motion detection as a proxy for user engagement; those with a software installation on the workstation computer track mouse movement and keyboard strokes as a proxy for user engagement. Both versions of commercial-use, Tier 2 Advanced Power Strips will put the workstation computer into a standby/sleep mode after a period absent of user engagement; this manages the active power usage of the workstation computer. Both versions also remove power to a number of switched outlets to turn off peripheral devices; this manages the standby power usage of attached peripheral devices. Commercial-use, Tier 2 Advanced Power Strips also have a number of "always-on" outlets intended for those workstation devices that always need power supplied such as a wireless router or internet hub/switch.

Algorithms

Unit kWh Savings per Year = Unit kWh Savings x Install Rate

Unit kW Peak Savings = Unit kW Peak Savings x Install Rate

Unit Dth Savings per Year = Heating Penalty x Unit kWh Savings per Year

Where:

Unit kWh Savings = 125 kWh (Ref. 4)

Unit kW Peak Savings = 0.011 kW (Ref. 4)

Heating Penalty = -0.0023 Dth/kWh (Ref. 3)

Install Rate = The percentage of rebated equipment that is assumed to be installed

Example:

Advanced Tier 2 Power Strips are directly installed throughout a small commercial office site.

Unit kWh Savings per Year = 125 kWh x 100% = 125 kWh

Unit kW Peak Savings = 0.011 kW x 100% = 0.011 kW

Unit Dth Savings per Year = -0.0023 x 125 = -0.29 Dth

Deemed Input Tables

Table 1. Install Rate based on Delivery Method (Ref. 5)

Delivery Method	Install Rate
Retail	NA
Direct Install	100%
Virtual Assessment + Unverified Self-Install	71%
Requested Efficiency Kit	71%
Distributed Efficiency Kit	71%
Distributed School Efficiency Kit	NA

Methodology and Assumptions

The estimated electric energy savings for this measure are based on the results of a 2016 Minnesota Conservation Applied Research and Development (CARD) study (Ref. 4). The study included detailed monitoring of eight workstations found to consume an average of 332 kWh per year. The savings for Tier 2 Advanced Power Strips are thought to be comparable to the savings from enabling Computer Power Management (CPM) in the study, which produced an average savings of 106 kWh per year (29% of total workstation energy). A savings range of 100-150 kWh for Tier 2 APS was suggested by the study author.

The peak demand savings for this measure are also based on metering results from the CARD study. Enabling CPM was found to produce an average demand savings of 9W between 1pm-5pm on weekdays

in summer months. This figure was scaled to 11W using the ratio of deemed APS savings to CPM savings (125 kWh/106 kWh).

The gas savings reflect the additional heating energy required due to the reduction in electrical energy consumption resulting from implementation of this measure. The heating penalty factor (-0.0023 Dth/kWh) is consistent with the factor used in the Commercial Lighting End Use measure (Ref. 3).

References

1. "Tier 2 Advanced Power Strips in Residential and Commercial Applications" San Diego Gas & Electric Emerging Technologies Program Technology Assessment Report, Alternative Energy Systems Consulting Inc., April 2015
2. 2008 DEER Effective Useful Life (EUL) for Plug Load Occupancy Sensors
3. HVAC cooling and heating interactive factor data based on DOE2/eQuest building simulation. The prototypes building models are based on the California DEER study prototypes (see http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf), and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3)
4. *Impacts of Office Plug Load Reduction Strategies.* Conservation Applied Research and Development (CARD) Final Report. Seventhwave et al, October 2016.
5. Illinois Statewide Technical Reference Manual v12.0 Vol. 2 – Commercial and Industrial Measures, 4.8.7 Advanced Power Strip – Tier 1 Commercial. September 22, 2023.

Revision History

Version	Description	Author	Date
1.0	Document Created	Franklin Energy Services	12/2/16
5.0	Included Install Rates	MN Department of Commerce	2025

Transportation

Commercial Transportation – Commercial/Public Electric Buses

Measure Detail	Measure Value
Measure ID	2.10.01
Target Market Segments	Municipal, commercial customers
Target End Uses	Miscellaneous, Efficient Fuel switching
Applicable To	Municipal, commercial customers
Actions	Replace working, replace on fail, new purchase with or without existing equipment
Required from Customer/Contractor	Quantity of equipment purchased, mileage if outside of the deemed range provided
Measure Energy Type	Electric, Gasoline/Diesel, EFS
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	not included, CF probably pretty high given mid day charging needed, ideally include, but limited data to support - for discussion
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	13.5
Unit Participant Incremental Cost	Actuals, see notes for ballpark, but this will likely be highly variable by situation

Measure Description

This measure includes replacement of failed, working order existing school buses or mass transit buses with like kind and size fully electric school buses and mass transit buses. The baseline case is considered to be a fully fossil fuel powered bus; school bus size A and C as well as a standard mass transit bus are outlined within the measure. Several fuel options are outlined within the measure, with diesel being the assumed primary fuel utilized. The performance case for the measure is designed to be a fully electric (not hybrid) like kind, size and function bus.

The Minnesota Energy Conservation and Optimization Act (Ref. 6,7) allows for efficient fuel switching (EFS) improvements where electricity or natural gas replaces another fuel used by the customer (i.e. natural gas, fuel oil, propane, etc) provided that the following criteria are met for each measure pursued:

1. The proposed efficient fuel switching measure results in a net reduction in the amount of source energy consumed for a particular use, measured on a fuel-neutral basis, using the utility's annual system average efficiency, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.
2. The proposed efficient fuel switching measure results in a net reduction of statewide greenhouse gas emissions (Ref 8), over the lifetime of the improvement. For an efficient fuel-switching improvement installed by an electric utility, the reduction in emissions must be measured using the utility's annual average emissions factor, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.

3. The proposed efficient fuel switching measure is cost-effective, considering the costs and benefits from the perspective of the utility, participants, and society.
4. The proposed efficient fuel switching measure should produce a similar or higher level of quality, service, or output as the technical assumptions identified in the baseline technology to be eligible (Ref. 9).

Algorithms

kWh Added per Year = kWh_{MILE} x Qty x $Miles_{ANNUAL}$

Fuel Savings per Year (MMBtu) = $Fuel_Energy_{DIESEL}$ x $Miles_{ANNUAL}$ / MPG_{DIESEL}

Net MMBtu Savings per Year (MMBtu) = Gasoline Saved per Year (MMBTU) - (Added kWh x $Conversion_{MMBtu}$)

Algorithm Inputs:

Variable	Definition	Units	Ref	Table Ref
kWh_{MILE}	kWH consumed per mile traveled. See table 1 for default values by vehicle type	kWh	1	1
Qty	Quantity of electric buses purchased	unit		
$Miles_{ANNUAL}$	Annual miles traveled, see Table 1 for default values by vehicle type. Substitute with actual mileage from customer as needed.	miles	1	1
$Fuel_Energy_{DIESEL}$	Conversion factor from gallons diesel to mmBtu. Energy, in mmBtu (or Dth) within every 1 gallon diesel. If different baseline fuel used, see Table 2 for conversion factors to be used for this input within the algorithm.	Gallons diesel / MMBtu	4	Apx F
MPG_{DIESEL}	Average miles per gallon (MPG) fuel economy. See table 1 for default values by vehicle type, diesel assumed.	miles per gallon	2,3,5	1
Conversion mmBtu	Conversion factor from kWh to MMBtu = 0.003412	kWh/MMBtu	4	Apx F

Example:

Quantity one Electric full sized (type C) school bus purchased. All other variables deemed, calculations outlined below:

kWh Added per Year = 2.2 x 1 x 14,200 miles = 31,240 kWh

Gasoline Savings per Year (MMBtu) = 0.1374 x 14,200 miles / 6.6 = 296 MMBtu

Net MMBtu Savings per Year (MMBtu) = 296 MMBtu - (31,240 kWh x 0.003412) = 189 MMBtu

Deemed Input Tables

Table 1: Deemed Variables and Savings by Vehicle Type (Ref 1,2,3,5)

Variable	Definition	School Bus - Type C (standard full sized)	School Bus - Type A (short)	Transit Bus
kWh_{MILE}	kWH consumed per mile traveled	2.2	1.4	2.15
$Miles_{ANNUAL}$	Annual miles traveled. See Notes for assumptions	14,200	14,200	19,128
MPG_{DIESEL}	Average miles per gallon (MPG) fuel economy running on diesel	6.6	10.5	3.4
Added kWh per Year (kWh)		31,240	19,880	41,125
Fuel Saved per Year (MMBTU)		296	186	773
Net MMBtu Savings per Year		189	118	633

Table 2: Baseline Fuel Energy Content (Ref 4)

Fuel Type	Conversion factor from gallons of fuel to MMBtu.
Diesel	0.1380
Biodiesel	0.1280
Gasoline	0.1250
Compressed Natural Gas (CNG)	0.1388
Liquid Petro Gas (LPG)	0.0920
Liquid Natural Gas (LNG)	0.1391

Table 3: Measure Emissions Savings (Baseline Diesel) (Ref 4)

Metric	Source	MtCO2e Annual Emissions Type C School Bus	MtCO2e Annual Emissions Type A School Bus	MtCO2e Annual Emissions Type Transit Bus
Emissions Emitted (Mt CO2e/yr)	Electric	13.1	8.3	17.3
Emissions Displaced (Mt CO2e/yr)	Diesel	22.4	14.1	58.5
Emissions Saved (Mt CO2e/yr)	Diesel	9.2	5.7	41.2

Table 4: Incremental Costs (Ref 1,3)

Type	Incremental First Costs
School Bus C (Standard)	$248,872
School Bus A (Short)	$212,909
Transit Bus	$916,210

Methodology and Assumptions

The majority of the deemed values proposed within this measure were derived from an electric school bus pilot program analyzed and reported on by the Minnesota Pollution Control Agency (Ref. 1), and by a final evaluation of electric transit buses conducted by NREL in Colorado. Resulting values were cross checked by all other references noted below.

The peak kW demand penalty will continue to be researched and evaluated for future addition into this measure. References below suggest a significant amount of peak day charging occurs to support the function of these bus types.

References

1. Electric School Bus Pilot Program Report. MN Pollution Control Agency. May 2024. https://www.pca.state.mn.us/air-water-land-climate/electric-and-cleaner-school-buses
2. Foothill Transit Battery Electric Bus Evaluation: Final Report. NREL. June 2021. https://www.nrel.gov/docs/fy21osti/80022.pdf
3. Recommended Total Cost of Ownership Parameters for Electric School Buses. World Resources Institute. April 2023. https://files.wri.org/d8/s3fs-public/2023-02/recommended-total-cost-ownership-esb-summary-methods-data.pdf?VersionId=dFh.syMjwVcYF9cBpomUkK5_hepMvyIB
4. MN TRM Appendix F. Fuel conversions from gallons gasoline to MMBtu
5. US Department of Energy. Average Fuel Economy by Major Vehicle Category. https://afdc.energy.gov/data/10310
6. Minn. Stat. § 216B.2402, subd. 4(2023). https://www.revisor.mn.gov/statutes/cite/216B.2402
7. Laws of Minn. 2024, art. 6, sec. 14. https://www.revisor.mn.gov/laws/2024/0/Session+Law/Chapter/126/
8. Minn. Stat. § 216H.01 subd. 2 (2016). https://www.revisor.mn.gov/statutes/cite/216H/full#stat.216H.01
9. Minnesota Department of Commerce Division of Energy Resources, Decision In the Matter of Technical Guidance for the Inclusion of Efficient Fuel-Switching, Load Management, and Pre-Weatherization Measures in CIP, (March 15, 2022). Docket No. E,G999/CIP-21-837. (eDocket No. 20223-183807-01). At 13. https://efiling.web.commerce.state.mn.us/edockets/searchDocuments.do?method=showPoup&documentId=%7B90098F7F-0000-C11B-B04F-C063DF81A5F9%7D&documentTitle=20223-183807-01

Revision History

Version	Description	Author	Date
4.2	New measure created	Cadmus	8/1/2024
5.0	Emissions values altered in Appendix F, outputs modified within this measure based on Appendix F	Cadmus	9/1/2025

Commercial Transportation – C/I Level 2 Electric Vehicle Charger

Measure Detail	Measure Value
Measure ID	2.10.02
Target Market Segments	Commercial, Industrial
Target End Uses	Miscellaneous
Applicable To	Commercial customers
Actions	Purchase and installation of applicable charger
Delivery Methods	Retail, Direct Install
Required from Customer/Contractor	Networked or non networked charger, Equipment application (commercial fleet, commercial employee, commercial public)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	10 (Ref. 4)
Unit Participant Incremental Cost	See Table 2 (Ref. 4)

Measure Description

This measure is for the savings associated with the installation of an ENERGY STAR rated Level 2, 240V AC electric vehicle charger for commercial applications. A networked charger refers to EV chargers connected to an online Energy Management tool(s). A non networked charger does not have an online management component.

Algorithms

Unit kWh Savings per Year $= (((Hours_{PLUG_STANDBY} + Hours_{UNPLUG_STANDBY}) \times SP_{BASE}) - ((Hours_{PLUG_STANDBY} \times SP_{EE_PLUG}) + (Hours_{UNPLUG_STANDBY} \times SP_{EE_UNPLUG})))/ 1000$

Unit Peak kW Savings $= kW_{AVERAGE} \times CF$

kW Avg $= (((SP_{BASE} - SP_{EE_PLUG}) \times Hours_{PLUG_STANDBY} / Hours_{TOTAL_STANDBY}) + ((SP_{BASE} - SP_{EE_UNPLUG}) \times Hours_{UNPLUG_STANDBY} / Hours_{TOTAL_STANDBY})) / 1000$

Algorithm Inputs:

Variable	Definition	Units	Ref	Table Ref
$Hours_{CHARGE}$	Annual hours plugged in and actively charging. See Table 1 for default values by application.	Hours	1,3	1
$Hours_{PLUG}$	Annual hours plugged in. See Table 1 for default values by application.	Hours	1,3	1
$Hours_{PLUG_STANDBY}$	Annual hours plugged in and in standby mode. Difference of annual hours plugged in and annual hours plugged in and actively charging. See Table 1 for default values by application.	Hours	1,3	1
$Hours_{UNPLUG_STANDBY}$	Annual hours unplugged. The difference between 8760 hours and annual plugged in hours. See Table 1 for default values by application.	Hours	1,3	1

$Hours_{TOTAL_STANDBY}$	Sum of hours plugged in and in standby mode and hours unplugged and in standby mode. See Table 1 for default values by application.	Hours	1,3	1
SP_{BASE}	Baseline average standby power. See Table 1.	Watt	3	1
SP_{EE_PLUG}	Efficient average standby power with vehicle plugged in. See Table 1.	Watt	3	1
SP_{EE_UNPLUG}	Efficient average standby power with no vehicle plugged in. See Table 1.	Watt	3	1
CF	Summer peak coincidence factor = 1.0		1	

Example:

Commercial installation of level 2 ENERGY STAR rated EV charger used for commercial fleet vehicles. The charger is non-networked. See the ENERGY STAR eligibility criteria v1.2 for this equipment (Ref 4).

Unit kWh Savings per Year = (((2,730 + 5,720) x 3.7) - (2,730 x 3.5 + 5,720 x 1.8))/1000 = 11 kWh

$kW_{AVERAGE}$ = (((3.7 – 3.5) x 2,730 / 8,450) + ((3.7 - 1.8) x 5,720 / 8,450))/1000 = 0.001 kW

Unit Peak kW Savings per Year = 0.001 x 1 = 0.001 kW

Deemed Input Tables

Table 1. Standby Hours and Energy Values by Application Type (Ref. 1,2,3)

Variable		Commercial (Fleet)	Commercial (Employee)	Commercial (Public)
$Hours_{CHARGE}$		310	660	380
$Hours_{PLUG}$		3,040	1,220	620
$Hours_{PLUG_STANDBY}$		2,730	560	240
$Hours_{UNPLUG_STANDBY}$		5,720	7,540	8,140
$Hours_{TOTAL_STANDBY}$		8,450	8,100	8,380
SP_{Base}	Networked	9.9	9.9	9.9
	Non-Networked	3.7	3.7	3.7
$SP_{EE\ PLUG}$	Networked	5.8	5.8	5.8
	Non-Networked	3.5	3.5	3.5
$SP_{EE\ UNPLUG}$	Networked	3.5	3.5	3.5
	Non-Networked	1.8	1.8	1.8

Table 2. Deemed Unit kWh Savings per Year, $kW_{Average}$, Unit Peak kW Savings, and Incremental Costs (Ref. 1,2,3)

Application	Unit kWh Savings per Year (kWh)		Unit Peak kW Savings (kW) *equal to $kW_{AVERAGE}$ since CF=1*		Incremental Cost ($)	
	Networked	Non-Networked	Networked	Non-networked	Networked	Non-networked
Fleet	48	11	0.006	0.001	$50.60	$89.51
Employee	51	14	0.006	0.002	$50.60	$89.51
Public	53	15	0.006	0.002	$50.60	$89.51

Methodology and Assumptions

Values for ENERGY STAR rated level 2 chargers power consumption is based on INL testing data.

Baseline steady-state power consumption values were based on power measurements before charging and after charging, with the average established at the baseline.

References

1. Illinois Statewide Technical Reference Manual v.12.0 Vol 3. September 2023. Measure 5.7.3 Level 2 Electric Vehicle Charger, pp. 487-489. https://www.icc.illinois.gov/programs/Illinois-Statewide-Technical-Reference-Manual-for-Energy-Efficiency
2. ENERGY STAR Market and Industry Scoping Report Electric Vehicle Supply Equipment (EVSE) September 2013. https://www.energystar.gov/sites/default/files/asset/document/Electric_Vehicle_Scoping_Report.pdf
3. Northwest Power and Conservation Council, Regional Technical Forum updated workbook for Level 2 Electric Vehicle Charger version 3.1. See Lvl2EVChrgrsv2_3.xls. https://rtf.nwcouncil.org/
4. ENERGY STAR Electric Vehicle Supply Equipment Criteria v1.2. Effective June 20, 2023. https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%201.2%20EVSE%20Final%20Specification_0.pdf

Revision History

Version	Description	Author	Date
4.2	New Measure	MN Department of Commerce	2024

Miscellaneous

Commercial Misc. – C/I Building Operator Certification

Measure Detail	Measure Value
Measure ID	2.11.01
Target Market Segments	Commercial, Industrial, Public
Target End Uses	HVAC, Lighting
Applicable To	Commercial, Industrial, and Public Buildings
Actions	Modify
Required from Customer/Contractor	Completion of Level I of Level II BOC training
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	5 years (See Ref. 2)
Unit Participant Incremental Cost	$1,200 per participant (Ref. 3)

Measure Description

This measure evaluates the impact of training and certifying building operators under the Building Operator Certification (BOC) program. BOC trains facility operators and managers to make informed decisions on energy efficient building management.

Eligible candidates for BOC training include building engineers, stationary engineers, maintenance supervisors, maintenance workers, facility coordinators, HVAC technicians, electricians, operations supervisors, operations techs, and others in the facility operation and maintenance field. However, work experience, education, and completion of BOC classes, exams, and on-the-job projects are also considered.

Energy is saved by influencing building operators and managers to pursue energy efficient projects and to make energy conscious decisions. Energy savings are captured on a per participant basis.

Algorithms

BOC Attributable Savings = Gross Savings x BOC Influence (varies by participant)
= See Below

Net BOC Attributable Savings = Savings Net of Utility Rebated
= BOC Attributable Savings x Rebate Factor
= See table below

Proposed Savings = [(Net BOC Attributable Savings – O&M Savings) x 0.35 + O&M Savings]
= See table below

Where:

Rebate Factor = 0 for incentivized projects, 1 for no incentive paid

Table 1. Building Operator Certification Program Savings

BOC Annual Savings Description	kWh	therm
Gross Savings (per participant)	188,599	4,641.2
BOC Attributable	130,746	3224.7
Net BOC Attributable	42,936	2,279.8
Gross per Square Foot*	1.040	0.0257
BOC Attributable per Square Foot*	0.721	0.0185
Net BOC Attributable per Square Foot*	0.237	0.0134
O&M per Square Foot*	0.058	0.00519
Proposed Net BOC Attributable per Square Foot*	0.121	0.00806

*Based on average facility size of 194,500 square feet

Example:

Certified building operator of a 240,000 square foot building serviced by gas and electric utilities.

Building kWh savings per year = 240,000 sq. ft. x 0.121 kWh/sq. ft.= 29,040 kWh/yr.

Building therm savings per year = 240,000 sq. ft. x 0.00806 therm/sq. ft = 1,934.4 therm/yr.

Methodology and Assumptions

Savings here are derived from analysis of 22 Consumers Energy BOC graduate organizations, where pre- and post-training data was collected. Additionally the analysis contains data from a similar study done in Minnesota programs by Navigant Consulting.

Assumes successful completion of Level I or Level II BOC training by eligible building operator or manager; savings are not dependent on which level is completed. The level of influence BOC training had on each participant's decision-making was captured in a survey released after training, which contributed to the BOC influence rate. Impacts by utility offered incentives were also considered in the influence rate by eliminating projects where rebates were offered from the pool of influence. The influence rate was applied to gross savings to determine the amount of energy savings specifically attributed to BOC training.

References

1. Building Operator Certification (Electric/Gas), 2012. Prepared by Consumers Energy Business Solutions, pages 1-9
2. The Impact and Process Evaluation Building Operator Training and Certification (BOC) Program Final Report, Section 1.4, page 4
3. The 2010 Building Operator Certification Pilot Summary Report, Section 2, page 3

Revision History

Version	Description	Author	Date
1.0	Document created	Franklin Energy Services	11/12/2015

Industrial Misc. – High Frequency Battery Chargers

Measure Detail	Measure Value
Measure ID	2.11.02
Target Market Segments	Industrial
Target End Uses	Industrial Process
Applicable To	Industrial customers with battery-powered motive equipment. See Methodology and Assumptions for charger requirements
Actions	Replace on Failure, Replace Working, New Construction
Required from Customer/Contractor	Operation shifts per day with forklift usage (1, 2, or 3)
Measure Energy Type	Electric
Unit kWh Savings per Year	ΔkWh
Unit Peak kW Savings	0 (see Methodology and Assumptions)
Unit Dth Savings per Year	0
Measure Lifetime (years)	20 years (Ref. 1)
Unit Participant Incremental Cost	$872.50 per charger (Ref. 1)

Measure Description

Industrial battery-powered motive equipment is widely utilized in warehouses, ports, airports, and manufacturing for decades. Large battery chargers are used with forklifts, transport equipment, electric vehicles, and golf carts. The most common technologies in use today are ferroresonant and silicon controlled rectifier (SCR). These technologies tend to be less efficient than high frequency chargers. There are three areas of inefficiency in battery charging:

1. Power Conversion Efficiency – the ratio of energy out of the charger versus the energy into the charger.
2. Charge Return – the ratio of energy out of the battery versus the energy into the battery.
3. Standby Losses – the energy used when no battery is connected to the charger.

Algorithms

Unit kWh Savings per Year = ΔkWh

Where:

N	=	number of chargers.
ΔkWh	=	deemed kWh savings per charger, varies by number of shifts with forklift use (Table1)

Example:

A manufacturer installs a high frequency battery charger in a facility with two shifts involving forklift usage.

Unit kWh Savings per Year = 2,688 kWh

Deemed Input Tables

Table 1. Deemed kWh savings (Ref. 1)

	8-hour shift	16-hour shift	24-hour shift
ΔkWh	1,460	2,688	3,638

Methodology and Assumptions

New 3-phase high frequency charger(s) shall have a minimum power conversion efficiency of 92%, and a minimum 8-hour shift operation for five days per week. The new charge return factor should be no greater than 1.10 at 100% or 80% depth of charge, and no greater than 1.15 at 40% depth of charge (Ref. 2). The new standby loss should be less than 10W (Ref. 2). The new battery charger must replace either a ferroresonant or silicon controlled rectifier (SCR) charger. This measure is only applicable to battery charging for forklifts, golf carts and other non-road electric vehicles.

It is assumed that charging occurs during off-peak hours with the existing and proposed chargers, resulting in zero peak kW savings. There may be peak kW impacts if opportunity charging is performed during peak hours.

References

1. Pacific Gas and Electric Company, Application Assessment Report #0808, ''Industrial Battery Charger Energy Savings Opportunities", May 29, 2009.
2. California Energy Commission, 2014 Appliance Efficiency Regulations, Page 167. http://www.energy.ca.gov/2014publications/CEC-400-2014-009/CEC-400-2014-009-CMF.pdf

Revision History

Version	Description	Author	Date
1.0	New measure	Franklin Energy Services	8/30/2017

Commercial Misc. – Modulating Gas Clothes Dryer

Measure Detail	Measure Value
Measure ID	2.11.03
Target Market Segments	Commercial
Target End Uses	Misc. gas loads
Applicable To	Commercial customers
Actions	Modify
Required from Customer/Contractor	Building type
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	14 (Ref. 1)
Unit Participant Incremental Cost	$525 (Ref. 2)

Measure Description

This measure involves the retrofit of a 30 to 200 pound commercial gas dryer with a two-stage modulating gas valve kit. This kit allows the dryer to reduce its firing rate during the latter stages of the drying cycle, when less heat is needed because there is not as much moisture remaining in the clothes.

Algorithms

Unit Dth Savings per Year = SF x N_{CYCLES}

Where:

SF = Savings factor, 0.006 Dth per cycle (Ref. 2, see below)

N_{CYCLES} = Number of cycles per year, refer to Table 1

Example:

A customer installed a modulating gas valve kit on a dryer in a laundromat.

Unit Dth Savings per Year = 0.006 x 1,483 = 8.9 Dth

Deemed Input Tables

Table 1. Yearly Cycle Count vs. Site Type

Site Type	Cycles Per Year
Coin-operated laundromats	1,483 (Ref. 3)
Multifamily dryers	1,074 (Ref. 3)
On-premise laundromats (dry cleaner, hospital, hotel, nursing home, etc.)	2,683 (Ref. 2)

Methodology and Assumptions

The CARD study (Ref. 2) is a small pilot study examining savings produced by the installation of two-stage modulating gas valve kits on 12 dryers at 6 sites: a laundromat, a dry cleaner, a university, two hotels, and a health care facility. It shows average savings of 161 therms for each modulating valve kit installed.

It also notes that savings appeared to be more dependent on the number of cycles than on dryer size. Therefore the algorithm here tries to accommodate that. The CARD study's Appendix B showcases the number of cycles for each dryer tested. Averaging the baseline and efficient number of cycles for each produces an average cycle count of 2,610. This indicates average per-cycle savings of 161 / 2,610 = 0.06 therms = 0.006 Dth.

This value can be used with DOE-estimated number of cycles for coin-operated and multifamily laundromats seen in Table 1 (Ref. 3). For on-premise cycle count, findings from the CARD study are used. Averaging the baseline and efficient number of cycles for non-laundromat sites produces an average cycle count of 2,683 for these sites.

References

1. Zhang, Y. and Wei, J. *Commercial Clothes Dryers. Codes and Standards Enhancement (CASE) Initiative for PY2013: Title 20 Standards Development.* July 2013. https://efiling.energy.ca.gov/GetDocument.aspx?tn=71757
   Life of retrofit kit is assumed to match that of a commercial dryer.
2. Gas Technology Institute. *Advanced Commercial Clothes Dryer Technologies Field Test.* January 15, 2018. http://mn.gov/commerce-stat/pdfs/card-dryer-retrofit.pdf
3. Illinois Energy Efficiency Stakeholder Advisory Group. Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 6.0. Volume 2: Commercial and Industrial Measures. February 8, 2017. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_2_C_and_I_020817_Final.pdf

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Cadmus	10/2018

Commercial Misc. – C/I Hydraulic Lubricants

Measure Detail	Measure Value
Measure ID	2.11.04
Target Market Segments	Commercial, Industrial
Target End Uses	Lubricants
Applicable To	Commercial and industrial customers
Actions	Replace on Failure, Replace Working
Required from Customer/Contractor	Motor horsepower, yearly hours of operation, cost of efficient lubricant, cost of baseline lubricant
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	0
Measure Lifetime (years)	10 (see Notes)
Unit Participant Incremental Cost	Actual cost should be used

Measure Description

Industrial hydraulic systems use hydraulic oil to transfer input energy to output power. Hydraulic oils also protect critical components from premature wear. Energy efficient hydraulic oil lubricants meet these requirements and reduce hydraulic system energy consumption. Energy efficient hydraulic oils have a lower coefficient of friction which reduces the friction between two moving parts (rotating pump equipment and hydraulic oil). This lower coefficient of friction reduces the energy required to produce output power. These oils also have a high viscosity index which reduces the effect temperature has on the viscosity of the hydraulic oil. The high viscosity index reduces viscosity changes over varied operating temperatures, which optimizes volumetric and mechanical efficiency at the pumps rated output. Additionally, energy efficient hydraulic oils reduce the operating temperature of the hydraulic system.

This is applicable for manufacturers using electric motors to power their hydraulic system both inside and outside conditioned areas, or for hydraulic systems on mobile equipment. The baseline equipment is hydraulic systems using non-energy efficient industrial hydraulic oils.

Savings are calculated based on a reduced coefficient of friction and the shear-stable high viscosity index value associated with energy-efficient hydraulic oils in hydraulic systems.

Algorithms

$kWh_{SAVED} = (HP \times 0.746 \times LF / \eta_{MOTOR}) \times HOU \times SF$

Where:

HP	=	Rated power consumption of electric motor, summed when pumps are in series
0.746	=	Conversion from horsepower to kW
LF	=	Motor load factor, 65% (Ref. 1)

η_{motor}	=	Motor efficiency. Actual, or see Appendix C and use the EPACT efficiency for the motor type and size. If unsure use a 93% estimate.
HOU	=	Annual hours of operation, user provided
SF	=	Savings factor, 3% (see Notes)

Example:

A 75 horsepower, 1200 RPM, ODP enclosure motor runs hydraulic equipment for 3,000 hours a year. The load factor is unknown.

kWh_{SAVED} = (75 HP x 0.746 x 65% / 93.6%) x 6000 x 3% = 6,127 kWh

Notes

The useful life of the lubricant is deemed to be 10 years when properly maintained. This is based on several factors:

- Customer experience with the product
- Results gained during hydraulic durability testing
- The Mobil DTE 20s Ultra series of products have a 6-year warranty (Ref. 2)
- Near-future Mobil DTE products will have a 10-year warranty

Incremental costs should equal the price difference between an energy-efficient hydraulic oil and a standard hydraulic oil which will vary across the state of Minnesota. Users should determine this for each project. Typically roughly one gallon per horsepower is required, and energy efficient oil will cost roughly $10 more per gallon.

The savings factor value of 3% was deemed based on several references. Various applications of energy-efficient hydraulic oils have produced measured energy savings from 3.3% to 7.1% (Ref. 3, Ref. 4, Ref. 5, Ref. 6, Ref. 7). A conservative savings factor of 3% is deemed.

To qualify as an energy efficient lubricant, the lubricant must:

- Have a viscosity Index ≥ 156 as determined by ASTM D2270, ensuring the oil maintains optimal efficiency across a wide temperature range
- Have a shear stability (kinematic viscosity loss) ≤ 11% as determined by CEC L-45-A-99, ensuring the efficiency benefits will not diminish much as the oil shears, and ensuring performance for the full measure life
- ISO 32 and ISO 46 oils must pass the JCMAS HK VG32W and VG46W specifications, ensuring oxidation stability across the full measure life
- Base oils not in the API Group IV or V as defined in API 1509 must pass the Bosch Rexroth 90245 specification, ensuring the oil protects from equipment wear.

References

1. U.S. Department of Energy. *Improving Motor and Drive System Performance; A Sourcebook for Industry*. 2008. Page 18. https://www.energy.gov/sites/prod/files/2014/04/f15/amo_motors_sourcebook_web.pdf
2. ExxonMobil. Mobil DTE 20 Ultra Series Limited Warranty. 2020.
3. Lev A. Bronshteyn and Jesa H. Kreiner. *Energy Efficiency of Industrial Oils*. March 25, 2008. Page 775 concludes: "Approximately five-to-eight percent energy are achievable by using energy-efficient industrial lubricants compared with current typical products." https://www.tandfonline.com/doi/abs/10.1080/10402009908982281
4. ExxonMobil. *Energy Saving Strategies for Plastics Injection Molding: Lubrication*. April 2020. https://ilsag.s3.amazonaws.com/Exxon-Mobil-EE-Idea-Attachments_April-2020.pdf
5. ExxonMobil. Mobil DTE 10 Excel™ 46 helps Volkswagen AG enhance energy efficiency on plastic injection molding machines. 2013. https://www.mobil.com/en/lubricants/for-businesses/industrial/lubricant-expertise/resources/plastic-injection-molding-machine-hydraulic-oil-efficiency
6. R.I. Taylor et al. *Lubricants & Energy Efficiency: Life-Cycle Analysis*. 2005. https://www.sciencedirect.com/science/article/abs/pii/S0167892205800586
7. ExxonMobil. Performance Summary. MPact Plastics, Pinetown KZN, South Africa. September 29, 2017.

Revision History

Version	Description	Author	Date
1.0	Initial version		9/2021

Commercial Misc. – C/I Gearbox Lubricants

Measure Detail	Measure Value
Measure ID	2.11.05
Target Market Segments	Commercial, Industrial
Target End Uses	Lubricants
Applicable To	Commercial and industrial customers
Actions	Replace on Failure, Replace Working
Required from Customer/Contractor	Motor horsepower, yearly hours of operation, cost of efficient lubricant, cost of baseline lubricant
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	0
Measure Lifetime (years)	10 (see Notes)
Unit Participant Incremental Cost	Actual cost should be used

Measure Description

Industrial gear reduction systems use gear oil to transfer input energy to output power. Gear oils also protect critical components from premature wear. Energy efficient gear oil lubricants meet these requirements and provide reduced energy consumption. Energy efficient gear oils have a lower coefficient of friction which reduces the friction between two moving parts (two gears meshing together covered in gear oil). This lower coefficient of friction reduces the energy required to yield output power. Second, these oils have a high viscosity index which reduces the effect temperature has on the viscosity of the gear oil. The high viscosity index reduces viscosity changes over varied operating temperatures, which optimizes volumetric and mechanical efficiency at the pumps rated output. Additionally, energy efficient gear oils reduce the operating temperature of the hydraulic system.

This is applicable for manufacturers using electric motors to power their gear reduction equipment both inside and outside conditioned areas, or for gear reduction systems on mobile equipment. The baseline equipment is gearboxes using non-energy efficient industrial gear lubricants

Algorithms

$kWh_{SAVED} = (HP \times 0.746 \times LF / \eta_{motor}) \times HOU \times SF \times n$

Where:

HP	=	Rated power consumption of electric motor, summed when pumps are in series
0.746	=	Conversion from horsepower to kW
LF	=	Motor load factor, 65% (Ref. 1)
η_{motor}	=	Motor efficiency. Actual, or see Appendix C and use the EPACT efficiency for the motor type and size. If unsure use a 93% estimate.
HOU	=	Annual hours of operation, user provided

SF	=	Savings factor, 1% per gear mesh (Ref. 2, Ref. 3)
n	=	Number of gear reductions served by the efficient gear lubricant

Example:

A 100 horsepower, 1200 RPM, ODP enclosure motor runs a 4-reduction gearbox for 2,000 hours a year. The load factor is unknown.

kWh_{SAVED} = (100 x 0.746 x 65% / 94.1%) x (2,000) x 1% x 4 = 4,122 kWh

Notes

The useful life of the lubricant is deemed to be 10 years when properly maintained. This is based on several factors:

- Customer experience with the product
- Results gained during hydraulic durability testing
- The Mobil DTE 20s Ultra series of products have a 6-year warranty (Ref. 2)
- Near-future Mobil DTE products will have a 10-year warranty

Incremental costs should equal the price difference between an energy-efficient gear oil and a standard gear oil which will vary across the state of Minnesota. Users should determine this for each project. Typically roughly one gallon per horsepower is required, and energy efficient oil will cost roughly $10 more per gallon.

The savings factor value of 1% was deemed based on several references. Various applications of energy-efficiency gear oils have produced measured energy savings from 3.3% to 7.1% (Ref. 3, Ref. 4). One study of gearboxes specifically showed savings of 0.9% (Ref. 5). A conservative savings factor of 1% is deemed.

To qualify as an energy efficient lubricant, the lubricant must:

- Have a viscosity Index ≥ 156 as determined by ASTM D2270, ensuring the oil maintains optimal efficiency across a wide temperature range
- Have a shear stability (kinematic viscosity loss) ≤ 11% as determined by CEC L-45-A-99, ensuring the efficiency benefits will not diminish much as the oil shears, and ensuring performance for the full measure life
- ISO 32 and ISO 46 oils must pass the JCMAS HK VG32W and VG46W specifications, ensuring oxidation stability across the full measure life
- Base oils not in the API Group IV or V as defined in API 1509 must pass the Bosch Rexroth 90245 specification, ensuring the oil protects from equipment wear.

References

1. U.S. Department of Energy. *Improving Motor and Drive System Performance; A Sourcebook for Industry*. 2008. Page 18. https://www.energy.gov/sites/prod/files/2014/04/f15/amo_motors_sourcebook_web.pdf
2. ExxonMobil. Mobil DTE 20 Ultra Series Limited Warranty. 2020.
3. Lev A. Bronshteyn and Jesa H. Kreiner. *Energy Efficiency of Industrial Oils*. March 25, 2008. Page 775 concludes: "Approximately five-to-eight percent energy are achievable by using energy-efficient industrial lubricants compared with current typical products." https://www.tandfonline.com/doi/abs/10.1080/10402009908982281
4. R.I. Taylor et al. *Lubricants & Energy Efficiency: Life-Cycle Analysis*. 2005. https://www.sciencedirect.com/science/article/abs/pii/S0167892205800586
5. ExxonMobil. Performance Summary. ArcerlorMittal – Minorca Mine. Virginia, MN. May 16, 2017.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper		9/2021

Commercial Misc. – Commercial Outdoor Lawn Equipment

Measure Detail	Measure Value
Measure ID	2.11.06
Target Market Segments	Commercial
Target End Uses	Miscellaneous, Efficient Fuel switching
Applicable To	Commercial customers
Actions	Replace Working, Replace on Fail, New purchase without existing equipment
Required from Customer/Contractor	Quantity of equipment purchased and type classification, hours of use of baseline equipment
Measure Energy Type	Electric, Gasoline, EFS
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	See Table 1
Unit Participant Incremental Cost	See deemed values by equipment type

Measure Description

The Minnesota Energy Conservation and Optimization Act (Ref. 1,6) allows for efficient fuel switching (EFS) improvements where electricity or natural gas replaces the use of another fuel used by the customer (i.e. natural gas, fuel oil, propane, etc) provided that the following criteria are met for each measure pursued:

1. The proposed efficient fuel switching measure results in a net reduction in the amount of source energy consumed for a particular use, measured on a fuel-neutral basis, using the utility's annual system average efficiency, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.
2. The proposed efficient fuel switching measure results in a net reduction of statewide greenhouse gas emissions (Ref 9), over the lifetime of the improvement. For an efficient fuel-switching improvement installed by an electric utility, the reduction in emissions must be measured using the utility's annual average emissions factor, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.
3. The proposed efficient fuel switching measure is cost-effective, considering the costs and benefits from the perspective of the utility, participants, and society;
4. The proposed efficient fuel switching measure should produce a similar or higher level of quality, level of service or output as the technical assumptions identified in the baseline technology to be eligible (Ref. 10).

Utilities can pursue efficient fuel switching energy savings as part of their ECO programs if an applicable incentive/program/rate is offered to customers and has measured participation. This measure includes the efficient fuel switching energy savings resulting from commercial electric outdoor equipment (Performance) replacing traditional gas-powered outdoor equipment (Baseline). This measure characterizes energy efficient fuel savings from electric push and riding lawn mowers, trimmers,

chainsaws and leaf blowers for commercial applications. Annual energy and emission assumptions for electric equipment are shown in the Tables below.

Algorithms

kWh Added per Year = Charging Consumption x HOU x Units

Charging Consumption = Energy Input x HOU

kW Savings (penalty) = Battery Draw x CF

Gasoline Savings per Year (MMBtu) = Gasoline Consumption x CF x HOU x Units

Net MMBtu Savings per year = Gasoline Savings per year - (Unit kWh Savings x 0.003412)

Where:

HOU = The estimated hours of use of the commercial equipment, measured in active engine run time hours. Actual estimate provided by customer based on historical use of baseline equipment that new electric equipment will replace, or see Table 1 default values by equipment type.

Units = Quantity of purchased electric equipment, by type.

Energy Input = kWh, actual from equipment specifications, or see Table 1 for default values.

Gasoline Consumption = Deemed annual gasoline consumption displaced, in gallons, by type, see Table 1 below.

0.125 = Conversion of gallons of gasoline to MMBtu of energy = 0.125 MMBtu per gallon of gasoline

0.003412 = Conversion from kWh to MMBtu

Battery Draw = Battery draw during charging (in negative kW to demonstrate kW penalty), see Table 3.

CF = Conversion of gallons of gasoline to MMBtu of energy = 0.120268 MMBtu per gallon of gasoline

Net Savings per year = Annual fuel consumption savings from the fuel switch, in MMBtu, by type, see Table 1 below, or calculated from above algorithm.

Example:

A commercial customer purchases five electric riding lawn mowers (5x) to replace a failed or end of life gasoline riding lawn mowers, instead of purchasing a like for like replacement of the gasoline riding lawn

mowers. The company has historically used the push mowers for an average of 246 hours per year (each piece of equipment).

Unit kWh Added = (9.7 kW x 246 HOU) x 5 Unit = 11,931 kWh/yr

Unit kW Savings = -1.12 x 0.913 CF = -1.023 kW

Unit Gasoline Savings per Year (MMBtu) = 246 gallons/yr x 0.125 x 5 Unit = 154 MMBtu

Net MMBtu Savings per year = (11,931 kWh/yr x 0.003412) + 153.75 MMBtu = 113 MMBtu

Deemed Input Tables

Table 1. Equipment Consumption and Savings by Type (Ref. 4, 5, 7, 8)

	Push Mower	Riding Mower	Leaf Blower	Trimmer	Chainsaw
Annual hours of Use	162	246	149	63	53
Electric Charging Consumption (kWh/yr)	259.2	2,386.2	253.3	50.4	74.2
Electric Energy Input (kW/hr)	1.6	9.7	1.7	0.8	1.4
Fuel Efficiency (Gal/hr)	0.16	1.00	0.15	0.10	0.15
Gasoline Consumption (Gal/yr)	25.92	246.00	22.35	6.30	7.95
Gasoline Consumption (MMBtu/yr)	3.24	30.75	2.79	0.79	0.99
Deemed Net Savings (MMBtu/yr)	2.36	22.61	1.93	0.62	0.74

Table 2. Peak Demand Penalty by Type (Ref. 8)

	Push Mower	Riding Mower	Leaf Blower	Trimmer	Chainsaw
Battery Draw (kW)	-0.42	-1.12	-0.20	0	0
Coincidence Factor	0.913	0.913	0.913	N/A	N/A
kW Penalty	-0.38	-1.02	-0.18	0	0

Table 3. Incremental Costs and EUL by Type (Ref. 2,3,4)

	Push Mower	Riding Mower	Leaf Blower	Trimmer	Chainsaw
Incremental Costs	$75.00	$380.00	$60.00	$60.00	$60.00
EUL	10	10	5	7	5

Table 4. Equipment Emissions by Type (Ref. 2, 3, 4)

	Push Mower	Riding Mower	Leaf Blower	Trimmer	Chainsaw
Emissions Emitted (Mt CO2e/yr) *Electric*	0.109	1.002	0.106	0.021	0.031
Emissions Displaced (Mt CO2e/yr) *Gasoline*	0.240	2.281	0.204	0.058	0.073
Emissions Saved (Mt CO2e/yr) *Gasoline*	0.132	1.279	0.098	0.036	0.041

Methodology and Assumptions

The emissions values presented in this measure represent emissions from stationary combustion of the specified fuel irrespective of the timing of the combustion or the efficiency of the method of combustion. Utilities able to analyze territory emissions on an hourly basis should utilize hourly emissions specific to their territory in place of TRM provided emissions data.

References

1. Minn. Stat. § 216B.2402, subd. 4(2023). https://www.revisor.mn.gov/statutes/cite/216B.2402
2. EPA. Emissions Factors for Greenhouse Gas Inventories. Website dataset last updated April 1, 2022. https://www.epa.gov/system/files/documents/2022-04/ghg_emission_factors_hub.pdf. Main website directory: https://www.epa.gov/climateleadership/ghg-emission-factors-hub
3. EPA. Data Explorer eGrid. Website dataset last updated April 26, 2022. https://www.epa.gov/egrid/data-explorer
4. University of Illinois. Quantification of the environmental and economic benefits of the electrification of lawn mowers on the US residential market. Accessed October 1, 2022. http://esol.ise.illinois.edu/static2/pdf/IJLCA2021.pdf
5. Statista. Retail Price of Gasoline by year in the US. Most recent 10 year average calculated. Accessed October 1, 2022. https://www.statista.com/statistics/204740/retail-price-of-gasoline-in-the-united-states-since-1990/
6. Laws of Minn. 2024, art. 6, sec. 14. https://www.revisor.mn.gov/laws/2024/0/Session+Law/Chapter/126/
7. CARB. Emissions Model for Small Off-Road Engines – SORE2020. September 2020. https://ww2.arb.ca.gov/sites/default/files/2020-09/SORE2020_Technical_Documentation_2020_09_09_Final_Cleaned_ADA.pdf
8. Illinois Statewide Technical Reference Manual v.12.0. September 2023. https://www.icc.illinois.gov/programs/Illinois-Statewide-Technical-Reference-Manual-for-Energy-Efficiency
9. Minn. Stat. § 216H.01 subd. 2 (2016). https://www.revisor.mn.gov/statutes/cite/216H/full#stat.216H.01

10. Minnesota Department of Commerce Division of Energy Resources, Decision In the Matter of Technical Guidance for the Inclusion of Efficient Fuel-Switching, Load Management, and Pre-Weatherization Measures in CIP, (March 15, 2022). Docket No. E,G999/CIP-21-837. (eDocket No. 20223-183807-01). At 13. https://efiling.web.commerce.state.mn.us/edockets/searchDocuments.do?method=showPoup&documentId=%7B90098F7F-0000-C11B-B04F-C063DF81A5F9%7D&documentTitle=20223-183807-01

Revision History

Version	Description	Author	Date
1.0	New measure and content	Cadmus	11/01/2022
4.2	Additional equipment added, some revision of outline of measure algorithm	Cadmus	9/1/2024
5.0	Emissions values altered in Appendix F, outputs modified within this measure based on Appendix F	Cadmus	9/1/2025

Commercial Misc. – C/I Electric Forklift

Measure Detail	Measure Value
Measure ID	2.11.07
Target Market Segments	Commercial, Industrial
Target End Uses	Miscellaneous process, Efficient Fuel switching
Applicable To	Commercial and industrial customers with forklifts powered by traditional lead acid battery systems, propane, or diesel with minimum 8-hour shift operation five days per week.
Actions	Time of Sale (TOS), Replace on Fail (RF)
Required from Customer/Contractor	Existing power source for forklifts and confirmation of minimum 8-hour shift operation five days per week.
Measure Energy Type	Electric, Gas, EFS
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	15 (Ref 1)
Unit Participant Incremental Cost	$34,400[2]

Measure Description

This measure includes replacement of forklifts powered by lead acid battery systems or fossil fuels (propane or diesel) with lithium-ion battery systems. This replacement allows the batteries to transfer power faster, reduce waste heat and reduce standby losses. The baseline is assumed to be forklifts powered by fossil fuels such as propane or diesel, or electric via lead acid batteries, in facilities with a minimum 8-hour shift operation, five days per week. The lithium-ion battery case is a one-for-one equivalent replacement of the lead acid battery in respect to capacity, shape, and weight. The fork truck may require a new charger to work with the new lithium-ion battery system.

The Minnesota Energy Conservation and Optimization Act (Ref. 7,8) allows for efficient fuel switching (EFS) improvements where electricity or natural gas replaces another fuel used by the customer (i.e. natural gas, fuel oil, propane, etc) provided that the following criteria are met:

1. The proposed efficient fuel switching measure results in a net reduction in the amount of source energy consumed for a particular use, measured on a fuel-neutral basis, using the utility's annual system average efficiency, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.
2. The proposed efficient fuel switching measure results in a net reduction of statewide greenhouse gas emissions (Ref 9), over the lifetime of the improvement. For an efficient fuel-switching improvement installed by an electric utility, the reduction in emissions must be measured using the utility's annual average emissions factor, or if the utility elects, a seasonal, monthly, or more granular level of analysis for the electric utility system over the measure's life.
3. The proposed efficient fuel switching measure is cost-effective, considering the costs and benefits from the perspective of the utility, participants, and society.

4. The proposed efficient fuel switching measure should produce a similar or higher level of quality, service, or output as the technical assumptions identified in the baseline technology to be eligible (Ref. 10).

Utilities can pursue efficient fuel switching energy savings as part of their ECO programs if an applicable incentive/program/rate is offered to customers and has measured participation. Annual participation within the applicable measure should be tracked to claim savings for any efficient fuel switching savings claimed.

This measure potentially includes the efficient fuel switching energy savings resulting from conversion of some or all of the non-electric heating energy of the baseline equipment to electric heating energy in the proposed equipment.

Algorithms

Electric Powered Baseline:

Unit kWh Savings per Year = Qty x (N x CAP x DoD x $(1/EE_{LAB} - 1/EE_{LIB})$)

Unit Peak kW Savings = 0

Fossil Fuel Powered Baseline:

Unit MMBtu Savings per Year (net) = Unit Dth Savings per Year +(Unit kWh Savings per Year / 293.07)

Unit kWh Savings per Year = -Qty x (N x CAP x DoD x $(1 / EE_{LIB})$)

Unit Dth Savings per Year = Qty x (N x CAP x DoD x $(1 / EE_{BASE})$) x (3,412 / 1,000,000)

Algorithm Inputs:

Variable	Definition	Units	Ref
Qty	Number of forklifts retrofitted, not necessarily the number of batteries if independent of machine or machine contains several battery units.		
N	Number of charges per year. Use actual, or if unknown, see Table 1 for default values by shift operation.		
CAP	Capacity of LI battery. Use actual or default of 35 kWh	kWh	3
DoD	Discharge depth for battery. Use actual or default of 80%	%	4
EE_{LAB}	Energy Efficiency of Lead Acid Battery. Use actual efficiency of battery for retrofit, for new or unknown, use 46%	%	5
EE_{LIB}	Energy Efficiency of Lithium Ion Battery. Use actual efficiency of LI battery, if unknown, use 73%.	%	5
$EE_{BASE,propane}$	Energy efficiency of baseline fork truck powered by propane. Use actual efficiency, if unknown, use 20.4%	%	6
$EE_{BASE,diesel}$	Energy efficiency of baseline fork truck powered by diesel. Use actual efficiency, if unknown, use 20.5%	%	6
1,000,000	Conversion Factor Btu/MMBtu	Btu/MMBtu	
3,142	Conversion Factor Btu/kWh	Btu/kWh	

293.07	Conversion from kWh to Dth	kWh/Dth	

Example:

A single forklift powered by diesel operating in a commercial warehouse is replaced by an electric fork truck with a lithium-ion battery. The hours of operation for the fork truck are 24 hrs/day - 5 days/week, based on a 3 shift schedule.

Unit kWh Savings per Year = -1 x (1560 x 35 x 0.8 x (1/0.73)) = -59,836 kWh *(penalty)*

Unit Dth Savings per Year = 1 x (1560 x 35 x 0.8 x (1 /0.205)) x (3,412/1,000,000)/10 = 731 Dth

Unit MMBtu Savings per Year (net) = 731 + (59,836 kWh / 293.07) = 526 MMBtu

Deemed Input Tables

Table 1: Number of Chares Per Year based on Operating Hours

Operating Hours	Number of Charges per year
1-shift (8 hrs/day – 5 days/week)	520
2-shift (16 hrs/day – 5 days/week)	1040
3-shift (24 hrs/day – 5 days/week)	1560
4-shift (24 hrs/day – 7 days/week)	2184

Table 2: Deemed Savings by per Battery Unit based on Deemed Inputs

Operating Hours	kWh Savings (penalty)	Dth Savings	Net MMBtu Savings
Electric Baseline			
1-shift (8 hrs/day – 5 days/week)	11,707	-	40
2-shift (16 hrs/day – 5 days/week)	23,414	-	80
3-shift (24 hrs/day – 5 days/week)	35,121	-	120
4-shift (24 hrs/day – 7 days/week)	49,169	-	168
Propane Baseline			
1-shift (8 hrs/day – 5 days/week)	(19,945)	244	175
2-shift (16 hrs/day – 5 days/week)	(39,890)	487	351
3-shift (24 hrs/day – 5 days/week)	(59,836)	731	526
4-shift (24 hrs/day – 7 days/week)	(83,770)	1,023	737
Diesel Baseline			
1-shift (8 hrs/day – 5 days/week)	(19,945)	242	174
2-shift (16 hrs/day – 5 days/week)	(39,890)	485	349
3-shift (24 hrs/day – 5 days/week)	(59,836)	727	523
4-shift (24 hrs/day – 7 days/week)	(83,770)	1,018	732

References

1. Lifetime of measure assumed to be limited by the lifetime of the lithium ion charger. See reference file Suzanne Foster Porter et al., "Analysis of Standards Options for Battery Charger Systems", (PG&E, 2010), 45
2. Estimates for new lithium ion, propane and diesel from Dennis, Allen and Vairamohan, Bashkar. "EPRI Forklift (Lift Truck) Comparison with Capital Costs." Electric Power Research Institute. Accessed April 19, 2022.
3. Renquist, Jacob V., Brian Dickman, and Thomas H. Bradley. June 19, 2012. "Economic comparison of fuel cell powered forklifts to battery powered forklifts." International Journal of Hydrogen Energy, Volume 37, Issue 17
4. Matley, Ryan. May 2009. "Measuring Energy Efficiency Improvements in Industrial Battery Chargers." Energy Systems Laboratory
5. Abdulhameed, Alshaebi, Husam Dauod, and Sang Won Yoon. May 2017. "Evaluation of Different Forklift Battery Systems Using Statistical Analysis and Discrete Event Simulation." Industrial and Systems Engineering Conference. Pittsburg, PA.
6. Dennis, Allen and Vairamohan, Bashkar. "EPRI Forklift (Lift Truck) Comparison with Capital Costs." Electric Power Research Institute. Accessed April 19, 2022. https://et.epri.com/ForkliftCalculator.html. Tank-to-wheel efficiency is based on dividing output electricity by input propane energy, assuming HHV of 91,333 BTU/gallon for propane and 138,500 BTU/gallon for diesel
7. Minn. Stat. § 216B.2402, subd. 4(2023). https://www.revisor.mn.gov/statutes/cite/216B.2402
8. Laws of Minn. 2024, art. 6, sec. 14. https://www.revisor.mn.gov/laws/2024/0/Session+Law/Chapter/126/
9. Minn. Stat. § 216H.01 subd. 2 (2016). https://www.revisor.mn.gov/statutes/cite/216H/full#stat.216H.01
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Revision History

Version	Description	Author	Date
5.0	New measure development	Cadmus	9/1/2025

Agriculture

Miscellaneous

Agriculture Misc. – Dairy Farm Long Daylighting

Measure Detail	Measure Value
Measure ID	3.11.01
Target Market Segments	Commercial
Target End Uses	Lighting
Applicable To	Agricultural customers
Actions	Replace on Failure, Replace Working, New Construction
Required from Customer/Contractor	Baseline lamp or fixture wattage and quantity, efficient lamp or fixture wattage and quantity
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	Refer to Appendix B for costs or use actual fixture costs.

Measure Description

This measure includes making energy efficient upgrades to fixtures or lamps used for long day lighting in dairy applications. Typically baseline fixtures will be metal halide or pulse start metal halide, with upgrades to linear fluorescent or LED. This measure uses the same baseline and energy efficient fixture wattages as described in Appendix B, but operates the fixtures for longer hours.

Long day lighting involves operating lighting for longer hours to simulate longer days, which increases milk production from the cows.

Algorithms

$kWh_{SAVED} = (kW_{BASE} \times Qty_{BASE} - kW_{EE} \times Qty_{EE}) \times HOURS$

$kW_{SAVED} = (kW_{BASE} \times Qty_{BASE} - kW_{EE} \times Qty_{EE}) \times CF$

Where:

kW_{BASE} = Wattage of baseline lamp/fixture in kW. Refer to Appendix B or use actual wattage.

kW_{EE} = Wattage of efficient lamp/fixture in kW. Refer to Appendix B or use actual wattage.

Qty_{BASE} = if unknown, assume equal to Qty_EE. Number of baseline lamps being replaced.

Qty_{EE} = Number of lamps or fixtures being installed

HOURS = 6,205 (Ref. 2, Ref. 3)

CF = 1.0 Coincidence factor

Example:

A dairy farm is looking to install ten 190W LED fixtures to replace ten 400W Metal Halide fixtures in a long day lighting application.

kW_{BASE}	0.455 kW
kW_{EE}	0.190 kW
Qty_{BASE}	10
Qty_{EE}	10

kWh_{SAVED} = (0.455 x 10 – 0.190 x 10) x 6,205 = 27,054 kWh

kW_{SAVED} = (0.455 x 10 – 0.190 x 10) x 1.0 = 4.36 kW

Methodology and Assumptions

Long day lighting studies (Ref. 3, Ref. 4) have determined that for long day lighting to work, the lights must deliver a minimum of 15 foot-candles at the eye level of the cows for 16 to 18 hours per day. Using a midpoint of 17 hours, 17 x 365 = 6,205 hours per year.

References

1. 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
2. Dahl, Geoffrey E. Photoperiod Management of Dairy Cattle for Performance and Health. Available Online: www.wcds.ca/proc/2003/Manuscripts/Chapter%2027%20Dahl.pdf
3. University of Wisconsin-Madison. Long Day Lighting in Dairy Barns. Healthy Farmers, Healthy Profits Project. Second Edition (August 2000). Available Online: http://bse.wisc.edu/HFHP/tipdairy.htm

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	9/29/16

Agriculture Misc. – Engine Block Heater Timer

Measure Detail	Measure Value
Measure ID	3.11.02
Target Market Segments	Commercial
Target End Uses	Misc. Electric Loads
Applicable To	Agricultural customers
Actions	Modify
Required from Customer/Contractor	Heater size
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	0
Measure Lifetime (years)	5 (Ref. 1)
Unit Participant Incremental Cost	$20 (Ref. 2)

Measure Description

This measure involves the installation of a plug-in timer that controls the operation of an engine block heater timer to modulate its operation.

Algorithms

$kWh_{SAVED} = P_{HEATER} \times (t_{HEATER} - t_{CONTROL}) \times Days \times UF / C$

Where:

P_{HEATER}	=	1,000 W, if unknown. Avg. power of engine block heater. (Ref. 2)
t_{HEATER}	=	10 hours/day. Time that heater will operate if uncontrolled. (Ref. 1 and Ref. 2)
$t_{CONTROL}$	=	2 hours/day. Time that heater will operate if controlled. (Ref. 3)
Days	=	90 days. Days the heater timer will be operating. (Ref. 4)
UF	=	0.8. Usage Factor. (Ref. 5)
C	=	1,000 W/kW. Conversion factor.

Example:

A customer installed a new timer control on a 1,200 W engine heater.

kWh_{SAVED} = 1,200 W x (10 hrs/day – 2 hrs/day) x 90 days x 0.8 / 1,000 W/kW = 691 kWh

Methodology and Assumptions

The incremental cost is the full cost of the timer since the base case is a block heater with no timer. Purchase costs typically start at $20. Timers for heaters over 1,800 Watts or heaters that operate on 240 volts will cost $40 to $60 plus installation. (Ref. 2)

References

1. Franklin Energy Services estimate.
2. Focus on Energy fact sheet: Engine Block Heaters Make Diesel Start-up a Snap http://www.focusonenergy.com/files/document_management_system/business_programs/engineblockheaters_factsheet.pdf (Accessed September 19, 2012). This document is no longer available online.
3. Vehicle Warm-Up, Natural Resources Canada (NRCAN). http://www.nrcan.gc.ca/energy/efficiency/communities-infrastructure/transportation/idling/4423. Accessed 5/21/15.
4. Franklin Energy Services estimate. This is based on operating for the three coldest months: December, January, and February.
5. Franklin Energy Services estimate. This reflects the reality that not all installed timers will be used or scheduled appropriately.
6. Heater is not going to be operating during the peak season (summer) when cold temperatures are not a concern.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	11/12/2015

Agriculture Misc. – High-Efficiency Fans

Measure Detail	Measure Value
Measure ID	3.11.03
Target Market Segments	Commercial
Target End Uses	HVAC
Applicable To	Agricultural customers
Actions	Replace on Failure, Replace Working, New Construction
Required from Customer/Contractor	Fan diameter, model number, VER
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	7 (Ref. 1)
Unit Participant Incremental Cost	$150 (Ref.1)

Measure Description

This measure involves the installation of high-efficiency, high-speed ventilation/exhaust fans that provide ventilation to destratify air, reduce animal heat stress, control insects or dry surfaces.

Algorithms

$kWh_{SAVED} = (CFM_{BASE} / VER_{BASE} - CFM_{EE} / VER_{EE}) / C \times HOURS$

$kW_{SAVED} = (CFM_{BASE} / VER_{BASE} - CFM_{EE} / VER_{EE}) / C \times CF$

Where:

CFM_{BASE}	=	Airflow (CFM) of baseline unit @ 0.10" static pressure, see Table 1
VER_{BASE}	=	Ventilating Efficiency Ratio (CFM/Watt) of baseline unit @ 0.10" static pressure (See Table 1)
CFM_{EE}	=	Airflow (CFM) of efficient unit @ 0.10" static pressure, see Table 1
VER_{EE}	=	Ventilating Efficiency Ratio (CFM/Watt) of efficient unit @ 0.10" static pressure, see Table 1 if unknown)
HOURS	=	Actuals if known. Default of 2,935 hours per year (Ref. 1)
C	=	1,000 W/kW. Conversion factor.
CF	=	1.0 (Ref. 1)

Example:

A cattle barn installed a new 36” circulation fan with a VER of 17.9 CFM/Watt.

kWh_{SAVED} = (9,780 CFM / 15.5 CFM/W – 9,780 CFM / 17.9 CFM/W) / 1,000 W/kW x 2,935 hours = 248 kWh

kW_{SAVED} = (9,780 CFM / 15.5 CFM/W – 9,780 CFM / 17.9 CFM/W) / 1,000 W/kW x 1.0 = 0.0906 kWh

Methodology and Assumptions

Table 1. Average Fan Performance Characteristics (Ref. 2)

Fan Diameter (in)	CFM_base	VER_base (cfm/W)	CFM_EE	VER_EE (cfm/W)
24" through 35"	5,647	11.9	5,647	15.0
36" through 47"	9,780	15.5	9,780	17.9
48" though 71"	21,130	17.7	21,130	22.8

References

1. Act on Energy Commercial Technical Reference Manual No. 2010-4, Pages 318-320.
2. BESS Labs Agricultural Ventilation Fan Testing Data, http://bess.illinois.edu/oldSearchResults.asp#. Accessed 5/21/15.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	11/12/2015
1.1	Added Table 1, Average Fan Characteristics	Franklin Energy Services	12/11/2015

Agriculture Misc. – High-Efficiency Grain Dryers

Measure Detail	Measure Value
Measure ID	3.11.04
Target Market Segments	Commercial, Industrial
Target End Uses	Industrial Process
Applicable To	Natural gas-fired grain dryers; input values provided are for corn
Actions	Replace Working, Replace on Fail
Required from Customer/Contractor	Installed cost of proposed dryer; documentation demonstrating existing and proposed dryer efficiencies, average bushels per year processed
Measure Energy Type	Gas
Unit kWh Savings per Year	0
Unit Peak kW Savings	0
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	20 (Ref. 3)
Unit Participant Incremental Cost	Installed cost of new dryer, provided by customer/contractor. $45,000 can be used as a planning estimate (Ref. 4.). Actual costs vary based on dryer capacity and other factors

Measure Description

This measure characterizes the efficiency gains from replacing existing grain dryers with high-efficiency grain dryers. High-efficiency grain dryers include features such as automated control, improved airflow, grain turners, and exhaust heat recapture and recycle, all of which serve to reduce the thermal energy required to evaporate a unit of water. Installing a high-efficiency dryer often involves a desire to increase processing speed as measured in bushels per hour; a customer may be switching from an in-bin dryer to a higher capacity continuous flow or batch dryer (Ref. 5).

Algorithms

Unit Dth Savings per Year = Bushels/yr x (M_{pre} - M_{post}) x (e_b - e_{ee})- / 1,000,000

Where:

M_{pre} = pre-dryer water mass per bushel of grain; at a typical moisture content of 22% for corn at harvest (Ref. 1), M_{pre} equals 60.66 lb/bushel (Ref. 2).

M_{post} = post-dryer water mass per bushel of grain; at a typical moisture content of 15% for corn post-drying (Ref. 1), Mpost equals 55.67 lb/bushel

e_b = Existing (baseline) dryer efficiency; typical value is 2,241 Btu/lb H_2O (Ref. 1)

e_{ee} = Proposed dryer efficiency; typical value is 1,625 Btu/lb H_2O (Ref. 1)

Example:

A grain storage facility replaces its existing grain dryer with a more efficient natural gas-fired unit. The dryer is expected to process 100,000 bushels of corn per month from October through December annually.

Unit Dth Savings per Year = (100,000 x 3) x (60.66-55.67) x (2,241 -- 1,625) / 1,000,000 = 922

Methodology and Assumptions

Before and after dryer efficiencies were obtained from recent grain dryer projects in the Wisconsin Focus on Energy program (13 projects in total). Wisconsin grain drying efficiencies were adjusted based on average monthly air enthalpy values for the period of October through December, the primary drying season. The effective adjustment was 96.6%. Moisture content removal is assumed to be from 22% moisture content to 15% moisture content, which is slightly conservative compared to the project data (23.5% to 15.2%).

Use of the typical input values provided will generate the energy savings per bushel of corn expected on average for installing an energy efficient grain dryer. Actual dryer efficiency is dependent on grain moisture content, ambient air temperature and humidity, and processing speed. A custom approach should be used where greater accuracy is desired.

References

1. Wisconsin Focus on Energy project data; 13 recent grain dryer projects in Wisconsin were used as the source of average pre- and post- drying moisture content (22% and 15%, respectively) and baseline and proposed dryer efficiency.
2. "Tables for Weights and Measurement: Crops". University of Missouri Extension, http://extension.missouri.edu/publications/DisplayPub.aspx?P=G4020. Accessed September 28, 2016.
3. Wisconsin Technical Reference Manual, October 2015. Midpoint of three sources:
    a. 10-12 years: "Computing a Grain Storage Rental Rate." Iowa State University Ag Extension, October 10, 2013. http://www.extension.iastate.edu/agdm/wholefarm/pdf/c2-24.pdf, accessed 9/28/16.
    b. 10-12 years: "Grain Drying Systems." Paper presented at the Facility Design Conference of the Grain Elevator & Processing Society, St. Charles, Illinois, July 28-31, 2002. http://www.uwex.edu/energy/pubs/GrainDryingSystems_GEAPS2002.pdf, accessed 9/28/16.
    c. 30 years: *Fundamentals of Engineering Thermodynamics.* Shapiro and Moran, 1995. Washington DC: McGraw Hill.

4. Based on a review of grain dryer projects in Iowa, which showed a cost between $80-100 per btu/hr for 5% moisture removal per hour. Typical dryer capacity is 500 Bu/hr; therefore estimated average cost is $90 x 500 = $45,000.
5. "Sizing Up Grain Dryers". Farm Industry News, May 1998. http://farmindustrynews.com/sizing-grain-dryers, accessed 9/28/16.

Revision History

Version	Description	Author	Date
1.0	New measure	Franklin Energy Services	9/28/2016

Agriculture Misc. – Livestock Waterer

Measure Detail	Measure Value
Measure ID	3.11.05
Target Market Segments	Commercial
Target End Uses	Livestock
Applicable To	Agricultural customers
Actions	Replace on Failure, New Construction
Required from Customer/Contractor	Retrofit or new, County
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	0
Measure Lifetime (years)	10 (Ref. 1)
Unit Participant Incremental Cost	$787.50 (Ref. 2)

Measure Description

This measure involves the installation of insulated or energy free livestock waterers to replace electric livestock waterers.

Algorithms

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) \times HOURS / C$

Where:

$Watts_{BASE}$ = 1,100 W for retrofit, 500 W for new installation. Power of baseline waterer (Ref. 1)

$Watts_{EE}$ = 250 W, if unknown. Power of efficient waterer (Ref. 1)

HOURS = Hours of heater operation, See Table 1. (Ref. 3)

C = 1,000 W/kW. Conversion factor.

Example:

A customer in Zone 2 installed a new energy efficient livestock waterer to replace a standard unit.

kWh_{SAVED} = (1,100 W - 250 W) x 2,934 hours / 1,000 W/kW = 2,494 kWh

Methodology and Assumptions

Table 1. Annual Hours Below Freezing

Zone	Hours < 32°F
Zone 1	3,325
Zone 2	2,934
Zone 3	2,692

Table 2. Average Annual Deemed Savings

Type	kWh
Energy Efficient Livestock Waterer	2,826
Energy Free Retrofit Livestock Waterer	2,494
Energy Free New Construction Livestock Waterer	2,288

Table 3. Temperature Data

Zone	City	Hours Below < 32°F	Zone Average
Zone 1	Int'l Falls	3,371	3,325
	Duluth	3,278	
Zone 2	Duluth	3,278	2,934
	Minneapolis	2,590	
Zone 3	Minneapolis	2,590	2,692
	Rochester	2,794	

References

1. Focus on Energy Technical Reference Manual, Page 2. https://focusonenergy.com/sites/default/files/Wisconsin%20Focus%20on%20Energy%20Technical%20Reference%20Manual%20August%202014.pdf
2. Act On Energy Technical Reference Manual (TRM), Pages 342-344.
3. A survey of TMY3 data for various locations in MN. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#M
4. Heater is not going to be operating during the peak season (summer) when cold temperatures are not a concern.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	11/12/2015

Agriculture Misc. – Milk Pre-Cooler

Measure Detail	Measure Value
Measure ID	3.11.06
Target Market Segments	Agriculture
Target End Uses	Dairy
Applicable To	Commercial customers
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	Number of cows
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	$2,500 (Ref. 2)

Measure Description

Dairy farms store milk at 38ºF in refrigerated storage tanks. A milk pre-cooler can be used to utilize well water to pre-cool the milk before it enters the storage tank. This results in energy savings by reducing

Algorithms

$kWh_{SAVED} = N_{COWS} \times Mdot_{MILK} \times Cp_{MILK} \times Delta_T \times Days / EER / C$

$kW_{SAVED} = CF \times (kWh_{SAVED}) / HOURS$

Where:

N_{COWS}	=	Number of cows milked, assume 303 (Ref. 9), unless known
$Mdot_{MILK}$	=	56 lbs. of milk/cow/day. Milk production, per cow, per day (Ref. 6)
Cp_{MILK}	=	0.93 Btu/lb. - °F. Heat capacity of whole milk (Ref. 4)
$Delta_T$	=	98ºF – 57ºF = 41ºF. Temperature drop of milk across pre-cooler (Ref. 5)
Days	=	365 days. Days, per year, the cows will be milked (Ref. 6)
EER	=	8.4 EER, if unknown. Efficiency of refrigeration system (Ref. 3)
C	=	1,000 W/kW. Conversion Factor
CF	=	1.0
HOURS	=	2,920 hours (Ref. 7)

Example:

A customer with a 130-cow farm, installed a new milk pre-cooler.

kWh_{SAVED} = 130 cows x 56 lbs. milk/cow/day x 0.93 Btu/lb.-F x 41°F x 365 day/yr. / 8.4 EER / 1,000 W/kW
= 12,062 kWh/year

kW_{SAVED} = 12,062 kWh / 2,920 hours = 4.13 kW

References

1. Focus on Energy Evaluation Business Programs Measure Life Study: Final Report August 25, 2009, Public Service Commission of Wisconsin.
2. Efficiency Maine – Commercial Technical Reference Manual, Version 2014.1. http://www.efficiencymaine.com/docs/EMT-Commercial-TRM.pdf. Accessed 07/01/15.
3. Sanford, Scott. "Milk Bulk Tank Refrigeration Condenser Cleaning Study Summary." University of Wisconsin-Madison, 2005.
4. *2014 ASHRAE Handbook - Refrigeration, page 19.4*.
5. Minnesota Department of Commerce – Division of Energy Resources, Dairy Cooperative Partnerships for Improved Efficiency Program Adoption, http://mn.gov/commerce-stat/pdfs/card-report-tmp-dairy-ee.pdf, accessed 8/23/17.
6. Product of 6.5 gallons and 8.6 lbs./gallon. Purdue University: Dairy Facts. http://www.ansc.purdue.edu/faen/dairy%20facts.html Accessed 8/15.
7. Raw milk for pasteurizing must be cooled within 4 hours (Ref. 8). Assuming two milkings, per day, the annual hours of operation is at most 2,920. (Ref. 6)
8. Dairy Farm Energy Management Guide: California, Ludington, Johnson, Kowalski, & Mage, Southern California Edison, 2004.
9. 2011 Michigan Dairy Farm Business Analysis Summary, Wittenberg, Eric and Wolf, Christopher. – pg. 3. Accessed 8/7/2017.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	8/21/17

Agriculture Misc. – Poultry Farm LED Lighting

Measure Detail	Measure Value
Measure ID	3.11.07
Target Market Segments	Commercial
Target End Uses	Lighting
Applicable To	Agricultural customers
Actions	Replace on Failure, Replace Working, New Construction
Required from Customer/Contractor	Baseline fixture wattage and quantity, LED lamp wattage and quantity, poultry farm type
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	7 years (Ref.1)
Unit Participant Incremental Cost	$30 (Ref. 2)

Measure Description

This measure includes the replacement of high-intensity discharge (HID), incandescent, and fluorescent fixtures with light emitting diode (LED) fixtures in poultry farms.

Algorithms

kWh_{SAVED} = ($Watts_{BASE}$ x Qty_{BASE} - $Watts_{EE}$ x Qty_{EE}) / C x HOURS x Days

kW_{SAVED} = ($Watts_{BASE}$ x Qty_{BASE} - $Watts_{EE}$ x Qty_{EE}) / C x CF

Where:

$Watts_{BASE}$	=	60 W, if unknown. Wattage of baseline lamp/fixture. (Ref. 3)
$Watts_{EE}$	=	10 W, if unknown. Wattage of LED lamp/fixture (Ref. 3)
Qty_{BASE}	=	if unknown, assume equal to Qty_EE. Number of baseline lamps being replaced.
Qty_{EE}	=	Number of LED lamps being installed
HOURS	=	16, if unknown; Refer to Table 1 for daily hours
C	=	1,000 W/kW. Conversion factor.
CF	=	1.0

Example:

A chicken broiler facility replacing 60 watt incandescent lamps with 10 watt LEDs.

kWh_{SAVED} = (60 W x 14 - 10 W x 14) / 1,000 W/kW x 16 hr/day x 365 days/yr = 4,088 kWh

kW_{SAVED} = (60 W x 14 - 10 W x 14) / 1,000 W/kW x 1.0 = 0.700 kW

Methodology and Assumptions

Table 1. Suggested Lighting Guide for Poultry Production (Ref. 4)

Type of Poultry	Age (Weeks)	Minimum Light Intensity Lux (foot-candles)	Photo Period (hours of light per day)
Chicken			
Chicken Broilers	0 to 0.4	20 to 30 (2 to 3)	24
	0.4 to 4	5 to 10 (0.5 to 1)	20 to 12
	4 to Market	6 to 10 (0.5 to 1)	20 to 24
Broiler Breeders	0 to 3	30 to 50 (3 to 5)	18
	4 to 20	10 to 30 (1 to 3)	9
	20 to 64	30 to 50 (3 to 5)	15
Chicken Layers	0 to 2	10 to 30 (1 to 3)	22 to 16
	2 to 6	10 to 30 (1 to 3)	16 to 8
	6 to 18	5 to 10 (0.5 to 1)	8 to 10
	18 to 80	5 to 10 (0.5 to 1)	15
Turkey			
Brooder – Commercial Turkey Hens or Toms	0 to 0.4	90 to 100 (9 to 10)	22 to 24
	0.4 to 1.2	30 to 50 (3 to 5)	16 to 22
Grow Out, Turkey Hens or Toms	1.2 to Market	10 to 30 (1 to 3)	16
Turkey Breeder Hens	0 to 5	20 (2)	24
	5 to 30	20 (2)	8
	30 and Up	20 (2)	13 to 15
Turkey Breeder Toms	0 to 5	20 (2)	24
	5 and Up	30 (3)	13 to 15
Average			**16**

References

1. Engineering estimate based on survey of manufacturer's rated life and the life extending effect of dimming. Typical rated life ranges from 35,000 - 60,000 hours (4 - 7 years). See "Info" tab for more details.
2. Average cost of LED fixtures based on Once Agricultural Lighting pricing. See "Info" tab for more details.

3. Field Demonstration of Advanced Lighting Technologies for Poultry Houses; Dr. Susan Watkins, Susan Sullivan, and Dr. H.L. Goodwin, University of Arkansas System's Division of Agriculture; 2011. Research shows that a majority of facility use 60 watt incandescent lamps. A majority of the facilities in the study went with 10 LED lamps. Accessed 07-16-15. http://poultryscience.uark.edu/Energy_Grant_Phase_1_Report.pdf
4. Energy Efficient Poultry Lighting Fact Sheet; Ontario Ministry of Agriculture, Food and Rural Affairs; Order No. 06-009; January 2006. The LED lamps used in the study range from 60,000 to 100,000 hours in Table 1, going with 60,000 hours for year round use is close to seven years. Referencing document Table 3 for daily hours. Accessed 07-16-15. http://www.omafra.gov.on.ca/english/engineer/facts/06-009.pdf

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	11/12/2015

Agriculture Misc. – VSD for Vacuum Dairy Pumps

Measure Detail	Measure Value
Measure ID	3.11.08
Target Market Segments	Agricultural
Target End Uses	Pumps
Applicable To	Dairy farms
Actions	Replace on Failure, Replace Working, New Construction
Required from Customer/Contractor	Vacuum pump motor horsepower
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	10 (Ref. 4)
Unit Participant Incremental Cost	$356/hp (Ref. 5)

Measure Description

This measure is for installing a variable speed drive (VSD) on a vacuum pump motor. The vacuum systems used for milking dairy cows rely on air pumps to continuously remove air from the milking system to reduce the vacuum pressure. A conventional vacuum system runs the vacuum pump motor at a constant speed while admitting air through the vacuum regulator to maintain a constant vacuum pressure as operational loads shift. A VSD saves energy by reducing the motor speed to maintain vacuum pressure.

Algorithms

$kWh_{SAVED} = (kW_{CS} – kW_{VSD}) \times t_{PUMP}$

$kW_{SAVED} = CF \times (kW_{CS} – kW_{VSD})$

Where:

kW_{CS}	=	Average Input kW of constant speed unit = HP x 0.746 x LF / eff_{MOTOR}
kW_{VSD}	=	Average Input kW of variable speed unit = C_1 x (2 x MU) + C_2
t_{PUMP}	=	Vacuum pump annual hours of operation = Qty_{COWS} x $Qty_{MILKINGS\ PER\ COW}$ x $Qty_{MILKING\ DAYS}$ /($hrs_{PER\ STALL}$ x qty_{STALLS})
HP	=	Nominal motor horsepower, from customer
0.746	=	Conversion factor from HP to kW (0.746 kW/HP)
LF	=	Motor load factor = 75% (Ref. 1)
Eff_{MOTOR}	=	Efficiency of vacuum pump motor, assumed to be 90% (Ref. 2)
C_1	=	0.0495, Regression Coefficient (Ref. 1)
C_2	=	1.7729, Regression Coefficient (Ref. 1)

MU = Quantity of milk units (teat positioner) = 3.2 x HP; estimated to be 64 MU (4 per stall, 16 total stalls) for a 20 hp vacuum pump; 1 MU = 1 Teat Positioner (Ref. 6)

Qty_{COWS} = Total quantity of cows being milked; assume 303 or customer-provided (Ref. 3)

$Qty_{MILKINGS\ PER\ COW}$ = Quantity of milking sessions, per day, per cow, assumed to be 2 (Ref. 1)

$Qty_{MILKING\ DAYS}$ = Quantity of milking days per year, assumed to be 365

$hrs_{PER\ STALL}$ = Duration of time spent during one milking session, assumed to be 5 hours (Ref. 6)

Qty_{STALLS} = Quantity of stalls per farm = MU/4, or customer-provided (Ref. 6)

CF = Coincidence Factor = 0.9 (Ref. 6)

Example:

A customer installed a new 20 hp VSD Vacuum Pump

kW_{CS} = 20 x 0.746 x 75% / 90% = 12.43 kW

kW_{VSD} = 0.0495 x (2 x 64 MU) + 1.7729 = 8.11 kW

t_{PUMP} = 303 cows x 2 milkings/cow/day x 365 days/yr /(5 cows/hrs/stall x 16 stalls) = 2,765 hrs./year

kWh_{SAVED} = (12.43 kW – 8.11 kW) x 2,765 hrs./year = 11,956 kWh/year

kW_{SAVED} = 0.9 x (12.43 – 8.11) = 3.89 kW

References

1. Efficiency of Maine – Commercial TRM. Version 2016. Pg. 86. Accessed 8/7/17. https://www.efficiencymaine.com/docs/EMT-TRM_Commercial_v2017_1.pdf
2. US DOE – Premium Efficiency Motor Selection and Application Guide, Pg. 2-4. Rough estimate based on NEMA Premium efficiencies of motors less than 20 hp. https://www.energy.gov/sites/prod/files/2014/04/f15/amo_motors_handbook_web.pdf Accessed 8/7/2017.
3. 2011 Michigan Dairy Farm Business Analysis Summary, Wittenberg, Eric and Wolf, Christopher. – pg. 3. https://www.msu.edu/user/steind/2011%20Michigan%20Dairy%20Farm%20Business%20Analysis.pdf Accessed 8/7/2017.
4. Focus on Energy Evaluation. Business Programs: Measure Life Study Appendix B (page 45 of PDF). https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf Accessed 8/7/2017.

5. Incremental cost determined by average installed price from Reference 1, divided by an assumed motor size of 15 hp (based on the range of 7.5 hp to 20 hp): $5,322 / 15 hp = $355.80/hp.
6. Internal Franklin Energy Services estimates.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	8/22/2017

Agriculture Misc. – VSD Milk Pump

Measure Detail	Measure Value
Measure ID	3.11.09
Target Market Segments	Commercial
Target End Uses	Dairy
Applicable To	Commercial customers
Actions	Replace on Failure, Replace Working, New Construction
Required from Customer/Contractor	Number of cows
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	15 (Ref.1)
Unit Participant Incremental Cost	$4000 (Ref. 2)

Measure Description

This measure involves the installation of a variable speed driven milk transfer pump.

Algorithms

$kWh_{SAVED} = N_{COWS} \times Mdot_{MILK} \times Cp_{MILK} \times Delta_T \times Days / EER / C$

$kW_{SAVED} = kWh_{SAVED} / HOURS$

Where:

EER	=	8.4 EER, if unknown. Efficiency of refrigeration system. (Ref. 3)
Cp_{MILK}	=	0.93 Btu/lb-°F. Heat capacity of whole milk. (Ref. 4)
Delta_T	=	15°F. Temperature drop of milk exiting pre-cooler. (Ref. 5)
N_{COWS}	=	Number of Cows Milked
$Mdot_{MILK}$	=	56 lbs of milk/cow/day. Milk production per cow per day. (Ref. 6)
Days	=	365 days. Days the cows will be milked. (Ref. 6)
C	=	1,000 W/kW. Conversion Factor
HOURS	=	2,920 hours (Ref. 7)

Example:

A customer with a 130-cow farm, installed a new VSD milk transfer pump.

kWh_{SAVED} = 130 cows x 56 lbs milk/cow/day x 0.93 Btu/lb-F x 15°F x 365 day/yr / 8.4 EER / 1,000 W/kW = 4,413 kWh/year

kW_{SAVED} = 4,413 kWh / 2,920 hours = 1.511 kW

References

1. Focus on Energy Evaluation Business Programs Measure Life Study: Final Report August 25, 2009, Public Service Commission of Wisconsin.
2. Assumed the average of VFD costs for 5 hp, 7.5 hp and 10 hp motor sizes. See VFD measure for the full table of costs. ($3,420, $4,200 and $4,300)
3. Sanford, Scott. "Milk Bulk Tank Refrigeration Condenser Cleaning Study Summary." University of Wisconsin-Madison, 2005.
4. 2014 ASHRAE Handbook - Refrigeration, page 19.4.
5. Sanford, Scott. 2004c. Variable Speed Milk Pumps. University of Wisconsin - Cooperative Extension Publication (A3784-7). Madison, Wisconsin: University of Wisconsin. https://attra.ncat.org/attra-pub/viewhtml.php?id=198. Accessed 5/21/15.
6. Product of 6.5 gallons and 8.6 lbs/gallon. Purdue University: Dairy Facts. http://www.ansc.purdue.edu/faen/dairy%20facts.html. Accessed 5/21/15.
7. Raw milk for pasturing must be cooled within 4 hours (Ref. 8). Assuming 2 milkings per day the annual hours of operation at most 2920 (Ref. 6)
8. Dairy Farm Energy Management Guide: California, Ludington, Johnson, Kowalski, & Mage, Southern California Edison, 2004.

Revision History

Version	Description	Author	Date
1.0	Created new workpaper	Franklin Energy Services	11/12/2015

Electric Utility Infrastructure

Lighting

Electric Utility Infrastructure Lighting – General Measure

Measure Detail	Measure Value
Measure ID	4.01.01
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Lighting
Actions	Replace Working, Replace on Fail, Modify, New Construction
Required from Customer/Contractor	Existing fixtures and quantities (retrofits only), installed fixtures and quantities, operating hours estimate, HVAC system (heating only, heating & cooling, exterior/unconditioned)
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	See Table 3
Unit Participant Incremental Cost	See Appendix B (Values originally developed for C/I applications, but apply to Infrastructure/Utility-owned projects as well)

Measure Description

Electric Utility Infrastructure lighting measures use a standard set of variables for hours of use, HVAC cooling interaction effects, and coincident factors. The following section provides the algorithms used for energy savings and the tables of supporting information. This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities. Wattage references in Appendix B apply to Infrastructure projects the same as C/I projects.

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = CF x (kW_Base - kW_EE) x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_heating_penalty_factor

Where:

kW_Base = Baseline fixture wattage (kW per fixture): see Appendix B

kW_EE = High-efficiency fixture wattage (kW per fixture): see Appendix B

Hrs = Annual operating hours. An estimate for actual operating hours should be used. Project documentation should include a justification for the chosen estimate. If an estimate is impossible to produce, use the

building type from Table 2 most similar to the proposed install space to determine hours.

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. If data is tracked at the site that would allow a project-specific CF to be calculated, that value should be used (for example, if lighting is tracked as a parasitic load at generation facilities). If an actual CF is not available, use the building type from Table 2 most similar to the proposed install space to determine CF.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy. It only applies if the proposed installation site uses mechanical cooling (use a value of 1.0 otherwise).

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand. It only applies if the proposed installation site uses mechanical cooling (use a value of 1.0 otherwise).

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting from Table 1. It only applies if the installation site uses gas space heating (use a value of 0 otherwise).

Example:

Replace (1) 60W incandescent with a 9W LED lamp in a utility-owned office space with gas heating and mechanical cooling.

kWh Savings = (0.043-0.009) x 4,439 x 1.095 = 165.23 kWh

kW Savings = 0.7 x (0.043-0.009) x 1.254 = 0.0.298 kW

Heating Penalty = (0.043-0.009) x 4,439 x -0.0023 = -0.347 Dth/year

Deemed Input Tables

Table 1. HVAC Interactive Factors by HVAC System (Ref. 2)

Lighting Measures	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only or Heating & Cooling
All Except Exterior/ Unconditioned	1.00	1.254	1.00	1.095	-0.0023

Exterior/ Unconditioned Space	1.00	1.00	1.00	1.00	0

Table 2. Deemed Peak Demand Coincidence Factors (Ref. 3) and Annual Operating Hours by Building Type (Ref. 4)

Building Type	CF	Hrs
Office	70%	4,439
Warehouse	70%	4,746
Other/Misc.	66%	4,576
24-Hour Facility	100%	8,760
Safety or Code Required	100%	8,760
Exterior lighting	0%	4,903

Table 3. Measure Life

Installed Technology	Measure Life (yrs)	Reference
Ceramic Metal Halide	13	8
Ceramic Metal Halide - Integrated Ballast	13	8
High Bay Fluorescent	15	6
High Bay LED	11.3	20
LED Exterior Canopy	10.2	7
LED Exterior (Wall & Area)	10.2	7
Low wattage plug-in CFL	1.8	16
Low wattage T8	15	6
Pin_Based CFL	2.3	17
Pulse Start Metal Halide	15	9
CFL Standard to Low Wattage	2.3	1
Controls	8	6
Exit Sign Retrofit with LED/LEC	16	6
Exterior Canopy/Soffit Retrofit with LEDs	10.2	7
Exterior Wall Pack Retrofit with LEDs	10.2	7
Parking Garage Fluorescent	15	6
High Pressure Sodium	15	18
Interior LED Screw-in Lamps	3.4	14
Interior LED Luminaire	11.3	15
Pin-Based CFL	2.3	9
Pin-Based LED	11.3	21
T5 fixtures	15	6
T8 fixtures	15	6
Refrigerator/Freezer Case LEDs	10	10
Stairwell Fixtures with Integral Occupancy	14.4	11
T8 Standard to Low Wattage Retrofit	8.1	12
Energy Standard Exempt T12 HO ballasts for outdoor signs and electronic ballast T12s	15	6

Installed Technology	Measure Life (yrs)	Reference
Nonexempt 8 foot magnetic ballast T12s are 4 years in 2013, 3 years in 2014, 2 years in 2015, and 1 year in 2016, 1 year in 2017, TBD in 2018	1	13
T8 Optimization	15	6

Methodology and Assumptions

HVAC cooling and heating interactive factor data based on DOE2/eQuest building simulation. The prototypes building models are based on the California DEER study prototypes (see http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf), and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

References

1. CFL lamp rated hours of 10,000 is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 2.3 years for measure life
2. HVAC cooling and heating interactive factor data based on DOE2/eQuest building simulation. The prototypes building models are based on the California DEER study prototypes (see http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf), and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).
3. Database of Energy Efficient Resources 2008 Measure Energy Analysis Revisions Version 2008.2.05-09-11 Planning/Reporting Version
4. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 6.5. Illinois TRM summarizes recent studies including: DEER 2005, DEER 2008, ComEd FY1 and FY2 evaluations, AmerEn Missouri Final Report: Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, and Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010
5. Lighting Efficiency input wattage guide, Xcel Energy, July, 2008, kW
6. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08
7. Product life based on 50,000 minimum rated life from Design Lights Consortium V4.0 Specification https://designlights.org/resources/file/TRT_V40_Final_FULLTABLE_FINAL_highlights 50,000 divided by the exterior hours of 4,903 arrives at 10.2 years.
8. State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation *Business Programs: Measure Life Study* Final Report: August 25, 2009
9. Residential and Commercial/Industrial Lighting and HVAC Measures for use as Energy Efficiency Measures/Programs Reference Document for the ISO Forward Capacity Market (FCM) June 2007 GDS Associates, Inc.

10. Assumes 6,205 hrs per year operation (17 hrs/day) and a lifetime of approximately 62,082 hours (this is the average rated life from DLC qualified product list). Accessed 7/31/12.
11. Xcel Energy 2013-2015 Triennial CIP Plan (Docket No. E,G002/CIP-12-447). Average of fixture lifetime (20 years) and control lifetime (~8 years).
12. Product life assumption of 36,000 hours determined from survey of on-line retailers, July 2012. 36,000 hours is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 8.1 years for measure life.
13. Measure life reduction due to legislation and market. See T12 Up to 4-Foot Retrofit section for more information.
14. LED lamp rated hours of 15,000 (ENERGY STAR qualified minimum) is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 3.4 years for measure life
15. Product life based on 50,000 minimum rated life from Design Lights Consortium V4.0 Specification
    https://designlights.org/resources/file/TRT_V40_Final_FULLTABLE_FINAL_highlights
    LED luminaire rated hours of 50,000 is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 11.3 years for measure life
16. Measure life for low wattage plug-in CFL lamps is based on 8,000 hours of life divided by the average annual operating hours of 4,431 to arrive at 1.81 years
17. CFL lamps rated hours of 10,000 is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 2.3 years for measure life.
18. Xcel Energy uses 20 years in 2013-2015 Minnesota CIP Triennial Plan (Docket No. E,G002/CIP-12-447), per communication with Commerce staff. Fixture may be considered permanent once installed. However, life was decreased to 15 years for consistency with maximum lifetimes for other technologies.
19. ANSI/ASHRAE/IES Standard 90.1-2010 edition
20. LED highbay rated hours of 50,000 is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 11.3 years
21. DLC is expected to adopt this category of lamps in late 2016; minimum rate lifetime will be 50,000 hours. 50,000 is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 11.3 years.
22. C/I Lighting – Lighting End Use Measure. State of Minnesota Technical Reference Manual for Energy Conservation Improvement Programs Version 2.0. Effective: January 1, 2017 – December 31, 2019.

Revision History

Version	Description	Author	Date
1.0	New EUI measure based on existing C/I measure	GDS Associates	11/21/2016

Electric Utility Infrastructure Lighting – CFL Standard to Low Wattage Retrofit

Measure Detail	Measure Value
Measure ID	4.01.02
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Lighting
Applicable To	Electric Utility Infrastructure
Actions	Replace Working, Replace on Fail
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Peak kW Savings	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Dth Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.

Measure Description

This measure replaces standard wattage plug-in CFL lamps with lower wattage plug-in CFL lamps, nominally 40 watt lamps replaced by 28 watt or 25 watt lamps. These lamps plug into the fixture and can be used with the existing ballast and base. Commonly referred to as Dulux, Biax, or PL lamps. This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithm and Assumptions

Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

Electric Utility Infrastructure Lighting – Controls

Measure Detail	Measure Value
Measure ID	4.01.03
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Lighting
Applicable To	Electric Utility Infrastructure
Actions	Modify
Required from Customer/Contractor	Control type/quantity, connected load (kW) to each control, estimated annual operating hours, HVAC system (heating only, heating & cooling, exterior/unconditioned)
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	See algorithm
Measure Lifetime (years)	8 years (Ref. 1)
Unit Participant Incremental Cost	See Table 3

Measure Description

Occupancy sensors represent an energy-efficient way to control lighting use in low occupancy areas such as halls, storage rooms, and restrooms. Instead of relying on people to remember to switch lights off when they leave a space, occupancy sensors perform this task. They measure the movement of people within a space. When movement is detected, the lights turn on automatically; they then shut off when they no longer sense movement. Each unit's shut-off time can be preset, given the needs of the space being controlled.

Systems use daylight sensor lighting controls to take advantage of available daylight in perimeter building spaces (open spaces within 10' to 15' of windows) or other areas that have access to daylight infiltration. Daylight sensor lighting controls can be used to turn lights on or off, stepped dimming (high/low or inboard/outboard), or continuous dimming based on light levels from available daylight. Especially useful in common spaces where task lighting is not critical (malls, warehouses, atriums, etc.) This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithms

Unit kWh Savings per Year = kW_connected x (1-PAF) x Hrs xHVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = CF x kW_connected x(1-PAF)x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = kW_connected x (1-PAF) x Hrs x HVAC_heating_penalty_factor

Where:

kW_connected = Total connected fixture load, determined as the sum of stipulated fixture wattages from the Retrofit Tables in the C/I Lighting Measure.

Hrs = Annual operating hours. An estimate for actual operating hours should be used. Project documentation should include a justification for the chosen estimate. If an estimate is impossible to produce, use the building type from Table 2 in the Lighting – General Measure most similar to the proposed install space to determine hours.

PAF = Deemed Power Adjustment Factor per Table 3.

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. If data is tracked at the site that would allow a project-specific CF to be calculated, that value should be used (for example, lighting parasitic loads at generation facilities). If an actual CF is not available, use the building type from Table 2 in the Lighting – General Measure most similar to the proposed install space to determine CF.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from efficient lighting from Table 1 in the Lighting – General Measure. Reduction in lighting energy results in a reduction in cooling energy. It only applies if the proposed installation site uses mechanical cooling.

HVAC_cooling_kWsavings_factor = Cooling system demand savings factor resulting from efficient lighting from Table 1 in the Lighting – General Measure. Reduction in lighting demand results in a reduction in cooling demand. It only applies if the proposed installation site uses mechanical cooling.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting from Table 1 in the Lighting – General Measure. It only applies if the installation site uses gas space heating.

Example:

Install a wall mounted occupancy sensor with a connected load of 0.560 kW (10 - 2L 32W T8 fixtures) in a utility-owned office space.

kWh = 0.560kW x (1-0.70) x 4,439 x 1.095 = 816.6 kWh

kW = 0.7 x 0.560 x (1-0.70) x 1.254 = 0.15 kW

Deemed Input Tables

Table 1. Deemed Power Adjustment Factors (Ref. 1) and Incremental Costs (Ref. 4)

Control Type	PAF	Incremental Cost
Occupancy Sensor - Wall Mount	0.700	$55
Occupancy Sensor - Ceiling Mount	0.700	$125
Daylighting - Continuous Dimming	0.567	$65
Daylighting - Multiple Step Dimming	0.648	$65
Daylighting - On/Off	0.729	$65

Codes and Legislation

Adoption of ASHRAE Standard 90.1-2010 will require occupancy sensors in many spaces for new construction.

Automatic Lighting Shutoff – interior lighting in buildings shall be controlled with an automatic control device to shut off building lighting in all spaces. This automatic control device shall function on either: a) a scheduled basis using a time-of-day operated control device that turns lighting off at specific programmed times – an independent program schedule shall be provided for areas of no more than 25,000 ft2 but not more than one floor – or b) an occupant sensor that shall turn lighting off within 30 minutes of an occupant leaving a space, or c) a signal from another control or alarm system that indicates the area is unoccupied.

Exceptions include: a) lighting required for 25-hour operation b) lighting in spaces where patient care is rendered and c) lighting in spaces where an automatic shutoff would endanger the safety or security of the room or building occupant(s).

Display/Accent Lighting – shall have a separate control device

Case Lighting – lighting in case for display purposes shall have a separate control device

Guest Room Lighting – Guestrooms in hotels, motels, boarding houses, or similar buildings shall have one or more control device(s) at the entry door that collectively control all permanently installed luminaires and switched receptacles, except those in the bathroom(s).

Task Lighting – Supplemental task lighting, including permanently installed undershelf or undercabinet lighting, shall have a control device integral to the luminaires or be controlled by a wall mounted control device provided the control device is readily accessible and located so that the occupant can see the controlled lighting.

Nonvisual Lighting – lighting for nonvisual applications, such as plant growth and food warming, shall have a separate control device.

Demonstration Lighting – lighting equipment that is for sale or for demonstrations in lighting education shall have a separate control device.

Stairwell Lighting – lighting in stairwells shall have on or more control devices to automatically reduce lighting power in any one controlled zone by at least 50% within 30 minutes of all occupants leaving that controlled zone.

Refer to Table 9.6.2 Control Factors Used in Calculating Additional Interior Lighting Power Allowance for more information. (Ref 6).

Notes

Adoption of ASHRAE Standard 90.1-2007 or 90.1-2010 will require occupancy sensors in many spaces for new construction.

References

1. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 6.5. Illinois TRM summarizes recent studies including: DEER 2005, DEER 2008, ComEd FY1 and FY2 evaluations, AmerEn Missouri Final Report: Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, and Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010
2. ANSI/ASHRAE/IES Standard 90.1-2010 edition
3. C/I Lighting – Controls Measure. State of Minnesota Technical Reference Manual for Energy Conservation Improvement Programs Version 2.0. Effective: January 1, 2017 – December 31, 2019.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

Electric Utility Infrastructure Lighting – Exit Sign Retrofit with LED/LEC

Measure Detail	Measure Value
Measure ID	4.01.04
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Lighting
Applicable To	Electric Utility Infrastructure
Actions	Replace Working, Replace on Fail
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Peak kW Savings	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Dth Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.

Measure Description

This measure evaluates the retrofit and replacement of incandescent exit signs with energy efficient LED and LEC exit signs. ENERGY STAR labeled exit signs operate on five watts or less per sign, compared to the standard signs, which use as much as 40 watts per sign. This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithm and Assumptions

Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Notes

EPA suspended the ENERGY STAR Exit Sign specification effective May 1, 2008. In EPAct 2005, Congress passed a new minimum federal efficiency standard for electrically-powered, single-faced exit signs with integral light sources that are equivalent to ENERGY STAR levels for input power demand. EPAct 2005 references the ENERGY STAR Version 2.0 specification. All exit signs manufactured on or after January 1, 2006 must have an input power demand of 5 watts or less per face.

References

1. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08
2. Calculated through energy modeling by FES 2012

3. Lighting Efficiency input wattage guide, Xcel Energy, July, 2008, kW
4. NYSERDA Deemed Savings Database, Labor cost assumes 25 minutes @ $18/hr taken from the State of Illinois Technical Reference Manual 2012 and 2012 manufacturer product survey and project data.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

Electric Utility Infrastructure Lighting – Exterior Canopy/Soffit Retrofit with LEDs

Measure Detail	Measure Value
Measure ID	4.01.05
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Lighting
Applicable To	Exterior canopy/soffit lighting within Electric Utility Infrastructure
Actions	Replace Working, Replace on Fail
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Peak kW Savings	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Dth Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.

Measure Description

Exterior high pressure sodium, metal halide, mercury vapor, and pulse start metal halide fixtures can all be replaced with energy efficient LED exterior light fixtures in canopy and soffit applications. Utilizing LED lighting, a large energy savings can be accomplished without a great lumen reduction in the area. This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithm and Assumptions

Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Requirements

It is suggested that all LED fixtures and retrofits appear on the Design Lights Consortium Qualified Product list available at www.designlights.org.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

Electric Utility Infrastructure Lighting – Exterior Wall Pack Retrofit with LEDs

Measure Detail	Measure Value
Measure ID	4.01.06
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Lighting
Applicable To	Exterior wall pack lighting within Electric Utility Infrastructure
Actions	Replace Working, Replace on Fail
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Peak kW Savings	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Dth Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.

Measure Description

Exterior high pressure sodium, metal halide, mercury vapor, and pulse start metal halide fixtures can all be replaced with energy efficient LED exterior wall pack fixtures. Utilizing LED lighting, a large energy savings can be accomplished without a great lumen reduction in the area. This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithm and Assumptions

Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Requirements

It is suggested that all LED fixtures and retrofits appear on the Design Lights Consortium Qualified Product list available at www.designlights.org.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

Electric Utility Infrastructure Lighting – Fluorescent to LED High Bay Systems

Measure Detail	Measure Value
Measure ID	4.01.07
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Lighting
Applicable To	Electric Utility Infrastructure
Actions	Replace Working
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Peak kW Savings	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Dth Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.

Measure Description

LED high bay fixtures offer increased efficiency with nearly equivalent light output as compared to linear fluorescent high bay systems. Integrated LED high bays also offer advanced controllability leading to an even greater increase in efficiency.

LED systems are often utilized in high bay ceiling applications over 15 feet. LED fixtures also offer an increased life time, reduced maintenance, and no decreased in operational performance in colder temperatures.

This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithm and Assumptions

Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Requirements

It is suggested that LED High Bay fixtures appear on the Design Lights Consortium Qualified Product List under the High Bay category.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

Electric Utility Infrastructure Lighting – High Pressure Sodium Retrofit

Measure Detail	Measure Value
Measure ID	4.01.08
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Lighting
Applicable To	Electric Utility Infrastructure
Actions	Replace on Fail, Replace Working
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Peak kW Savings	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Dth Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.

Measure Description

This measure evaluates high pressure sodium fixtures replaced by pulse start metal halides, high bay fluorescent fixtures, parking garage fluorescent, and ceramic metal halides.

Pulse start metal halide systems typically consume 20% less energy than high pressure sodium systems, produce the same light at lower wattages, and can often use more efficient ballasts depending on the application.

High bay fluorescent systems are often utilized in high bay ceiling applications over 15 feet. High bay fluorescent and parking garage fluorescent systems offer lower depreciation rates, better dimming options, virtually instant start-up and re-strike, better color rendition, and reduced glare.

Ceramic metal halides can be utilized to replace high pressure sodium in lower wattage applications and result in better color rendition, lower wattage consumption, and improved color temperature.

This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithm and Assumptions

Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Notes

New construction wattage tables are available in the CI Lighting New Construction file.

The Energy Independence and Security Act of 2007 legislation sets standards for ballasts used in new metal halide luminaires that operate lamps from 150 to 500 watts. New metal halide luminaires must contain ballasts that meet new efficiency standards. Pulse-start metal halide ballasts must have a minimum ballast efficiency of 88%, magnetic probe-start ballast a minimum efficiency of 94%. New

metal halides operating lamps of 150-500 watts manufactured on or after January 1, 2009 contain pulse-start, magnetic or electronic, metal halide ballasts with a minimum efficiency of 88%.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

Electric Utility Infrastructure Lighting – Incandescent Over 100W Retrofit

Measure Detail	Measure Value
Measure ID	4.01.09
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Lighting
Applicable To	Electric Utility Infrastructure
Actions	Replace Working, Retrofit
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Peak kW Savings	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Dth Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.

Measure Description

This measure replaces Incandescent fixtures over 100 watts with various technologies including ceramic metal halides, high pressure sodium fixtures, integrated ballast ceramic metal halides, LED lamps, LED luminaire, pin-based CFL, pulse start metal halides, T5 fixtures, and T8 fixtures. The replacement fixture technology will depend on the specific application and environment. This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithm and Assumptions

Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Requirements

It is suggested that all LED fixtures and retrofits appear on the Design Lights Consortium Qualified Product list available at www.designlights.org and LED and CFL lamps appear on the ENERGY STAR Qualified Product list available at www.energystar.gov.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

Electric Utility Infrastructure Lighting – Incandescent Up to 100W Retrofit

Measure Detail	Measure Value
Measure ID	4.01.10
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Lighting
Applicable To	Electric Utility Infrastructure
Actions	Replace Working, Retrofit
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Peak kW Savings	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Dth Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.

Measure Description

This measure replaces Incandescent fixtures up to 100 watts with various technologies including ceramic metal halides, LED lamps, LED luminaire, pin-based CFL, pulse start metal halides, and T8 fixtures. The replacement fixture technology will depend on the specific application and environment. This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithm and Assumptions

Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Requirements

It is suggested that all LED fixtures and retrofits appear on the Design Lights Consortium Qualified Product list available at www.designlights.org and LED and CFL lamps appear on the ENERGY STAR Qualified Product list available at www.energystar.gov.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

Electric Utility Infrastructure Lighting – LED Troffer Retrofit Kits

Measure Detail	Measure Value
Measure ID	4.01.11
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Lighting
Applicable To	Electric Utility Infrastructure
Actions	Replace Working
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Peak kW Savings	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Dth Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.

Measure Description

LED Troffers offer an energy efficient alternative to T8 linear fluorescent fixtures. Kits are available to convert an existing recessed troffer to LED without requiring removal of the fixture. LED integrated fixtures offer similar light output with a reduction of energy consumption. Integrated LED fixtures also offer controllability beyond capabilities of linear fluorescent technology and integration with many complex control systems. This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithm and Assumptions

Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Requirements

It is suggested that all LED fixtures and retrofits appear on the Design Lights Consortium Qualified Product list available at www.designlights.org.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

Electric Utility Infrastructure Lighting – LED Troffers

Measure Detail	Measure Value
Measure ID	4.01.12
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Lighting
Applicable To	Electric Utility Infrastructure
Actions	Replace Working
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Peak kW Savings	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Dth Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.

Measure Description

LED Troffers offer an energy efficient alternative to T8 linear fluorescent fixtures. The LED integrated fixtures offer similar light output with a reduction of energy consumption. Integrated LED fixtures also offer controllability beyond capabilities of linear fluorescent technology and integration with many complex control systems.

This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithm and Assumptions

Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Requirements

It is suggested that all LED fixtures and retrofits appear on the Design Lights Consortium Qualified Product list available at www.designlights.org.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

Electric Utility Infrastructure Lighting – Mercury Vapor Retrofit

Measure Detail	Measure Value
Measure ID	4.01.13
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Lighting
Applicable To	Electric Utility Infrastructure
Actions	Replace on Fail, Replace Working
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Peak kW Savings	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Dth Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.

Measure Description

This measure evaluates mercury vapor fixtures replaced by pulse start metal halides, high bay fluorescent fixtures, high pressure sodium fixtures, parking garage fluorescent fixtures, and ceramic metal halides.

Pulse start metal halide systems typically consume 20% less energy than mercury vapor systems, produce the same light at lower wattages, and can often use more efficient ballasts depending on the application.

High bay fluorescent systems are often utilized in high bay ceiling applications over 15 feet. High bay fluorescent and parking garage fluorescent systems offer lower depreciation rates, better dimming options, virtually instant start-up and re-strike, better color rendition, and reduced glare.

Ceramic metal halides can be utilized to replace mercury vapor systems in lower wattage applications and result in better color rendition, lower wattage consumption, and improved color temperature.

This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithm and Assumptions

Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

Electric Utility Infrastructure Lighting – Metal Halide Retrofit

Measure Detail	Measure Value
Measure ID	4.01.14
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Lighting
Applicable To	Electric Utility Infrastructure
Actions	Replace on Fail, Replace Working
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Peak kW Savings	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Dth Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.

Measure Description

This measure evaluates probe start metal halides replaced by pulse start metal halides, high bay fluorescent fixtures, and ceramic metal halides. Pulse start metal halide systems typically consume 20% less energy than standard metal halide systems, produces the same light at lower wattages, and can often use more efficient ballasts depending on the application.

High bay fluorescent and parking garage fluorescent systems are often utilized in high bay ceiling applications over 15 feet. High bay fluorescent and parking garage fluorescent systems offer lower depreciation rates, better dimming options, virtually instant start-up and re-strike, better color rendition, and reduced glare.

Ceramic metal halides can be utilized to replace probe start metal halides in lower wattage applications and result in better color rendition, lower wattage consumption, and improved color temperature. This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithm and Assumptions

Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

Electric Utility Infrastructure Lighting – Pulse Start Metal Halide Retrofit

Measure Detail	Measure Value
Measure ID	4.01.15
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Lighting
Applicable To	Electric Utility Infrastructure
Actions	Replace on Fail, Replace Working
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Peak kW Savings	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Dth Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.

Measure Description

This measure evaluates pulse start metal halide fixtures replaced by lower wattage pulse start metal halides, high bay fluorescent fixtures, and ceramic metal halides.

Pulse start metal halide fixtures can be replaced by lower wattage pulse start metal halides when the space they are in is considered over lit.

High bay fluorescent and fluorescent systems are often utilized in high bay ceiling applications over 15 feet. High bay fluorescent and fluorescent systems offer lower depreciation rates, better dimming options, virtually instant start-up and re-strike, better color rendition, and reduced glare.

Ceramic metal halides can be utilized to replace pulse start metal halides in lower wattage applications and result in better color rendition, lower wattage consumption, and improved color temperature. This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithm and Assumptions

Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

Electric Utility Infrastructure Lighting – Stairwell Fixtures with Integral Occupancy Sensors

Measure Detail	Measure Value
Measure ID	4.01.16
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Lighting
Applicable To	Electric Utility Infrastructure
Actions	Replace on Fail, Replace Working
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Peak kW Savings	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Dth Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.

Measure Description

This measure involves replacement of existing fluorescent stairwell fixtures with fluorescent or LED stairwell fixtures with integral occupancy sensors and step-dimming ballasts, allowing for automatic adjustment of light output based on stairwell occupancy.

This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithm and Assumptions

Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Methodology and Assumptions

The efficient wattages in Appendix B include multipliers reflecting the rated level of dimming and an average duty cycle of 3% determined from M&V of a large installation sponsored by Xcel Energy.

Notes

In 2009 the Department of Energy announced new lamp rulemaking for general service fluorescent lamps. The efficiency standard requires general service fluorescent lamps covered in this rulemaking to meet minimum lumen per watt (LPW) requirements; products that do not meet the minimum LPW requirements as of July 14, 2012 can no longer be produced. 700 series T8 lamps affected by this rulemaking have been postponed for two years until July 2014. T12 lamps remain on the same timeline.

Requirements

It is suggested that all LED fixtures and retrofits appear on the Design Lights Consortium Qualified Product list available at www.designlights.org.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

Electric Utility Infrastructure Lighting – T12 8-Foot Retrofit

Measure Detail	Measure Value
Measure ID	4.01.17
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Lighting
Applicable To	Electric Utility Infrastructure
Actions	Replace Working, Replace on Fail
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Peak kW Savings	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Dth Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.

Measure Description

This measure evaluates the replacement of 8 foot T12 lamps and magnetic or electronic ballasts with energy efficient T8, T5, and T5HO lamps and ballasts. The replacements can be 8 foot or 4 foot lamps. Changing from T12 lamp and ballast systems to T8, T5, or T5HO systems will reduce the energy consumption of the system while maintaining similar light outputs. This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithm and Assumptions

Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Methodology and Assumptions

Measure Life is reduced based on remaining useful life of magnetic ballasts in the market place. Using the analysis completed in the Texas Docket 39146 Appendix C, a current remaining useful life of T12 magnetic ballasts at the end of 2012 is 4.1 years, or 4 years. The following documents were used in this analysis:

- "Fluorescent Lamp Ballasts Preliminary Analytical Tools: National Impact Analysis" (Ref. 7)
- "Fluorescent Lamp Ballast Technical Support Document for the Final Rule, 2000" (Ref. 8)

The Illinois Statewide Technical Reference Manual goes further to conclude the measure life should decrease from four years in 2012 to three years in 2013, two years in 2014, and one year in 2015. (Ref. 9)

Notes

EPAct 2005 and 2000 DOE Ballast Rule. 2000 DOE Ballast Rule no longer allows ballasts that do not pass the new requirements to be manufactured after July 1, 2010 and EPAct 2005 no longer allows ballasts that do not pass the new requirements to be sold after October 1, 2010.

Ballasts affected by the rulemaking are those that operate:

- T12 4-foot linear and 2-foot U-shaped Rapid Start lamps with medium bi-pin bases
- T12 8-foot Instant Start lamps with single pin bases
- T12 8-foot Rapid Start HO lamps with recessed double contact (RDC) bases

Exceptions to the ballast standards:

- Dimming ballasts that dim to 50% or less of maximum output
- T12 HO ballasts capable of starting at ambient temperatures as low as -20° F or less and for use in outdoor illuminated signs
- Ballasts having a power factor of less than 0.90 and designed and labeled for use only in residential applications.
- 2 foot and 3 foot lamp and ballast systems
- 2009 DOE Lamp Rulemaking for GSFL and IRL Lamps. New efficiency standards for General Service Fluorescent lamps (GSFLs), linear and U-shaped require these covered lamp types to meet minimum lumen per watt (LPW) requirements; products that do not meet the minimum LPW requirements as of July 14, 2012 can no longer be produced.

The following lamp types are affected by these standards:

- Lamp Type| Energy Conservation Standard (lm/W)
- 4-foot (T8-T12) Medium Bi-pin ≥25W 89/88
- 2-foot (T8-T12) U-Shaped ≥25W 84/81
- 8-foot (T8-T12) Single Pin Slimline ≥52W 97/93
- 8-foot (T8-T12) High Output 92/88
- 4-foot (T5) Miniature Bi-pin Standard Output ≥26W 86/81
- 4-foot (T5) Miniature Bi-pin high Output ≥49W 76/72
- New T12 lamps that meet the new standards are now available in the market allowing T12s to still be installed

References

1. DOE 2010b "Fluorescent Lamp Ballasts Preliminary Analytical Tools: National Impact Analysis" U.S. Department of Energy: 2010.
2. DOE 2000b. "Fluorescent Lamp Ballast Technical Support Document for the Final Rule, 2000." September 2000.

3. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 6.5.
4. C/I Lighting – T12 8-Foot Retrofit Measure. State of Minnesota Technical Reference Manual for Energy Conservation Improvement Programs Version 2.0. Effective: January 1, 2017 – December 31, 2019.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

Electric Utility Infrastructure Lighting – T12 Up to 4-Foot Retrofit

Measure Detail	Measure Value
Measure ID	4.01.18
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Lighting
Applicable To	Electric Utility Infrastructure
Actions	Replace Working, Retrofit
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Peak kW Savings	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Dth Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.

Measure Description

This measure evaluates the replacement of T12 lamps and magnetic or electronic ballasts up to 4 feet in length with energy efficient T8, T5, and T5HO lamps and ballasts. The replacement of T12 lamps and ballasts with T8, T5, and T5HO lamp and ballast systems results in a lower wattage system with similar light output. This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithm and Assumptions

Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Methodology and Assumptions

Measure Life is reduced based on remaining useful life of magnetic ballasts in the market place and the July 14, 2012 Federal Standards eliminating standard T12 lamps.

Reviewing the market and a pending study of the T12s in the Minnesota market, the measure life is 1 year at full savings for T12s. The remaining 14 years of the measure life will utilize T8 baseline for savings.

This is set to be re-visited at the completion of the T12 market study.

Notes

EPAct 2005 and 2000 DOE Ballast Rule. 2000 DOE Ballast Rule no longer allows ballasts that do not pass the new requirements to be manufactured after July 1, 2010 and EPAct 2005 no longer allows ballasts that do not pass the new requirements to be sold after October 1, 2010.

Ballasts affected by the rulemaking are those that operate:

- T12 4-foot linear and 2-foot U-shaped Rapid Start lamps with medium bi-pin bases
- T12 8-foot Instant Start lamps with single pin bases
- T12 8-foot Rapid Start HO lamps with recessed double contact (RDC) bases

Exceptions to the ballast standards:

- Dimming ballasts that dim to 50% or less of maximum output
- T12 HO ballasts capable of starting at ambient temperatures as low as -20° F or less and for use in outdoor illuminated signs
- Ballasts having a power factor of less than 0.90 and designed and labeled for use only in residential applications.
- 2 foot and 3 foot lamp and ballast systems

2009 DOE Lamp Rulemaking for GSFL and IRL Lamps. New efficiency standards for General Service Fluorescent lamps (GSFLs), linear and U-shaped require these covered lamp types to meet minimum lumen per watt (LPW) requirements; products that do not meet the minimum LPW requirements as of July 14, 2012 can no longer be produced.

The following lamp types are affected by these standards:

- Lamp Type| Energy Conservation Standard (lm/W)
- 4-foot (T8-T12) Medium Bi-pin ≥25W 89/88
- 2-foot (T8-T12) U-Shaped ≥25W 84/81
- 8-foot (T8-T12) Single Pin Slimline ≥52W 97/93
- 8-foot (T8-T12) High Output 92/88
- 4-foot (T5) Miniature Bi-pin Standard Output ≥26W 86/81
- 4-foot (T5) Miniature Bi-pin high Output ≥49W 76/72
- New T12 lamps that meet the new standards are now available in the market allowing T12s to still be installed.

Requirements

It is suggested that high performance and reduced wattage T8 lamps appear on the Consortium for Energy Efficiency Qualified Product List available at www.cee1.org.

References

1. DOE 2010b "Fluorescent Lamp Ballasts Preliminary Analytical Tools: National Impact Analysis" U.S. Department of Energy: 2010.
2. DOE 2000b. "Fluorescent Lamp Ballast Technical Support Document for the Final Rule, 2000." September 2000.

3. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 6.5.
4. ANSI/ASHRAE/IES Standard 90.1-2010 edition
5. C/I Lighting – T12 Up to 4-Foot Retrofit Measure. State of Minnesota Technical Reference Manual for Energy Conservation Improvement Programs Version 2.0. Effective: January 1, 2017 – December 31, 2019.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

Electric Utility Infrastructure Lighting – T8 Standard to Low Wattage Retrofit

Measure Detail	Measure Value
Measure ID	4.01.19
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Lighting
Applicable To	Electric Utility Infrastructure
Actions	Replace on Fail, Replace Working, New Construction
Measure Energy Type	Electric, Gas
Unit kWh Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Peak kW Savings	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.
Unit Dth Savings per Year	Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.

Measure Description

High performance T8 lighting with low wattage lamps incorporates improvements to lamp and ballast technologies. They deliver light levels comparable with standard 32 watt T8 systems at lower wattages and with improved lamp life. This measure replaces 32W standard T8 systems with low watt T8 systems. This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithm and Assumptions

Refer to the Lighting – General Measure for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Requirements

It is suggested that all low wattage T8 lamps appear on the Consortium for Energy Efficiency Qualified Product list available at www.cee1.org.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

HVAC

Electric Utility Infrastructure HVAC – Chiller Systems

Measure Detail	Measure Value
Measure ID	4.02.01
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	HVAC
Applicable To	Electric Utility Infrastructure
Actions	Replace on Fail, Replace Working or New Construction
Required from Customer/Contractor	New chiller type, nominal cooling capacity in tons, integrated part load value, full load value; $EFLH_{COOL}$ estimate or building type (refer to Table 2), project location (county) Chilled water leaving temperature, condenser leaving temperature and condenser gpm; if water cooled centrifugal chiller is not designed to operate at standard AHRI conditions
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	20 years (Ref. 1)
Unit Participant Incremental Cost	See Table 1

Measure Description

This measure analyzes the space cooling savings potential of the installation of high-efficiency chillers including; all air cooled chillers, water cooled screw, scroll, and centrifugal chillers. This measure is applicable to chillers with efficiencies provided at AHRI conditions, but also accommodates water cooled centrifugal chillers with efficiencies provided at other conditions. The incremental cost is associated with base equipment cost and does not include any installation costs. This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithms

Unit kWh Savings per Year = Nominal Capacity x (IPLV_base - IPLV_EE) x $EFLH_{COOL}$

Unit Peak kW Savings = Nominal Capacity x (FLV_base - FLV_EE) x CF

Where:

Nominal Capacity = the nominal rating of the cooling capacity of the energy efficient chiller (tons)

$IPLV_{EE}$ = the integrated part load value (IPLV) of the energy efficient chiller (kW/ton) at AHRI standard conditions*

For efficiencies provided at other than AHRI conditions:

$IPLV_{EE}$ = $IPLV_{CS}$ / K_{ADJ} = the integrated part load value of energy efficient chiller at operating conditions divided by K_{ADJ} for water cooled centrifugal chillers if chiller designed not to operate at AHRI standard conditions

$IPLV_{Base}$ = the integrated part load efficiency of the baseline chiller (kW/ton), $IPLV_{Base}$ = $IPLV_{AHRI}$ per Table 1.

$EFLH_{COOL}$ = the equivalent full load hours of chiller operation. If the proposed project will serve a unique space type, an estimate for $EFLH_{COOL}$ should be made and justification should be provided in the project documentation. If the space is similar to one of the building types listed in Table 2, the hours from that table can be used. If no estimate can be made and no building types in Table 2 match the proposed space, the Miscellaneous value from Table 2 should be used.

FLV_{EE} = the equivalent full load value of the energy efficient chiller (kW/ton), FLV at AHRI standard conditions, provided by the contractor/customer.

For efficiencies provided at other than AHRI conditions:

FLV_{EE} = FLV_{CS} / k_{ADJ} = the equivalent full load value of the energy efficient chiller at operating conditions divided by k_{ADJ} for water cooled centrifugal chillers if chiller not designed not to operate at AHRI standard conditions

FLV_{Base} = the full load efficiency of the baseline chiller (kW/ton), FLV_{Base} = FLV_{AHRI} per Table 1.

CF = Deemed coincident demand factor, equal to 0.90 (Ref. 2)

For Water Cooled Centrifugal Chillers not tested at AHRI Standard Conditions** (Ref. 3):

$IPLV_{CS}$ = for water cooled centrifugal chillers not designed to run at AHRI Standard test conditions*, the integrated part load value provided by customer/contractor at operating conditions (kW/ton)

FLV_{CS} = for water cooled centrifugal chillers not tested at AHRI Standard test conditions*, the equivalent full load value provided by customer/contractor at operating conditions (kW/ton)

k_{ADJ} = A x B

where:

A	=	$0.00000014592 \times (LIFT)^4 - 0.0000346496 \times (LIFT)^3 + 0.00314196 \times (LIFT)^2 - 0.147199 \times (LIFT) + 3.9302$
B	=	$0.0015 \times LvgEvap + 0.934$
LIFT	=	LvgCond – LvgEvap
LvgCond	=	Full Load Condenser leaving fluid temperature (°F)
LvgEvap	=	Full Load Evaporator leaving fluid temperature (°F)

* Standard AHRI test conditions are 44°F leaving chilled water temperature, 85°F entering condenser water temperature with 3 gpm/ton condenser water flow.

** These adjustment factors are applicable to centrifugal chillers designed for a minimum leaving water temperature of at least 36°F and a maximum condenser entering water temperature of 115 °F and LIFT ≥ 20°F and ≤ 80°F.

Example:

Retrofit of an existing water cooled centrifugal chiller installed in a Generation Facility with an estimated 1,298 effective full load cooling hours, 600 ton cooling capacity not rated at AHRI conditions. Design FLV = 0.50 and Design IPLV of 0.45, Climate Zone 3. The new chiller is full-load optimized and designed to operate with a condenser water leaving temperature of 91.16°F and evaporator leaving temperature of 42°F.

Lift = 91.16°F - 42°F = 49.16°F

$A = 0.00000014592 \times (49.16)^4 - 0.0000346496 \times (49.16)^3 + 0.00314196 \times (49.16)^2 - 0.147199 \times (49.16) + 3.9302 = 1.0228$

$B = 0.0015 \times 42 + 0.934 = 0.997$

$K_{ADJ} = 1.0228 \times 0.997 = 1.02$

$FLV_{EE} = 0.50 / 1.02 = 0.49$

$IPLV_{EE} = 0.40 / 1.02 = 0.44$

Unit kWh Savings per Year = 600 x (0.539 - 0.44) x 1298 = 77,101 kWh

Unit Peak kW Savings per Year = 600 x (0.57 - 0.49) x 0.9 = 43.0 kW

Deemed Input Tables

Table 1. Deemed Full Load and Integrated Part Load Baseline Efficiencies per AHRI 550/590 and Incremental Costs (Ref. 4, 5)

Equipment	PATH A*		PATH B**		Incremental Cost($/ton)
	FLV_AHRI (kW/ton)	IPLV_AHRI (kW/ton)	FLV_AHRI (kW/ton)	IPLV_AHRI (kW/ton)	
Water Cooled Scroll or Screw Chiller < 75 tons	0.780	0.630	0.800	0.600	130
Water Cooled Scroll or Screw Chiller ≥ 75 and < 150	0.775	0.615	0.790	0.586	90
Water Cooled Scroll or Screw Chiller ≥ 150 and < 300	0.680	0.580	0.718	0.540	90
Water Cooled Scroll or Screw Chiller ≥ 300 tons	0.620	0.540	0.639	0.490	40
Water Cooled Centrifugal Chiller < 150 tons	0.634	0.596	0.639	0.450	130
Water Cooled Centrifugal Chiller ≥ 150 and < 300	0.634	0.596	0.639	0.450	85
Water Cooled Centrifugal Chiller ≥ 300 and < 600	0.576	0.549	0.600	0.400	85
Water Cooled Centrifugal Chiller ≥ 600 tons	0.570	0.539	0.590	0.400	40
Air Cooled Chiller with Condenser < 150 tons	1.255	0.96	NA	NA	110
Air Cooled Chiller with Condenser > 150	1.255	0.94	NA	NA	110

* Path A is for traditional applications and where the intended applications are expected to have significant operating times at full load conditions, typically a non VFD controlled unit.

** All Path B chillers must be equipped with demand limiting controls or VFD controlled units.

*** FLV_AHRI = 12 / EER and IPLV_AHRI = 12 / SEER

Table 2. Equivalent Full Load Hours of cooling ($EFLH_{COOL}$) per zone in Minnesota by building type (Ref. 6)

Building Type	Zone 1	Zone 2	Zone 3
Office-Low Rise	257	359	446
Office-Mid Rise	373	529	651
Office-High Rise	669	1061	1263
Warehouse	164	343	409
Other/Miscellaneous	443	612	729

Methodology and Assumptions

$EFLH_{COOL}$ were determined from based prototypes building models on the California DEER study prototypes modified Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Assumed ventilation rates complied with the requirements of ASHRAE standard 62.1 – 2004.

Notes

Savings are based upon AHRI rated chillers and those water cooled centrifugal chillers operating within the limits of the nonstandard conditions listed above.

Table 1 chiller sizes were expanded to cover the scope the 2015 MN Energy Code, Table C.403.2.3 (7), Minimum Efficiency Requirements: Water Chilling Packages

References

1. ASHRAE, 2007, Applications Handbook, Ch. 36, table 4, Comparison of Service Life Estimates
2. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, and primary data has not been identified.
3. 2015 Minnesota Energy Code, Section C403.2.3.1 Water-cooled centrifugal chilling packages. https://codes.iccsafe.org/public/document/code/357/5880017
4. 2015 Minnesota Energy Code, Table C.403.2.3 (7), Minimum Efficiency Requirements: Water Chilling Packages. https://codes.iccsafe.org/public/document/code/357/5880017
5. 2008 Deer www.deeresources.com - Average across Tier 1 equivalent equipment.
6. Calculated through energy modeling of California DEER study prototypes modified by Illinois field data with TMY3 Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3) by FES 2012.

Revision History

Version	Description	Author	Date
1.0	New EUI measure based on existing C/I measure	GDS Associates	11/21/2016
2.0	Updated FLV and IPLV values	Mark Garofano	11/2018

Electric Utility Infrastructure HVAC – Chiller Tune-up

Measure Detail	Measure Value
Measure ID	4.02.02
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	HVAC
Applicable To	Electric Utility Infrastructure
Actions	O&M
Required from Customer/Contractor	Chiller type, nominal cooling capacity in tons, integrated part load value, full load value; building type (refer to Table 2), project location (county)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	5 (Ref. 1)
Unit Participant Incremental Cost	$5/ton (default/planning figure; Use actual cost of tune-up) (Ref. 2)

Measure Description

This measure describes savings for air cooled or water chiller tune-up completed in accordance with the following recommended tune-up requirements:

- Clean condenser coil/tubes
- Check cooling tower for scale or buildup
- Check contactors condition
- Check evaporator condition
- Check low-pressure controls
- Check high-pressure controls
- Check filter, replace as needed
- Check belt, replace as needed
- Check crankcase heater operation
- Check economizer operation

This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithms

kWh_{SAVED} = Nominal Capacity x $IPLV_{BASE}$ x $EFLH_{COOL}$ x MF_E

kW_{SAVED} = Nominal Capacity x FLV_{BASE} x CF x MF_D

Where:

$EFLH_{COOL}$ = the equivalent full load hours of chiller operation. If the proposed project will serve a unique space, an estimate for $EFLH_{COOL}$ should be made and justification should be provided in the project documentation. If the space is similar to one of the building types listed in Table 2, the hours from that table can be used. If no estimate can be made and no building types in Table 2 match the proposed space, the Miscellaneous value from Table 2 should be used.

Capacity = the nominal rating of the cooling capacity of the energy efficient chiller (tons)

Chiller efficiencies = because existing chiller efficiency typically cannot be determined without extensive testing, code minimum efficiencies are recommended for base efficiency.

$IPLV_{BASE}$ = the integrated part load efficiency of the baseline chiller (kW/ton), $IPLV_{BASE}$ = $IPLV_{AHRI}$ per Table 1. Alternatively, actual efficiency may be used if verified via testing.

FLV_{BASE} = the full load efficiency of the baseline chiller (kW/ton), FLV_{BASE} = FLV_{AHRI} per Table 1. Alternatively, actual efficiency may be used if verified via testing.

CF = Coincidence factor = 0.9(Ref. 3)

MF_E = Maintenance energy saving factor, MF_E = 5 % (Ref. 4)

MF_D = Maintenance demand saving factor, MF_D = 2.5 % (Ref. 4)

Example:

Tune up of a 200 ton air cooled chiller serving a utility-owned mid-rise office building in Zone 2:

kWh_{SAVED} = 200 x 0.94 x 529 x 0.05 =4,973 kWh

kW_{SAVED} = 200 x 1.26 x 0.9 x 0.025 = 5.67 kW

Deemed Input Tables

Table 1. Deemed Full Load and Integrated Part Load Baseline Efficiencies per AHRI 550/590 (Ref. 5)

Equipment	PATH A*		PATH B**	
	FLV_AHRI (kW/ton)	IPLV_AHRI (kW/ton)	FLV_AHRI (kW/ton)	IPLV_AHRI (kW/ton)
Water Cooled Scroll or Screw Chiller < 75 tons	0.780	0.630	0.800	0.600
Water Cooled Scroll or Screw Chiller ≥ 75 and < 150 tons	0.775	0.615	0.790	0.586
Water Cooled Scroll or Screw Chiller ≥ 150 and < 300 tons	0.680	0.580	0.718	0.540
Water Cooled Scroll or Screw Chiller ≥ 300 tons	0.620	0.540	0.639	0.490
Water Cooled Centrifugal Chiller < 150 tons	0.634	0.596	0.639	0.450
Water Cooled Centrifugal Chiller ≥ 150 and < 300 tons	0.634	0.596	0.639	0.450

Equipment	PATH A*		PATH B**	
	FLV_AHRI (kW/ton)	IPLV_AHRI (kW/ton)	FLV_AHRI (kW/ton)	IPLV_AHRI (kW/ton)
Water Cooled Centrifugal Chiller ≥ 300 and < 600 tons	0.576	0.549	0.600	0.400
Water Cooled Centrifugal Chiller ≥ 600 tons	0.570	0.539	0.590	0.400
Air Cooled Chiller with Condenser < 150 tons	1.255	0.960	NA	NA
Air Cooled Chiller with Condenser > 150	1.255	0.940	NA	NA

* Path A is for traditional applications and where the intended applications are expected to have significant operating times at full load conditions, typically a non VFD controlled unit.

** All Path B chillers must be equipped with demand limiting controls or VFD controlled units.

Table 2. Equivalent Full Load Hours of cooling ($EFLH_{COOL}$) per zone in Minnesota by building type (Ref. 6)

Building Type	Zone 1	Zone 2	Zone 3
Office-Low Rise	257	359	446
Office-Mid Rise	373	529	651
Office-High Rise	669	1061	1263
Warehouse	164	343	409
Other/Miscellaneous	443	612	729

Methodology and Assumptions

Measurements and corrections must be performed with standard industry tools and practices, and the results tracked by the efficiency program.

$EFLH_{COOL}$ were determined from based prototypes building models on the California DEER study prototypes modified Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

References

1. Wisconsin Public Service Commission equipment useful life database, 2013
2. State of Wisconsin Public Service Commission, Focus on Energy Evaluation, Business Programs: Incremental Cost Study, 2009. This study is compiled program project cost data. An average value from chiller types and sizes is roughly $5/ton the range is roughly $2 to 8$/ton
3. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, and primary data has not been identified.
4. United States Department of Energy, Building Technologies Program: Hospitals Benefit by Improving Inefficient Chiller systems white paper, August 2011. The paper found that coil cleaning, the primary savings measure associated with this cooling tune-up measure, reduces annual cooling energy consumption by 5-7%. Demand savings are conservatively assumed to be on half this, or 2.5%.

5. 2015 Minnesota Energy Code, Table C.403.2.3 (7), Minimum Efficiency Requirements: Water Chilling Packages. https://codes.iccsafe.org/public/document/code/357/5880017
6. Calculated through energy modeling of California DEER study prototypes modified by Illinois field data with TMY3 Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3) by FES 2012

Revision History

Version	Description	Author	Date
1.0	New EUI measure based on existing C/I measure	GDS Associates	11/21/2016
2.0	Updated FLV and IPLV values	Mark Garofano	11/2018

Electric Utility Infrastructure HVAC – Unitary Equipment Economizer Addition or Repair

Measure Detail	Measure Value
Measure ID	4.02.03
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	HVAC
Applicable To	Electric Utility Infrastructure customers where air unitary equipment has been installed, or has failed closed
Actions	Modify
Required from Customer/Contractor	Existing equipment type, existing equipment nominal cooling capacity in tons, existing equipment EER/SEER, building type (refer to Table 1), project location (county)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	0
Measure Lifetime (years)	10 years (Ref. 1)
Unit Participant Incremental Cost	For economizer addition, see Table 2 (Ref. 2) For economizer repair, use actual cost

Measure Description

This measure includes the retrofit of existing equipment or the optional addition of an air side economizer on new equipment where not required by code. This measure analyzes the cooling savings potential of the installation of an air side economizer on unitary equipment. This measure is applicable to dx and water cooled air systems. This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

This measure also includes the repair of economizers that have failed closed, or been manually disabled in a closed position. This is a common occurrence that often costs less to rectify than installing a new economizer, while providing the same savings as that action. This measure does not apply to economizers that have failed open, cases of which are generally noticed and rectified soon after onset.

Algorithms

Unit kWh Savings per Year = Size x (12/SEER_EE) x $EFLH_{COOL}$ x SF x SM Unit

Where:

Size = Nominal Cooling capacity in tons of the new equipment (1 ton = 12,000 btu/h)

$EFLH_{COOL}$ = the equivalent full load hours of HVAC equipment operation. If the proposed project will serve a unique space, an estimate for $EFLH_{COOL}$ should be made and justification should be provided in the project documentation. If the space is similar to one of the building types listed

in Table 1, the hours from that table can be used. If no estimate can be made and no building types in Table 1 match the proposed space, the Miscellaneous value from Table 1 should be used. (Ref. 3)

SEER_EE = Energy efficiency ratio of the existing equipment, provided by the customer. Assume SEER = 10.9 if unavailable. (Ref. 5)

SF = Deemed savings factor based upon zone. See Table 2. (Ref. 6)

SM = Deemed System Multiplier. SM = 1 for Constant Air Volume (CAV) Systems and SM = 1.4 for Variable Air Volume (VAV) systems. (Ref. 7)

Example:

Install an economizer by retrofitting a packaged rooftop installed in a utility-owned low-rise office building, 20 ton cooling capacity, SEER 14.4, VAV system, Climate Zone 1.

Unit kWh Savings per Year = 20 x (12 / 14.4) x 257 x 0.24 x1.4 = 1,439 kWh

Deemed Input Tables

Table 1. Equivalent Full Load Hours of cooling ($EFLH_{COOL}$) per zone in Minnesota by building type (Ref. 3)

Building Type	Zone 1	Zone 2	Zone 3
Office-Low Rise	257	359	446
Office-Mid Rise	373	529	651
Office-High Rise	669	1061	1263
Warehouse	164	343	409
Other/Miscellaneous	443	612	729

Table 2. Deemed Savings Factor for Zone and incremental costs

Equipment	Savings Factor (Ref. 6)			Incremental Cost** (Ref. 2)
	Zone 1	Zone 2	Zone 3	
Units* less than or equal to 10 tons	0.240	0.130	0.100	$1,500
Units* 11-20 tons	0.240	0.130	0.100	$1,900
Units* 21-30 tons	0.240	0.130	0.100	$2,100
Units* 31-60 tons	0.240	0.130	0.100	$2,500
Units* 61-100 tons	0.240	0.130	0.100	$4,000

* Units include packaged and built up air-handler units.

** An additional $1000 should be included when retrofitting existing units.

Methodology and Assumptions

$EFLH_{COOL}$ were determined from based prototypes building models on the California DEER study prototypes modified Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Assumed ventilation rates complied with the requirements of ASHRAE standard 62.1 – 2004.

Methodology assumes 30% savings for VAV over CV systems. Savings were derived through energy modeling using fixed dry bulb control with a high temperature limit of 65˚F.

Incremental costs include controls and programming and assume similar cost between dx and water cooled equipment.

Savings assume economizer is given preference over demand control ventilation strategy.

Notes

Current code requires incorporation of economizer on all cooling systems 2.75 tons and greater for all three Minnesota weather zones with exceptions (Ref 8):

1. Where more than 25% of the air designed to be supplied by the system is to spaces that are designed to be humidified above 35°F (1.7 °C) dew-point temperature to satisfy process needs.
2. Systems expected to operate less than 20 hours per week.
3. Where the use of *outdoor air* for cooling will affect supermarket open refrigerated casework systems.

References

1. "Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures", by GDS Associates, Inc. June 2007, pg. 6
2. "Economizers for Packaged Air Systems", Energy Efficiency Office, Department of Natural Resources, Canada
3. Calculated through energy modeling by FES 2012
4. "ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment"
5. "Small Commercial HVAC, Surveying the Frontier of Energy Efficiency", by Lee DeBallie, PE – Energy Center of Wisconsin
6. Calculated through energy modeling of California DEER study prototypes modified by Illinois field data with TMY3 Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3) by FES 2012
7. Calculated from the inverse of 0.7. Typical energy consumption of VAV systems are 70% of CV systems. Multiplier verified through energy modeling by FES 2012 and modeling results verified by "Energy Cost and IAQ Performance of Ventilation Systems and Controls – Project Report#2: Assessment of CV and VAV Ventilation Systems and Outdoor Air Control Strategies", pg. 7, by Indoor Environmental Division, EPA, January 2000

8. 2015 Minnesota Energy Code, Section C403.3.1 Economizers.

Revision History

Version	Description	Author	Date
1.0	New EUI measure based on existing C/I measure	GDS Associates	11/21/2016
2.0	Added option for economizer repair	Mark Garofano	11/2018

Electric Utility Infrastructure HVAC – Unitary and Split Systems

Measure Detail	Measure Value
Measure ID	4.02.04
Target Market Segments	Infrastructure – Generation Facilities; Utility-owned sites
Target End Uses	HVAC
Applicable To	Electric Utility Infrastructure
Actions	Replace on Fail, Replace Working, New Construction
Required from Customer/Contractor	New equipment type, new equipment nominal cooling capacity in tons, new equipment EER/SEER, building type (refer to Table 1), project location (county)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	20 years (Ref. 1)
Unit Participant Incremental Cost	See Table 2

Measure Description

This measure includes installation of electric DX packaged, split, and condensing units; and PTACs in replacement and new construction applications. This measure analyzes the cooling savings potential of the installation of higher efficiency air-conditioning equipment. This measure is applicable to DX cooling only, DX cooling and electric heat, and DX cooling and gas heat units. The incremental cost is associated with base equipment cost and does not include any installation costs. This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithms

Unit kWh Savings per Year = Size x (12/SEER_base – 12/SEER_EE) x (EFLH_cool) (for packaged, split units less than or equal to 5.4 tons, and PTAC units)

Unit kWh Savings per Year = Size x (12/IEER_base – 12/IEER_EE) x (EFLH_cool) (for packages and split units greater than 5.4 tons)

Unit Peak kW Savings = Size x (12/EER_base – 12/EER_EE) x CF

Where:

Size = Nominal cooling capacity in tons of the new equipment (1 ton = 12,000 btu/h)

SEER_base = Seasonal energy efficiency ratio of the baseline equipment, based on federal manufacturing requirements. See Table 2 for DX Packaged, Split and Condensing Units; for PTAC units.

SEER_EE = Seasonal energy efficiency ratio of the high-efficiency equipment, provided by the customer/contractor.

IEER_base = Integrated energy efficiency ratio of the baseline equipment, based on federal manufacturing requirements. See Table 2 for DX Packaged, Split and Condensing Units.

IEER_EE = Integrated energy efficiency ratio of the high-efficiency equipment, provided by the customer/contractor.

EFLH_cool = the equivalent full load hours of HVAC equipment operation. If the proposed project will serve a unique space, an estimate for $EFLH_{COOL}$ should be made and justification should be provided in the project documentation. If the space is similar to one of the building types listed in Table 1, the hours from that table can be used. If no estimate can be made and no building types in Table 1 match the proposed space, the Miscellaneous value from Table 1 should be used.

EER_base = Energy efficiency ratio of the baseline equipment, based on federal manufacturing requirements. See Table 2 for DX packaged, split, and condensing units; see Table 3 for PTAC units.

EER_EE = Energy efficiency ratio of the high-efficiency equipment, provided by the customer/contractor. If unknown, useEER = 1.12 x SEER – 0.02 x $SEER^2$ (Ref. 2)

CF = Deemed coincidence factor, equal to 0.9 (Ref. 3)

Example:

Retrofit packaged rooftop installed in a generation facility with estimated 865 effective full load run hours, 7.5 ton cooling capacity, IEER 12.5, EER 12, Climate Zone 3.

Unit kWh Savings per Year = 7.5 x (12 / 11.2 - 12 /12.5) x 865 = 723 kWh

Unit Peak kW Savings per Year = 7.5 x (12 /11 - 12 /12) x 0.9 = 0.614 KW

Deemed Input Tables

Table 1. Equivalent Full Load Hours of cooling per zone in Minnesota by building type (Ref. 4)

Building Type	Zone 1	Zone 2	Zone 3
Office-Low Rise	257	359	446
Office-Mid Rise	373	529	651
Office-High Rise	669	1061	1263
Warehouse	164	343	409
Other/Miscellaneous	443	612	729

Table 2. Deemed baseline efficiency and incremental costs for DX Packaged, Split, and Condensing Units (Ref. 5, 6, 7)

Equipment	SEER_base or IEER_base*	EER_base*	Incremental Cost
DX Condensing Units > 11.3 tons	14.0	10.5	$100/ton
DX Packaged and Split Units <= 5.4 tons	13.0	11.4	$165/ton
DX Packaged and Split Units 5.5-11.3 Tons	11.2	11.0	$150/ton
DX Packaged and Split Units 11.4-19.9 Tons	11.0	10.8	$140/ton
DX Packaged and Split Units 20-63.3 Tons	9.9	9.8	$125/ton
DX Packaged and Split Units > 63.3 tons	9.6	9.5	$110/ton

*Efficiency values take from ASHRAE 90.1-2010 Table C403.2.3(1) for units with gas heating, for units with no heating or electric resistance heating add 0.2 to the above values.

Table 3. Deemed baseline efficiency and incremental costs for PTAC Units (Ref. 5, 7)

Equipment	Cooling Capacity (Btu/h)	EER_base	Incremental Cost
PTAC, Standard Size (used for New Construction)	< 7,000	11.7	$250/ton
	7,000-15,000	13.8 - (0.300 x Cap/1000)	$250/ton
	> 15,000	9.3	$250/ton
PTAC, Non-Standard Size (used for Replacements* only)	< 7,000	9.4	$250/ton
	7,000-15,000	10.9 - (0.213 x Cap/1000)	$250/ton
	> 15,000	7.7	$250/ton

*Replacement unit shall be factory labeled as follows "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS", Replacement efficiencies apply only to units with existing sleeves less than 16 inches (406mm) in height and less than 42 inches (1067 mm) in width.

Methodology and Assumptions

EFLH_Cool data based on DOE2/eQuest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Assumed ventilation rates complied with the requirements of ASHRAE standard 62.1 - 2004.

References

1. ASHRAE Owning and Operating Equipment Data Base - Equipment Life/Maintenance Cost Survey
2. ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment
3. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified.
4. Calculated through energy modeling of California DEER study prototypes modified by Illinois field data with TMY3 Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3) by FES 2012

5. Title 10, Code of Federal Regulations, Part 431 - Energy Efficiency Program for Certain Commercial and Industrial Equipment, Subpart F - Commercial Air Conditioners and Heat Pumps. January 1, 2010.
6. Xcel MN Workpapers 2010
7. Based on a review of TRM incremental cost assumptions from Vermont, Wisconsin, and California. This assumes that baseline shift from IECC 2006 to IECC 2009 carries the same incremental costs.
8. C/I HVAC – Unitary and Split Systems Measure. State of Minnesota Technical Reference Manual for Energy Conservation Improvement Programs Version 2.0. Effective: January 1, 2017 – December 31, 2019.

Revision History

Version	Description	Author	Date
1.0	New EUI measure based on existing C/I measure	GDS Associates	11/21/2016

Electric Utility Infrastructure HVAC – Variable Speed Drives

Measure Detail	Measure Value
Measure ID	4.02.05
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	HVAC
Applicable To	Electric Utility Infrastructure for space heating and cooling applications
Actions	Modify, Replace Working (Retrofit), New Construction (limited sizes, see Notes)
Required from Customer/Contractor	Horsepower, application type, motor efficiency, annual operating hours
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	0
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	See Table 1 (Ref.2)

Measure Description

This measure applies to variable speed drives installed on HVAC systems including;

- HVAC Fans - supply fans, return fans, and cooling tower fans
- HVAC Pumps - hot water heating and chilled water cooling pumps

The VSD will vary the speed of the motor in a HVAC application with a diversified load.

In the applicable HVAC applications, the power of the motor is approximately proportional to the cube of the speed, providing significant energy savings.

Measure Cost

Actual costs should be used, if known. For smaller motors (< 20 hp), default project costs are given in the following table (Ref. 2). VSDs installed on larger motors must use actual costs.

Table 5. Incremental Cost by Motor Horsepower (Ref. 2)

HP	Cost
1 - 5 hp	$ 1,330
7.5 hp	$ 1,622
10 hp	$ 1,898
15 hp	$ 2,518
20 hp	$ 3,059

Algorithms

Annual kWh Savings = (0.746 x hp x LF / Eff x Hours x ESF

Where:

0.746 = Conversion from hp to kW

hp = Rated Motor horsepower. Actual value.

LF = Motor load factor at the pump or fan design flow rate. Use actual value if known. If unknown, use default value of 65% (Ref. 3).

Eff = Efficiency of motor. Use actual value if known. If unknown, use default NEMA premium efficiency rating by size and type of motor found in Table 4 (Ref. 4).

Hours = Annual operating hours. Actual run hours must be used; justification for run hours assumption must be included in project documentation.

ESF = Energy Savings Factor. ESF is the sum product of DutyCycle and PLR_{BASE} across all flow rates, minus the sum product of DutyCycle and PLR_{EFF} across all flow rates. See Table 5 below for example ESF values.

$$= \sum_{0\%}^{100\%} (\text{DutyCycle} \times PLR_{BASE}) - \sum_{0\%}^{100\%} (\text{DutyCycle} \times PLR_{EFF})$$

DutyCycle = Percentage of motor runtime at each flow rate. At generation facilities, it is expected that a duty cycle will be known with a reasonable degree of accuracy. Duty Cycle should be in the form of Table 2 below. See Table 3 for an example Duty Cycle.

Table 2. Duty Cycle Format

Flow Rate (Percentage of design flow)	Duty Cycle (Percentage of motor runtime at each flow rate)
0% to 10%	
10% to 20%	
20% to 30%	
30% to 40%	
40% to 50%	
50% to 60%	
60% to 70%	
70% to 80%	
80% to 90%	
90% to 100%	

PLR_{BASE} = Part Load Ratio for the baseline control strategy. The ratio of percentage of peak power draw that occurs at each flow rate percentage. Consult Table 6 to find PLR_{BASE} values depending on the existing control strategy.

PLR_{EFF} = Part Load Ratio for the VSD. The ratio of percentage of peak power draw that occurs at each flow rate percentage. Consult Table 6 to find PLR_{EFF} values. They should either be the Pump VSD or Fan VSD values.

Example:

A 100 hp boiler feedwater pump currently using a throttling valve is retrofitted with a VSD. The pump runs for 3,000 hours per year, the motor load factor is 90% and the motor efficiency is 95%. The motor duty cycle is found in Table 3 below.

ESF is calculated using example the duty cycle in Table 3, PLR_{BASE} (from Table 6 – pump throttling valve values), and PLR_{EFF} (from Table 6 – pump VSD values).

Table 3. Example ESF Calculation (Ref. 6)

Flow Rate (Percentage of design flow)	Example Duty Cycle (Percentage of motor runtime at each flow rate)	PLR_{BASE} (Throttling Valve)	PLR_{EFF} (VSD)
10% to 20%	6%	0.67	0.06
20% to 30%	11%	0.73	0.09
30% to 40%	13%	0.78	0.12
40% to 50%	17%	0.82	0.18
50% to 60%	24%	0.87	0.27
60% to 70%	17%	0.90	0.39
70% to 80%	9%	0.94	0.55
80% to 90%	2%	0.97	0.75
90% to 100%	1%	1.00	1.00

ESF = [(0.06 x 0.67) + (0.11 x .73) +(0.13 x 0.78) + (0.17 x 0.82) + (0.24 x 0.87) + (0.17 x 0.90) + (0.09 x 0.94) + (0.02 x 0.97) + (.01 x 1.0)] – [(0.06 x 0.06) + (0.11 x 0.09) + (0.13 x 0.12) + (0.17 x 0.18) + (0.24 x 0.27) + (0.17 x 0.39) + (0.09 x 0.55) + (0.02 x 0.75) + (0.01 x 1)] = 0.8371 – 0.2653 = 0.5718

Unit kWh Savings per Year = (0.746 x 100 x 0.90 / 0.95) x 3,000 x 0.5718 = 121,234 kWh

Deemed Input Tables

Table 4. Default NEMA Premium Motor Efficiencies (Ref. 4)

Size HP	Open Drip Proof (ODP)			Totally Enclosed Fan-Cooled (TEFC)		
	# of Poles			# of Poles		
	6	4	2	6	4	2
	Speed (RPM)			Speed (RPM)		
	1200	1800 Default	3600	1200	1800	3600
1	0.825	0.855	0.770	0.825	0.855	0.770
1.5	0.865	0.865	0.840	0.875	0.865	0.840
2	0.875	0.865	0.855	0.885	0.865	0.855
3	0.885	0.895	0.855	0.895	0.895	0.865
5	0.895	0.895	0.865	0.895	0.895	0.885
7.5	0.902	0.910	0.885	0.910	0.917	0.895
10	0.917	0.917	0.895	0.910	0.917	0.902
15	0.917	0.930	0.902	0.917	0.924	0.910

Size HP	Open Drip Proof (ODP)			Totally Enclosed Fan-Cooled (TEFC)		
	# of Poles			# of Poles		
	6	4	2	6	4	2
	Speed (RPM)			Speed (RPM)		
	1200	1800 Default	3600	1200	1800	3600
20	0.924	0.930	0.910	0.917	0.930	0.910
25	0.930	0.936	0.917	0.930	0.936	0.917
30	0.936	0.941	0.917	0.930	0.936	0.917
40	0.941	0.941	0.924	0.941	0.941	0.924
50	0.941	0.945	0.930	0.941	0.945	0.930
60	0.945	0.950	0.936	0.945	0.950	0.936
75	0.945	0.950	0.936	0.945	0.954	0.936
100	0.950	0.954	0.936	0.950	0.954	0.941
125	0.950	0.954	0.941	0.950	0.954	0.950
150	0.954	0.958	0.941	0.958	0.958	0.950
200	0.954	0.958	0.950	0.958	0.962	0.954
250	0.954	0.958	0.950	0.958	0.962	0.958
300	0.954	0.958	0.954	0.958	0.962	0.958
350	0.954	0.958	0.954	0.958	0.962	0.958
400	0.958	0.958	0.958	0.958	0.962	0.958
450	0.962	0.962	0.958	0.958	0.962	0.958
500	0.962	0.962	0.958	0.958	0.962	0.958

Table 5. HVAC Fan Run Hours for Various Building Types (Ref. 7, see Notes)

Building Type	Total HVAC Fan Run Hours	Heating Pump Run Hours	Cooling Pump and Cooling Tower Fan Run Hours
Large Office	6,704	5,346	2,456
Medium Office	6,534	3,537	2,337
Small Office	6,198	3,858	2,516
Warehouse	6,434	5,305	564

Table 6. Suggested Duty Cycle for HVAC Fans and Pumps (Ref. 8)

Flow Fraction (Percentage of design flow)	Percentage of Time at Flow Fraction
0% to 10%	0.0%
10% to 20%	1.0%
20% to 30%	5.5%
30% to 40%	15.5%
40% to 50%	22.0%
50% to 60%	25.0%
60% to 70%	19.0%
70% to 80%	8.5%
80% to 90%	3.0%
90% to 100%	0.5%

Table 7. Part Load Ratio for Flow rate bins Based on Control Types for Pumps (Ref. 5) and Fans (Ref. 6)

Control Type	Flow rate (percentage of design flow)								
	10% to 20%	20% to 30%	30% to 40%	40% to 50%	50% to 60%	60% to 70%	70% to 80%	80% to 90%	90% to 100%
Pump Baseline values ($PLR_{Baseline}$)									
No Control	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bypass Valve	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Throttling Valve	0.67	0.73	0.77	0.82	0.87	0.90	0.94	0.97	1.00
Pump VSD value (PLR_{EFF})									
VSD – pump	0.06	0.09	0.12	0.18	0.27	0.39	0.55	0.75	1.0
Fan Baseline values ($PLR_{Baseline}$)									
No Control or Bypass Damper	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Discharge Dampers	0.55	0.63	0.7	0.77	0.83	0.88	0.93	0.97	1.00
Outlet Damper, Backward Inclined & Airfoil Fans	0.53	0.57	0.64	0.72	0.80	0.89	0.96	1.02	1.05
Inlet Damper Box	0.60	0.62	0.64	0.66	0.69	0.74	0.81	0.92	1.07
Inlet Guide Vane, Backward Inclined & Airfoil Fans	0.56	0.57	0.59	0.60	0.62	0.67	0.74	0.85	1.00
Inlet Vane Dampers	0.40	0.42	0.44	0.48	0.53	0.60	0.70	0.83	0.99
Outlet Damper, Forward Curved Fans	0.26	0.30	0.37	0.45	0.54	0.65	0.77	0.91	1.06
Eddy Current Drives	0.20	0.25	0.32	0.41	0.51	0.63	0.76	0.90	1.04
Inlet Guide Vane, Forward Curved Fans	0.22	0.23	0.26	0.31	0.39	0.49	0.63	0.81	1.04
Fan VSD value (PLR_{EFF})									
Fan - VSD	0.10	0.11	0.15	0.20	0.29	0.41	0.57	0.76	1.01

Notes

Hours of use for equipment come from the U.S. Department of Energy's Commercial Reference Buildings (Ref. 7). These standardized building models have typical HVAC systems, and were simulated with Minneapolis weather. This produced energy usage and run times for various HVAC equipment including fans and pumps. The run times are used for hours of use values. HVAC fans existed as discrete equipment for every building type. Pump heating hours were derived by summing the hours that both pumps and gas heat were in use. Pump cooling hours were derived by summing the hours that both pumps and electric cooling were in use. HVAC cooling tower fans are assumed to have the same hours of use as cooling pumps. The standalone retail, strip mall, and warehouse reference buildings did not have pumps in their HVAC systems. Their heating and cooling pumps are assumed to operate whenever their gas heat and electric cooling, respectively, are operating.

Speed or capacity control is required by the 2015 Minnesota energy code by size and application; for VAV fan units greater than or equal to 7.5 Hp without variable pitch fan blades, non-multi-stage

hydronic pumping systems with a design output greater than 300,000 Btu/h, heat rejection fans greater than or equal to 7.5 hp.

It is generally accepted that VSDs provide this capacity control for these sizes, and should be considered the baseline for New Construction

Operation below 30% of design speed is not recommended.

References

1. 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008
2. Ohio TRM 8/6/2010 varies by motor/fan size based on equipment costs from Granger 2008 Catalog pp 286-289, average across available voltages and models. Labor costs from RS Means Data 2008 Ohio average cost adjustment applied.
3. U.S. Department of Energy. *Improving Motor and Drive System Performance; A Sourcebook for Industry*. 2008. Page 18. https://www.energy.gov/sites/prod/files/2014/04/f15/amo_motors_sourcebook_web.pdf
4. Douglass, J. (2005). Induction Motor Efficiency Standards. Washington State University and the Northwest Energy Efficiency Alliance, Extension Energy Program, Olympia, WA. Also listed in the IL Statewide TRM. Retrieved online 12/12/16 at: http://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/motor_efficiency_standards.pdf
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Revision History

Version	Description	Author	Date
1.0	New EUI measure based on existing C/I measure	GDS Associates	11/21/2016
2.0	Updated calculation approach and default values, requiring custom hours of use	Mark Garofano	11/2018

Compressed Air

Electric Utility Infrastructure Compressed Air – Compressed Air Leak Detection

Measure Detail	Measure Value
Measure ID	4.06.01
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Industrial Process
Applicable To	Electric Utility Infrastructure
Actions	Operation and Maintenance
Required from Customer/Contractor	Number of Leaks Repaired, Leak size (CFM), Air Compressor Type, Air Compressor Control Strategy, and Annual operating hours of compressor The customer must also maintain a 2 or 3 tag leak detection, repair, and monitoring system to receive incentives. Incentives can only be paid after the detected leaks have been repaired, and tested to ensure the repairs were actually performed.
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	1 (Ref. 1)
Unit Participant Incremental Cost	$8 per horsepower (Ref. 2)

Measure Description

This measure shows the energy savings potential associated with reducing compressed air losses through ultrasonic leak detection, and the repair of compressed air leaks. Compressed air leaks can be responsible for as much as 20-30% of the total air compressor output in a facility. This measure is applicable for compressed air systems in utility-owned sites (such as generation facilities) where they are used for blow off, pneumatic tools, and or a variety of other processes.

The incremental cost is associated with base equipment cost and does not include any installation costs.

This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithms

Unit kWh Savings per Year = N_leaks x CFM_leaks x C_aircomp x t x Control_factor

Unit Peak kW Savings = (unit kWh Savings per Year x CF)/t

Where:

N_leaks = Number of leaks repaired

CFM_leaks = CFM loss per leak (review table 1)

C_aircomp = See Table 2. If unknown compressor type, use 0.19 kW/CFM (Ref. 3)

Control_factor = See Table 3. If unknown control type, use 0.3 %kW/%load (Ref. 4)

t = Hours of operation per year. If unknown, use default of 6136 (Ref. 5)

CF = Coincidence Factor (0.845) (Ref. 6)

Example:

An ultrasonic leak detection service is performed at the facility, and identifies 10 small leaks, of 1/64th inch diameter. Assumptions:

- Facility Operates at 100 PSIG
- Facility Operates 3 Shifts (6240 hours per year)
- Single-acting Reciprocating Air Compressor
- Inlet Valve Modulated Compressor Controls

Using the cfm value from Table 1 for a very small leak

Unit kWh Savings per Year = 10 x 0.41 x .23 x 6,240 x .31 = 1,824 kWh/year

Unit Peak KW Savings per Year = (1,824 x 0.845)/6,240 = 0.247 KW

Deemed Input Tables

Table 1. CFM per Leak Size for Compressed Air Leaks* (Ref. 7)

Pressure (psig)	Orifice Diameter (inches)					
	1/64	1/32	1/16	1/8	1/4	3/8
70	0.3	1.2	4.8	19.2	76.7	173
80	0.33	1.3	5.4	21.4	85.7	193
90	0.37	1.5	5.9	23.8	94.8	213
100	0.41	1.6	6.5	26	104	234
125	0.49	2	7.9	31.6	126	284

*Leak Loss Recorded in [CFM]

Table 2. kW/CFM efficiencies for several compressor types* (Ref. 3)

Type	Efficiency
Single-acting Reciprocating Air Compressor	0.23 kW/CFM
Double-acting Reciprocating Air Compressor	0.155 kW/CFM
Lubricant-injected Rotary Screw Compressor	0.185 kW/CFM
Lubricant-free Rotary Screw Compressor	0.2 kW/CFM
Centrifugal Compressor	0.18 kW/CFM
AVERAGE:	**0.19 kW/CFM**

*Data from Compressed Air Challenge "Fundamentals of Compressed Air Systems" Pg 28-32

Table 3. Efficiency Factors per control type for air compressors (Ref. 4)

Control Type	%kW/%load
Inlet Valve Modulated	0.31
Variable Displacement	0.69
Variable Speed Drive	0.85

*Data extrapolated from Compressed Air Challenge "Fundamentals of Compressed Air Systems" Pg 90-91

Methodology and Assumptions

Assumptions were made based on average data for several different types of air compressors from Fundamentals of Compressed Air. Averages were assumed for compressor type to make calculations simpler.

Notes

Savings are based on a load-unload control style compressor. Load-unload style compressors will have much less savings than their VSD or Variable Displacement counterparts. There are limited studies available on the market saturation of VSD air compressors, and therefore estimates based on the load-unload model are more conservative, and more likely.

References

1. 1 year measure life is based on typical recommendation of annual leak survey.
2. Engineering estimate: estimated from previous project cost data review and engineering judgment.
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5. US DOE, Evaluation of the Compressed Air Challenge® Training Program, Page 19
6. KEMA, New Jersey's Clean Energy Program Energy Impact Evaluation and Protocol Review, July 10, 2009.
7. "Energy Tips: Minimize Compressed Air Leaks" http://www.energystar.gov/ia/business/industry/compressed_air3.pdf
8. Industrial Compressed Air – Compressed Air Leak Detection Measure. State of Minnesota Technical Reference Manual for Energy Conservation Improvement Programs Version 2.0. Effective: January 1, 2017 – December 31, 2019.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

Electric Utility Infrastructure Compressed Air – No Loss Drains

Measure Detail	Measure Value
Measure ID	4.06.02
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Industrial Process
Applicable To	Electric Utility Infrastructure
Actions	Replace Working, Replace on Fail
Required from Customer/Contractor	CAGI Data Sheet for Air Compressor, Annual Hours of Operation
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	13 (Ref. 5)
Unit Participant Incremental Cost	$450/drain (Ref. 4)

Measure Description

This measure includes replacement of a failed or working open tube, timed, or manual condensate drain in a compressed air system with a qualified electronic, pneumatic, or hybrid "no loss drain" that is designed to automatically adjust with system demand and completely eliminate condensate with zero compressed air loss. This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithms

Unit kWh Savings per Year = kW_100_CFM x Hours x Drain_CFM/100

Unit Peak kW Savings = kW_100_CFM x Drain_CFM x CF/100

Where:

kW_100_CFM = Compressor efficiency, kW/100 CFM as listed on Compressed Air and Gas Institute (CAGI) datasheet. 20 kW/100 CFM is default value

Hours = Annual hours of operation. Use actual if known, If unknown, use 6136 hr default value. (Ref. 2)

Drain_CFM = Average CFM of existing drain, 3 CFM (Ref. 3)

CF = Coincidence Factor = 0.80

Example:

Install a no loss drain on a 40 hp compressed air system, with a CAGI efficiency of 16 kW/100CFM and running 2,000 hr/yr

Unit kWh Savings per Year = 16 x 3 x 2000 / 10 = 960

Unit kW Savings per Year = 16 x 3 x 0.8 / 100 = 0.39

Notes

The default value of 20 kW/100 cfm is from a market survey of 5 yr old model air compressor systems. Kaeser, Sullair, Ingersoll Rand

The average drain loss (cfm) assumes a timed drain system operating approximately 5% of the time. Average size is 1/4" orifice.

Focus on Energy (WI) and New York Standard Approach uses a CF = 0.80.

Consider updating default hours in future update.

References

1. US Department of Energy. Improving Compressed Air System Performance - A Sourcebook for Industry. November 2003.
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3. Orr, Ross. The Importance of Condensate Drains on Air System Efficiency. airbestpractices.com. May 2012.
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6. Industrial Compressed Air – No-Loss Drains Measure. State of Minnesota Technical Reference Manual for Energy Conservation Improvement Programs Version 2.0. Effective: January 1, 2017 – December 31, 2019.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

Electric Utility Infrastructure Compressed Air – VSD Air Compressors < 50 hp

Measure Detail	Measure Value
Measure ID	4.06.03
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Industrial Process
Applicable To	Electric Utility Infrastructure
Actions	Replace Working, Replace on Fail, New Construction
Required from Customer/Contractor	CAGI Data sheet (new), CAGI Data sheet (existing) or nameplate data, Compressed air system operating hours Optional inputs: Annual facility hours where compressed air is required
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	15 (Ref. 1)
Unit Participant Incremental Cost	$428/hp (Replace Working) or $100/hp (Replace on Fail or New Construction)

Measure Description

This measure includes replacement of an inlet modulated, variable displacement, or load/no load controlled air compressor units < 50 hp with variable speed drive (VSD) controlled units. Base load units do not qualify. This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithms

Unit kWh Savings per Year = hp x SF x C x Hours

Unit Peak kW Savings = hp x SF x C x CF

Where:

hp	=	nominal horsepower of VSD air compressor motor
SF	=	Savings Factor: reference Table 1
Hours	=	annual facility hours where compressed air is required. Use actual if known. If unknown, use default 4024 (Ref. 2)
C	=	conversion constant = 0.746 kW/hp
CF	=	coincidence factor, Default = 0.95

Example:

Replace an inlet modulated 25 hp air compressor with a 25 hp VSD air compressor.

Unit kWh Savings per Year = 25 x 18% x 0.746 x 4024 = 13,509 kWh

Unit kW Savings per Year = 25 x 18% x 0.746 x 0.95 = 3.2 kW

Deemed Input Tables

Table 1. Savings factor for VSD replacing existing control strategy (Ref. 3)

	Existing Control		
	Inlet Modulating	Load/No Load	Variable Displacement
% Savings Factor	18%	15%	6%

Notes

$428/hp from surveyed cost from MI and Ohio implemented projects. Full install cost for "replace working"

$100/hp is the incremental cost for replace upon fail or new construction

Focus on Energy (WI) and New York Standard Approach uses a CF = 0.80. The Illinois TRM lists CF = 0.95 and Vectren lists it at 1.0.

Savings factor assumes 75% loaded and the savings factor was interpolated from the part load curves of reference 3 (pages 43-45)

References

1. Measure Life Study. Energy & Resource Solutions. Prepared for the Massachusetts Joint Utilities; Table 1-1. 2005.
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4. Industrial Compressed Air – Variable Speed Drive Air Compressors < 50 hp Measure. State of Minnesota Technical Reference Manual for Energy Conservation Improvement Programs Version 2.0. Effective: January 1, 2017 – December 31, 2019.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

Miscellaneous

Electric Utility Infrastructure Misc. – Conservation Voltage Reduction

Measure Detail	Measure Value
Measure ID	4.11.01
Target Market Segments	Infrastructure
Target End Uses	Distribution
Applicable To	Electric Utility Infrastructure - Retrofit existing distribution equipment or add to new construction design plans
Actions	Retrofit, New Construction
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	0
Measure Lifetime (years)	See Measure Life section
Unit Participant Incremental Cost	See Measure Cost section

Measure Description

This measure defines a protocol for determining energy savings from installing an automatic conservation voltage regulation (CVR) system, also called an automated voltage feedback control system or a voltage optimization system.

For the purposes of this TRM, CVR is defined as controlling distribution substation source voltage and/or feeder line voltage(s) so end-use loads consume less energy. The system uses source voltage regulators or transformer load tap changers (LTCs) to automatically adjust voltages based on remote end-of-line (EOL) voltage sensing. All voltages affected by the CVR system, including source voltage, line voltages, and all affected EOL voltages are collectively referred to as the Voltage Control Zone (VCZ).

CVR systems can use existing or concurrently deployed AMI technology to gather EOL voltage measurements by polling meters or monitoring meter voltage alarms. CVR systems can also be implemented with dedicated EOL voltage sensors. For all types of installations, when the EOL voltage rises or falls outside designed setpoints, the CVR system continuously adjusts source voltage to bring EOL voltage back within setpoints. The system should measure and log source voltage, collected EOL voltage(s), delivered real power, and delivered reactive power. The system should also record hourly local temperature either by direct measurement or by accessing the nearest NOAA weather station feed. Fixed voltage reduction and line drop compensation (source voltage adjusted based on feeder load level) projects are not eligible to use this measure.

The savings calculation for this measure is divided into two methods: estimated savings and measured savings. Studies show there is some variance in savings achieved by CVR projects, and predictive tools are not yet highly accurate. Therefore, the estimated savings methodology intentionally results in a conservative savings value. Measured savings are more accurate and likely to be greater but require one year of system performance data to calculate. Users may choose to combine the methods to claim

estimated savings immediately upon project completion and the remainder of measured savings the following year. In all cases, project parameters (including CVR system characteristics, cost, and expected measure lifetime) must be justified by accompanying project documentation.

This measure should be used only for calculating savings from installing CVR and not as an engineering design tool. When installing CVR, ensure all appropriate codes and standards are followed. Of particular importance, feeders with CVR installed must still deliver EOL voltage within the range required by ANSI C84.1.

Measure Life

Savings from CVR can persist indefinitely as long as the system is properly maintained and regularly recalibrated. A maximum measure life of 15 years can be used if project supporting documentation includes a plan to ensure persistence of energy savings. (Ref. 1) (Ref. 2) For an example, see Appendix E. Without such a plan the measure life is assumed to be three years.

Measure Cost

Actual project costs should be used. Invoices showing the full materials, software communication infrastructure, and labor costs to design and install an automatic CVR system should be included with project documentation. If measured savings are claimed, labor costs to conduct required system performance measurements and modeling in the first year of operation are also included in the project cost. The cost of AMI deployment does not count toward the cost of implementing CVR unless it is used solely for CVR purposes.

Definition of Baseline Conditions

The baseline condition for this measure is a distribution substation and feeder(s) with no Conservation Voltage Reduction control system installed. Project documentation should include existing baseline voltage setpoint and bandwidth values for the affected substation and feeder(s).

Definition of Post-Install Conditions

The post-install condition for this measure is a distribution substation with an automatic CVR control system installed on at least one feeder. The system must be able to engage and disengage remotely. It must automatically, continuously regulate source and/or line voltages in response to EOL voltage measurements.

For the purpose of calculating savings, the system must measure and record the period averages for the following at least hourly: source voltage on all phases, EOL voltages used for CVR feedback, system kW, system kVAR, and local temperature. For each period, the system must also record whether the CVR system is engaged or disengaged. Each of these data points should include the date and time of measurement.

Savings Overview

Savings for this measure can be calculated using two different methods. The first is estimated savings based on historical energy data from the VCZ, a load flow software simulation, and provided inputs

based on studies of CVR performance. Estimated savings can be claimed upon project completion. The estimated savings methodology intentionally results in a conservative savings value. This is done to allow flexibility in system design and to account for variability in system performance, while preserving a relatively simple calculation methodology.

The second method is based on measured system performance. Measured savings can be claimed after one year of monitoring system operation. Calculating measured savings requires monitoring the VCZ with CVR engaged and with CVR disengaged to build a statistical analysis of the system's performance.

Measure users may choose to use both methods for the same project. Estimated savings can be claimed immediately upon project completion and additional measured savings can be claimed the following year if measured savings are greater than the estimated savings. Because estimated savings are intentionally conservative, measured savings are likely to be greater than estimated savings.

CVR added to the design of a new distribution substation cannot use the estimated savings methodology; those projects must use the measured savings methodology.

Algorithms

Estimated Annual kWh Savings $= PreEnergy \times CVRF \times EstimatedPercentVR \times AdjustmentFactor$

Measured Annual kWh Savings (Ref. 3) $= \left(\sum_{i}^{8,760} OffEnergy_i - OnEnergy_i\right) - (ClaimedEstimatedSavings)$

Required supplemental calculated values

$$MeasuredPercentVR_i = \frac{(PreVoltage - OnVoltage_i)}{PreVoltage}$$

$$CVRF_i = \frac{\left[\frac{(OffEnergy_i - OnEnergy_i)}{OffEnergy_i}\right]}{\left[\frac{(PreVoltage - OnVoltage_i)}{PreVoltage}\right]}$$

Where:

PreEnergy	=	Total energy delivered to the VCZ over the period of one year prior to the CVR system operating (kWh). This can be measured either directly at the substation source or can be the sum of energy consumption over one year at all EOL applications within the VCZ.
EstimatedPercentVR	=	Average percentage reduction in the controlled source voltage enabled by CVR over the period of one year. Developed from software load flow simulations.
AdjustmentFactor	=	50%. Factor used to ensure estimated savings are conservative.
i	=	an index that defines an hour of the year for which each value of time-series variables apply.

$OnEnergy_i$	=	Total energy delivered in the VCZ during period i with the CVR system operating (kWh). Developed from a statistical model using measurements of the VCZ with the CVR system engaged.
$OffEnergy_i$	=	Total energy delivered in the VCZ during period *i* with the CVR system disengaged (kWh). Developed from a statistical model using measurements of the VCZ with the CVR system disengaged.
$MeasuredPercentVR_i$	=	Average percentage reduction in the controlled source voltage for period *i* enabled by CVR. Developed from a statistical model using measurements of the VCZ with the CVR system engaged.
PreVoltage	=	Source voltage setting prior to installing CVR (volts).
$OnVoltage_i$	=	Average source voltage for period i while CVR is engaged (volts). Developed from a statistical model using measurements of the VCZ with the CVR system engaged.
$CVRF_i$	=	CVR Factor for period *i* is the ratio of the percentage of the change in energy delivered for every 1% change in average voltage. For estimated savings, a single, weighted average value of CVRF is used for all periods (Table 1 below). For measured savings, CVRF values and the periods (*i*) they apply to are determined using linear regression analysis. See Savings Methodology below for determining CVRF values.
ClaimedEstimatedSavings	=	Identical to Estimated Annual kWh Savings if those savings have already been claimed prior to calculating measured savings. If Estimated savings were not claimed for this project, the value is 0.

Savings Methodology

Method One – Estimated Savings

Before implementation, savings for a proposed CVR project are determined using historical energy consumption data for the VCZ, a load flow software simulation to produce an estimated voltage reduction value, and an estimated CVRF value found in Table 1 below. Project supporting documentation should include justification for all values used to calculate savings.

The value for PreEnergy should come from historical load profile data for the proposed VCZ. SCADA data for the substation is likely the best source for this data. If necessary, it can come from customer billing history as long as a full accounting for all energy consumption in the VCZ can be constructed.

To generate values for EstimatedPercentVR, industry standard distribution modeling software should be used to build a load flow simulation to represent the VCZ. Most likely the model will already be defined by engineers to design the CVR system. The simulation should be adjusted such that that the minimum EOL voltage in the VCZ is controlled to be just above the lowest possible level allowed by ANSI C84.1 (116V is often used as an EOL voltage target setpoint). The resulting average percentage of reduction in source voltage predicted by the simulation over a period of one year is the value for

EstimatedPercentVR. For example, if the simulation predicts an average voltage setting of 119V and the original PreVoltage setting is 121V, the value of EstimatedPercentVR is (121-119) / 121 = 1.65%.

The actual EstimatedPercentVR value will depend on feeder length, load type, and other VCZ characteristics, so it must be produced for the specific project. However, for reference, a survey of shows that an average voltage reduction of 2.63% (Ref. 4) was achieved by installed CVR systems.

If approximate Air Conditioning and Electric Space Heat load percentages are known for the VCZ, use Table 1 below to determine an estimated CVRF value. If the end-use applications in the VCZ are unknown, use a CVRF value of 0.60 (Ref. 5). Note that for the Estimated Savings Methodology, a single average CVRF value is used for all periods.

Table 1. CVRF Values for Estimated Savings Methodology (Ref. 6)

% Space Heat of Annual Load	% Air Conditioning of Annual Load				
	<20%	20%-40%	40%-60%	60%-80%	>80%
<20%	0.800	0.825	0.850	0.875	0.900
20%-40%	0.675	0.700	0.725	0.750	0.775
40%-60%	0.550	0.575	0.600	0.625	0.650
60%-80%	0.425	0.450	0.475	0.500	0.525
>80%	0.300	0.325	0.350	0.375	0.400

Method Two – Measured Savings

After implementation, energy savings for a CVR project are determined by directly collecting data on the VCZ with CVR installed. Data is collected both with the CVR system operating and with the CVR system disengaged. From the collected data, linear regression analysis is used to construct a model of the VCZ operation for each period (*i*) of a full year. The model is developed for both an operating CVR system and a disengaged system. Comparing the two models over a full year results in the final measured savings for the CVR system.

Over the first year of operating the CVR system, there should be twelve separate weeks (one per month) in which the system alternates 24 hours engaged followed by 24 hours disengaged (it is assumed that the CVR system is engaged for the other 40 weeks of the year). The purpose is to generate data to characterize the VCZ under all conditions experienced over the year. Of special importance, the goal is to generate enough data to compare periods where all operating conditions are nearly identical except whether CVR is engaged or disengaged.

A multivariable linear regression should be run to define a model that describes VCZ conditions both with and without CVR engaged. One model should be run with $OnVoltage_i$ and $OnEnergy_i$ as the dependent variables using data from periods when the CVR system is engaged. A second model should be run with $OffEnergy_i$ as the dependent variable using data from periods when the system is disengaged. Both models should use the same set of explanatory variables. The user can choose explanatory variables to best fit the specific CVR system but will typically include local temperature, time of day, season, and weekday/weekend. At least two explanatory variables should be used to ensure that the model captures system variability over the course of a year.

Both models should produce a full year of modeled values for the dependent variables. That is, for all periods *i*, the user has modeled values of $OnVoltage_i$, $OnEnergy_i$, and $OffEnergy_i$. Using these modeled values as inputs to the time series savings algorithm defined above will allow annual energy savings to be calculated.

Because the models produce values for $OnEnergy_i$ and $OffEnergy_i$ directly, $MeasuredPercentVR_i$ and $CVRF_i$ are not needed to calculate energy savings. However, these values must be calculated according to the algorithms above for all periods *I* and submitted with the supporting project documentation.

Example:

Estimated Savings:

A proposed CVR system will be installed on a VCZ that delivers 40,000,000 kWh annually. A load flow simulation predicts that source voltage can be reduced by an average of 2.5% over the course of a year and still deliver ANSI-compliant EOL voltage to customers. The air conditioning and electric heat load percentage in the VCZ is unknown.

Annual Estimated kWh savings for the CVR system are: 40,000,000 x 2.5% x 0.60 x 50% = 300,000 kWh

Measured Savings:

As a simplified example of a linear regression model applied to one period, consider a system that collects data including time of day, weekday/weekend, temperature, and season. One measured period is 3PM on a summer weekday, the temperature is 75F and the CVR system is engaged. Source voltage is controlled by the CVR system to be 118V and the measured energy consumed in the VCZ is 10,000 kWh.

A second period occurs at 3PM on a summer weekday, the temperature is 75F and the CVR system is disengaged. Source voltage is set at the pre-CVR install level of 121V and measured energy consumed in the VCZ is 10,200 kWh.

The values of explanatory variables are identical in the two periods (weekday/weekend, season, time of day, and temperature) and define period *i* in the statistical models.

For this period *i*:

kWh savings are $OffEnergy_i$ – $OnEnergy_i$ = 10,200-10,000 = 200 kWh.

$MeasuredPercentVR_i$ = (121-118) / 121 = 2.48%

$CVRF_i$ = [($OffEnergy_i$-$OnEnergy_i$)/OffEnergyi]/$MeasuredPercentVR_i$
= [(10,200-10,000) / 10,200] / 2.48% = 0.79

This is an overly simplified example for only one period of the year. An actual multivariable linear regression model will produce statistical correlations between explanatory variables dependent variables over the set of data collected for one year.

For a specific example of modeling savings using Heating and Cooling Degree Days as explanatory variables, see the Regional Technical Forum M+V Protocol #1, Sections 9.1.3.1 – 9.1.3.2 (Ref. 6).

Notes

Potential users of this measure are encouraged to review the references listed below to gain further perspective on CVR functionality and savings potential.(Ref. 4) (Ref. 5) (Ref. 7) (Ref. 8) (Ref. 9) (Ref. 10) In particular, a report produced by the Electric Power Research Institute (EPRI) analyzing CVR tests conducted on substations operated by Sacramento Municipal Utility District (SMUD) outlines examples of actual CVR results, illustrates the range of possible outcomes, and discusses lessons learned from pilot CVR implementation.

References

1. Engineering Judgement. Based on the combined effects of limited lifetime of communication infrastructure products and frequency of substation updates. Savings from a maintained system are likely to endure longer than 15 years, but must be recalculated to account for updated conditions.
2. Regional Technical Forum, "Simplified Voltage Optimization Measurement and Verification Protocol"
3. Annual kWh Savings formula is heavily adapted, but originally based on: Regional Technical Forum Standard Protocol #1 for Automated CVR, 2012. (Section 9.2, Alternative Method)
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8. Global Energy Partners, LLC. "Utility Distribution System Efficiency (DEI): Phase 1". June, 2008.
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10. The Brattle Group. Prepared for Pepco Maryland. "Impact Evaluation of Pepco Maryland's Phase 1 Conservation Voltage Reduction (CVR) Program." July 2015.

Revision History

Version	Description	Author	Date
1.0	New measure	GDS Associates	12/02/2016

Electric Utility Infrastructure Misc. – Efficient Conductors for Transmission and Distribution Lines

Measure Detail	Measure Value
Measure ID	4.11.02
Target Market Segments	Infrastructure
Target End Uses	Transmission, Distribution
Applicable To	Transmission or Distribution Lines owned by the utility
Actions	Replace on Fail, Early Replacement, New Construction
Required from Customer/Contractor	Peak current carried by the conductor (Amperes); Baseline conductor resistance (Ohms/length); Efficient conductor resistance (Ohms/length); Length of the conductor; loss factor over the conductor or load factor if applicable
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	25 Years. The average expected lifetime of the equipment (per typical utility depreciation schedule) exceeds the ECO planning horizon, thus the measure life is capped at 25 years.
Unit Participant Incremental Cost	See Incremental Cost section

Measure Description

The size and type of conductor used on a transmission or distribution line has a significant effect on the efficiency of the line. Larger conductors and different designs have a lower resistance and thus lower I^2R losses (Ref. 1). Replacing a length of conductor (re-conductoring) with a relatively larger conductor to carry the same load has the effect of reducing the kW loss for that length.

This measure is designed to calculate the energy savings attributable to choosing to install low-loss transmission or distribution line conductors. ROF, NC, and Early Replacement scenarios are all eligible for this measure, but note that each has different baseline assumptions. ROF and NC scenarios are appropriate when a conductor is used which exceeds minimum code for the application. Early Replacement is appropriate in instances where conductors are replaced before the end of their useful lives for the purpose of energy efficiency.

In order to qualify as eligible to claim greater savings using the “Early Replacement” assumptions, the existing line must sufficiently serve an existing load, the load must not be expanding, and the existing line must have been installed less than 25 years prior to the current project. Also, there must be no changes to any other network components that affect the operating conditions of the conductor (for example, changing the voltage of the line or upgrading to higher-temperature-rated terminals). If any of these conditions are not met, use the New Construction assumptions to calculate savings.

Incremental Cost

For Replace on Fail and New Construction projects:

Actual project costs should be used to determine incremental cost. Conductor costs are volatile and heavily dependent on the price of metals, which could quickly render a deemed value inaccurate. To claim savings, the actual cost for the installed, efficient materials should be submitted with project documentation as well as a quote for the baseline materials. Incremental cost for the project is the actual cost of the proposed project materials minus the quoted price of the baseline materials.

It is assumed that labor costs for the installation are identical for the efficient and baseline cases. Therefore, incremental cost is driven by the difference in materials cost only.

For Early Replacement projects:

Actual project costs should be used. Invoices showing the full materials and labor costs for the project should be included with project documentation.

Algorithms

Single Phase:

Annual kWh Savings = Length x $(I_peak)^2$ x (R_base – R_ee) x Length x LossFactor x 8,760 / 1,000

Peak kW Savings = Length x $(I_peak)^2$ x (R_base – R_ee) / 1,000

Three Phase:

Annual kWh Savings = 3 x Length x $(I_peak)^2$ x (R_base – R_ee) x Length x LossFactor x 8,760 / 1,000

Peak kW Savings = 3 x Length x $(I_peak)^2$ x (R_base – R_ee) / 1,000

Where:

I_peak = Peak current (Amperes). Provided by customer/contractor. Use actual measured load data if possible. If no load data is available, use the design peak load multiplied by a correction factor of 0.8. For projects replacing a distribution line with varying current load, instead of calculating savings for each individual length of conductor, an average can be used: average the current at the beginning of the segment and the current at the end of the segment at peak load.

R_base = Base Conductor Resistance (Ohms/length). Provided by customer/contractor. This should come from manufacturer specifications or a recognized industry reference such as the Aluminum Electrical Conductor Handbook (excerpt in Table 2 below). When choosing the resistance value, ensure to use the appropriate temperature rating of the conductor depending on design parameters (terminal ratings, etc).

For Replace on Fail and New Construction, R_base should correspond to a conductor that meets minimum standard requirements for the project according to the National Electric Code.

For Early Replacement, use the actual conductor resistance associated with the existing conductor. See the requirements above to ensure the project qualifies to use the Early Replacement assumptions.

R_ee = Efficient Conductor Resistance (Ohms/length). Provided by customer/contractor. Use single phase or three phase values as appropriate. This should come from manufacturer specifications or a recognized industry reference such as the Aluminum Electrical Conductor Handbook (excerpt in Table 1 below).

Length = Length of the line being installed (ensure to use the same units as the resistance rating of the conductor or convert appropriately). Provided by customer/contractor.

3 = Multiplier for each phase of 3 phase power

8,760 = Hours in a year

1,000 = Conversion from kilowatts to watts

LossFactor = Ratio of average losses to peak instantaneous losses over the conductor, provided by customer/contractor. Note that this is not the same as the load factor. Actual loss factor should be used if known.

For transmission conductors, the loss factor should be known or calculated using the method described in the Notes section. For distribution conductors, if the loss factor is unknown and not possible to calculate, use the table below to estimate loss factor using the load factor of the conductor.

Table 1. Load Factor to Loss Factor Conversion Formulas (Ref. 2)

Load Type Served	Load Factor to Loss Factor Conversion Formula	Approximate Expected LossFactor
Rural-Residential	LossFactor = (0.05 x LoadFactor) + (0.95 x LoadFactor^2)	0.10
Urban-Residential	LossFactor = (0.07 x LoadFactor) + (0.93 x LoadFactor^2)	0.16
Commercial	LossFactor = (0.25 x LoadFactor) + (0.75 x LoadFactor^2)	0.09
Industrial	LossFactor = (0.31 x LoadFactor) + (0.69 x LoadFactor^2)	0.28
Mixed/Unknown	LossFactor = (0.20 x LoadFactor) + (0.80 x LoadFactor^2)	0.20

LoadFactor = Measured ratio of average load (Amperes) to peak load of the conductor over a period of one year.

Example

A five-mile length of 3 phase bare 2/0 ACSR conductor (code word Quail) is required by code to replace a failed overhead line, but 3/0 ACSR conductor (code word Pigeon) is installed instead. The peak current is 115 amperes, the segment is rated at 25C, and the Loss Factor is 30%.

From the Aluminum Electrical Conductor Handbook:

R_base = 0.683 Ohms/mile (0.1301Ohms/1000ft x 5.28 = 0.683 Ohms/mile)

R_ee = 0.546 Ohms/mile (0.1034Ohms/1000ft x 5.28 = 0.546 Ohms/mile)

Annual kWh Savings = 3 x $(115)^2$ x (0.683 – 0.546) x 5 x 0.30 x 8,760 / 1,000 = 71,422 kWh

Peak kW Savings = 3 x $(115)^2$ x (0.683 – 0.546) x 5 / 1,000 = 27.18 kW

For this example, an invoice for five miles of 3 phase 3/0 ACSR at a cost of $42,000 and a quote for five miles of 2/0 ACSR for $34,000 is included with the project documentation to demonstrate the project's incremental cost of $8,000.

Table 2. Example Reference for Conductor Resistance Characteristics of Aluminum Conductor, Steel Reinforced (ACSR) (Ref. 3)

			Resistance (Ohms per 1000ft)		
AWG	Strands	kCmil	25C	50C	75C
2	6/1	66.36	0.2591	0.3080	0.3360
1	6/1	83.69	0.2059	0.2474	0.2073
1/0	6/1	105.6	0.1633	0.1972	0.2161
2/0	6/1	133.1	0.1301	0.1616	0.1760
3/0	6/1	167.8	0.1034	0.1208	0.1443
4/0	6/1	211.6	0.0822	0.1066	0.1157
	18/1	266.8	0.0657	0.0723	0.0788
	18/1	336.4	0.0523	0.0574	0.0625
	18/1	477.0	0.0369	0.0405	0.0441
	18/1	556.5	.00318	0.0348	0.0379

This table is meant as an example reference for common conductor types and is by no means exhaustive. If a proposed conductor is not found on this table, a manufacturer specification should be included in project documentation.

Notes

This energy savings measure does not consider loss-of-strength, temperature limitations, substation equipment compatibility, reactive power effects, or any other design parameter outside of energy efficiency.

It may be worth considering updating guidance documents for replacing failed lines to recommend installing lower-loss lines as a matter of protocol. It is unlikely that energy efficiency will be considered on a project-by-project basis when replacing failed lines.

If a Loss Factor is not known directly, it can be calculated using a load profile for the affected line. To do this, integrate the square of the instantaneous load over the profile time period and divide by the length of the time period. If a load profile is available, this method will likely generate greater savings than the conservative load factor to loss factor conversion prescribed in the algorithm above.

A direct cost quote for baseline materials is the preferred documentation to show incremental cost for the project, but a cost quote for a substantially similar project generated within a year of the proposed project is also acceptable.

The Loss Factor variable represents the ratio between average losses and peak losses. It can be calculated by using interval data for the applicable conductor and applying the following equation:

$$LossFactor = \sum_{n=1}^{Int} \left(\frac{Load_n^2}{Peak\ Load^2} \right) / Int$$

Where Int is the number of intervals (preferably over one year), $Load_n$ is the average load (Amperes) in interval n, and Peak Load is the highest value of Load for all n intervals. If neither the Loss Factor itself nor the interval data required to calculate the Loss Factor are available, use the table above to estimate loss factor using the load factor of the conductor.

Reactance and other inductive properties of conductors are not considered for the purposes of this measure—savings are calculated and reported in real power and energy units.

References

1. Booth & Associates, Inc. Distribution System Loss Management Manual. National Rural Electric Cooperative Association. 1991.
2. Guidelines on The Calculation and Use of Loss Factors, Electric Authority, Te Mana Hiko, February 14, 2013 (conversion formulas derived from the source)
3. Excerpt from Aluminum Association, *Aluminum Electrical Conductor Handbook,* 1989.

Revision History

Version	Description	Author	Date
1.0	New measure	GDS Associates	10/31/2016
1.1	Fixed equations, adding Length variable	Cadmus	1/2019

Electric Utility Infrastructure Misc. – Efficient Transformer

Measure Detail	Measure Value
Measure ID	4.11.03
Target Market Segments	Infrastructure
Target End Uses	Transmission
Applicable To	Electric Utility Infrastructure
Actions	Replace on Fail, Early Replacement, New Construction
Required from Customer/Contractor	Peak load served by the transformer (kVA) ; Baseline Transformer rated full-load capacity (kVA); Efficient Transformer rated full-load capacity (kVA) ; Baseline Transformer full-load losses from nameplate or manufacturer specification; Baseline Transformer no-load losses from nameplate or manufacturer specification ; Efficient Transformer full-load losses from nameplate or manufacturer specification; Efficient Transformer no-load losses from nameplate or manufacturer specification; Loss factor (or load factor)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	25 Years. The average expected lifetime of the equipment (per typical utility depreciation schedule3) exceeds the ECO planning horizon, thus the measure life is capped at 25 years.
Unit Participant Incremental Cost	See Incremental Cost section

Measure Description

Electric transformers of any type are never 100% efficient, but in many cases a higher efficiency option can be installed to minimize losses. Loss characteristics of a transformer consist of both load losses and no-load losses. Load losses vary with the load on the transformer and are also known as winding losses because they occur primarily in the transformer's windings. No-load losses occur because of the electrical currents and magnetic fields necessary to magnetize the transformer core and are present at a constant value whenever the transformer is energized regardless of load conditions[1]. This measure analyzes the energy savings potential of the installation of higher efficiency transformers with lower load and no-load losses.

Replace on Fail, New Construction, and Early Replacement scenarios are all eligible for this measure. ROF and NC scenarios are appropriate when a new transformer is installed which exceeds the minimum efficiency transformer code for the application.

Early Replacement is appropriate in instances where efficient transformers are installed to replace existing equipment before the end of its useful life for the purpose of achieving energy efficiency. The existing equipment must be functional, serving the existing load, and must have been installed less than 25 years prior to the current project. If the load served has changed significantly (+/-10%) since the original installation, use the New Construction assumptions. A new transformer rated at a lower kVA

capacity **can** be installed to replace an existing transformer and achieve energy conservation as long as the same load is still being served.

This measure is designed to calculate energy savings only and should not be substituted for distribution or transmission engineering design.

Algorithms

$$\text{Annual kWh Savings (Ref. 1)} = 8{,}760 \times \left(\left[\left(\frac{Load_{peak}}{FLC_{base}}\right)^2 \times FLL_{base} \times LossFactor + NLL_{base}\right] - \left[\left(\frac{Load_{peak}}{FLC_{ee}}\right)^2 \times FLL_{ee} \times LossFactor + NLL_{ee}\right]\right)$$

$$\text{Peak kW Savings} = \left[\left(\frac{Load_{peak}}{FLC_{base}}\right)^2 \times FLL_{base} + NLL_{base}\right] - \left[\left(\frac{Load_{peak}}{FLC_{ee}}\right)^2 \times FLL_{ee} + NLL_{ee}\right]$$

Where:

8,760	=	Average hours in a year
Load_peak	=	Load during peak period (kVA), provided by customer/contractor
FLC_base	=	Base transformer rated full-load capacity (kVA), provided by customer/contractor
FLC_ee	=	Efficient transformer rated full-load capacity (kVA), provided by customer/contractor
FLL_base	=	Full-load losses of base transformer, winding kW loss at rated load (kW), provided by customer/contractor. From transformer nameplate or manufacturer specification.
FLL_ee	=	Full-load losses of efficient transformer, winding kW loss at rated load (kW), provided by customer/contractor. From transformer nameplate or manufacturer specification.
NLL_base	=	No-load losses of base transformer (kW), provided by customer/contractor. From transformer nameplate or manufacturer specification.
NLL_ee	=	No-load losses of efficient transformer (kW), provided by customer/contractor. From transformer nameplate or manufacturer specification.
LossFactor	=	Loss factor, ratio of average losses to peak losses on the network segment served by the transformer. Provided by customer/contractor. Note that this is not the same as the load factor (instantaneous losses are proportional to load squared). Actual Loss Factor should be used if known or calculated using interval load data if possible (see Notes section for method).

For transmission transformers, the Loss Factor should be known or calculated. For distribution transformers, if the Loss Factor is unknown and not possible to calculate, use the table below to estimate loss factor using the load factor of the network segment served by the transformer.

Table 1. Load Factor to Loss Factor Formulas (Ref. 2)

Load Type Served	Load Factor to Loss Factor Conversion Formula	Approximate Expected LossFactor
Rural-Residential	LossFactor = (0.05 x LoadFactor) + (0.95 x LoadFactor^2)	0.10
Urban-Residential	LossFactor = (0.07 x LoadFactor) + (0.93 x LoadFactor^2)	0.16
Commercial	LossFactor = (0.25 x LoadFactor) + (0.75 x LoadFactor^2)	0.09
Industrial	LossFactor = (0.31 x LoadFactor) + (0.69 x LoadFactor^2)	0.28
Mixed/Unknown	LossFactor = (0.20 x LoadFactor) + (0.80 x LoadFactor^2)	0.20

LoadFactor = Measured ratio of average load (Amperes) to peak load of the conductor over a period of one year.

Definition of Baseline Equipment

For Replace on Fail and New Construction projects:

Baseline values used in the savings calculations should reflect characteristics of a standard efficiency transformer that would typically be installed if energy efficiency were not considered. The baseline equipment can be established by one of two methods:

1. If the proposed transformer fits into a category for which federal standards are defined, the standard minimum efficiency transformer should be used as the baseline. Standards are developed by the Department of Energy and published in the Federal Register 10CFR 431 (Ref. 4). For example, although the federal standards increased the minimum required efficiency in 2016, most transformers with a NEMA premium or CEE Tier 2 rating will still achieve energy conservation. Standards are defined for low-voltage dry-type distribution transformers, liquid-immersed distribution transformers, and medium-voltage dry-type distribution transformers.
2. If the proposed transformer does not fit into a category for which standards are defined, characteristics of transformers previously installed on similar projects can be used as the baseline. To be considered a similar project, a standard-efficiency transformer rated at the same kVA capacity as the proposed high-efficiency transformer must have been installed to serve a peak load within 10% of the proposed peak load. The baseline transformer must have been installed within 5 years prior to the proposed project. Documentation demonstrating the transformer characteristics and loading conditions of the baseline project should be available upon request.

For Early Replacement (or Replace Working) projects:

The existing transformer characteristics as found on the nameplate or original design documentation should be used as the baseline values in the savings calculations. The existing equipment must be functional, serving the existing load, and must have been installed less than 25 years prior to the current project. If the load served has changed significantly (+/-10%) since the original installation, use the New Construction assumptions.

Incremental Cost

For Replace on Fail and New Construction projects:

Actual project costs should be used to determine incremental cost. To claim savings, an invoice showing the actual cost for the installed materials should be submitted with project documentation. A justification for the cost of the assumed baseline transformer materials should also be included. Justification can be a quote or an invoice from a previous project that demonstrates what it would have cost to install the baseline equipment. Incremental cost for the project is the actual cost of the proposed project materials minus the price of the baseline materials.

It is assumed that labor costs for the installation are identical for the high-efficiency and baseline cases. Therefore, incremental cost is driven by the difference in materials cost only.

For Early Replacement (or Replace Working) projects:

Actual project costs should be used. Invoices showing the full materials and labor costs for the project should be included with project documentation.

Example:

A functional 12,000 kVA transformer with full-load losses of 50 kW and no-load losses of 20 kW is replaced with a more efficient transformer with the same full-load capacity and full-load losses of 45 kW and no-load losses of 18 kW. The peak load is 10,000 kVA and the Loss Factor shown in historical data is 25%.

$$\text{Annual kWh Savings} = 8{,}760\ \text{hrs/yr} \times \left(\left[\left(\frac{10{,}000\ \text{kVA}}{12{,}000\ \text{kVA}}\right)^2 \times 50\text{kW} \times 0.25\ +\ 20\text{kW}\right] - \left[\left(\frac{10{,}000\ \text{kVA}}{12{,}000\ \text{kVA}}\right)^2 \times 45\text{kW} \times 0.25\ +\ 18\text{kW}\right]\right) = 25{,}119\ \text{kWh/yr}$$

$$\text{Peak kW Savings} = \left[\left(\frac{10{,}000\ \text{kVA}}{12{,}000\ \text{kVA}}\right)^2 \times 50\text{kW}\ +\ 20\text{kW}\right] - \left[\left(\frac{10{,}000\ \text{kVA}}{12{,}000\ \text{kVA}}\right)^2 \times 45\text{kW}\ +\ 18\text{kW}\right] = 5.47\ \text{kW}$$

In this example, the full cost of the project can be claimed if the existing transformer is less than 25 years old and the load has not changed more than 10% since the existing transformer was installed.

Methodology and Assumptions

Assume that peak coincidence factor for transformer demand reduction is 1.0. Transmission and distribution demand savings occur at peak load by definition.

Notes

It is anticipated that this measure will be most useful either during the substation design process (for large transmission transformers) or as an incentive to adopt a policy of installing higher efficiency transformers as a matter of practice (for distribution transformers).

If a utility institutes a policy of installing high-efficiency transformers as a matter of standard practice, a representative sample of project invoices and transformer characteristics can be used to determine incremental costs and savings for the program.

The Loss Factor variable represents the ratio between average load losses and peak load loss. It can be calculated by using interval data for the applicable network segment and applying the following equation:

$$LossFactor = \sum_{n=1}^{Int} \left(\frac{Load_n^2}{Peak\ Load^2} \right) / Int$$

Where Int is the number of intervals (preferably over one year), $Load_n$ is the average load in interval n, and Peak Load is the highest value of load for all n intervals.

If neither the loss factor itself nor the interval data required to calculate the loss factor are available, use the table above to estimate loss factor using the load factor of the network segment served by the transformer.

References

1. Developed from engineering expertise and several sources including: Booth & Associates, Inc. Distribution System Loss Management Manual. National Rural Electric Cooperative Association. 1991.
2. Guidelines on The Calculation and Use of Loss Factors, Electric Authority, Te Mana Hiko, February 14, 2013 (conversion formulas derived from the source)
3. Claimed lifetimes of transformer equipment easily exceed 25 years. The most commonly-cited reference is REA Bulletin 183-1 from 1977, found at: http://www.rd.usda.gov/files/UPA_Bulletin_183-1.pdf. For one example of MN-specific depreciation schedule, see the 2014 MN PUC Docket E017/D-13-795 at: http://minnesotapuc.legistar.com/gateway.aspx?M=F&ID=6fab26a3-0dff-44c8-ac2d-2b497ef6d005.pdf
4. 10 CFR 431.196 – Energy conservation standards and their effective dates. Summary published by the Legal Information Institute at the Cornell University Law School at: https://www.law.cornell.edu/cfr/text/10/431.196

Revision History

Version	Description	Author	Date
1.0	New measure	GDS Associates	10/31/2016

Electric Utility Infrastructure Misc. – Generation Equipment Retrofit

Measure Detail	Measure Value
Measure ID	4.11.04
Target Market Segments	Infrastructure
Target End Uses	Generation
Applicable To	Electric Utility Infrastructure – Retrofit existing generation equipment owned by the utility
Actions	Retrofit
Required from Customer/Contractor	The customer shall include documentation supporting all plant data included in the above calculations to determine the energy savings. Results from initial- and post-performance tests, conducted in compliance with ASME Performance Test codes must be available upon request. Depreciation schedules or manufacturer expected equipment lifetime for all major components of the project must be available upon request to verify measure life.
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	0
Measure Lifetime (years)	See Measure Life section

Measure Description

This measure applies only to generation plant upgrades of the primary power generation equipment and ancillary systems providing direct support to the primary generation equipment. If improvements are associated with parasitic loads, which can be captured through the use of other TRM measures, then the energy efficiency improvements shall be determined using the other TRM measures. Examples of improvements that would be captured using this measure include combustion turbine upgrades, steam turbine upgrades, enhanced boiler maintenance, coal mill upgrades, reciprocating engine enhancements, and boiler feedwater pump upgrades (changing drive to VFD is not included). Examples of improvements that would not be included in this measure include VFDs, lighting, building HVAC, and other parasitic loads.

Any project that improves a generation facility's efficiency by reducing fuel consumption (decreases Btu input) or increasing its generation capacity will cause a change in gross plant heat rate. Thus, all generation facility energy efficiency improvements can be measured by capturing the change in the plant's gross heat rate. For some examples, generation facility reduces fuel consumption by improving boiler heat transfer; maintenance cycle for cleaning combustion turbine compressor blades is accelerated by two years; gross generation output of a generation facility is increased by improving boiler steam production to the steam turbine without increasing fuel consumption; inlet cooling is added to combustion turbines. This measure outlines a protocol for calculating energy savings from similar types of projects.

The measure is designed to be flexible enough to apply to a wide range of projects, thus input variables are not prescribed directly. Instead, individual project parameters (including generation plant characteristics, cost, and expected measure lifetime) must be justified by the accompanying project documentation.

A project that consists of multiple sub-actions (for example, replacing soot blowers at the same time as modifying a furnace heat transfer surface) is eligible as a single project as long as the overall plant heat rate and capacity are known before and after the project.

At gas generation facilities, a reduction in gas input will be claimed directly as gas savings. All other improvements are converted into equivalent electric savings.

Note: Projects that *only* reduce parasitic loads should claim savings directly using the appropriate measure (VFD, lighting, etc.). Those measures will calculate savings without reference to the plant's heat rate.

Measure Life

Measure lifetime is equal to the shortest expected individual lifetime of all equipment installed as part of the project. For capital purchases that claim depreciation (for a rate case or tax purposes), the depreciation cycle determines the life of the equipment. For noncapital equipment, the expected lifetime according to the manufacturer should be used. The maximum measure lifetime is 25 years.

Definition of Baseline Conditions

An initial unit performance test conducted within three years prior to the proposed project shall be used to determine values for Initial Gross Heat Rate (HR_0), and Initial Plant Gross Output (kW_0).

In the special case where a proposed project will improve the plant heat rate for only part of the year (for example, a combustion turbines enhancement intended to improve hot weather performance, such as inlet chilling), the HR_0 and kW_0 shall be determined using the highest average four-hour period temperature during the summer months of June July and August over the last ten years. For example, if the highest four-hour 10-year average temperature in July is 96 °F, the historical HR_0 and kW_0 for that operating temperature will be used.

Generation facility load factor (LF) will be based upon an average of historical data collected over the most recent five years.

Unit performance tests should be performed in accordance with ASME Performance Test Codes for the applicable type of generation facility.

Definition of Post-Install Conditions

Once the generation facility improvements are complete, the Post-Heat Rate (HR_1) and Post-Plant Net Output (kW_1) is to be determined by completing a post unit performance test. Operating and ambient conditions used to determine HR_1 and kW_1 are to be adjusted to match the initial unit performance test or ambient conditions used for establishing HR_0 and kW_0.

Unit performance tests should be performed in accordance with ASME Performance Test Codes for the applicable type of generation facility.

Algorithms

Project Resulting in Reduced Natural Gas Consumption

For projects completed at natural gas generation facilities in which the only impact is a reduction in input btu (use Case 4 in the Example Calculations section), the reduced input is directly claimed as gas savings using the following algorithm:

Equation 1: $\Delta\, MMBTU/yr = MNLd \times \left((HR_0 - HR_1)\ \times\ kW_0\right) \times LF \times H$

All Other Projects

For all projects completed at non-gas generation facilities (use cases 1, 2, and 3) and for natural gas generation facility projects that do not reduce fuel consumption (use cases 5 and 6), all savings are converted into equivalent electric savings with the following algorithm:

Equation 2: $\Delta\, kWh/yr = MNLd \times \left[\frac{(HR_0 - HR_1)}{HR_1} \times kW_0 \times LF \times H\right]$

Where:

MNLd	=	percentage of load served by the generation facility that is located within Minnesota.
HR_0	=	Initial Heat Rate. Gross heat rate for the plant (BTU fuel consumption divided by gross generator kWh), which comes from a plant performance test completed in the last three years prior to implementation of the project.
HR_1	=	Post Heat Rate. Gross Heat Rate for the plant (BTU fuel consumption divided by gross generator kWh) based upon plant performance test conducted after implementation of the project (ensuring to adjust operating and ambient weather conditions to match the initial plant performance test).
LF	=	Load factor. Average load factor for the plant over the five-year period prior to project implementation (net plant kWh generation divided by plant rated net kW_0 output multiplied by 8,760 hours. Equation 3: $LF = \frac{Average\ Annual\ kWh\ production\ over\ 5\ years}{kW_0 \times 8{,}760\ hours}$
kW_0	=	Initial Plant Capacity. Gross output of the plant (in kW), which comes from a plant performance test completed in the last three years prior to implementation of the project.
kW_1	=	Post Plant Capacity. Gross output capacity of the plant (in kW), which comes from a plant performance test completed after the completion of the project.

H	=	Average hours per year, operating under the conditions addressed by the Improvement. In most instances this will be 8,760 hours (average annual hours in a year). In the special case where a proposed project will improve the plant heat rate for only part of the year, H shall be set to that number of hours. For example, if a combustion turbine project installs inlet chillers that improve operations above 85°F, then HR shall be set equal to the number of hours the ambient temperature exceeds 85°F.
10^6	=	Conversion factor from Btu to MMbtu

Note that if the input BTU is not changing (use cases 2 and 5), the savings formula simplifies to:

Equation 4: $\Delta kWh = MNLd \times [kW_1 - kW_0] \times LF \times H$

Example:

There are six general use cases that can utilize this measure for calculating savings. By applying the algorithms above, the following table demonstrates examples of the possible uses of this measure.

Table 1. Annual Savings by Use Case

	Case	Description	HR_0 (BTU/kWh)	HR_1 (BTU/kWh)	kW_0	kW_1	Annual Electric Savings (MWh)	Annual Gas Savings (MMBtu)
Non-Natural Gas Generation Facility	1	Heat Rate Improvement Only	10,000	9,000	100,000	100,000	70,128	0
	2	Net Generation Improvement Only	10,000	8,696	100,000	115,000	105,164	0
	3	Heat Rate & Generation Improvement	10,000	9,000	100,000	120,000	84,154	0
Natural Gas Generation Facility	4	Heat Rate Improvement Only	10,000	9,000	100,000	100,000	0	701,280
	5	Net Generation Improvement Only	10,000	8,696	100,000	15,000	105,164	0
	6	Heat Rate & Generation Improvement	10,000	9,000	100,000	120,000	84,154	0

For these examples, load factor is assumed to be 80% and all facilities are assumed to be serving 100% Minnesota loads.

Case 1: Non–Natural Gas Generation Facility: Heat rate improvement only, no increase in capacity.

Case 2: Non–Natural Gas Generation Facility: Net generation increase only, with a constant BTU input.

Case 3: Non–Natural Gas Generation Facility: Heat rate and net generation improvement.

Case 4: Natural Gas Generation Facility: Heat rate improvement only, no increase in capacity.

Case 5: Natural Gas Generation Facility: Net generation increase only, with a constant BTU input.

Case 6: Natural Gas Generation Facility: Heat rate and net generation improvement.

Example Project 1 – Generation Improvement:

Steam turbine high pressure and intermediate pressure turbine is replaced with higher efficiency turbine sections. Gross plant output increases without any change in fuel consumption (Case 2). Operations before and after modifications are as follows:

Table 2. HP/IP Steam Turbine Replacement

Parameter	Variable	Quantity	Unit
Initial Plant Output	kW_0	860,000	kW
Initial Plant Heat Rate	HR_0	9,680	BTU/kWh
Load Factor	LF	85%	
Minnesota Load Portion	MNLd	100%	
Post Plant Output	kW_1	877,200	kW
Post Plant Heat Rate	HR_1	9,490	BTU/kWh
Annual Hours	H	8,760	hrs
Electric Savings (EQ2)	ΔkWh	128,159,000	kWh

Revision History

Version	Description	Author	Date
1.0	New measure	GDS Associates	10/31/2016

Electric Utility Infrastructure Misc. – Variable Speed Drives (non-HVAC)

Measure Detail	Measure Value
Measure ID	4.11.05
Target Market Segments	Infrastructure – Generation Facilities; Utility-owned sites
Target End Uses	Motors
Applicable To	Motors within Electric Utility Infrastructure
Actions	Retrofit Existing, New Construction
Required from Customer/Contractor	Motor Horsepower, Load Factor (if known), Motor Efficiency (if unknown, Motor size and type are required instead), annual operating hours, existing control type, and approximate duty cycle for the pump or fan application
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	0
Unit Dth Savings per Year	0
Measure Lifetime (years)	10 years (Ref. 1)
Unit Participant Incremental Cost	See Measure Cost section

Measure Description

This measure applies to a Variable Speed Drives (VSDs or VFDs) installed on fan or pump motors at utility-owned facilities. VSDs control the speed of a motor driving a variable load based on differential pressure, flow, temperature, or other control variable. Power drawn by a motor is proportional to the motor's rotational speed cubed, so when the speed can be slowed in response to lower loading conditions, significant power reductions are possible.

Examples of eligible applications include: boiler feedwater pumps, condenser water circulation pumps, cooling tower fans, flue gas fans, induced or forced draft fans, water circulation pumps, or blowdown pumps.

In order to be eligible, the project must meet the following criteria:

- Must be installed on a primary motor (backup or redundant motors are not eligible)
- Must be installed on an AC motor (DC motors are not eligible)
- Must be installed on a motor driving a centrifugal fan or pumping application (material handling and other applications must complete custom calculation)
- Individual motors must not exceed 500 hp (>500 hp should use custom load profiles)
- Motor must serve a variable load
- Routine replacements do not qualify
- VSDs required by code are not eligible (IECC 2015 or other applicable codes)
- VSDs installed on HVAC equipment should use the dedicated measure
- VSDs installed on air compressors should use the dedicated measure

Measure Cost

Actual costs should be used, if known. For smaller motors (<20 hp), default project costs are given in the following table (Ref. 2). VSDs installed on larger motors must use actual costs.

Table 1. Project Cost by Motor Size

HP	Cost
1-5 hp	$1,330
7.5 hp	$1,622
10 hp	$1,898
15 hp	$2,518
20 hp	$3,059

Algorithms

$$Annual\ kWh\ Savings = \left(0.746 \times hp \times \frac{LF}{Eff}\right) \times Hours \times ESF$$

Where:

hp = Rated motor horsepower. Actual value.

LF = Motor load factor at the pump or fan design flow rate. Use actual value if known. If unknown, use default value of 75% (Ref. 3)

Eff = Efficiency of motor. Use actual value if known. If unknown, use default NEMA premium efficiency rating by size and type of motor (found in Table 3 below) (Ref. 4)

Hours = Annual operating hours. Actual run hours must be used for Generation/Utility applications. Justification for run hours assumption must be included in project documentation.

Duty Cycle = Percentage of motor runtime at each flow rate. At generation facilities, it is expected that a duty cycle will be known with a reasonable degree of accuracy. See Table 2 below for an example of a duty cycle table:

Table 2. Duty Cycle Format

Flow Rate (Percentage of design flow)	Duty Cycle (Percentage of motor runtime at each flow rate)
0% to 10%	
10% to 20%	
20% to 30%	
30% to 40%	
40% to 50%	
50% to 60%	
60% to 70%	

Flow Rate (Percentage of design flow)	Duty Cycle (Percentage of motor runtime at each flow rate)
70% to 80%	
80% to 90%	
90% to 100%	

$PLR_{Baseline}$ = Part Load Ratio for the baseline control strategy. The ratio of the percentage of peak power draw that occurs at each flow rate percentage. Consult Table 5 to find $PLR_{Baseline}$ values depending on the existing control strategy.

PLR_{EFF} = Part Load Ratio for the VSD. The ratio of percentage of peak power draw that occurs at each flow rate percentage. Consult Table 5 to find $PLR_{Baseline}$ values. They should either be the Pump VSD or Fan VSD values.

ESF = Energy Savings Factor. ESF is the sum-product of DutyCycle and $PLR_{Baseline}$ across all flow rates minus the sum-product of DutyCycle and PLR_{EFF} across all flow rates. See Table 4 below for example ESF values.

$$ESF = \sum_{0\%}^{100\%} (DutyCycle \times PLR_{Baseline}) - \sum_{0\%}^{100\%} (DutyCycle \times PLR_{EFF})$$

Example:

A 100 hp boiler feedwater pump currently using a throttling valve is retrofitted with a VSD. The pump runs for 3,000 hours per year, the motor load factor is 90% and the motor efficiency is 95%. The motor duty cycle is found in Table 2 below.

ESF is calculated using example the duty cycle in Table 2, $PLR_{Baseline}$ (from Table 5 – pump throttling valve values), and PLR_{EFF} (from Table 5 – pump VSD values).

Table 3. Example ESF Calculation (Ref. 5)

Flow Rate (Percentage of design flow)	Example Duty Cycle (Percentage of motor runtime at each flow rate)	$PLR_{Baseline}$ (Throttling Valve)	PLR_{EFF} (VSD)
0% to 10%	0%	0.80	0.05
10% to 20%	6%	0.81	0.06
20% to 30%	11%	0.82	0.09
30% to 40%	13%	0.83	0.12
40% to 50%	17%	0.85	0.18
50% to 60%	24%	0.87	0.27
60% to 70%	17%	0.90	0.39
70% to 80%	9%	0.93	0.55
80% to 90%	2%	0.96	0.75
90% to 100%	1%	1.0	1.0

ESF = [0 x .8 + .06 x .81 + .11 x .82 + .13 x .83 + .17 x .85 + .24 x .87 + .17 x .90 + .09 x .93 + .02 x .96 + .01 x 1.0] - [0 x .0 5 + .06 x .06 + .11 x .09 + .13 x .12 +.17 x .18 + .24 x .27 + .17 x .39 +.09 x .55 + .02 x .75 + .01 x 1]

ESF = 0.8659 – 0.2653 = 0.601

Unit kWh Savings per Year = (.746 x 100 x 0.90/0.95) x 3,000 x 0.601 = 127,425 kWh

Deemed Input Tables

Table 4. Default NEMA Premium Motor Efficiencies (Ref. 4)

Size HP	Open Drip Proof (ODP)			Totally Enclosed Fan-Cooled (TEFC)		
	Number of Poles			Number of Poles		
	6	4	2	6	4	2
	Speed (RPM)			Speed (RPM)		
	1,200	1,800 Default	3,600	1,200	1,800	3,600
1	0.825	0.855	0.770	0.825	0.855	0.770
1.5	0.865	0.865	0.840	0.875	0.865	0.840
2	0.875	0.865	0.855	0.885	0.865	0.855
3	0.885	0.895	0.855	0.895	0.895	0.865
5	0.895	0.895	0.865	0.895	0.895	0.885
7.5	0.902	0.910	0.885	0.910	0.917	0.895
10	0.917	0.917	0.895	0.910	0.917	0.902
15	0.917	0.930	0.902	0.917	0.924	0.910
20	0.924	0.930	0.910	0.917	0.930	0.910
25	0.930	0.936	0.917	0.930	0.936	0.917
30	0.936	0.941	0.917	0.930	0.936	0.917
40	0.941	0.941	0.924	0.941	0.941	0.924
50	0.941	0.945	0.930	0.941	0.945	0.930
60	0.945	0.950	0.936	0.945	0.950	0.936
75	0.945	0.950	0.936	0.945	0.954	0.936
100	0.950	0.954	0.936	0.950	0.954	0.941
125	0.950	0.954	0.941	0.950	0.954	0.950
150	0.954	0.958	0.941	0.958	0.958	0.950
200	0.954	0.958	0.950	0.958	0.962	0.954
250	0.954	0.958	0.950	0.958	0.962	0.958
300	0.954	0.958	0.954	0.958	0.962	0.958
350	0.954	0.958	0.954	0.958	0.962	0.958
400	0.958	0.958	0.958	0.958	0.962	0.958
450	0.962	0.962	0.958	0.958	0.962	0.958
500	0.962	0.962	0.958	0.958	0.962	0.958

Table 5. Example Energy Savings Factors (using example Duty Cycle from Table 2)

Baseline Control Type	ESF
Pump – No Control	0.73
Pump - Bypass Valve	0.67
Pump - Throttling Valve	0.60
Fan - No Control or Bypass Damper	0.71
Fan - Discharge Dampers	0.50
Fan - Outlet Damper, Backward Inclined & Airfoil Fans	0.47
Fan - Inlet Damper Box	0.41
Fan - Inlet Guide Vane, Backward Inclined & Airfoil Fans	0.34
Fan - Inlet Vane Dampers	0.24
Fan - Outlet Damper, Forward Curved Fans	0.22
Eddy Current Drives	0.19
Inlet Guide Vane, Forward Curved Fans	0.10

Table 6. Part Load Ratio for Flow Rate Bins Based on Control Types (Ref. 6)

Control Type	Flow rate (percentage of design flow)									
	0% to 10%	10% to 20%	20% to 30%	30% to 40%	40% to 50%	50% to 60%	60% to 70%	70% to 80%	80% to 90%	90% to 100%
Pump Baseline values ($PLR_{Baseline}$)										
No Control	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Bypass Valve	0.90	0.90	0.91	0.91	0.93	0.93	0.95	0.96	0.98	1.0
Throttling Valve	0.8	0.81	0.82	0.83	0.85	0.87	0.9	0.93	0.96	1.0
Pump VSD value (PLR_{EFF})										
VSD – pump	0.05	0.06	0.09	0.12	0.18	0.27	0.39	0.55	0.75	1.0
Fan Baseline values ($PLR_{Baseline}$)										
No Control or Bypass Damper	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Discharge Dampers	0.46	0.55	0.63	0.7	0.77	0.83	0.88	0.93	0.97	1.0
Outlet Damper, Backward Inclined & Airfoil Fans	0.53	0.53	0.57	0.64	0.72	0.8	0.89	0.96	1.02	1.05
Inlet Damper Box	0.56	0.6	0.62	0.64	0.66	0.69	0.74	0.81	0.92	1.07
Inlet Guide Vane, Backward Inclined & Airfoil Fans	0.53	0.56	0.57	0.59	0.6	0.62	0.67	0.74	0.85	1.0
Inlet Vane Dampers	0.38	0.4	0.42	0.44	0.48	0.53	0.6	0.7	0.83	0.99
Outlet Damper, Forward Curved Fans	0.22	0.26	0.3	0.37	0.45	0.54	0.65	0.77	0.91	1.06
Eddy Current Drives	0.17	0.2	0.25	0.32	0.41	0.51	0.63	0.76	0.9	1.04
Inlet Guide Vane, Forward Curved Fans	0.21	0.22	0.23	0.26	0.31	0.39	0.49	0.63	0.81	1.04
Fan VSD value (PLR_{EFF})										
Fan - VSD	0.09	0.1	0.11	0.15	0.2	0.29	0.41	0.57	0.76	1.01

References

1. 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008. Use value for process VFDs.
2. Ohio TRM 8/6/2010 varies by motor/fan size based on equipment costs from Granger 2008 Catalog pp 286-289, average across available voltages and models. Labor costs from RS Means Data 2008 Ohio average cost adjustment applied.
3. United States Industrial Electric Motor Systems Market Opportunities Assessment, EERE, US DOE, Dec 2002 - Source for motor load factor data
4. Douglass, J. (2005). Induction Motor Efficiency Standards. Washington State University and the Northwest Energy Efficiency Alliance, Extension Energy Program, Olympia, WA. Also listed in the IL Statewide TRM. Retrieved online 12/12/16 at: http://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/motor_efficiency_standards.pdf
5. Default Flow Fractions used in the Toshiba VFD Energy Savings Estimator tool.
6. Based on similar table developed for the IL TRM VFD measure. Verified values and added pump control types by entering the average load profiles into the Toshiba VFD Energy Savings Estimator tool.

Revision History

Version	Description	Author	Date
1.0	New measure	GDS Associates	12/12/2016

Electric Utility Infrastructure Misc. – Motors

Measure Detail	Measure Value
Measure ID	4.11.06
Target Market Segments	Infrastructure - Generation Facilities; Utility-owned sites
Target End Uses	Fans, Pumps, Motors, HVAC, Process
Applicable To	Motors within Electric Utility Infrastructure
Actions	Replace Working, Replace on Fail, New Construction
Required from Customer/Contractor	New Motor Enclosure Type (ODP/TEFC), RPM, Horsepower, Efficiency; Action Type (Replace on Fail, Replace Working, or New Construction); Building Type and Application (see Table 2)
Measure Energy Type	Electric
Unit kWh Savings per Year	See algorithm
Unit Peak kW Savings	See algorithm
Unit Dth Savings per Year	0
Measure Lifetime (years)	6 years (Replace Working), 20 years (Replace on Fail, New Construction) (Ref. 1, 2, 4)
Unit Participant Incremental Cost	Incr. Cost for EPACT to NEMA Premium Efficiency or EPACT to Enhanced NEMA Premium (Replacing Working); Incr. Cost for NEMA Premium Efficiency to Enhanced NEMA Premium (Replace on Fail and New Construction). See Appendix C. (Ref. 6)

Measure Description

This measure includes one-for-one replacement of working or failed/near-failure 1-200 hp motors with motors that meet or exceed NEMA Premium Efficiency levels in industrial and nonindustrial applications, as well as installation of motors in new construction.

For replacement of working motors, the new motor efficiency must be at least NEMA Premium Efficiency. For replacement of failed/near-failure motors or new construction, the new motor efficiency must exceed NEMA Premium Efficiency. This measure is adapted from the similar C/I measure with small modifications to apply to utility-owned facilities.

Algorithms

Unit kWh Savings per Year = hp x LF x Conversion x (1/Eff_base – 1/Eff_EE) x Hrs

Unit Peak kW Savings = hp x LF x Conversion x (1/Eff_base – 1/Eff_EE) x CF

Where:

Hrs	=	Annual operating hours. It is strongly recommended to use actual hours if possible. If actual hours are unknown, use deemed annual operating hours by motor hp, see Table 1. These values were derived assuming industrial applications.
LF	=	Motor load factor, deemed at 75% (Ref. 1, 4)
hp	=	Rated horsepower of new motor

Eff_EE	=	Efficiency of new motor. Eff_EE = NEMA Premium Efficiency or NEMA Premium Efficiency + 1%. See Appendix C.
Eff_base	=	Baseline motor efficiency. Eff_base = EPACT efficiency (Replace Working), NEMA Premium Efficiency (Replace on Fail, New Construction). See Appendix C.
Conversion	=	Standard conversion from hp to kW = 0.746 kW/hp
CF	=	Coincidence Factor = 0.78 (Ref. 1, 2)

Deemed Input Tables

Table 1. Deemed annual operating hours by motor horsepower for industrial applications (Ref. 3)

Motor HP	Hrs
5	2,745
7.5	3,391
10	3,391
15	3,391
20	3,391
25	4,067
30	4,067
40	4,067
50	4,067
60	5,329
75	5,329
100	5,329
125	5,200
150	5,200
200	5,200

Table 2. Deemed annual operating hours by building type and application (Ref. 4)

Building Type and Application	Hrs
Office HVAC Pump	2,000
Warehouse HVAC Pump	2,241
Office Ventilation Fan	6,192
Warehouse Ventilation Fan	6,389
Office Other Non-Industrial Application	4,500
Warehouse Other Non-Industrial Application	4,500
Industrial/Manufacturing	See Table 1

Methodology and Assumptions

Measure lives for replacement of failed motors or motors in new construction was 15-20 years in most TRMs prior to the EISA standard for motors taking effect in December 2010. No sources were found for lifetime of early replacement motors since most states have disallowed rebates for industrial Premium Efficiency motors. However, a review of several TRMs showed that for other measures, the lifetime of

early replacements is typically about one-third of the full measure life. Therefore, the lifetime of this measure was set to 6 years (approximately one-third of 15-20 years.)

Notes

According to the EISA standard, general purpose motors (subtype I) manufactured after December 19, 2010, with a power rating of at least 1 horsepower but not greater than 200 horsepower, shall have a nominal full-load efficiency that is not less than as defined in NEMA MG– 1 (2006) Table 12–12 (aka "NEMA Premium®" efficiency levels).

References

1. NYSERDA (New York State Energy Research and Development Authority); NY Energy $mart Programs Deemed Savings Database - Source for coincidence factor, measure life, and motor load factor
2. Franklin Energy Services review, November 2013
3. United States Industrial Electric Motor Systems Market Opportunities Assessment, EERE, US DOE, Dec 2002 - Source for operating hours for industrial motors and source for motor load factor data (Tables 1-18 and 1-19)
4. Efficiency Vermont's Technical Reference User Manual, 2004 - Source for operating hours for commercial motors (p.15) and source for measure life and source for existing motor efficiencies and source for motor load factor default value
5. CEE (Consortium for Energy Efficiency) Premium Efficiency Motors Initiative – source for premium motor efficiencies
6. Xcel Energy Minnesota Electric and Natural Gas Conservation Improvement Program Plan for 2013-2015 (Docket No. E,G002/CIP-12-447) – source for incremental costs.
7. C/I Motors Measure. State of Minnesota Technical Reference Manual for Energy Conservation Improvement Programs Version 2.0. Effective: January 1, 2017 – December 31, 2019.

Revision History

Version	Description	Author	Date
1.0	New measure based on C/I measure	GDS Associates	11/21/2016

Appendix A – Climate Zones

Weather-dependent measures in the Minnesota TRM reference three different climate zones, which are shown in the map below. The boundaries follow county lines. The TRM is designed such that weather-dependent measures have county as a required input from customers or contractors. The county can be mapped to the climate zone using Table A-1.

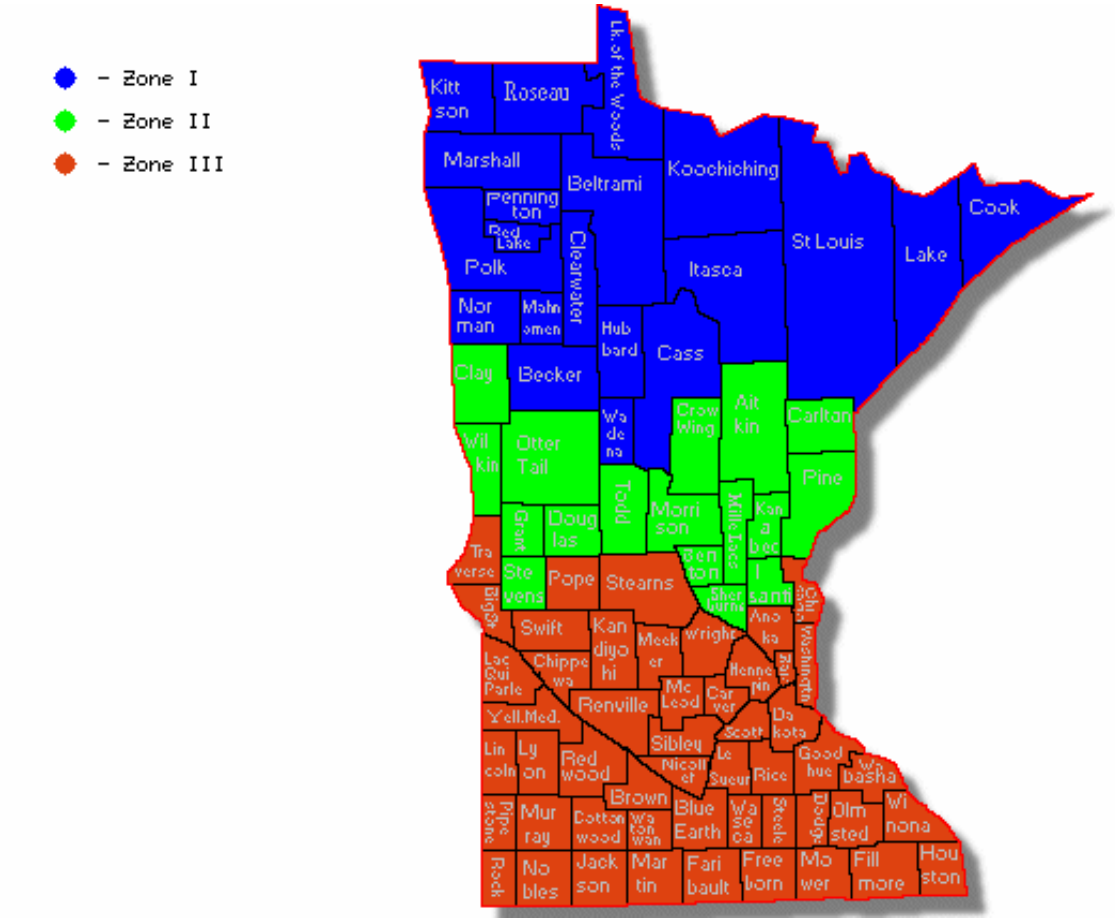

Figure A-1. Minnesota counties by climate zone (1, 2, and 3)

Table A-1. Minnesota Counties by Climate Zone

Zone 1	Zone 2	Zone 3	
Becker	Aitkin	Anoka	Mower
Beltrami	Benton	Big Stone	Murray
Cass	Carlton	Blue Earth	Nicollet
Clearwater	Clay	Brown	Nobles
Cook	Crow Wing	Carver	Olmsted
Hubbard	Douglas	Chippewa	Pipestone
Itasca	Grant	Chisago	Pope
Kittson	Isanti	Cottonwood	Ramsey
Koochiching	Kanabec	Dakota	Redwood
Lake	Mille Lacs	Dodge	Renville
Lake of the Woods	Morrison	Faribault	Rice
Mahnomen	Otter Tail	Fillmore	Rock
Marshall	Pine	Freeborn	Scott
Norman	Sherburne	Goodhue	Sibley
Pennington	Stevens	Hennepin	Stearns
Polk	Todd	Houston	Steele
Red Lake	Wilkin	Jackson	Swift
Roseau		Kandiyohi	Traverse
St. Louis		Lac qui Parle	Wabasha
Wadena		Le Sueur	Waseca
		Lincoln	Washington
		Lyon	Watonwan
		McLeod	Winona
		Martin	Wright
		Meeker	Yellow Medicine

Appendix B – C/I Lighting Tables

Appendix B is available as a Microsoft Excel spreadsheet (*.xls) on the Minnesota Department of Commerce, Division of Energy Resources website.

https://mn.gov/commerce/energy/industry-government/cip/technical-reference-manual/

Appendix C – C/I Motor Tables

Table C-1. Efficiencies and Incremental Cost by Motor Size

RPM	Enclosure	Horse-Power	EPACT Efficiency (A)	NEMA Premium Efficiency (B)	Enhanced NEMA Premium Efficiency (C)	Incremental Cost (A to B)	Incremental Cost (B to C)	Incremental Cost (A to C)
900	ODP	1	74.00%	75.50%	76.50%	$826.86	$134.12	$960.98
900	ODP	1.5	75.50%	77.00%	78.00%	$821.85	$148.55	$970.40
900	ODP	2	85.50%	86.50%	87.50%	$907.18	$152.09	$1,059.27
900	ODP	3	86.50%	87.50%	88.50%	$953.05	$165.78	$1,118.83
900	ODP	5	87.50%	88.50%	89.50%	$976.06	$183.25	$1,159.31
900	ODP	7.5	88.50%	89.50%	90.50%	$1,323.26	$263.65	$1,586.91
900	ODP	10	89.50%	90.20%	91.20%	$1,475.12	$313.83	$1,788.95
900	ODP	15	89.50%	90.20%	91.20%	$2,541.29	$441.22	$2,982.51
900	ODP	20	90.20%	91.00%	92.00%	$2,861.24	$534.64	$3,395.88
900	ODP	25	90.20%	91.00%	92.00%	$3,261.14	$661.36	$3,922.50
900	ODP	30	91.00%	91.70%	92.70%	$3,513.58	$763.56	$4,277.14
900	ODP	40	91.00%	91.70%	92.70%	$4,222.09	$963.09	$5,185.18
900	ODP	50	91.70%	92.40%	93.40%	$4,628.91	$1,097.83	$5,726.74
900	ODP	60	92.40%	93.00%	94.00%	$5,831.16	$1,513.84	$7,345.00
900	ODP	75	93.60%	94.10%	95.10%	$6,697.92	$1,835.34	$8,533.26
900	ODP	100	93.60%	94.10%	95.10%	$8,402.69	$2,219.55	$10,622.24
900	ODP	125	93.60%	94.10%	95.10%	$10,323.06	$2,783.49	$13,106.55
900	ODP	150	93.60%	94.10%	95.10%	$10,693.62	$3,287.22	$13,980.84
900	ODP	200	93.60%	94.10%	95.10%	$12,801.47	$4,084.77	$16,886.24
900	ODP	250	94.50%	95.00%	96.00%	$15,888.00	$5,030.61	$20,918.61
900	ODP	300	94.50%	95.00%	96.00%	$20,204.33	$6,186.20	$26,390.53
900	ODP	350	94.50%	95.00%	96.00%	$29,220.28	$10,114.74	$39,335.02
900	ODP	400	94.90%	95.10%	96.10%	$32,992.47	$11,547.96	$44,540.43
900	ODP	450	95.30%	95.50%	96.50%	$56,915.81	$13,102.94	$70,018.75
900	ODP	500	95.30%	95.50%	96.50%	$59,663.64	$13,566.69	$73,230.33

RPM	Enclosure	Horse-Power	EPACT Efficiency (A)	NEMA Premium Efficiency (B)	Enhanced NEMA Premium Efficiency (C)	Incremental Cost (A to B)	Incremental Cost (B to C)	Incremental Cost (A to C)
900	TEFC	1	74.00%	75.50%	76.50%	$826.86	$102.14	$929.00
900	TEFC	1.5	77.00%	78.50%	79.50%	$821.85	$127.33	$949.18
900	TEFC	2	82.50%	84.00%	85.00%	$907.18	$140.56	$1,047.74
900	TEFC	3	84.00%	85.50%	86.50%	$953.05	$143.19	$1,096.24
900	TEFC	5	85.50%	86.50%	87.50%	$976.06	$154.81	$1,130.87
900	TEFC	7.5	85.50%	86.50%	87.50%	$1,323.26	$243.84	$1,567.10
900	TEFC	10	88.50%	89.50%	90.50%	$1,475.12	$281.46	$1,756.58
900	TEFC	15	88.50%	89.50%	90.50%	$2,541.29	$394.32	$2,935.61
900	TEFC	20	89.50%	90.20%	91.20%	$2,861.24	$468.88	$3,330.12
900	TEFC	25	89.50%	90.20%	91.20%	$3,261.14	$583.79	$3,844.93
900	TEFC	30	91.00%	91.70%	92.70%	$3,513.58	$688.67	$4,202.25
900	TEFC	40	91.00%	91.70%	92.70%	$4,222.09	$828.56	$5,050.65
900	TEFC	50	91.70%	92.40%	93.40%	$4,628.91	$914.17	$5,543.08
900	TEFC	60	91.70%	92.40%	93.40%	$5,831.16	$1,198.38	$7,029.54
900	TEFC	75	93.00%	93.60%	94.60%	$6,697.92	$1,574.58	$8,272.50
900	TEFC	100	93.00%	93.60%	94.60%	$8,402.69	$1,706.93	$10,109.62
900	TEFC	125	93.60%	94.10%	95.10%	$10,323.06	$2,204.66	$12,527.72
900	TEFC	150	93.60%	94.10%	95.10%	$10,693.62	$2,720.06	$13,413.68
900	TEFC	200	94.10%	94.50%	95.50%	$12,801.47	$3,281.06	$16,082.53
900	TEFC	250	94.50%	95.00%	96.00%	$15,888.00	$4,068.24	$19,956.24
900	TEFC	300	95.00%	95.80%	96.80%	$20,204.33	$5,231.28	$25,435.61
900	TEFC	350	95.00%	95.80%	96.80%	$29,220.28	$7,024.51	$36,244.79
900	TEFC	400	95.00%	95.80%	96.80%	$32,992.47	$8,766.74	$41,759.21
900	TEFC	450	95.00%	95.80%	96.80%	$56,915.81	$9,653.64	$66,569.45
900	TEFC	500	95.00%	95.80%	96.80%	$59,663.64	$13,405.81	$73,069.45
1200	ODP	1	80.00%	82.50%	83.50%	$826.86	$132.19	$959.05
1200	ODP	1.5	84.00%	86.50%	87.50%	$821.85	$147.75	$969.60
1200	ODP	2	85.50%	87.50%	88.50%	$907.18	$194.37	$1,101.55

RPM	Enclosure	Horse-Power	EPACT Efficiency (A)	NEMA Premium Efficiency (B)	Enhanced NEMA Premium Efficiency (C)	Incremental Cost (A to B)	Incremental Cost (B to C)	Incremental Cost (A to C)
1200	ODP	3	86.50%	88.50%	89.50%	$953.05	$241.00	$1,194.05
1200	ODP	5	87.50%	89.50%	90.50%	$976.06	$308.94	$1,285.00
1200	ODP	7.5	88.50%	90.20%	91.20%	$1,323.26	$396.04	$1,719.30
1200	ODP	10	90.20%	91.70%	92.70%	$1,475.12	$503.88	$1,979.00
1200	ODP	15	90.20%	91.70%	92.70%	$2,541.29	$597.59	$3,138.88
1200	ODP	20	91.00%	92.40%	93.40%	$2,861.24	$785.47	$3,646.71
1200	ODP	25	91.70%	93.00%	94.00%	$3,261.14	$929.56	$4,190.70
1200	ODP	30	92.40%	93.60%	94.60%	$3,513.58	$1,101.02	$4,614.60
1200	ODP	40	93.00%	94.10%	95.10%	$4,222.09	$1,237.90	$5,459.99
1200	ODP	50	93.00%	94.10%	95.10%	$4,628.91	$1,511.65	$6,140.56
1200	ODP	60	93.60%	94.50%	95.50%	$5,831.16	$1,800.99	$7,632.15
1200	ODP	75	93.60%	94.50%	95.50%	$6,697.92	$2,088.27	$8,786.19
1200	ODP	100	94.10%	95.00%	96.00%	$8,402.69	$2,511.90	$10,914.59
1200	ODP	125	94.10%	95.00%	96.00%	$10,323.06	$3,542.24	$13,865.30
1200	ODP	150	94.50%	95.40%	96.40%	$10,693.62	$3,678.13	$14,371.75
1200	ODP	200	94.50%	95.40%	96.40%	$12,801.47	$4,149.86	$16,951.33
1200	ODP	250	95.40%	95.80%	96.80%	$15,888.00	$7,674.66	$23,562.66
1200	ODP	300	95.40%	95.80%	96.80%	$20,204.33	$13,215.63	$33,419.96
1200	ODP	350	95.40%	95.80%	96.80%	$29,220.28	$15,757.67	$44,977.95
1200	ODP	400	95.80%	95.90%	96.90%	$32,992.47	$20,629.90	$53,622.37
1200	ODP	450	96.20%	96.30%	97.30%	$56,915.81	$21,879.28	$78,795.09
1200	ODP	500	96.20%	96.30%	97.30%	$59,663.64	$27,043.98	$86,707.62
1200	TEFC	1	80.00%	82.50%	83.50%	$826.86	$335.29	$1,162.15
1200	TEFC	1.5	85.50%	87.50%	88.50%	$821.85	$369.14	$1,190.99
1200	TEFC	2	86.50%	88.50%	89.50%	$907.18	$459.42	$1,366.60
1200	TEFC	3	87.50%	89.50%	90.50%	$953.05	$579.35	$1,532.40
1200	TEFC	5	87.50%	89.50%	90.50%	$976.06	$628.15	$1,604.21
1200	TEFC	7.5	89.50%	91.00%	92.00%	$1,323.26	$999.79	$2,323.05

RPM	Enclosure	Horse-Power	EPACT Efficiency (A)	NEMA Premium Efficiency (B)	Enhanced NEMA Premium Efficiency (C)	Incremental Cost (A to B)	Incremental Cost (B to C)	Incremental Cost (A to C)
1200	TEFC	10	89.50%	91.00%	92.00%	$1,475.12	$1,143.20	$2,618.32
1200	TEFC	15	90.20%	91.70%	92.70%	$2,541.29	$1,333.58	$3,874.87
1200	TEFC	20	90.20%	91.70%	92.70%	$2,861.24	$1,780.01	$4,641.25
1200	TEFC	25	91.70%	93.00%	94.00%	$3,261.14	$2,029.22	$5,290.36
1200	TEFC	30	91.70%	93.00%	94.00%	$3,513.58	$2,534.01	$6,047.59
1200	TEFC	40	93.00%	94.10%	95.10%	$4,222.09	$2,679.48	$6,901.57
1200	TEFC	50	93.00%	94.10%	95.10%	$4,628.91	$3,080.99	$7,709.90
1200	TEFC	60	93.60%	94.50%	95.50%	$5,831.16	$3,796.69	$9,627.85
1200	TEFC	75	93.60%	94.50%	95.50%	$6,697.92	$4,452.65	$11,150.57
1200	TEFC	100	94.10%	95.00%	96.00%	$8,402.69	$5,497.36	$13,900.05
1200	TEFC	125	94.10%	95.00%	96.00%	$10,323.06	$6,416.66	$16,739.72
1200	TEFC	150	95.00%	95.80%	96.80%	$10,693.62	$7,027.70	$17,721.32
1200	TEFC	200	95.00%	95.80%	96.80%	$12,801.47	$8,074.69	$20,876.16
1200	TEFC	250	95.00%	95.80%	96.80%	$15,888.00	$10,248.92	$26,136.92
1200	TEFC	300	95.00%	95.80%	96.80%	$20,204.33	$12,409.92	$32,614.25
1200	TEFC	350	95.00%	95.80%	96.80%	$29,220.28	$14,940.51	$44,160.79
1200	TEFC	400	95.00%	95.80%	96.80%	$32,992.47	$19,790.80	$52,783.27
1200	TEFC	450	95.00%	95.80%	96.80%	$56,915.81	$21,034.55	$77,950.36
1200	TEFC	500	95.00%	95.80%	96.80%	$59,663.64	$26,175.99	$85,839.63
1800	ODP	1	82.50%	85.50%	86.50%	$826.86	$134.91	$961.77
1800	ODP	1.5	84.00%	86.50%	87.50%	$821.85	$150.71	$972.56
1800	ODP	2	84.00%	86.50%	87.50%	$907.18	$165.41	$1,072.59
1800	ODP	3	86.50%	89.50%	90.50%	$953.05	$175.79	$1,128.84
1800	ODP	5	87.50%	89.50%	90.50%	$976.06	$223.67	$1,199.73
1800	ODP	7.5	88.50%	91.00%	92.00%	$1,323.26	$293.32	$1,616.58
1800	ODP	10	89.50%	91.70%	92.70%	$1,475.12	$360.47	$1,835.59
1800	ODP	15	91.00%	93.00%	94.00%	$2,541.29	$469.00	$3,010.29
1800	ODP	20	91.00%	93.00%	94.00%	$2,861.24	$617.20	$3,478.44

RPM	Enclosure	Horse-Power	EPACT Efficiency (A)	NEMA Premium Efficiency (B)	Enhanced NEMA Premium Efficiency (C)	Incremental Cost (A to B)	Incremental Cost (B to C)	Incremental Cost (A to C)
1800	ODP	25	91.70%	93.60%	94.60%	$3,261.14	$751.60	$4,012.74
1800	ODP	30	92.40%	94.10%	95.10%	$3,513.58	$871.88	$4,385.46
1800	ODP	40	93.00%	94.10%	95.10%	$4,222.09	$947.00	$5,169.09
1800	ODP	50	93.00%	94.50%	95.50%	$4,628.91	$1,380.89	$6,009.80
1800	ODP	60	93.60%	95.00%	96.00%	$5,831.16	$1,612.77	$7,443.93
1800	ODP	75	94.10%	95.00%	96.00%	$6,697.92	$1,951.58	$8,649.50
1800	ODP	100	94.10%	95.40%	96.40%	$8,402.69	$2,288.79	$10,691.48
1800	ODP	125	94.50%	95.40%	96.40%	$10,323.06	$2,602.07	$12,925.13
1800	ODP	150	95.00%	95.80%	96.80%	$10,693.62	$2,810.35	$13,503.97
1800	ODP	200	95.00%	95.80%	96.80%	$12,801.47	$3,524.00	$16,325.47
1800	ODP	250	95.40%	95.80%	96.80%	$15,888.00	$4,632.20	$20,520.20
1800	ODP	300	95.40%	95.80%	96.80%	$20,204.33	$6,722.38	$26,926.71
1800	ODP	350	95.40%	95.80%	96.80%	$29,220.28	$7,021.10	$36,241.38
1800	ODP	400	95.40%	95.80%	96.80%	$32,992.47	$13,672.54	$46,665.01
1800	ODP	450	95.80%	96.20%	97.20%	$56,915.81	$14,746.17	$71,661.98
1800	ODP	500	95.80%	96.20%	97.20%	$59,663.64	$15,510.64	$75,174.28
1800	TEFC	1	82.50%	85.50%	86.50%	$826.86	$131.56	$958.42
1800	TEFC	1.5	84.00%	86.50%	87.50%	$821.85	$147.06	$968.91
1800	TEFC	2	84.00%	86.50%	87.50%	$907.18	$143.64	$1,050.82
1800	TEFC	3	87.50%	89.50%	90.50%	$953.05	$210.67	$1,163.72
1800	TEFC	5	87.50%	89.50%	90.50%	$976.06	$269.84	$1,245.90
1800	TEFC	7.5	89.50%	91.70%	92.70%	$1,323.26	$334.48	$1,657.74
1800	TEFC	10	89.50%	91.70%	92.70%	$1,475.12	$516.20	$1,991.32
1800	TEFC	15	91.00%	92.40%	93.40%	$2,541.29	$604.09	$3,145.38
1800	TEFC	20	91.00%	93.00%	94.00%	$2,861.24	$822.06	$3,683.30
1800	TEFC	25	92.40%	93.60%	94.60%	$3,261.14	$1,048.92	$4,310.06
1800	TEFC	30	92.40%	93.60%	94.60%	$3,513.58	$1,213.65	$4,727.23
1800	TEFC	40	93.00%	94.10%	95.10%	$4,222.09	$1,415.66	$5,637.75

RPM	Enclosure	Horse-Power	EPACT Efficiency (A)	NEMA Premium Efficiency (B)	Enhanced NEMA Premium Efficiency (C)	Incremental Cost (A to B)	Incremental Cost (B to C)	Incremental Cost (A to C)
1800	TEFC	50	93.00%	94.50%	95.50%	$4,628.91	$1,829.03	$6,457.94
1800	TEFC	60	93.60%	95.00%	96.00%	$5,831.16	$2,161.11	$7,992.27
1800	TEFC	75	94.10%	95.40%	96.40%	$6,697.92	$2,587.48	$9,285.40
1800	TEFC	100	94.50%	95.40%	96.40%	$8,402.69	$3,030.26	$11,432.95
1800	TEFC	125	94.50%	95.40%	96.40%	$10,323.06	$3,883.21	$14,206.27
1800	TEFC	150	95.00%	95.80%	96.80%	$10,693.62	$4,506.23	$15,199.85
1800	TEFC	200	95.00%	96.20%	97.20%	$12,801.47	$5,168.35	$17,969.82
1800	TEFC	250	95.00%	96.20%	97.20%	$15,888.00	$6,582.87	$22,470.87
1800	TEFC	300	95.40%	96.20%	97.20%	$20,204.33	$9,154.16	$29,358.49
1800	TEFC	350	95.40%	96.20%	97.20%	$29,220.28	$9,594.10	$38,814.38
1800	TEFC	400	95.40%	96.20%	97.20%	$32,992.47	$19,389.97	$52,382.44
1800	TEFC	450	95.40%	96.20%	97.20%	$56,915.81	$20,971.17	$77,886.98
1800	TEFC	500	95.80%	96.20%	97.20%	$59,663.64	$22,097.04	$81,760.68
3600	ODP	1	76.30%	77.00%	78.00%	$826.86	$117.34	$944.20
3600	ODP	1.5	82.50%	84.00%	85.00%	$821.85	$131.56	$953.41
3600	ODP	2	84.00%	85.50%	86.50%	$907.18	$150.13	$1,057.31
3600	ODP	3	84.00%	85.50%	86.50%	$953.05	$149.11	$1,102.16
3600	ODP	5	85.50%	86.50%	87.50%	$976.06	$159.83	$1,135.89
3600	ODP	7.5	87.50%	88.50%	89.50%	$1,323.26	$173.97	$1,497.23
3600	ODP	10	88.50%	89.50%	90.50%	$1,475.12	$255.13	$1,730.25
3600	ODP	15	89.50%	90.20%	91.20%	$2,541.29	$309.51	$2,850.80
3600	ODP	20	90.20%	91.00%	92.00%	$2,861.24	$419.40	$3,280.64
3600	ODP	25	91.00%	91.70%	92.70%	$3,261.14	$504.57	$3,765.71
3600	ODP	30	91.00%	91.70%	92.70%	$3,513.58	$613.33	$4,126.91
3600	ODP	40	91.70%	92.40%	93.40%	$4,222.09	$694.38	$4,916.47
3600	ODP	50	92.40%	93.00%	94.00%	$4,628.91	$844.17	$5,473.08
3600	ODP	60	93.00%	93.60%	94.60%	$5,831.16	$954.07	$6,785.23
3600	ODP	75	93.00%	93.60%	94.60%	$6,697.92	$1,246.14	$7,944.06

RPM	Enclosure	Horse-Power	EPACT Efficiency (A)	NEMA Premium Efficiency (B)	Enhanced NEMA Premium Efficiency (C)	Incremental Cost (A to B)	Incremental Cost (B to C)	Incremental Cost (A to C)
3600	ODP	100	93.00%	93.60%	94.60%	$8,402.69	$1,506.52	$9,909.21
3600	ODP	125	93.60%	94.10%	95.10%	$10,323.06	$1,770.44	$12,093.50
3600	ODP	150	93.60%	94.10%	95.10%	$10,693.62	$2,249.70	$12,943.32
3600	ODP	200	94.50%	95.00%	96.00%	$12,801.47	$2,694.86	$15,496.33
3600	ODP	250	94.50%	95.00%	96.00%	$15,888.00	$3,367.82	$19,255.82
3600	ODP	300	95.00%	95.40%	96.40%	$20,204.33	$3,791.55	$23,995.88
3600	ODP	350	95.00%	95.40%	96.40%	$29,220.28	$5,387.46	$34,607.74
3600	ODP	400	95.40%	95.80%	96.80%	$32,992.47	$7,671.58	$40,664.05
3600	ODP	450	95.80%	96.20%	97.20%	$56,915.81	$8,012.64	$64,928.45
3600	ODP	500	95.80%	96.20%	97.20%	$59,663.64	$9,061.82	$68,725.46
3600	TEFC	1	75.50%	77.00%	78.00%	$826.86	$122.57	$949.43
3600	TEFC	1.5	82.50%	84.00%	85.00%	$821.85	$137.26	$959.11
3600	TEFC	2	84.00%	85.50%	86.50%	$907.18	$146.61	$1,053.79
3600	TEFC	3	85.50%	86.50%	87.50%	$953.05	$155.73	$1,108.78
3600	TEFC	5	87.50%	88.50%	89.50%	$976.06	$173.05	$1,149.11
3600	TEFC	7.5	88.50%	89.50%	90.50%	$1,323.26	$194.59	$1,517.85
3600	TEFC	10	89.50%	90.20%	91.20%	$1,475.12	$274.06	$1,749.18
3600	TEFC	15	90.20%	91.00%	92.00%	$2,541.29	$319.08	$2,860.37
3600	TEFC	20	90.20%	91.00%	92.00%	$2,861.24	$467.86	$3,329.10
3600	TEFC	25	91.00%	91.70%	92.70%	$3,261.14	$571.37	$3,832.51
3600	TEFC	30	91.00%	91.70%	92.70%	$3,513.58	$720.03	$4,233.61
3600	TEFC	40	91.70%	92.40%	93.40%	$4,222.09	$848.05	$5,070.14
3600	TEFC	50	92.40%	93.00%	94.00%	$4,628.91	$1,108.32	$5,737.23
3600	TEFC	60	93.00%	93.60%	94.60%	$5,831.16	$1,273.39	$7,104.55
3600	TEFC	75	93.00%	93.60%	94.60%	$6,697.92	$1,840.77	$8,538.69
3600	TEFC	100	93.60%	94.10%	95.10%	$8,402.69	$2,236.93	$10,639.62
3600	TEFC	125	94.50%	95.00%	96.00%	$10,323.06	$2,768.05	$13,091.11
3600	TEFC	150	94.50%	95.00%	96.00%	$10,693.62	$3,435.41	$14,129.03

RPM	Enclosure	Horse-Power	EPACT Efficiency (A)	NEMA Premium Efficiency (B)	Enhanced NEMA Premium Efficiency (C)	Incremental Cost (A to B)	Incremental Cost (B to C)	Incremental Cost (A to C)
3600	TEFC	200	95.00%	95.40%	96.40%	$12,801.47	$4,010.66	$16,812.13
3600	TEFC	250	95.40%	95.80%	96.80%	$15,888.00	$4,960.41	$20,848.41
3600	TEFC	300	95.40%	95.80%	96.80%	$20,204.33	$6,543.88	$26,748.21
3600	TEFC	350	95.40%	95.80%	96.80%	$29,220.28	$9,593.18	$38,813.46
3600	TEFC	400	95.40%	95.80%	96.80%	$32,992.47	$10,753.82	$43,746.29
3600	TEFC	450	95.40%	95.80%	96.80%	$56,915.81	$14,377.80	$71,293.61
3600	TEFC	500	95.40%	95.80%	96.80%	$59,663.64	$17,487.75	$77,151.39

Appendix D – Commercial Building Models

The following table defines the characteristics of the models used for the C/I measures by Franklin Energy Services.

Table D-1. Model Characteristics Used For C/I Measures

Building Type	Building Characteristics			General Occupancy Schedule				HVAC Equipment		
	Total Sq Ft	Number of Floors Above Grade	Secondary Spaces Breakdown (balance is primary space)	Weekday	Saturday	Sunday	Holiday	Air System	Cooling Equipment Type	Heating Equipment Type
Convenience Store	6,000	1	Office: 2%, Dry storage: 15%	7am-10pm	9am-9pm	10am-5pm	10am-5pm	Constant volume packaged rooftop unit	DX	Natural gas heater in RTU
Education - Community College/University	1,000,000	3	classrooms: 43.1%, ind work: 8%, computer rooms: 2.8%, corridor: 3%, dining: 2.4%, dorm: 17%, kitchen: 1.1%, office 22.7%	7am-Midnight (Typical Break Schedules - Summer Occupancy 40%)	7am-7pm	10am-Noon	10am-Noon	Variable Air Volume (VAV), [constant volume packaged rooftop unit, kitchen]	Centrifugal Chiller, (DX Kitchen)	Boiler, hot water (Natural gas heater in RTU, kitchen)
Education - Primary	75,000	2	offices: 6%, gym 5%, kitchen 2%, cafeteria 5%, library: 6%	8am-4pm (20% in summer)	closed	closed	closed	Constant volume unit ventilators	Screw air cooled chiller	Boiler, hot water

Building Type	Building Characteristics			General Occupancy Schedule				HVAC Equipment		
	Total Sq Ft	Number of Floors Above Grade	Secondary Spaces Breakdown (balance is primary space)	Weekday	Saturday	Sunday	Holiday	Air System	Cooling Equipment Type	Heating Equipment Type
Education - Secondary	225,000	2	gym: 10%, aux. gym 6%, auditorium 5%, kitchen 1%, cafeteria: 3%, offices 3%, library 4%	8am-4pm (20% in summer)	closed	closed	closed	Constant volume unit ventilators	Screw air cooled chiller	Boiler, hot water
Health/Medical - Clinic	67,500	3	30% exam, 30% corridor/lobby, 20% office, 20% storage/utility	7am-7pm	9am-5pm	closed	closed	Constant volume packaged rooftop unit	DX	Natural gas heater in RTU
Health/Medical - Hospital	200,000	4	56% lobby/corridor, 20% treatment rooms, 9% food service, 11% patient rooms, 3% office	24/7	24/7	24/7	24/7	Constant volume indoor units	Centrifugal water cooled chiller	Natural gas heater in RTU
Lodging	56,000	2	office: 3%, laundry 2.4%, Mtg room 2%, exercise 1%, employee lounge 1%	24/7	24/7	24/7	24/7	Packaged terminal heat pump	Packaged terminal AC	Heat pump, supplemental electric

Building Type	Building Characteristics			General Occupancy Schedule				HVAC Equipment		
	Total Sq Ft	Number of Floors Above Grade	Secondary Spaces Breakdown (balance is primary space)	Weekday	Saturday	Sunday	Holiday	Air System	Cooling Equipment Type	Heating Equipment Type
Manufacturing Facility	120,000	1	10% office space on two floors, 90% manufacturing on single floor	Office: 8am-5pm, mfg: 6am-10pm	Office: closed, mfg: 6am-10pm	closed	closed	Mfg: Make-up air unit; Office: RTU	Mfg.: none; Office: DX	Natural gas heater in MAU & RTU
Office - High-rise	537,600	20		8am-5pm	20% 8am-noon	closed	closed	Variable Air Volume (VAV)	Centrifugal water cooled chiller	Boiler, hot water
Office - Low-rise	7,500	1		8am-5pm	closed	closed	closed	Constant volume packaged rooftop unit	DX	Natural gas heater in RTU
Office - Mid-rise	50,000	5		8am-5pm	20% 8am-noon	closed	closed	Variable Air Volume (VAV)	Centrifugal water cooled chiller	Boiler, hot water
Restaurant	7,500	1	kitchen 27%, dining 73%	7am-8pm	7am-8pm	7am-8pm	closed	Constant volume packaged rooftop unit	DX	Natural gas heater in RTU

Building Type	Building Characteristics			General Occupancy Schedule				HVAC Equipment		
	Total Sq Ft	Number of Floors Above Grade	Secondary Spaces Breakdown (balance is primary space)	Weekday	Saturday	Sunday	Holiday	Air System	Cooling Equipment Type	Heating Equipment Type
Retail - Department Store	45,000	1	back space 17%, point of sale 7%	9am-9pm	9am-9pm	10am-5pm	10am-5pm	Constant volume packaged rooftop unit	DX	Natural gas heater in RTU
Retail - Strip Mall	3,000	1	storage: 15%	9am-9pm	9am-9pm	10am-5pm	10am-5pm	Constant volume packaged rooftop unit	DX	Natural gas heater in RTU
Warehouse	100,000	1	high bay storage: 80%, office 20%	6am-6pm	closed	closed	closed	Constant volume packaged rooftop unit	DX	Natural gas heater in RTU

Appendix E – Conservation Voltage Reduction Examples

Method below is from "Simplified Voltage Optimization (VO) Measurement and Verification Protocol" produced by the Regional Technical Forum. Note that Voltage Optimization is another term for Conservation Voltage Reduction.

System improvements typically have a useful life exceeding 35 years. However, control settings are easily altered over time unless they are integrated into utility operating and design standards. For new operating design standards to become entrenched, a three- year monitoring and documentation period is recommended. Standards that become entrenched tend to extend the life of VO perpetually.

This three-year period includes the following:

1. On a monthly basis, a utility must document that voltage control settings within each the VO voltage control zone are maintained as necessary to be consistent with those determined during the original VO project.
2. On an annual basis, provide total kWh usage on the voltage control zone and provide average voltage at Substation and EOL.
3. A utility must maintain this documentation (or provide it to the appropriate organization) annually for a three-year period.
4. During this three-year period, if the voltage control settings have been off-line, either intentionally or unintentionally for a period of 30 days or longer, the utility must continue to maintain the voltage control setting documentation for a period equal to 30 days or longer beyond the original three-year documentation period.
5. Verify performance thresholds for each voltage-control-zone and corrective actions taken if any. Thresholds include:
    a. Feeder power factor – Average hourly > 0.98 from *metered* data
    b. Feeder power factor – Maximum hourly > 0.96 from *metered* data
    c. EOL primary voltage must be > [114 Volts + '' the voltage regulation bandwidth + secondary maximum allowed voltage-drop] from *metered* data
    d. Regulator primary voltage must be < [126 Volts - '' the voltage regulation bandwidth + secondary maximum allowed voltage-drop] from *metered* data
    e. Feeder load unbalance must be < 0.15 from system modeling
    f. Feeder Source 3-phase feeder neutral current < 40 Amps from *metered* data
    g. Feeder maximum adjusted primary voltage-drops <3.3% from system modeling
    h. Feeder maximum voltage-drop variance < 2.0 V on a 120V base.

Appendix F – Standard Conversion Factors

Table F-1. Fuel Conversion Factors (Ref. 1,2)

Fuel Type	Starting Unit	Heat Content, Conversion Factor to mmBtu or Dth (mmBtu/Unit)	Heat Content, Conversion Factor to kWh (kWh/Unit)
Electricity	1 kWh	0.003412	1.00
All	1 Dth or 1 MMBTU	1	293.07
Natural Gas, CNG	1 CF	0.00103	0.30
Landfill Gas	1 CF	0.0005	0.15
Biomass Gas	1 CF	0.0007	0.21
Propane	1 CF	0.0025	0.73
Liquified Natural Gas (LNG)	1 gallon	0.0474	13.89
Ethanol	1 gallon	0.084	24.62
Propane	1 gallon	0.091	26.67
Liquified Petro Gas (LPG)	1 gallon	0.092	26.96
Gasoline	1 gallon	0.125	36.63
Biodiesel	1 gallon	0.128	37.51
Fuel Oil #1 (Kerosene)	1 gallon	0.135	39.56
Diesel #2	1 gallon	0.138	40.44
Fuel Oil #2	1 gallon	0.138	40.44
Fuel Oil #6	1 gallon	0.150	43.96
Municipal Solid Waste	1 short ton (US)	9.95	2,916.05
Biomass Solids (byproducts)	1 short ton (US)	10.39	3,045.00
Biomass solids (Agricultural)	1 short ton (US)	17.48	5,122.86
Coal (mixed, electric power sector)	1 short ton (US)	19.73	5,782.27
Coal (mixed, industrial sector)	1 short ton (US)	22.35	6,550.11
Wood, Wood Residuals	1 short ton (US)	17.48	5,122.86
Wood, Wood Residuals	1 lb	0.0087	2.55

Grid electric CO_2e shown in Table F-2 has been derived from the output emissions rate for the full fuel mix of the eGRID subregion of 'MROW' for 2025, incorporating all transmission losses, and generation efficiencies. All other fuel CO_2e emissions shown in Table F-2 have been derived from the EPA Emissions Factors for Greenhouse Gas Inventories for stationary combustion. CO_2e incorporates three pollutants: CO_2, CH_4 and N_2O. To calculate CO_2e, for each of the three, the pollutant factor is multiplied by the 100-year global warming potential of 1, 28 and 265 for CO_2, CH_4 and N_2O, respectively. The sum of the three is the cumulative CO_2e emissions factor. The global warming potential values are taken from the IPCCC Greenhouse Gas Protocol Fifth Assessment Report. The values in Table F-2 represent emissions from stationary combustion of the specified fuel irrespective of the timing of the combustion or the efficiency of the method of combustion. When directly comparing emissions from different fuel sources, the

efficiency of the method of combustion should be factored into the conversion. Utilities able to analyze territory emissions on an hourly basis should utilize hourly emissions specific to their territory in place of TRM provided emissions data.

Table F-2. CO_2e Greenhouse Gas Emissions Factors – Stationary Combustion (Ref. 1,3,4,5)

Fuel Type	From EPA, CO2	Converted to CO2e		
	CO2 kG CO2 per mmBtu	CO2e kG CO2e per mmBtu	CO2e Metric tons per mmBtu or Dth	CO2e Metric tons per kWh
Grid Electricity (MROW)	123.18	123.18	0.12318	0.00042
Geothermal (steam)	11.81	11.81	0.01181	0.00004
Landfill Gas	52.07	52.33	0.05233	0.00018
Biomass Gas	52.07	61.70	0.06170	0.00021
Natural Gas / Compressed Natural Gas (CNG) / Liquified Natural Gas (LNG)	53.06	53.11	0.05311	0.00018
Liquified Petroleum Gases (LPG)	61.71	61.95	0.06195	0.00021
Propane	62.87	63.11	0.06311	0.00022
Ethanol	68.44	68.50	0.06850	0.00023
Gasoline	70.22	70.46	0.07046	0.00024
Biodiesel	73.84	73.90	0.07390	0.00025
Fuel Oil #1 Kerosene	75.20	75.44	0.07544	0.00026
Diesel #2	73.96	74.20	0.07420	0.00025
Fuel Oil #2	73.96	74.20	0.07420	0.00025
Fuel Oil #6	75.10	75.34	0.07534	0.00026
Municipal Solid Waste	90.70	92.71	0.09271	0.00032
Wood, Wood Residuals	93.80	94.96	0.09496	0.00032
Coal (mixed, electric power sector)	95.52	96.25	0.09625	0.00033
Coal (mixed, industrial sector)	94.67	95.40	0.09540	0.00033
Biomass Solids (byproducts)	105.51	107.52	0.10752	0.00037
Biomass solids (Agricultural)	118.17	120.18	0.12018	0.00041

The values in Table F-3 represent emissions from mobile combustion of the specified fuel by vehicle mode noted, irrespective of the timing of the combustion or the efficiency of the method of combustion. When directly comparing emissions from different fuel sources, the efficiency of the method of combustion should be factored into the conversion.

Table F-3. CO_2e Greenhouse Gas Emissions Factors – Mobile Vehicle Combustion (Ref. 1,2,4,5)

Fuel Type	From EPA, CO2	Passenger Vehicles		Commercial Vehicles	
	CO2 Kg CO2 per Gallon	CO2e kG CO2e per Gallon	CO2e kG CO2e per mmBtu	CO2e kG CO2e per Gallon	CO2e kG CO2e per mmBtu
Gasoline - Vehicle Engine	8.78	8.85	70.81	8.86	70.84
Diesel #2	10.21	10.36	75.06	10.39	75.26
Biodiesel	9.45	9.60	74.98	9.62	75.19
Natural Gas / Compressed Natural Gas (CNG)/ Liquified Natural Gas (LNG)	4.50 per gal 0.0544 per SCF	4.59	96.76	5.79	122.13
Ethanol	5.75	5.79	68.91	5.89	70.15
Liquified Petroleum Gases (LPG)	5.68	5.72	62.16	5.82	63.27

The values in Table F-4 represent emissions from mobile combustion of the specified fuel by equipment mode noted, irrespective of the timing of the combustion or the efficiency of the method of combustion. When directly comparing emissions from different fuel sources, the efficiency of the method of combustion should be factored into the conversion.

Table F-4. CO_2e Greenhouse Gas Emissions Factors – Mobile Equipment Combustion (Ref. 1,2,4,5)

Fuel Type	From EPA, CO2	Equipment (Yard/Garden Equipment, Commercial/ Industrial Equipment, Recreational Equipment)	
	CO2 Kg CO2 per Gallon	CO2e kG CO2e per Gallon	CO2e kG CO2e per mmBtu
Gasoline - 2 Stroke Engine	8.78	9.14	73.12
Gasoline - 4 Stroke Engine	8.78	9.27	74.19
Diesel #2	10.21	10.46	75.83

References

1. EPA. Emissions Factors for Greenhouse Gas Inventories. Website dataset last updated January 2025.https://www.epa.gov/system/files/documents/2025-01/ghg-emission-factors-hub-2025.pdf . Main website directory: https://www.epa.gov/climateleadership/ghg-emission-factors-hub

2. Heat content of Liquid Natural Gas (LNG) in weighthttps://world-nuclear.org/information-library/facts-and-figures/heat-values-of-various-fuels EPA. Data Explorer eGrid. Website dataset last updated April 30, 2025. https://www.epa.gov/egrid/data-explorer
3. Intergovernmental Panel on Climate Change (IPCC). Greenhouse Gas Protocol, Fifth Assessment Report (AR5). Accessed September 22, 2022, verified September 1, 2025. https://www.ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf
4. U.S. Energy Information Administration. Carbon Dioxide Emissions Coefficients. Data last revised February 9, 2022. https://www.eia.gov/environment/emissions/co2_vol_mass.php

Revision History

Version	Description	Author	Date
4.0	New Appendix and content	Cadmus	11/1/2022
5.0	Updates to emissions values based on updated source data, particularly MROW, and GWP factors for CO2e. Ensured consistent calculation and representation of CO2e (distinct from CO2) with original EPA sources, for stationary versus mobile combustion sources.	Cadmus	9/1/2025

Appendix G – Residential HVAC – ASHP Model and Calculator

Appendix G is available as a Microsoft Excel spreadsheet (*.xls) on the Minnesota Department of Commerce, Division of Energy Resources website.

https://mn.gov/commerce/energy/industry-government/cip/technical-reference-manual/

Appendix H – List of Preweatherizaton Measures Eligible for Inclusion in Low-income Energy Conservation Programs

The Commissioner approved (Ref 1) the following list of preweatherization measures as eligible for inclusion in low-income energy conservation programs:

- Ventilation repairs or replacement
- Remediation of vermiculite and presumed asbestos containing materials related to the energy efficiency upgrade
- Mold and moisture related mitigation
    - o Structural repair (foundation, walls, roofing, windows/doors, repair or replacement)
    - o Grading for seepage control
    - o Gutters/downspouts repair, replacement, or addition
    - o Sump pumps – repair, replacement, or addition
    - o Black mold removal
- Radon mitigation
- Structural repair or replacement (non-moisture related) – foundation, roofing, windows/doors, walls
- Plumbing leaks/sewer problems, including red-tagged plumbing
- Major and minor electrical repair and upgrading related to the energy efficiency upgrade
    - o Replace knob and tube wiring, upgrading panel, etc.
    - o Upgrading electrical panel, outlets, junction boxes
    - o Repairing loose and damaged wiring
- Inaccessible crawl spaces
- Remediation of excessive clutter or hoarding
- Addressing improper or ineffective HVAC venting (e.g., chimney liners)
- Integrated pest management (bugs and vermin remediation and blocking)
- Carbon monoxide and smoke detectors
- Repairing or replacing unsafe dryer venting
- Flue repair
- Gas valve repair
- Sensor repair

This list is meant to be comprehensive but not exhaustive, and utilities may propose additional measures for the Department to consider, including other health and safety related repairs that are preventing energy efficiency upgrades or installations. If utilities are uncertain whether their proposed preweatherization projects are eligible under this proposed list, they should contact Department of Commerce CIP Staff to ensure eligibility.

References

1. Minnesota Department of Commerce Division of Energy Resources, Decision In the Matter of Technical Guidance for the Inclusion of Efficient Fuel-Switching, Load Management, and Pre-Weatherization Measures in CIP, (March 15, 2022). Docket No. E,G999/CIP-21-837. (eDocket No. 20223-183807-01). At 28. https://efiling.web.commerce.state.mn.us/edockets/searchDocuments.do?method=showPoup&documentId=%7B90098F7F-0000-C11B-B04F-C063DF81A5F9%7D&documentTitle=20223-183807-01

Revision History

Version	Description	Author	Date
4.2	New Appendix and content	MN Department of Commerce	2024

Appendix I – MN Load Profile Memo

Executive Summary

As part of an effort to compile an update of the Minnesota Technical Reference Manual (TRM), EnerNex was tasked with assisting Franklin Energy in researching available end use electric load data, determining the most appropriate reference data for Minnesota, developing an end use load profile for each end use researched and identifying areas where the data could be refined for Minnesota with further studies or surveys. EnerNex reviewed multiple existing load profiles, including from such sources as the Electric Power Research Institute (EPRI), and Itron, and created approximate end use estimates based on national averages and Census region data. In order to refine this output, Minnesota specific end use surveys should be conducted. What follows is an overview of the process that was used to create the end use load profiles with a discussion of available data, and recommendations for refining the Minnesota load profiles in subsequent iterations.

The load profile estimations were developed by referencing source data that estimated the percentage of commercial and residential customers that utilize electricity for the end use specified and then finding estimated average annual energy consumption for those end uses. The tables below summarize these two variables for each residential and commercial end use. In some instances, the % of customers utilizing a specified end use can be equal to or greater than 100%. When the "% of customers utilizing" number exceeds 100%, it indicates that an average customer has more than one of the device (as is the case with residential refrigerators and televisions).

Residential End Use	% of Customers Utilizing	Estimated annual kWh Per Customer
Water Heater	36	4857
Space Heating	15	822
Air Conditioning	64	641
Indoor Lighting	100	1230
Exterior Lighting	100	645
Refrigerator	127	596

Cooking Equipment	67	1185
Clothes Dryer	60	769
Clothes Washer	79	590
Computers	92	236
Televisions	286	166
Dishwasher	78	206
Pool/Spa	3	2300

Table 1 Major Residential End Uses and End Use Energy Estimates

Commercial End Use	% of Total Sales	Estimated annual kWh Per Customer
Interior Lighting	28.7	22,813
Exterior Lighting	5.84	4,637
Cooling	15	11,835
Space Heating	9	7,221
Motors	4.2	3,328
Cooking Equipment	4.2	3,321
Refrigeration	14	10,831
Ventilation	12	9,628
Air Compressors	0.96	760
Office Equipment	6.1	4,821
Water Heating	1.52	1,207
Total	**101.5**	**80,405**

Table 2 Major Commercial End Uses and End Use Energy Estimates