State of Minnesota
Technical Reference Manual
for
Energy Conservation Improvement Programs

Version 2.0

Effective:

January 1, 2017 – December 31, 2019

Minnesota Department of Commerce
Division of Energy Resources

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Acknowledgements

This document was primarily constructed from energy efficiency and conservation measure specifications developed by Franklin Energy Services with input from Minnesota Department of Commerce, Division of Energy Resources staff and Minnesota utilities. Commerce staff appreciates the significant contributions that Minnesota utilities, consultants, and other stakeholders have made to the Technical Reference Manual (TRM) through sharing information and participating in TRM advisory committee and technical work group meetings.

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 improvement programs (CIP) in Minnesota. The TRM also documents the calculations that are embedded in the Minnesota Department of Commerce, Division of Energy Resources (DER) TRM Smart Measure Library on ESP®[1], a set of working models for real time savings calculations and tracking that is available to all Minnesota utilities on ESP®.

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 CIP administrators may reference when developing, implementing and reporting on CIP 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-defined pre- and post- 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 CIP programs. Minnesota utilities may propose additional measures as standard offerings in their CIP plans, or implement custom measures without pre-approval from Commerce.

[1] ESP® is Cloud-based software application for energy efficiency program management and reporting developed by Energy Platforms, LLC with funding from the Minnesota Department of Commerce. ESP® is launched from www.energyplatforms.com. All Minnesota utilities are granted free access to all features within ESP®. Contact Commerce staff at CIP.Contact@state.mn.us to obtain a login to ESP®.

Summary of Changes from TRM V 1.3

Measure	Version/Description
Electric Efficiency Measures	
Agriculture - Engine Block Heater Timer	1.0 New
Agriculture - High Efficiency Fans	1.0 New 1.1 Added Table 1, Average Fan Characteristics
Agriculture - Livestock Waterer	1.0 New
Agriculture - Poultry Farm LED Lighting	1.0 New
Agriculture - VSD Milk Pump	1.0 New
C/I HVAC - Chiller Systems	2.0 Updated measure to reflect new MN Code, Added 'Other/Misc Building' Type
C/I HVAC - Chiller Tune-up	1.0 New
C/I HVAC - ECM Circulators	1.0 New
C/I HVAC - Heat Pump Systems	2.0 Changed from Heating Degree Days to EFLHHeat. Updated Table 2 to include building types. Added Other/Miscellaneous building type for EFLHCool. Correct reference to COPs. Change base line to 2015 Minnesota Energy Code.
C/I HVAC - High Volume Low Speed Fans	2.0 Added HVAC Cooling kWh and kW savings and Heating penalty factors
C/I HVAC - Mini Split Ductless Systems A/C only and Heat Pump	1.0 New
C/I HVAC - Unitary and Split Systems	2.0 Updated to new MN code, added IEER efficiency levels, added 'Other/Misc' building type
C/I HVAC - Unitary Equipment Economizer	2.0 Added/Updated economizer code requirements
C/I HVAC - Variable Speed Drives	2.0 Updated energy code requirements for new construction
C/I Lighting - Lighting End Use	4.0 New Master C/I Lighting Section, energy standards updated where applicable. Updated baseline and efficient wattages and costs in Appendix B. Added suggested requirements.
C/I Lighting - CFL Standard to Low Wattage Retrofit	
C/I Lighting - Exit Sign Retrofit with LED/LEC	
C/I Lighting - Exterior Canopy/Soffit Retrofit with LEDs	3.3 Added suggested requirements for fixtures.
C/I Lighting - Exterior Wall Pack Retrofit with LEDs	1.1 Added suggested requirements for fixtures.
C/I Lighting - Fluorescent to LED High Bay Systems	1.0 New
C/I Lighting - High Pressure Sodium Retrofit	

C/I Lighting - Incandescent Over 100W Retrofit	3.5 Added suggested requirements for fixtures/lamps.
C/I Lighting - Incandescent Up to 100W Retrofit	3.5 Added suggested requirements for fixtures/lamps.
C/I Lighting - Mercury Vapor Retrofit	
C/I Lighting - Metal Halide Retrofit	
C/I Lighting - Pulse Start Metal Halide Retrofit	
C/I Lighting - Stairwell Fixtures with Integral Occupancy Sensors	1.1 Added suggested requirements for fixtures/lamps.
C/I Lighting - T8 Standard to Low Wattage Retrofit	3.5 Added suggested requirements for fixtures/lamps.
C/I Lighting - T12 8-Foot Retrofit	
C/I Lighting - T12 Up to 4-Foot Retrofit	3.6 Added suggested requirements for fixtures/lamps. Revised measure life.
C/I Lighting - T8 Optimization	
C/I Lighting - LED Troffers	1.0 New
C/I Lighting - Controls	3.5 Added suggested requirements for fixtures/lamps.
C/I Lighting - New Construction	3.5 Added Code information
C/I Lighting - Refrigerator/Freezer Case LEDs	2.2 Added suggested requirements for fixtures/lamps.
C/I Motors	
C/I Refrigeration - Anti-Sweat Heat Control	
C/I Refrigeration - ENERGY STAR Refrigerator and Freezer	
C/I Refrigeration - Evaporator Fan Motor Retrofit	
C/I Envelope - Fast Acting Doors	New
Commercial Beverage Machine Controls	
Commercial Food Service - Electric Oven and Range	4.2 Hours of use changed to 365.25
Commercial Food Service - ENERGY STAR Electric Combination Oven	
Commercial Food Service - ENERGY STAR Electric Convection Oven	2.0 Updated to new Energy Star requirements 2.1 Hours of use changed to 365.25
Commercial Food Service - ENERGY STAR Electric Fryer	1.3 Hours of use changed to 365.25
Commercial Food Service - ENERGY STAR Electric Griddle	1.3 Hours of use changed to 365.25
Commercial Food Service - ENERGY STAR Electric Hot Food Holding Cabinet	1.2 Hours of use changed to 365.25

Commercial Food Service - ENERGY STAR Electric Steamer	2.0 Updated operating hours 3.0 Updated the Energy-to-Food value
Commercial Hot Water- Electric Water Heaters	1.0 Recommended for removal
Commercial Hot Water - Faucet Aerator (1.5 gpm) with Electric Water Heater	4.0 The calculation has been simplified and updated with values for unknown factors, baseline flow rate has been updated
Commercial Hot Water - Heat Pump Water Heater	1.0 New
Commercial Hot Water - Pre-Rinse Sprayers (1.6 gpm) with Electric Water Heater	3.0 The average temperature has been increased from 105°F to 110°F based on the results of a 2011 EPA study. added the Senior Living but not the Congregation, due to high variability in usage.
Commercial HVAC - Forced-Air Heating Maintenance	2.0 Changed from Heating Degree Days to EFLHHeat. Updated Table 2 to include building types.
Commercial HVAC - Programmable Thermostats with Electric Heating	New
Industrial Compressed Air - No Loss Drains	
Industrial Compressed Air - Variable Speed Drive Air Compressors < 50hp	
Industrial Compressed Air - Compressed Air Leak Detection	New
Public - LED Traffic Signal	
Residential Appliances - ENERGY STAR Clothes Washers	
Residential Appliances - ENERGY STAR Dishwashers	
Residential Appliances - ENERGY STAR Refrigerators and Freezers	
Residential Appliances - Secondary Refrigerator/Freezer Removal	
Residential HVAC - Central AC/ASHP	3.0 Changed from HDD to EFLHHeat algorithm.
Residential HVAC - Central AC/ASHP Quality Install Additional Savings	3.0 Updated approach and savings Changed from HDD to EFLHHeat algorithm.
Residential HVAC - Central AC/ASHP Tune-up	3.0 Updated EFLH terminology and source description
Residential HVAC - Duct Sealing	New
Residential HVAC - ECM Circulators	New
Residential HVAC - ECM Blower Motors	2.0 Included interactive effect of negative Dth gas savings and aligned % of homes with CAC with lighting measure assumptions, measure includes new furnaces and retrofits
Residential HVAC - ENERGY STAR Room A/C	

Residential HVAC - ENERGY STAR Dehumidifiers	3.0 Removed old federal efficiency criteria tables.
Residential HVAC - Ground Source Heat Pump Systems	1.0 New
Residential HVAC - Mini Split Ductless Systems A/C only and Heat Pump	1.0 New
Residential HVAC - Thermostats with Electric Heating	2.0 New, Added Smart Thermostat tiers to Programmable Thermostat Measure
Residential Lighting - Lighting End Use	2.0 New Master Residential Lighting Section, corrected HVAC Heating Penalty Factor, added in service rate, added delivery methods
Residential Lighting - CFLs and ENERGY STAR Torchieres	3.0 Updated wattages, added default value
Residential Lighting - ENERGY STAR LED Lamps and Fixtures	1.4 Updated wattages, incremental costs where applicable
Residential Lighting - ENERGY STAR CFL Fixtures	
Residential Lighting - ENERGY STAR Outdoor Fixtures	1.0 New
Residential Lighting - ENERGY STAR Ceiling Fan	
Residential Lighting - Controls	1.0 New
Residential Lighting - LED Holiday Lighting	2.8 Added gas heating penalty.
Residential Hot Water - Drainpipe Heat Exchanger with Electric Water Heater	2.5 Added unknown location and removed gas information.
Residential Hot Water - Electric Water Heater <REMOVED>	4.3 Removed
Residential Hot Water - Electric Water Heater Setback	
Residential Hot Water – Electric Water Heater Jacket Insulation	3.0. Updated hours from 8,760 to 8,766.
Residential Hot Water - Faucet Aerator (1.5 gpm) with Electric Water Heater	4.0 The calculation has been updated with values for unknown factors. (i.e. if location is unknown, etc.) 4.1 All hours of use changed to 365.25 and commercial usage updated.
Residential Hot Water - Heat Pump Water Heater	1.0 New
Residential Hot Water - Low Flow Showerheads (1.5 gpm) with Electric Water Heater	4.0 The calculation has been updated with values for unknown factors. (i.e. if location is unknown, etc.) Multiple showerheads is already taken into account in this calculation. 4.1 All hours of use changed to 365.25
Residential Hot Water - Thermostatic Restriction Valve	1.0 New electric and gas versions

Residential Hot Water - Pipe Insulation with Electric Water Heater	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.
Residential Load Management Technologies	1.0 New
Residential Plug Load - Advanced Tier 2 Power Strips	1.0 New
Residential - Variable Speed Pool Pumps	1.0 New
Gas Efficiency Measures	
C/I Envelope - Loading Dock Door and Pit Seals	1.0 New
C/I HVAC - Destratification Fan	
C/I HVAC - Infrared Heater	2.0 Changed from Heating Degree Days to EFLHHeat. Added hours by building type.
C/I HVAC - Steam Trap	3.0 Changed to heating hour algorithm. Added building types and varying hours by application.
Commercial HVAC - Boiler Modifications, Space Heating Only	3.6 Update - Changed from Heating Degree Days to Equivalent Full Load Hours, Added Building Types
Commercial HVAC - Boilers, Space Heating Only	4.0 Update - Changed from Heating Degree Days to Equivalent Full Load Hours, Added Building Types
Commercial HVAC - Condensing Unit Heaters	1.0 New
Commercial HVAC - Energy Recovery Ventilator	2.0 Added kW savings and updated code requirements 2.1 Changed to total (sensible and latent) energy savings.
Commercial HVAC - Exhaust Energy Recovery	2.0 Corrected reference numbering. Changed equation format to be consistent with other measures. 2.1 changed to sensible only based equation. Removed EFLH. Added kW and kWh penalties, corresponding references and heating application table.
Commercial HVAC - Forced-Air Heating Maintenance	2.0 Changed from Heating Degree Days to EFLHHeat. Added hours by building type.
Commercial HVAC - Programmable Thermostats with Gas Heating	1.0 New
Commercial Food Service - ENERGY STAR Gas Combination Oven	
Commercial Food Service - ENERGY STAR Gas Convection Oven	2.0 Updated to new Energy Star requirements
Commercial Food Service - ENERGY STAR Gas Fryer	
Commercial Food Service - ENERGY STAR Gas Griddle	
Commercial Food Service - ENERGY STAR Gas Steamer	

Commercial Food Service - Gas Conveyor Oven	
Commercial Food Service - Gas Oven, Broiler, Pasta Cooker	
Commercial Food Service - Gas Rack Oven	
Commercial Hot Water - Faucet Aerator (1.5 gpm) with Gas Water Heater	4.0 The calculation has been updated with values for unknown factors. (i.e. if location is unknown, etc.)
Commercial Hot Water - Pre-Rinse Sprayers (1.6 gpm) with Gas Water Heater	3.0 The average temperature has been increased from 105°F to 110°F based on the results of a 2011 EPA study. added the Senior Living but not the Congregation, due to high variability in usage.
Commercial Hot Water - Gas Water Heater	7.0 Corrected the instantaneous EF requirement
Residential Hot Water - Drainpipe Heat Exchanger with Gas Water Heater	
Residential Hot Water - Faucet Aerator (1.5 gpm) with Gas Water Heater	4.0 The calculation has been updated with values for unknown factors. (i.e. if location is unknown, etc.)
Residential Hot Water - Gas Water Heater	5.0 Updated with new efficiency requirements
Residential Hot Water - Gas Water Heater Setback	
Residential Hot Water - Low Flow Showerheads (1.5 gpm) with Gas Water Heater	4.0 The calculation has been updated with values for unknown factors. (i.e. if location is unknown, etc.) Multiple showerheads is already taken into account in this calculation.
Residential Hot Water - Pipe Insulation with Gas Water Heater	
Residential HVAC - Electronic Ignition Hearth	
Residential HVAC - Furnaces and Boilers	3.0 Changed from HDD to EFLHHeat algorithm and added kWh and kW savings and heating penalty factors. 3.1 Indicated fan savings are for furnaces with ECM motors only.
Residential HVAC - Furnaces & Boiler Tune-Up	3.0 New, Boiler Tune-up added to Furnace Tune-ups, Added Service Recommendations and changed algorithm format to EFLH
Residential HVAC - Thermostats with Gas Heating	2.0 New, Added Smart Thermostat tiers to Programmable Thermostat Measure, reference corrected.
Residential HVAC - Furnace Quality Installation/Maintenance	1.0 New
Residential Insulation and Air Sealing	1.4 Removed limit of R-5 for uninsulated assemblies
Combined Electric and Gas Efficiency Measures	

Commercial Food Service - ENERGY STAR® Dishwasher	1.0 New
Commercial HVAC - Demand Control Ventilation	2.3 Added 2015 Minnesota Energy Code Information. Added 'Other/Misc' building type
Commercial HVAC - Guest Room Energy Management Controls	1.0 New
C/I HVAC- Parking Garage Exhaust Fan CO Control and Heating	1.0 New
C/I - Building Operator Certification	1.0 New
Appendices	
Appendix A - Climate Zones	
Appendix B - C/I Lighting Tables	Added Combinations, Costs

Electric Efficiency Measures

Agriculture – Engine Block Heater Timer

Version No. 1.0

Measure Overview

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.

Actions: Modify
Target Market Segments: Commercial
Target End Uses: Misc. Electric Loads

Applicable to: Agricultural customers

Algorithms

Unit kWh Savings per Year = P_heater x (t_heater - t_control) x Days x UF / C

Unit Peak kW Savings = 0

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 5 (Ref. 1)

Unit Participant Incremental Cost = $20 (Ref. 2) 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 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.

CF = 0 (Ref. 6)

Required from Customer/Contractor: heater size.

Example:

A customer installed a new timer control on a 1,200 W engine heater.

*Unit kWh Savings per Year = 1,200 W * (10 hrs/day – 2 hrs/day) * 90 days * 0.8 / 1,000 W/kW = 691 kWh*

Unit Peak kW Savings = 0 kW

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.

Version / Description	Author	Date
1) Document created	Franklin Energy Services	11/12/2015

Agriculture – Livestock Waterer

Version No. 1.0

Measure Overview

Description: This measure involves the installation of insulated or energy free livestock waterers to replace electric livestock waterers.

Actions: Replace on Failure, New Construction
Target Market Segments: Commercial
Target End Uses: Livestock

Applicable to: Agricultural customers

Algorithms

Unit kWh Savings per Year = (Watts_base - Watts_EE) x hours / C

Unit Peak kW Savings = 0

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 1)

Unit Participant Incremental Cost = $787.50 (Ref. 2)

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.

CF = 0 (Ref. 4)

Required from Customer/Contractor: Retrofit or new, County.

Example:

A customer in Zone 2 installed a new energy efficient livestock waterer to replace a standard unit.

*Unit kWh Savings per Year = (1,100 W - 250 W) * 2,934 hours / 1,000 W/kW = 2,494 kWh*

Unit Peak kW Savings = 0 kW

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.

Agriculture – High Efficiency Fans

Version No. 1.1

Measure Overview

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.

Actions: Replace on Failure, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: HVAC

Applicable to: Agricultural customers

Algorithms

Unit kWh Savings per Year = (CFM_base/VER_base - CFM_EE/VER_EE) / C x Hours

Unit Peak kW Savings = (CFM_base/VER_base - CFM_EE/VER_EE) / C x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 7 (Ref. 1)

Unit Participant Incremental Cost = $150 (Ref.1)

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 = 2,935 hours per year (Ref. 1)

C = 1,000 W/kW. Conversion factor.

CF = 1.0 (Ref. 1)

Required from Customer/Contractor: fan diameter, model number, VER.

Example:

A cattle barn installed a new 36" circulation fan with a VER of 17.9 CFM/Watt.

*Unit kWh Savings per Year = (9,780 CFM / 15.5 CFM/W – 9,780 CFM / 17.9 CFM/W) / 1,000 W/kW * 2,935 hours = 248 kWh*

*Unit Peak kW Savings = (9,780 CFM / 15.5 CFM/W – 9,780 CFM / 17.9 CFM/W) / 1,000 W/kW *1.0 = 0.0906 kWh*

Deemed Input Tables

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.

Document Revision History:

Version / Description	Author	Date
2) Document created	Franklin Energy Services	11/12/2015
1.1) Added Table 1, Average Fan Characteristics	Franklin Energy Services	12/11/2015

Agriculture – Poultry Farm LED Lighting

Version No. 1.0

Measure Overview

Description: This measure includes the replacement of high-intensity discharge (HID), incandescent, and fluorescent fixtures with light emitting diode (LED) fixtures in poultry farms.

Actions: Replace on Failure, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Lighting

Applicable to: Agricultural customers

Algorithms

Unit kWh Savings per Year = (Watts_base x Qty_base - Watts_EE x Qty_EE) / C x Hours x Days

Unit Peak kW Savings = (Watts_base x Qty_base - Watts_EE x Qty_EE) / C x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 7 years (Ref.1)

Unit Participant Incremental Cost = $30 (Ref. 2)

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

Required from Customer/Contractor: Baseline fixture wattage and quantity, LED lamp wattage and quantity, poultry farm type.

Example:

A chicken broiler facility replacing 60 watt incandescent lamps with 10 watt LEDs.

Electric Energy Savings (kWh/yr) = (60 W x 14 - 10 W x 14) / 1,000 W/kW x 16 hr/day x 365 days/yr = 4,088 kWh

Peak Demand Savings (kW) = (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 Tor	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

Agriculture – VSD Milk Pump

Version No.

1.0

Measure Overview

Description: This measure involves the installation of a variable speed driven milk transfer pump.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Dairy

Applicable to: Commercial customers

Algorithms

Unit kWh Savings per Year = N_cows x Mdot_milk x Cp_Milk x Delta_T x Days / EER / C

Unit Peak kW Savings = Unit kWh Savings per Year / Hours

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 (Ref. 1)

Unit Participant Incremental Cost = $4000 (Ref. 2)

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)

CF = 0

Required from Customer/Contractor: number of cows

Example:

A customer with a 130-cow farm, installed a new VSD milk transfer pump.

*Unit kWh Savings per Year = 130 cows * 56 lbs milk/cow/day * 0.93 Btu/lb-F * 15°F * 365 day/yr / 8.4 EER / 1,000 W/kW = 4,413 kWh/year*

Unit Peak kW Savings = 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.

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	11/12/2015

C/I HVAC - Chiller Systems

Version No. 2.1

Measure Overview

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.

Actions: Replace on Fail, Replace Working or New Construction.
Target Market Segments: Commercial, Industrial
Target End Uses: HVAC

Applicable to: Commercial & Industrial customers where chillers can be installed to meet space cooling requirements.

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

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 20 years (Ref. 1)

Unit Participant Incremental Cost = See Table 1

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)

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.

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.

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

$A = 0.00000014592 \times (49.16)^4 – 0.0000346496 \times (49.16)^3 + 0.00314196 \times (49.16)^2 -$

$0.147199 \times (49.16) + 3.9302 = 1.0228$

$B = 0.0015 \times 42 + 0.934 = 0.997$

$K_{adj} = 1.0228 \times 0.997 = 1.02$

$FLV_{EE} = 0.50 / 1.02 = 0.49$

$IPLV_{EE} = 0.40 / 1.02 = 0.44$

$\text{Unit kWh Savings per Year} = 600 * (0.54 - 0.44) * 1298 = 79{,}865 \text{ kWh}$

$\text{Unit Peak kW Savings per Year} = 600 * (0.57 - 0.49) * 0.9 = 43.0 \text{ kW}$

Deemed Input Tables:

Table 1: Deemed Full Load and Integrated Part Load Baseline Efficiencies per AHRI 550/590 and Incremental Costs (Ref. 4, 5)

	PATH A****		PATH B*****		Incremental Cost ($/ton)
Equipment	FLV_AHRI (kW/ton)	IPLV_AHRI (kW/ton)	FLV_AHRI (kW/ton)	IPLV_AHRI (kW/ton)	
Water Cooled Scroll or Screw Chiller < 75 tons	0.78	0.63	0.80	0.60	130
Water Cooled Scroll or Screw Chiller ≥ 75 and < 150 tons	0.78	0.62	0.79	0.59	90
Water Cooled Scroll or Screw Chiller ≥ 150 and < 300 tons	0.68	0.58	0.72	0.54	90
Water Cooled Scroll or Screw Chiller ≥ 300 tons	0.62	0.54	0.64	0.50	40
Water Cooled Centrifugal Chiller < 150 tons	0.63	0.60	0.64	0.45	130
Water Cooled Centrifugal Chiller ≥ 150 and < 300	0.63	0.60	0.64	0.45	85
Water Cooled Centrifugal Chiller ≥ 300 and < 600	0.58	0.55	0.60	0.40	85
Water Cooled Centrifugal Chiller ≥ 600 tons	0.57	0.54	0.59	0.40	40
Air Cooled Chiller with Condenser < 150 tons	1.26	0.96	NA	NA	110
Air Cooled Chiller with Condenser > 150	1.26	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
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.

4. 2015 Minnesota Energy Code, Table C.403.2.3 (7), Minimum Efficiency Requirements: Water Chilling Packages

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.

Documentation Revision History:

Version	Description	Author
1	New specification replacing ChillersAirCooled_v03 and ChillersCentrifugal_v03. Followed methodology in Xcel Energy 2010-2012 CIP Plan (Docket No. E,G002/CIP-09-198)	JP
1.1	Changed 'Equivalent' to 'Equivalent' for Table 1.	SK
1.2	Revised format to customer's current requirements. 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.	FES
1.3	Changed 'ARI' to 'AHRI' throughout, wording changes	JP
2.0	Updated measure to reflect new MN Code	FES

C/I HVAC - Chiller Tune-up

Version No.

1.0

Measure Overview

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

Actions: O&M
Target Market Segments: Commercial, Industrial
Target End Uses: HVAC

Applicable to: Commercial & Industrial customers where chillers are used to meet space cooling requirements.

Algorithms

Unit kWh Savings per Year = Nominal Capacity x IPLV_base x $EFLH_{Cool}$ x MFe

Unit Peak kW Savings = Nominal Capacity x FLV_base x CF x MFd

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane 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)

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 = the integrated part load efficiency of the baseline chiller (kW/ton), IPLV_base =

IPLV_AHRI per Table 1.

FLV_base = the full load efficiency of the baseline chiller (kW/ton), FLV_base = FLV_AHRI per Table 1.

CF = Coincidence factor = 0.9 (Ref. 3)

MFe = Maintenance energy saving factor, MFe = 5 % (ref. 4)

MFd = Maintenance demand saving factor, MFd = 2.5 % (ref. 4)

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)

Example:

Tune up of a 200 ton air cooled chiller serving community college in Zone 2:

Unit kWh Savings per Year = 200 x 0.94 x 782 x 0.05 = 7,351 kWh

Unit Peak kW Savings = 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)

	PATH A*		PATH B**	
Equipment	FLV_AHRI (kW/ton)	IPLV_AHRI (kW/ton)	FLV_AHRI (kW/ton)	IPLV_AHRI (kW/ton)
Water Cooled Scroll or Screw Chiller < 75 tons	0.78	0.63	0.80	0.60
Water Cooled Scroll or Screw Chiller ≥ 75 and < 150 tons	0.78	0.62	0.79	0.59
Water Cooled Scroll or Screw Chiller ≥ 150 and < 300 tons	0.68	0.58	0.72	0.54
Water Cooled Scroll or Screw Chiller ≥ 300 tons	0.62	0.54	0.64	0.50
Water Cooled Centrifugal Chiller < 150 tons	0.63	0.60	0.64	0.45
Water Cooled Centrifugal Chiller ≥ 150 and < 300	0.63	0.60	0.64	0.45
Water Cooled Centrifugal Chiller ≥ 300 and < 600	0.58	0.55	0.60	0.40
Water Cooled Centrifugal Chiller ≥ 600 tons	0.57	0.54	0.59	0.40
Air Cooled Chiller with Condenser < 150 tons	1.26	0.96	NA	NA
Air Cooled Chiller with Condenser > 150	1.26	0.94	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
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 compile 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
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

Documentation Revision History:

Version/Description	Author	Date
1.0 Measure created	FES	11/12/15

C/I HVAC - ECM Circulators

Version No. 1.0

Measure Overview

Description: Electronically commutated (EC) circulators (pumps) are high-efficiency brushless DC motors. They are typically fractional horsepower motors that enjoy several benefits over the more common permanent split capacitor (PSC) fractional horsepower motor.

Actions: Replace Working, Replace on Fail, New Construction
Target Market Segments: Commercial
Target End Uses: Pumps

Applicable to: Commercial facilities with domestic hot water and space heating/cooling circulation pumps.

Algorithms

Unit kWh Savings per Year = kWbase x tbase - kWECM x tproposed

Unit Peak kW Savings = (kWbase - kWECM) x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 (Ref. 1)

Unit Participant Incremental Cost = $6 per Watt (Ref. 2)

Where:

kWbase = kWECM / 18% (Ref. 3)

kWECM = 0.050 kW, 0.250 kW, 0.700 kW (Ref. 4)

tbase = See Table 1

tproposed = See Table 1

CF_DHW = 1.0 (Ref. 5)

CF_CW = 0.299 (Ref. 6)

CF_HW = 0

Required from Customer/Contractor: Motor wattage, motor application.

Example:

A customer installed a new 250W ECM pump on their domestic hot water heater.

Unit kWh Savings per Year = 0.250 kW / 18% x 4,000 hours - 0.250 kW x 2,190 hours = 5,008 kWh

Unit Peak kW Savings = (0.250 kW / 18% - 0.250 kW) x 1.0 = 1.140 kW

Deemed Input Tables:

Table 1: Annual Operating Hours

Annual Hours	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: Coincident Peak Impact

EC Motor Size	DHW Circulator	Heating Water Circulator	Cooling Water Circulator
< 100 W	0.228 kW	0.000 kW	0.068 kW
100 - 500 W	1.139 kW	0.000 kW	0.341 kW
500 - 750 W	3.189 kW	0.000 kW	0.953 kW

Table 3: Estimated Energy Savings

EC Motor Size	DHW Circulator	Heating Water Circulator	Cooling Water Circulator
< 100 W	1,002 kWh	588 kWh	271 kWh
100 - 500 W	5,008 kWh	2,941 kWh	1,356 kWh
500 - 750 W	14,023 kWh	8,234 kWh	3,798 kWh

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. General sizes chosen to represent given size ranges.

5. Assumes baseline pump would be operating during the peak period. Franklin Energy Services.

6. Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 2.0, June 7, 2013, page 235.

7. Estimate based on EPRI Report Assessment of New Energy Efficient Circulator Pump Technology (40%*8,760 hr = 3,504 hr) and recommendation by Grundfos representatives (60%*8,760 hr = 5,256 hr).

8. Hours of use for pumps with an aqua-stat control in multi-family applications (6 hr/d * 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*24/(70°F-Design Temps).

10. Estimated based on an average of CDD65. Hours = CDD65*24/(Design Temps-70°F).

Documentation Revision History:

Version / Description	Author	Date
1. Measure created	Franklin Energy Services	11/10/2015

C/I HVAC - Heat Pump Systems

Version No. 2.0

Measure Overview

Description: This measure includes replacement of non-working and working unitary air source heat pump (ASHP), ground water source heat pump (GWSHP) and ground source heat pump (GSHP) equipment. This measure analyzes the heating and cooling savings potential of the installation of higher efficiency unitary heat pump equipment.

The incremental cost is associated with base equipment cost and does not include any installation costs.

Actions: Replace on Fail, Replace Working or New Construction.
Target Market Segments: Commercial & Industrial
Target End Uses: HVAC

Applicable to: Commercial & Industrial customers where heat pump unitary equipment can be installed.

Algorithms

Unit kWh Savings per Year (ASHP units less than 5.5 tons) = Size x $EFLH_{Cool}$ x (12 / SEER_Base - 12 / SEER_EE) + (Size x $EFLH_{Heat}$) x (12/HSPF_base - 12/HSPF_EE)

Unit kWh Savings per Year = Size x $EFLH_{Cool}$ x (12 / IEER_Base - 12 / IEER_EE) + (Size x $EFLH_{Heat}$) x (3.52 / COP_base - 3.52 / COP_EE)

Unit Peak kW Savings = Size x (12/EER_Base - 12/EER_EE) x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 years (Ref. 1)

Unit Participant Incremental Cost = See Table 3 (Ref. 2) or Table 4 (Ref. 3)

Where:

CF = Deemed coincidence factor, equal to 0.9 (Ref. 4)

COP_base = Heating system performance factor of baseline or existing ASHP, provided by customer/contractor. If unknown see Table 3 (Ref. 5)

COP_EE = Heating system performance factor of efficient ASHP, provided by customer/contractor

EER_base = Energy efficiency ratio of the baseline equipment, based on the 2015 Minnesota Energy coded minimal efficiency ratings. See Table 3 (ref. 5)

EER_EE = Energy efficiency ratio of the high efficiency equipment, provided by the customer. If unknown, use EER = 0.875 x SEER (ref. 7)

$EFLH_{Cool}$ = 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 ASHP, provided by customer/contractor or use HSPF_base = 7.7 if unknown (ref. 5)

HSPF_EE = Heating system performance factor of efficient ASHP, provided by customer/contractor

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 (Ref. 5)

IEER_EE = Integrated energy efficiency ratio of the high efficiency equipment, provided by the customer/contractor.

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.

Required from Customer/Contractor: Equipment size (tons), IEER or EER of new equipment, IEER 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)

Example:

New ASHP packaged rooftop installed in midrise office, 7.5 ton cooling capacity, IEER 14 and COP Of 3.4, Climate Zone 3.

Unit KWh Savings per Year = 7.5 x 651 x [(12 / 11.2 - 12 / 14)] + 7.5 x 1793 x (3.52 / 3.3 - 3.52 / 3.4) = 1468 KWh

Unit Peak KW Savings per Year = 7.5 x (12 /11.0 - 12 / (14 x 0.875)) x 0.9 = 0.75 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	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. 8)

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 3: Deemed baseline efficiency for heating and cooling, incremental costs

Equipment	SEER_base (Ref. 5)	IEER_base (Ref. 5)	EER_base (Ref. 5)	HSPF_base (Ref. 5)	COP_base (Ref. 5)	Incremental Cost (Ref. 2)
ASHP Units less than or equal to 5.4 tons	13.0	-	11.4	7.7	-	See Table 4
ASHP Units 5.5-11.3 tons	-	11.2	11.0	-	3.3*	$165/ton
ASHP Units 11.4-19.9 tons	-	10.7	10.6	-	3.2*	$150/ton
ASHP Units 20-63.3 tons	-	9.6	9.5	-	3.2*	$140/ton
GSHP Units (closed loop)	-	15.3	13.4**	-	3.6	$150/ton
GWSHP Units (open loop)	-	18.5	16.2***	-	3.1	$150/ton

*COP based upon 47°F DB and 43°F WB Outdoor air temperature.
** COP based upon GWSHP 77°F entering water.
*** COP based upon GWSHP 59°F entering water.

Table 4. ASHP units 5.4 tons or less Incremental cost (Ref. 3)

Efficiency Level	Incremental Cost
SEER 14	$137/ton
SEER 15	$274/ton
SEER 16	$411/ton
SEER 17	$548/ton
SEER 18	$685/ton

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).

$EFLH_{Heat}$ 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.

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.

Notes:

Base line ground source heat pump SEER is based upon an entering temperature of 59 deg. F entering water temperature.

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. Minnesota 2015 Energy Code - TABLE C403.2.3(2) MINIMUM EFFICIENCY REQUIREMENTS: ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS.

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.

Documentation Revision History:

Version	Description	Author	Date
1	New deemed savings specification replacing/utilizing Heat Pump Units.	FES	
1.1	Corrected table references, Required Inputs	JP	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. Change base line to 2015 Minnesota Energy Code.	FES	11/12/15

C/I HVAC - High Volume Low Speed Fans

Version No. 2.0

Measure Overview

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.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial, Industrial
Target End Uses: HVAC

Applicable to: Commercial, industrial, or agricultural customers that currently use non HVLS fans

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

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 years (Ref. 1)

Unit Participant Incremental Cost = Refer to Table 3

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)

Required from Customer/Contractor: Size (diameter) of HVLS fans being installed, facility use type.

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	8,766

Table 2: HVAC Interactive Factors by HVAC System (Ref. 7)

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
Space Type	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only or Heating & Cooling
Conditioned	1.00	1.254	1.00	1.095	-0.0023
Unconditioned Space	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 Supplemental Cooling System in Dairy Free Stall Barns

4. 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

5. 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.

6. 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.

7. 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).

Documentation Revision History

Version / Description	Author	Date
1)Original document	FES	8/1/2012
2)Added HVAC Cooling kWh and kW savings and Heating penalty factors	FES	11/12/2015

C/I HVAC - Mini Split Ductless Systems A/C only and Heat Pump

Version No. 1.0

Description: This measure includes replacement of non-working and working air source heat pump (ASHP) equipment, furnaces with split system air conditioning systems, and electric resistance heating with mini split ductless A/C or heat pump systems.

Actions: Replace on Fail, Replace Working, New Construction

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.

Algorithms:

Baseline Heating, Existing ASHP or Electric Resistance:

Unit Heating Baseline kWh per Year = Size x 12 / HSPF_Base x $EFLH_{Heat}$

Baseline Heating, Gas Furnace:

Unit Heating Dth Baseline per Year = Btuh_input / 1,000,000 x (1 / AFUE_Base) x $EFLH_{Heat}$

Baseline Cooling, Split System A/C:

Unit Cooling kWh Baseline per Year = Size x 12 / SEER_Base x EFLH_cool

Proposed Heating:

Unit Heating Proposed kWh per Year = Size x 12 / HSPF_Proposed x $EFLH_{Heat}$

Proposed Cooling:

Unit Cooling Proposed kWh per Year = Size x 12 / SEER_Proposed x EFLH_cool

Savings, A/C Only:

Unit kWh Savings per Year = Unit Cooling kWh Baseline per Year - Unit Cooling Proposed kWh per Year

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

Savings, Existing ASHP or Electric Resistance:

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) / EFLH_cool x CF

Savings, Gas Furnace with Split System A/C:

Unit Dth Savings per Year = Unit Heating Dth Baseline (Furnace) per Year

Unit kWh Savings 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) / EFLH_cool x CF

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 years for commercial/industrial (Ref. 1)

Unit Participant Incremental Cost (Ref. 2) = Actual costs should be used, for planning purposes an averaged full installed cost was determined to be $2,500/ton.

Where:

Size = mini split ductless cooling capacity in tons (1 ton = 12,000 btu/h)

Btuh_input = furnace capacity in Btu/hr

12 = unit conversion, EER to kW/ton

1,000,000 = unit conversion, BTU per Dtherm

HSPF_Base = HSPF in heating mode for the baseline HVAC system, select from table below:

Baseline Heating System	HSPF_Base	Reference
Commercial ASHP	7.7	Ref. 4
Electric Resistance	3.412	Assumed (=100% efficient)

HSPF_Proposed = actual HSPF in heating mode for the proposed heat pump

SEER_Base = SEER in cooling mode for the baseline HVAC system, select from the table below:

Baseline Cooling System	SEER_Base	Reference
Thru-the-wall A/C	10.6	Ref. 3
Commercial ASHP	13.0	Ref. 4
Commercial Split System A/C	13.0	Ref. 4

SEER_Proposed = actual SEER of the mini split ductless system

AFUE_Base = AFUE rating of baseline furnace: 80% if replace existing furnace, 90% if new construction (Ref. 5)

$EFLH_{cool}$ = Effective Full Load Hours for cooling, see table below (Ref. 6):

Building Type	Equivalent Full Load Hours for Cooling		
	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

$EFLH_{heat}$= Effective Full Load Hours for heating, see table below (Ref. 7):

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	1887	1699	1546
Education - Community	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	1763	1587	1444
Retail - Strip Mall	1701	1531	1393
Warehouse	1872	1685	1533
Other/Miscellaneous	2123	1911	1739

CF = 0.90, coincidence factor (Ref. 8)

Required inputs from customer/contractor:

1. Existing HVAC system type (furnace with split system A/C, air source heat pump, electric heat with split system or other thru-the-wall A/C)
2. mini split system size
3. furnace system size (if applicable)
4. proposed system heating AFUE or HSPF
5. proposed system cooling SEER

Example:

Assume a 2.5 ton air source heat pump is being replaced by a mini-split system in a low-rise office building in zone 1. Assuming that 2 1 ton mini splits, and one ½ ton mini split will be installed.

Cooling savings:

2.5 tons x 12 x 257 hours x (1/13 SEER – 1/20 SEER) = 207.6 kWh

Heating Savings:

2.5 tons x 12 x 1966 hours x (1 / 7.7 – 1/11) = 2298 kWh

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 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.

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 requirements (14.5 SEER, 8.2 HSPF)

For multi-head systems, system capacity is the minimum of the: total indoor unit capacity and outdoor unit capacity.

References

1. Measure Life Report - Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.

http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf

2. Based upon review of Ductless Heat Pumps for Residential Customers in Connecticut, Swift, Joseph R, and Rebecca A. Meyer, The Connecticut Light and Power Company, 2010 ACEEE Summer Study on Energy Efficiency in Buildings (2-292). Also supported by findings in 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. January 1, 2013.

http://www.gpo.gov/fdsys/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-sec430-32.pdf

4. 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.

http://www.ecfr.gov/cgi-bin/text-idx?SID=683dd820ec02f5e7beaa862cd5239790&mc=true&node=pt10.3.431&rgn=div5

5.US Department of Energy. Though the federal minimum efficiency is 78% there are very few models available at this efficient; a review of AHRI shows that most low efficiency units are 80%.

http://buildingsdatabook.eere.energy.gov/ChapterIntro7.aspx

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 (Zone3) 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.

Documentation Revision History

Version / Description	Author	Date
1.0 Initial draft, new workpaper	Franklin Energy Services	7/31/2015

C/I HVAC - Unitary and Split Systems

Version No. 2.0

Measure Overview

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.

Actions: Replace on Fail, Replace Working or New Construction.
Target Market Segments: Commercial & Industrial
Target End Uses: HVAC

Applicable to: Commercial & Industrial customers where DX unitary equipment can be installed.

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

Unit Dth Savings per Year =0

Unit Gallons Fuel Oil Savings per Year =0

Unit Gallons Propane Savings per Year =0

Measure Lifetime (years) = 20 years (ref 1)

Unit Participant Incremental Cost = See Table 2

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_base = EER_base/0.875.

SEER_EE = Seasonal energy efficiency ratio of the high efficiency equipment, provided by the customer/contractor. If unknown, use SEER = EER / 0.875 (ref. 2)

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 = 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 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, use EER = .875 x SEER (ref. 2)

CF = Deemed coincidence factor, equal to 0.9 (ref. 3)

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)

Example 1:

Retrofit packaged rooftop installed in Medical Clinic, 7.5 ton cooling capacity, IEER 12.5, EER 12, Climate Zone 3.

*Unit kWh Savings per Year = 7.5 * (12 / 11.2 - 12 /12.5) * 865 = 723 KWh*

*Unit Peak kW Savings per Year = 7.5 * (12 /11 - 12 /12) * 0.9 = 0.614 KW*

Example 2:

Replacement PTAC unit installed in motel, 9,000 Btu/hr cooling capacity, EER 13.0, Climate Zone 2.

*EER_base = 10.9 - (0.213 * 9,000/1,000) = 9.0*

SEER_base = 9.0 / 0.875 = 10.3

SEER_EE = 13 / 0.875 = 14.9

*Unit kWh Savings per Year = 9,000/12,000 * (12/10.3 – 12/14.9) * 606 = 163.4 kWh*

*Unit Peak kW Savings per Year = 9,000/12,000 * (12/9.0 – 12/13.0) * 0.9 = 0.277 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	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 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	Incre-mental Cost
PTAC, Standard Size (used for New Construction)	< 7,000	11.7	$250/ton
	7,000-15,000	13.8 - (0.300 * 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 * 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.

Documentation Revision History:

Version	Description	Author	Date
1.0	New deemed savings specification replacing Rooftop Units, Split Systems, Condensing Units, and PTAC sheets	JP	
1.1	Updated to specify SEER to EER conversion and EER to SEER conversion	JP	
1.2	Corrected algorithm to specify 12/EER instead of 1/EER, name changed from UnitarySystems to CommercialUnitarySystems	JP	
1.3	Corrected “Eqiuvalent” to “Equivalent” for Table 1 heading	SK	
1.3	Revised format to customer’s current requirements. Updated to 2004 SEER and EER levels. Revised to hours in Table 1. Added references 3 thru 6. Updated references 1 & 2. Revised PTAC cost/ton.	FES	
1.4	Added higher baseline efficiencies per ASHRAE 90.1 2010 in Table 2	JP	
1.5	Changed name from Commercial Unitary Systems to C/I HVAC – Unitary and Split Systems, updated baseline efficiency specifications for PTACs to reflect federal manufacturing requirements, updated description and example.	JP	3/29/14

2.0	Updated to energy code, including IEER efficiencies, included Other/Miscellaneous building type	FES	11/12/15

C/I HVAC - Unitary Equipment Economizer

Version No. 2.1

Measure Overview

Description: This measure includes the retro-fit 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.

Actions: Modify
Target Market Segments: Commercial & Industrial
Target End Uses: HVAC

Applicable to: Commercial & Industrial customers where air unitary equipment has been installed.

Algorithms

Unit kWh Savings per Year = Size x (12/SEER_EE) x $EFLH_{cool}$ x SF x SM Unit

Peak kW Savings = 0

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 years (Ref. 1)

Unit Participant Incremental Cost = See Table 2 (Ref. 2)

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. If unknown, use SEER = EER/0.875 (Ref. 4) 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)

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)

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 * (12 / 14.4) * 558 * 0.24 *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 $1000 should be included when retro-fitting 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 percent 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.

Documentation Revision History:

Version	Description	Author	Date
1	New savings specification for retrofit/incorporation of air economizer on air systems.	FES	

1.1 Minor edits JP		
1.2 Changed Action Type from Replace Working to Modify	JP	6/6/2014
2.0 Added/Updated economizer code requirements	FES	11/12/2015

C/I HVAC - Variable Speed Drives

Version No. 2.0

Measure Overview

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.

Actions: Modify, Replace Working (Retrofit), New Construction (limited sizes, see Notes)
Target Market Segments: Commercial, Industrial
Target End Uses: HVAC

Applicable to: Commercial and Industrial for space heating and cooling applications.

Algorithms

Unit kWh Savings per Year = HP x Load_Factor x Conversion / Eff x Hrs x ESF

Unit Peak kW Savings = 0

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 (Ref. 1)

Unit Participant Incremental Cost: See Table 4 (Ref.2)

Where:

HP = Rated horsepower of new drive, assumed to be the same as associated motor.

Load_Factor = Motor load factor = 75%. (Ref. 3)

Conversion = .746 (1 HP = .746 kW)

Eff = Efficiency of motor, if unknown see default values by size in Table 2 (Ref. 5)

Hrs = Annual operating hours, if unknown see default values by application in Table 1 (Ref.4)

ESF = Energy Savings Factor per Table 3 (Ref. 6,7)

Required from Customer/Contractor: Horsepower, application type (see Table 1), application (see Table 3), motor efficiency (optional), annual operating hours (optional).

Example:

For 20 hp chilled water pump retrofitted with a variable speed drive:

Unit kWh Savings per Year = 20 x 0.75 x 0.746 / 0.91 x 2,170 x 0.432 = 11,527 kWh

Deemed Input Tables:

Table 1: Deemed annual operating hours by application type (Ref. 4)

Application Type	Annual Operating Hours
Chilled Water Pump	2,170
Heating Hot Water Pump	4,959
Condenser Water Pump	2,170
HVAC Fan	5,236
Cooling Tower Fan	1,032

Table 2: Motor Efficiency (Ref. 5)

Horsepower (HP)	Motor Efficiency
5	0.87
7.5	0.88
10	0.90
15	0.90
20	0.91
25	0.91
30	0.92
40	0.92
50	0.93
60	0.93
75	0.93
100	0.93

Table 3: Energy Savings Factor (Ref. 6, 7)

Application	ESF
HVAC Pumps	
Hot Water Pump	0.482
Chilled Water or Condenser Water Pump	0.432
HVAC Fans, Supply or Return	
Constant Volume (no flow control)	0.535
Air Foil/inlet Guide Vanes	0.227
Forward Curved Fan, with discharge dampers	0.179
Forward Curved Inlet Guide Vanes	0.092
Fan Average (unknown type)	0.258
Cooling Tower Fan	0.249

Table 4: HVAC VSD Incremental Costs, Including equipment and installation costs (Ref. 2)

Horsepower (HP)	Fan	Pump
5	$1,840	$3,420
7.5	$2,620	$4,200
10	$2,640	$4,300
15	$2,740	$4,600
20	$3,520	$5,460
25	$4,540	$6,580
30	$4,840	$7,340
40	$4,960	$7,540
50	$6,780	$9,160
60	$10,260	$13,360
75	$12,380	$15,460
100	$15,340	$18,580

Methodology and Assumptions:

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.

Variable speed does not include multi-speed (two or three speed) applications.

Costs do not include motor replacement cost.

Assumes existing motor is VFD compatible.

Savings and costs are based upon single motor application and do not consider series or parallel applications.

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. CL&P and UI Program Savings Documentation for 2008 Program Year, total installation cost is double material cost, this includes labor and additional items such as sensors other required modifications

3. United States Industrial Electric Motor Systems Market Opportunities Assessment, EERE, US DOE, Dec 2002 - Source for motor load factor data

4. Pennsylvania Technical Reference Manual, June 2011, average of hours by application across all building types

5. Average of Premium Efficiency Motor specification abd EPAct Motor specification averaged over all types and speeds, by horsepower

6. CL&P and UI Program Savings Documentation for 2008 Program Year, savings factor based on bin spreadsheet calculation, all applications except cooling tower fans

7. Cooling tower savings factor, Pennsylvania Technical Reference Manual, June 2011, savings based on building simulation

Documentation Revision History:

Version/Description	Author	Date
1) New Measure	FES	8/1/2012
1.1) Minor revisions	JP	2/12/2013
1.2) Added annual operating hours as an optional input from customer/contractor, clarified Required Inputs	JP	1/6/2014
2.0) Updated energy code requirements for new construction	FES	11/12/2015

C/I Lighting – Lighting End Use

Version No. 4.0

Measure Overview

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.

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

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = see Table 3

Unit Participant Incremental Cost: see Appendix B

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 = 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.

Required from Customer/Contractor: Existing fixtures and quantities (retrofits only), installed fixtures and quantities, building type, HVAC system (heating only, heating & cooling, exterior/unconditioned).

Example Calculation:

Replace (1) 60W incandescent with a 9W LED lamp in an office space.

*kWh Savings = (0.043-0.009)*4,439*1.095 = 165.23 kWh*

kW Savings = 0.7(0.043-0.009)*1.254 = 0.0.298 kW*

*Heating Penalty = (0.043-0.009)*4,439*-0.0023 = -0.347 Dth/year*

Deemed Input Tables:

Table 1: HVAC Interactive Factors by HVAC System (Ref. 2)

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
Lighting Measures	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%	8,766
Safety or Code Required	100%	8,766
Exterior lighting	0%	4,903

Table 3: Measure Life

Installed Technology	Measure Life	Reference
Ceramic Metal Halide	13	8
Ceramic Metal Halide - Integrated Ballast	13	8
High Bay Fluorescent	15	6
High Bay LED	10.9	22
LED Exterior Canopy	10.2	14
LED Exterior (Wall & Area)	10.2	14
Low wattage plug in CFL	1.8	17
Low wattage T8	15	6
Pin based CFL	2.3	18
Pulse Start Metal Halide	15	9
CFL Standard to Low Wattage	8,000 hr	1
Controls	8	6
Exit Sign Retrofit with LED/LEC	16	6
Exterior Canopy/Soffit Retrofit with LEDs	50,000 hr	7
Exterior Wall Pack Retrofit with LEDs	50,000 hr	7
Parking Garage Fluorescent	15	6
High Pressure Sodium	15	19
Interior LED Lamps (35,000 hour life)	7.9	15
Interior LED Luminaire (35,000 hour life)	7.9	16
Pin-Based CFL	2.3	9
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	36,000 hr	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	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).

Notes:

New construction requirements and information is available in the New Construction section.

References:

1. Product life assumption of 8,000 hours determined through survey of on-line retailers, July 2012

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 assumption of 50,000 hours from Illinois Technical Reference Manual, July 2012, confirmed with survey of online retailers, July 2012

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

13. Measure life reduction due to legislation and market. See T12 Up to 4-Foot Retrofit section for more information.

14. LED exterior canopy, area, and wall pack fixture rated hours of 50,000 is divided by the exterior operating hours of 4,903 to arrive at 10.2 years for measure life.

15. LED lamp rated hours of 35,000 is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 7.9 years for measure life

16. LED luminaire rated hours of 35,000 is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 7.9 years for measure life

17. Measure life for plug in low wattage 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

18. 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.

19. 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.

20. ANSI/ASHRAE/IES Standard 90.1-2010 edition

21. LED highbay rated hours of 50,000 is divided by the “other” operating hours of 4,576 hours to arrive at 10.9 years.

Revisions:

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

C/I Lighting - CFL Standard to Low Wattage Retrofit

Version No. 3.4

Measure Overview

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.

Actions: Replace Working, Replace on Fail
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

Algorithm and Assumptions:

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for lamp wattages.

C/I Lighting - Exit Sign Retrofit with LED/LEC

Version No. 3.4

Measure Overview

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.

Actions: Replace Working, Replace on Fail
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

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 be FES 2012

5. Lighting Efficiency input wattage guide, Xcel Energy, July, 2008, kW

6. 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.

C/I Lighting - Exterior Canopy/Soffit Retrofit with LEDs

Version No.

3.3

Measure Overview

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.

Actions: Replace working, Replace on Fail
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Exterior canopy/soffit lighting at any facility type

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.

C/I Lighting - Exterior Wall Pack Retrofit with LEDs

Version No.

1.1

Measure Overview

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.

Actions: Replace working, Replace on Fail
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Exterior wall pack lighting at any facility type

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.

C/I Lighting - Fluorescent to LED High Bay Systems

Version No.

1.0

Measure Overview

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.

Actions: Replace working
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

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.

C/I Lighting - High Pressure Sodium Retrofit

Version No.

3.4

Measure Overview

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 percent 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.

Actions: Replace on fail, replace working
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buidlings

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%.

C/I Lighting - Incandescent Over 100W Retrofit

Version No.

3.5

Measure Overview

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.

Actions: Replace working, Retrofit
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

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 and LED and CFL lamps appear on the ENERGY STAR Qualified Product list available at www.energystar.gov.

C/I Lighting - Incandescent Up to 100W Retrofit

Version No.

3.5

Measure Overview

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.

Actions: Replace working, Retrofit
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting
Applicable to: Commercial, Industrial, and Public Buildings

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 and LED and CFL lamps appear on the ENERGY STAR Qualified Product list available at www.energystar.gov.

C/I Lighting - Mercury Vapor Retrofit

Version No.

3.5

Measure Overview

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 percent 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.

Actions: Replace on fail, replace working
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

Algorithm and Assumptions:

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

C/I Lighting - Metal Halide Retrofit

Version No.

3.6

Measure Overview

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 percent 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.

Actions: Replace on fail, replace working
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting
Applicable to: Commercial, Industrial, and Public Buildings

Algorithm and Assumptions:

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

C/I Lighting - Pulse Start Metal Halide Retrofit

Version No.

3.6

Measure Overview

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.

Actions: Replace on fail, replace working

Target Market Segments: Commercial, Industrial, Public, Other
Target End Uses: Lighting
Applicable to: Commercial, Industrial, and Public Buildings

Algorithm and Assumptions:

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

C/I Lighting - Stairwell Fixtures with Integral Occupancy Sensors

Version No.

1.1

Measure Overview

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.

Actions: Replace on Fail, Replace Working
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

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.

C/I Lighting - T8 Standard to Low Wattage Retrofit

Version No.

3.5

Measure Overview

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.

Actions: Replace on fail, replace working, new construction
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

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.

C/I Lighting - T12 8-Foot Retrofit

Version No.

3.6

Measure Overview

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.

Actions: Replace Working, Replace on Fail
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

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.

C/I Lighting - T12 Up to 4-Foot Retrofit

Version No.

3.6

Measure Overview

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.

Actions: Replace working, Retrofit
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

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

eptions 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

C/I Lighting - T8 Optimization

Version No.

3.6

Measure Overview

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.

Actions: Replace working
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

Algorithm and Assumptions:

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

C/I Lighting – LED Troffers

Version No.

1.0

Measure Overview

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.
Actions: Replace working
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

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.

C/I Lighting – LED Troffer Retrofit Kits

Version No.

1.0

Measure Overview

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.
Actions: Replace working
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

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.

C/I Lighting - Controls

Version No.

3.5

Measure Overview

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.)

Actions: Modify
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

Algorithm and Assumptions:

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

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

Unit Gallons Fuel Oil/Propane Savings per Year = 0

Measure Lifetime (years) = 8 years (Ref. 1)

Unit Participant Incremental Cost: See Table 3

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

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. CF will be determined based on customer provided building type in table 2.

HVAC_cooling_kWhsavings_factor = Cooling system energy savings factor resulting from 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 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 lighting control from Table 1.

Required from Customer/Contractor: Control type/quantity, connected load (kW) to each control, building type, HVAC system (heating only, heating & cooling, exterior/unconditioned)

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 * (1-0.70) * 4,439 * 1.095 = 816.6 kWh*

*kW = 0.7 * 0.560 * (1-0.70) * 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 undercabinent 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

C/I Lighting - New Construction

Version No.

3.5

Measure Overview

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 wallpacks and area/pole lighting, LED parking garage wallpack 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.

Actions: New Construction
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Lighting

Applicable to: Commercial, Industrial, and Public Buildings

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 4: 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
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.

C/I Lighting - Refrigerator/Freezer Case LEDs

Version No.

2.2

Measure Overview

Description: This measure involves replacement of existing fluorescent refrigerated case lighting with Design Lights Consortium-qualified (DLC) LED fixtures.

Actions: Replace on Fail, Replace Working
Target Market Segments: Commercial, Industrial
Target End Uses: Lighting

Applicable to: Grocery stores, convenience stores and other refrigerated sales facilities

Algorithm and Assumptions:

Refer to Lighting End Use for appropriate algorithm and inputs. Refer to Appendix B for wattages.

Algorithms

Unit kWh Savings per Year = (kW_base - kW_eff) x Hrs x (1 + Refr_Factor)

Unit Peak kW Savings = CF x (kW_base - kW_eff) x (1 + Refr_Factor)

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 3)

Unit Participant Incremental Cost = Efficient fixture cost. See Appendix B.

Where:

kW_base = Baseline fixture wattage, see Appendix B

kW_eff = Efficient fixture wattage, see Appendix B

Hrs = 6,205 hours (Ref. 1)

CF = 90%; Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. (Ref. 2)

Refr_Factor = 0.40 (for refrigerator applications) (Ref. 4)

= 0.77 (for freezer applications) (Ref. 4)

Required from Customer/Contractor: Unit type (refrigerator or freezer), existing fixtures, installed fixtures.

Example:

A convenience store retrofits its reach-in cooler with LED lights.

Unit kWh Savings per Year = (0.076 kW - 0.038 kW) x (6,205 hours) x (1 + 0.40) = 330 kWh
Unit Peak kW Savings = 90% x (0.076 kW - 0.038 kW) x (1 + 0.40) = 0.0479 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

Requirements:

It is suggested that all LED fixtures and retrofits appear on the Design Lights Consortium Qualified Product list available at www.designlights.org.

References:

1. State of Ohio Energy Efficiency Technical Reference Manual, 2010. Prepared by Vermont Energy Investment Corporation. Pages 180-182.

2. 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.

3. 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.

4. US DOE Publication #46230-00, "Energy Savings Potential for Commercial Refrigeration Equipment", 1996, Arthur C. Little, Inc

5. Based on a review of TRM incremental cost assumptions from Oregon and Vermont, supplemented with completed project information from New York.

C/I Motors

Version No.

2.0

Measure Overview

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 non-industrial 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.

Actions: Replace Working, Replace on Fail, New Construction
Target Market Segments: Commercial, Industrial
Target End Uses: Fans, Pumps, Motors, HVAC, Process

Applicable to: Motors in industrial and HVAC applications.

Algorithms

Unit kWh Savings per Year = HP x LF x Conversion x (1/Eff_base – 1/Eff_new) x Hrs

Unit Peak kW Savings = HP x LF x Conversion x (1/Eff_base – 1/Eff_new) x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane 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)

Where:

Hrs = Deemed annual operating hours by end use (non-industrial 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_new = Efficiency of new motor. Eff_new = NEMA Premium Efficiency or NEMA Premium Efficiency + 1%. See Appendix C.

Eff_base = Baseline motor efficiency. Eff_base = EPACT efficency (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)

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).

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
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.

Documentation Revision History:

Version / Description	Author	Date
1 New spec	JP	11.13.13
2 Design changes to accommodate Replace on Fail and New Construction in addition to Replace Working, corrected incremental cost information.	JP	5.9.14

C/I Refrigeration - Anti-Sweat Heat Control

Version No.

1.2

Measure Overview

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.

Actions: Modify, New Construction
Target Market Segments: Commercial, Industrial
Target End Uses: Refrigeration

Applicable to: Commercial and Industrial Refrigeration

Algorithms

Unit kWh Savings per Year = kW_base * n_door * ESF * BF * 8766

Unit Peak kW Savings = 0

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $200 (ref. 2)

Where:

kW_base = connected load kW for reach-in cooler or freezer door and frame with a heater. Assumed to be 0.195 kW for freezers and 0.092 kW for coolers (ref. 3)

n_door = number of doors controlled by sensor, actual installed

8766 = 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.

Required from Customer/Contractor: Equipment type (cooler or freezer), number of doors, temperature (high/medium/low), humidity or conductivity-based control

Example:

Install anti-sweat humidity-based heat control on 2-door low-temperature freezer

Unit kWh Savings per Year = 0.195 * 2 * 0.55 * 1.36 * 8766 = 2557 kWh

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

Documentation Revision History:

Version / Description	Author	Date
1) New measure	Franklin Energy	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 8760 to 8766	JP	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.	JP	3/2/2014

C/I Refrigeration - ENERGY STAR Refrigerator and Freezer

Version No. 3.0

Measure Overview

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.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial, Industrial
Target End Uses: Refrigeration

Applicable to: Commercial and industrial refrigeration

Algorithms

Unit kWh Savings per Year = (kWh_base - kWh_ee) * 365.25

Unit Peak kW Savings = kWh Savings/8766 X CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = See Table 1

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

8766 = operating hours over the course of a year

365.25 = days per year

CF = Coincidence Factor, assumed to be 0.9 (ref. 2)

Required from Customer/Contractor: Actual installed frozen compartment volume in cubic feet, solid or glass door, refrigerator or freezer

Example:

Install ENERGY STAR glass door refrigerator with a volume of 15 ft^3.

*Unit kWh Savings per Year = ((0.22 * 15 + 1.95) - (0.15 * 15 + 0.32)) * 365.25 = 979 kWh*

*Unit Peak kW Savings = 979/8766 * 0.9 = 0.101 kW*

Deemed Input Tables:

Table 1. The incremental capital cost (ref. 3)

Door Type and Volume (ft^3)	Refrigerator incremental Cost, per unit	Freezer Incremental Cost, per unit
Solid or Glass Door		
0 < V < 15	$143	$142
15 ≤ V < 30	$164	$166
30 ≤ V < 50	$164	$166
V ≥ 50	$249	$407

Table 2. Baseline maximum daily energy consumption in kWh (ref. 4)

Type	kWh_base
Solid Door Refrigerator	0.11 * V + 0.26
Glass Door Refrigerator	0.22 * V + 1.95
Solid Door Freezer	0.23 * V + 0.54
Glass Door Freezer	0.56 * V + 2.61

Table 3. Efficient maximum daily energy consumption in kWh (ref. 5)

Door Type and Volume (ft^3)	Refrigerator	Freezer
	kWh_ee	kWh_ee
Solid Door		
0 < V < 15	≤ 0.02V + 1.60	≤ 0.250V + 1.550
15 ≤ V < 30	≤ 0.09V + 0.55	≤ 0.200V + 2.30
30 ≤ V < 50	≤ 0.01V + 2.95	≤ 0.25V + 0.80
V ≥ 50	≤ 0.06V + 0.45	≤ 0.14V + 6.30
Glass Door		
0 < V < 15	≤ 0.10V + 1.07	≤ 0.56V + 1.61
15 ≤ V < 30	≤ 0.15V + 0.32	≤ 0.30V + 5.50
30 ≤ V < 50	≤ 0.06V + 3.02	≤ 0.55V - 2.00
V ≥ 50	≤ 0.08V + 2.02	≤ 0.32V + 9.49

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. TBD

3. Nadel, S., Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers, ACEEE, December 2002

4. Federal Energy Standards, accessed 12/16/14.

< http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/52

5. ENERGY STAR Program Requirements for Commercial Refrigerators and Freezers Version 3.0, Accessed on 12/15/14.

<http://www.energystar.gov/index.cfm?c=commer_refrig.pr_crit_commercial_refrigerators>

Documentation Revision History:

Version / Description	Author	Date
1.) New measure	Franklin Energy	8/20/2012
2.) Corrected example, changed 365 days/yr to 365.25, changed 8760 h/yr to 8766, changed name	JP	2/11/2013
2.1 Corrected example	JP	5/8/2014
2.2 Updated to new standard	Franklin Energy	12/18/2014
2.3 Changed example description	JP	1/5/2015

C/I Refrigeration - Evaporator Fan Motor Retrofit

Version No.

1.2

Measure Overview

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).

Actions: Replace Working
Target Market Segments: Commercial, Industrial
Target End Uses: Refrigeration

Applicable to: Commercial and Industrial Refrigeration

Algorithms

Unit kWh Savings per Year = (W_base - W_ee)/1000 * LF * DC_evap * (1 + 1/(DG * COP)) * 8766

Unit Peak kW Savings = (W_base - W_ee)/1000 * LF * DC_evap * (1 + 1/(DG * COP)) * CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 (Ref. 1)

Unit Participant Incremental Cost = $100 (ref. 1)

Where:

W_base = Input wattage of existing/baseline evaporator fan motor. The value is from nameplate or See Table 1 if unknown.

W_ee = Input wattage of new energy efficient evaporator fan motor. The value is from nameplate or See Table 1 if unknown.

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. 2)

COP = Coefficient of performance of compressor in the refrigerator/freezer. COP = 2.5 for refrigerator, COP = 1.3 for freezer (ref. 1, 2)

8766 = Operating hours over the course of a year

CF = Coincidence factor = 0.9 (Ref. 4)

Required from Customer/Contractor: Equipment type (refrig or freezer), motor category (1-14W, 16-23W, 1/20 HP)

Optional inputs from customer/contractor: Input wattages of existing and new evaporator fan motors.

Example:

Replace SP evaporator fan motor with ECM fan motor for cooler

*Unit kWh Savings per Year = (93 - 30)/1000 * 0.9 * 1 * (1 + 1/(0.98 * 2.5)) * 8766 * 1 = 700.0*

Deemed Input Tables:

Table 1. Variables for HE Evaporator Fan Motor (ref. 3)

Motor Category	Weighting Percentage (population)[1]	Motor Output Watts	SP Efficiency	SP Input Watts	PSC Efficiency	PSC Input Watts	ECM Efficiency	ECM Input Watts
1-14 watts (Using 9 watt as industry average)	91%	9	18%	50	41%	22	66%	14
16-23 watts (Using 19.5 watt as industry average)	3%	19.5	21%	93	41%	48	66%	30
1/20 HP (~37 watts)	6%	37	26%	142	41%	90	66%	56

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.

Documentation Revision History:

Version	Description	Author	Date
1	New measure	FES	8/20/2012
1.1	Minor revisions, changed name, corrected required inputs, removed qty from algorithms, changed hours from 8760 to 8766 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)	JP	2/8/2013
1.2	Corrected Required Inputs	JP	3/29/2014

C/I Envelope – Fast Acting Doors

Version No. 1.0

Measure Overview

Description: High speed doors save energy by lowering infiltration by reducing the time that rooms are exposed to each other. They also provide better insulation between divided spaces.

Savings are achieved by improving the seal of the doorway, increasing the door speed and reducing the amount of time the door simply stands open. The methodology for estimating energy savings for this measure is well documented (2014 ASHRAE Refrigeration Handbook, Refrigeration Load, Chapter 24).

Actions: Modify, New Construction
Target Market Segments: Commercial, Industrial
Target End Uses: HVAC

Applicable to: Commercial and Industrial Refrigeration

Algorithms

Unit kWh Savings per Year = Sensible and Latent Refrigeration Load x Freezer / Cooler Performance / Conversion Factor x Annual Operating Hours

Unit Peak kW Savings = Sensible and Latent Refrigeration Load x Freezer / Cooler Performance / Conversion Factor

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12

Unit Participant Incremental Cost = approximately $150/SF of automated door

Where:

Sensible and Latent Refrigeration Load = Number of Doors x 3790 x Doorway Width x Doorway Height$^{1.5}$ x Sensible Heat Load of Infiltration Air x (1 / Sensible Heat Ratio of the Infiltration Air Heat Gain) x Door Loss Factor

Number of Doors = Number of doors being replaced

Door Width = Typically 8 ft wide

Door Height = Typically 10 ft high

Sensible Heat Load of Infiltration Air = See Table 1

Sensible Heat Ratio of the Infiltration Air Heat Gain = See Table 1

Door Loss Factor = 0.42 for strip curtains, 1.0 for open doorways (Ref. 1)

Annual Operating Hours = 8766 hours

Freezer/Cooler Performance (COP) = 2.5 kW/ton for freezers, 1.3 kW/ton for coolers (Ref. 2)

Conversion Factor = 12,000 Btuh/ton

Required from Customer/Contractor: Existing doorway type, transition type, area of doorway, number of doors.

Example:

Replacing an open doorway, between a loading dock and a cooler, with a 8ft x 10ft fast acting door

Sensible and Latent Refrigeration Load = 1 Door x 3790 x 8 ft x (10 ft)$^{1.5}$ x 0.08 ton/in2 x (1 / 0.87) x 1.0 = 88,166 Btu/h

Unit kWh Savings per Year = 88,166 Btu/h x 1.3 kW/ton / 12,000 Btuh/ton x 8766 hours = 83,727 kWh

Unit Peak kW Savings = 88,166 Btu/h x 1.3 kW/ton / 12,000 Btuh/ton = 9.551 kW

Replacing a strip curtain doorway, between a loading dock and a cooler, with a 8ft x 10ft fast acting door

Sensible and Latent Refrigeration Load = 1 Door x 3790 x 8 ft x (10 ft)$^{1.5}$ x 0.08 ton/in2 x (1 / 0.87) x 0.42 = 37,030 Btu/h

Unit kWh Savings per Year = 88,166 Btu/h x 1.3 kW/ton / 12,000 Btuh/ton x 8766 hours = 35,165 kWh

Unit Peak kW Savings = 88,166 Btu/h x 1.3 kW/ton / 12,000 Btuh/ton = 4.012 kW

Deemed Input Tables:

Table 1: Sensible Heat Ratio of the Infiltration Air Heat Gain

	Freezer to Cooler	Freezer to Dock	Cooler to Dock
Sensible Heat Load of Infiltration Air (Ton/ft², Ref. 3)	0.27	0.45	0.08
Sensible Heat Ratio of the Infiltration Air Heat Gain (ref. 3)	0.95	0.78	0.87

References:

1. Pennsylvania Technical Reference Manual 2015 Table 3-115 p.418 (Value = 1.00 - 0.58)

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 page 24.5 - 24.7

Documentation Revision History:

Version / Description	Author	Date

1. Created specification for Commercial and Industrial Fast Acting Doors	FES	11/01/15

Commercial Beverage Machine Controls

Version No. 4.1

Measure Overview

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.

Actions: Replace Working (addition to working equipment)
Target Market Segments: Commercial
Target End Uses: Plug Loads

Applicable to: Commercial facilities with vending machines

Algorithms (Ref. 1)

Unit kWh Savings per Year = Wbase / 1000 x Hours x SavingsFactor

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

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 5 (Ref. 3)

Unit Participant Incremental Cost = $180 (Ref. 4)

Where:

Wbase = 400 W; connected Wattage of the controlled equipment (Ref. 2)

Hours = 8,766 (average hours per year)

SavingsFactor = 46% (Ref. 2)

CF = 0.27 (Ref. 5)

Required from Customer/Contractor:

n/a

Example:

A customer installed Vending Miser controls on their cold beverage vending machine.

Unit kWh Savings per Year = 400W / 1000 x (8,766 hours) x 46% = 1,613 kWh

Unit Peak kW Savings = 1,613 kWh / 8,766 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

Documentation Revision History:

Version / Description	Author	Date
1. Original from Nexant with extraneous tabs hidden	Nexant	
2. Reformatted	Joe Plummer, DER	
2.1 Changed action from New Construction to Replace Working	Joe Plummer, DER	
3. 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. Updated the CF to 0.27 per Reference 5	Franklin Energy Services	1/4/2013
4.1 Changed Action from Retrofit to Replace Working	JP	4/3/2013
4.1 Changed Target End Use from Specialty to Plug loads	JP	4/3/2013
4.1 Changed annual hours from 8,760 to 8,766 for consistency with other measures	JP	4/3/2013

Commercial Food Service - Electric Oven and Range

Version No.

4.1

Measure Overview

Description: This measure includes replacement of failed or working electric ovens and ranges with new high efficiency ovens and ranges. May also include new construction if facility does not have gas service.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs x Rapid_Cook_Factor x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = (kW_Base - kW_EE) x CF x Rapid_Cook_Factor x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = 0 (heating effects are negligible)

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 4)

Unit Participant Incremental Cost = See Table 1

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*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

Hrs = Deemed annual operating hours by building type per Table 3

HVAC_cooling_kWhsavings_factor = Deemed cooling system energy savings factor resulting from efficient cooking per Table 2

CF = Deemed coincident demand factor based on cooking establishment type per Table 3.

HVAC_cooling_kWsavings_factor = Deemed cooling system demand savings factor resulting from efficient cooking per Table 2 below

Required from Customer/Contractor: Building type, heating only or heating and cooling, and new equipment
type.

Example:

A high school cafeteria installed a new high efficiency flashbake oven.

Unit kWh Savings per Year = (1.24 kW - 0.91 kW) x 2,282 hrs x 1.67 x 1.03 = 1,295 kWh

Unit Peak kW Savings = (1.24 kW - 0.91 kW) x 39% x 1.67 x 1.04 = 0.224 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: HVAC Interactive Factors (Ref. 1)

HVAC system	HVAC Cooling kWh Savings Factor	HVAC cooling kW Savings Factor
Heating only	1.00	1.00
Heating and cooling	1.03	1.04

Table 3: Deemed Coincident Peak Demand Factors and Annual Operating Hours by Building Type (Ref. 2)

Building Type	CF	Hrs
Fast Food Limited Menu	32%	1,604
Fast Food Expanded Menu	41%	1,822
Pizza	46%	2,851
Full Service Limited Menu	51%	2,049
Full Service Expanded Menu	36%	1,731
Cafeteria	39%	2,282

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. HVAC Interactive Factors developed based on the HVAC Interaction Factor extracted from the Arkansas Food Service Deemed Savings table

2. Hours, CF taken from Project on Restaurant Energy Performance-End-Use Monitoring and Analysis, Appendixes I and II, Claar, et. al., May 1985

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

Documentation Revision History:

Version / Description	Author	Date
2. Original from Nexant with extraneous tabs hidden	Nexant	
3. Added some clarifying notes	JP	
3.1 Modified Hrs description to reflect that operating hours will be deemed	JP	3/21/2012
3.2 Removed food warmers because baseline and efficient product efficiencies were identical. Original Nexant specs also did not show any savings.	JP	3/26/2012
4. Removed measures per note above and reformatted	Franklin Energy Services	8/29/2012
4.1 Changed measure name, changed description	JP	2/8/2013
4.2 Hours of use changed to 365.25	FES	1/13/2016

Commercial Food Service – ENERGY STAR Electric Combination Oven

Version No.

2.1

Measure Overview

Description:

This measure includes the replacement of an electric combination oven with an ENERGY STAR electric combination oven, or installation of an ENERGY STAR combination oven in new construction.

ENERGY STAR combination ovens incorporate timesaving features via sophisticated control packages.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = (Eday_base - Eday_prop) x Days

Unit Peak kW Savings = Unit kWh Savings per Year / (OpHrs x Days) x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $3,824 (Ref. 2)

Where:

Eday_base (kWh/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs - LBFood / PC_base - T_pre / 60] + E_pre_base

Eday_prop (kWh/day) = LBFood x Efood / Eff_prop + IdleRate_prop x [OpHrs - LBFood / PC_prop - T_pre / 60] + E_pre_prop

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 (Ref. 4)

Eff_prop = 65.5% (Ref. 6)

IdleRate_base = 7.5 kW; Idle Energy Rate (Ref. 2)

IdleRate_prop = 2.4 kW; (Ref. 7)

OpHrs = 8 hrs/day; Daily operating hours (Ref. 5)

PC_base = 80 lbs/hr; Production Capacity (Ref. 2)

PC_prop = 100 lbs/hr (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = 3.00 kWh; Preheat energy (Ref. 2)

E_pre_prop = 1.50 kWh (Ref. 2)

Days = See Table 1

CF = 0.9 (Ref. 2)

Required from Customer/Contractor: building type

Example:

A cafeteria in a large office building installed a new ENERGY STAR electric combination oven.

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 = 75.6 kWh/day

Eday_prop (kWh/day) = (200 lbs/day) x (0. 0732 kWh/lb) / (65.5%) + [2.4 kW x (8 hrs/day - (200 lbs/day / 100 lbs/hr) - (15 min / 60 min/hr))] + 1.50 kWh/day = 37.7 kWh/day

Unit kWh Savings per Year = (75.6 kWh/day - 43.2 kWh/day) x 250 days/yr = 9,475 kWh

Unit Peak kW Savings = 9,475 kWh / (8 hr/day x 250 days/yr) x 0.9 = 4.264 kW

Deemed Input Tables:

Table 1: Operation Days by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365.25
Sit-Down Restaurant	365.25
Grocery	365.25
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Hotel	365.25
Other Commercial	250

Methodology and Assumptions:

Table 2: ENERGY STAR Electric Combination Oven Criteria (Ref. 6,7)

Operation	Idle Rate, kW	Cooking-Energy Efficiency, %
Steam Mode	≤ 0.133P+0.6400	≥ 55
Convection Mode	≤ 0.080P+0.4989	≥ 76
Average (assuming 6-pan unit)	**2.4**	**65.5**

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 7-23. http://www.fishnick.com/equipment/techassessment/7_ovens.pdf

6. Average of steam and convection cooking efficiencies listed in ENERGY STAR Commercial Ovens Key Product Criteria, Version 2.1. http://www.energystar.gov/index.cfm?c=ovens.pr_crit_comm_ovens. Accessed 7/9/14.

7. Sum of steam and convection oven idle rates (summed because they can be used simultaneously), assuming 6-pans to be conservative, rounded to nearest tenth. Ref. 6.

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/27/2012

2. Updated to include ENERGY STAR version 2.1 specification	Franklin Energy Services	07/31/2014
2.1 Updated description to include new construction, changed 365 to 365.25 for consistency with other measures, put Table 2 in Methodology & Assumptions section	JP	7/31/2014

Commercial Food Service – ENERGY STAR Electric Convection Oven

Version No. 2.0

Measure Overview

Description:

This measure includes installation of high efficiency ENERGY STAR electric convection ovens instead of standard efficiency units. Energy efficient commercial electric ovens reduce energy consumption primarily through sophisticated control packages.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = (Eday_base - Eday_prop) x Days

Unit Peak kW Savings = Unit kWh Savings per Year / (OpHrs x Days) x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $1,682 (Ref. 2)

Where:

Eday_base (kWh/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs - LBFood / PC_base - T_pre / 60] + E_pre_base

Eday_prop (kWh/day) = LBFood x Efood / Eff_prop + IdleRate_prop x [OpHrs - LBFood / PC_prop - T_pre / 60] + E_pre_prop

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_prop = 71% (Ref. 4)

IdleRate_base = 2.00 kW; Idle Energy Rate (Ref. 2)

IdleRate_prop = 1.6 kW; (Ref. 4)

OpHrs = 8 hrs/day; Daily operating hours (Ref. 5)

PC_base = 70 lbs/hr; Production Capacity (Ref. 2)

PC_prop = 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_prop = 1.00 kWh (Ref. 2)

Days = See Table 1

CF = 0.9 (Ref. 6)

Required from Customer/Contractor: building type

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) / (71%) + [1.60 kW x (8 hrs/day - (100 lbs/day / 80 lbs/hr) - (15 min / 60 min/hr))] + 1.00 kWh/day = 21.7 kWh/day

Unit kWh Savings per Year = (25.4 kWh/day - 21.7 kWh/day) x 365.25 days/yr = 1,351 kWh

Unit Peak kW Savings = 1,349 kWh / (8 hr/day x 365.25 days/yr) x 0.9 = 0.416 kW

Deemed Input Tables:

Table 1: Operation Days by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365.25
Sit-Down Restaurant	365.25
Grocery	365.25
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Hotel	365.25
Other Commercial	250

Notes:

There is no code requirement for this technology.

ENERGY STAR requires that Full Size Electric Ovens have a cooking energy efficiency ≥ 71% and an idle energy rate ≤ 1.6 kW (Ref. 4)

ENERGY STAR requires that Half Size Electric Ovens have a cooking energy efficiency ≥ 71% and an idle energy rate ≤ 1.0 kW (Ref. 4)

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. *Commercial Ovens Key Product Criteria,* http://www.energystar.gov/index.cfm?c=ovens.pr_crit_comm_ovens. Accessed 11/11/2015.

5. *Technology Assessment: Ovens,* Food Service Technology Center, 2002. Page 7-22. http://www.fishnick.com/equipment/techassessment/7_ovens.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

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/14/2012
1.1 Renamed measure	JP	2/8/2013
1.2 Corrected preheat energy labels	JP	10/29/13
2.0 Updated ENERGY STAR requirements	FES	11/11/2015
2.1 Changed hours of operation to 365.25	FES	1/13/2016

Commercial Food Service – ENERGY STAR Electric Fryer

Version No. 1.2

Measure Overview

Description: This measure includes installation of high efficiency ENERGY STAR electric fryers instead of standard efficiency units. Energy efficient commercial electric fryers reduce energy consumption primarily through the application of advanced controls and insulation.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = (Eday_base - Eday_prop) x Days

Unit Peak kW Savings = Unit kWh Savings per Year / (OpHrs x Days) x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $1,344 (Ref. 2)

Where:

Eday_base (kWh/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs - LBFood / PC_base - T_pre / 60] + E_pre_base

Eday_prop (kWh/day) = LBFood x Efood / Eff_prop + IdleRate_prop x [OpHrs - LBFood / PC_prop - T_pre / 60] + E_pre_prop

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%; Heavy load cooking energy efficiency % (Ref. 2)

Eff_prop = 80% (Ref. 2)

IdleRate_base = 1.05 kW; Idle Energy Rate (Ref. 2)

IdleRate_prop = 1.00 kW (Ref. 2)

OpHrs = 12 hrs/day; Daily operating hours (Ref. 6)

PC_base = 65 lbs/hr; Production Capacity (Ref. 2)

PC_prop = 70 lbs/hr (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = 2.3 kWh/day; Preheat energy (Ref. 2)

E_pre_prop = 1.7 kWh/day (Ref. 2)

Days = See Table 1

CF = 0.9 (Ref. 5)

Required from Customer/Contractor: building type

Example:

A fast food restaurant installed a new ENERGY STAR Electric Fryer

Eday_base (kWh/day) = (150 lbs/day) x (0.167 kWh/lb) / (75%) + [1.05 kW x (12 hr/day - (150 lbs/day / 65 lb/hr) - (15 min / 60 min/hr))] + 2.3 kWh/day = 45.6 kWh/day

Eday_prop (kWh/day) = (150 lbs/day) x (0.167 kWh/lb) / (80%) + [1.00 kW x (12 hr/day - (150 lbs/day / 70 lb/hr) - (15 min / 60 min/hr))] + 1.7 kWh/day = 42.6 kWh/day

Unit kWh Savings per Year = (45.6 kWh/day - 42.6 kWh/day) x 365.25 days/yr = 1,096 kWh

Unit Peak kW Savings = 1,095 kWh / (12 hr/day x 365.25 days/yr) x 0.9 = 0.225 kW

Deemed Input Tables:

Table 2: Operation Days by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365.25
Sit-Down Restaurant	365.25
Grocery	365.25
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Hotel	365.25
Other Commercial	250

Notes:

There is no code requirement for this technology.

ENERGY STAR requires Standard Open Deep-Fat Electric Fryers have a heavy-load cooking efficiency ≥ 80% and an idle energy rate ≤ 1,000 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 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 Fryers Key Product Criteria,* http://www.energystar.gov/index.cfm?c=fryers.pr_crit_fryers. Accessed August, 15, 2012.

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. *Technology Assessment: Fryer,* Food Service Technology Center, 2002. Page 2-21. http://www.fishnick.com/equipment/techassessment/2_fryers.pdf

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/14/2012
1.1 Changed measure name	JP	2/8/2013
1.2 Corrected preheat energy labels	JP	10/30/2013
1.3 Hours of use changed to 365.25	FES	1/13/2016

Commercial Food Service – ENERGY STAR Electric Griddle

Version No. 1.2

Measure Overview

Description: This measure includes installation of high efficiency ENERGY STAR electric griddles instead of standard efficiency units. Energy efficient commercial electric griddles reduce energy consumption primarily through application of advanced controls and improved temperature uniformity.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = (Eday_base - Eday_prop) x Days

Unit Peak kW Savings = Unit kWh Savings per Year / (OpHrs x Days) x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $2,162 (Ref. 2)

Where:

Eday_base (kWh/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs - LBFood / PC_base - T_pre / 60] + E_pre_base

Eday_prop (kWh/day) = LBFood x Efood / Eff_prop + IdleRate_prop x [OpHrs - LBFood / PC_prop - T_pre / 60] + E_pre_prop

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_prop = 70% (Ref. 2)

IdleRate_base = 2.50 kW; Idle Energy Rate (Ref. 2)

IdleRate_prop = 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_prop = 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_prop = 2.00 kWh; (Ref. 2)

Days = See Table 1

CF = 0.9 (Ref. 6)

Required from Customer/Contractor: building type

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_base (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 365.25 days/yr = 2,212 kWh

Unit Peak kW Savings = 2,212 kWh / (12 hrs/day x 365.25 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	365.25
Sit-Down Restaurant	365.25
Grocery	365.25
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Hotel	365.25
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. *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. 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

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/14/2012
1.1 Renamed measure	JP	2/8/2013
1.2 Fixed preheat energy labels	JP	10/30/13
1.3 Hours of use changed to 365.25	FES	1/13/2016

Commercial Food Service – ENERGY STAR Electric Hot Food Holding Cabinet

Version No. 1.1

Measure Overview

Description:

This measure includes installation of high efficiency ENERGY STAR electric hot food holding cabinets (HFHCs) 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.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = (kW_base - kW_prop) x Hours x Days

Unit Peak kW Savings = (kW_base - kW_prop) x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = See Table 1 (Ref. 2)

Where:

kW_base = Wattage of baseline unit. See Table 1. (Ref. 6)

kW_prop = 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)

Required from Customer/Contractor: building type, cabinet volume

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 365.25 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_prop	Incremental Cost
Full-Size	20	2.000	0.294	$1,891
3/4-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	365.25
Sit-Down Restaurant	365.25
Grocery	365.25
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Hotel	365.25
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.

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. *Commercial Hot Food Holding Cabinets Key Product Criteria,* http://www.energystar.gov/index.cfm?c=hfhc.pr_crit_hfhc. Accessed 8/24/12.
6. 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
7. *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.

Documentation Revision History:

Version / Description	Author	Date
1. 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

Commercial Food Service – ENERGY STAR Electric Steamer

Version No. 3.0

Measure Overview

Description: This measure includes replacement of commercial electric steamers with new 5 or 6-pan ENERGY STAR electric steamers.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = (Eday_base - Eday_prop) x Days

Unit Peak kW Savings = Unit kWh Savings per Year / (OpHrs x Days) x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $2,490 (Ref. 2)

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_prop (kWh/day) = LBFood x Efood / Eff_prop + (IdleRate_prop + Res_Rate_prop) x (OpHrs - LBFood / PC_prop - 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_prop = 50% (Ref. 2)

IdleRate_base = See Table 1; Idle Energy Rate (Ref. 2)

IdleRate_prop = See Table 1; (Ref. 2)

OpHrs = 12 hrs/day; Daily operating hours (Ref. 2)

PC_base = See Table 1; Production Capacity (Ref. 2)

PC_prop = See Table 1 (Ref. 2)

Res_Rate_base = 1.910 kW; Residual Energy Rate (Ref. 2)

Res_Rate_prop = 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)

Required from Customer/Contractor: building type, number of pans

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_prop (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 365.25 days/yr = 15,158 kWh

Unit Peak kW Savings = 15,147 kWh / (12 hr/day x 365.25 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_prop (%)	50%	50%	50%	50%
IdleRate_base (kW)	1.000	1.325	1.675	2.000
IdleRate_prop (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_prop (lbs/hr)	50	67	83	100
Res_Rate_base (kW)	1.910	1.910	1.910	1.910
Res_Rate_prop (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	365.25
Sit-Down Restaurant	365.25
Grocery	365.25
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Hotel	365.25
Other Commercial	250

Notes:

There is no code requirement for this technology.

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. *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.

Documentation Revision History:

Version / Description	Author	Date
1. 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 ot 0.0308 kWh/lb.	Franklin Energy Services	11/11/2015

Commercial Hot Water - Faucet Aerator (1.5 gpm) with Electric Water Heater

Version No.

4.0

Measure Overview

Description: This measure includes replacing an existing faucet aerator with low-flow aerator.

Actions: Replace Working
Target Market Segments: Replace Working
Target End Uses: DHW

Applicable to: Commercial facilities with electric water heaters. Measure includes installation of 1.5 GPM aerators only.

Algorithms

Unit kWh Savings per Year = ((GPM_base - GPM_low) x L x NOPF x Days x DF / GPMfactor) x EPG

Unit Peak kW Savings = Unit kWh Savings / (24 hr/day * Days)

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 1)

Unit Participant Incremental Cost = $6.70 (Ref. 6)

Where:

EPG = Density x Specific Heat x (Tfaucet - Tcold) / (ReEff x ConversionFactor)

NOPF = People / Faucets

GPM_base = 1.39 gpm (Ref. 2); Flow rate of existing 2.2 GPM aerator, adjusted for throttled flow uses

GPM_low = 0.94 gpm (Ref. 2); Flow rate of proposed 1.5 GPM aerator, adjusted for throttled flow uses

L = 3 min/person/day; Usage time (Ref. 9)

People = Provided by customer; Number of people in facility. If unknown, assume 10 people.

Faucets = Provided by customer; Number of faucets in facility. If unknown, assume 3 faucets. (Ref. 8)

DF = See Table 2; Drain Factor that accounts for uses that are volumetric in nature and aren't affected by low-flow aerators

GPM Factor = See Table 2; Factor accounts for differences in use between commercial and residential applications

Days = See Table 3; Days of operation

Specific Heat = 1.0 Btu / (lb x °F); Specific heat of water

Density = 8.34 lbs / gal; Density of water

Tfaucet = 91°F; Temperature of typical faucet usage (Ref. 2)

Tcold = Average groundwater temperature per Table 1 (Ref. 4)

ReEff = Recovery Efficiency = 98% (electric water heater) (Ref. 2)

Conversion Factor = 3,412 Btu/kWh (electric water heater)

Required from Customer/Contractor: confirmation of gas water heater, project location (county), number of people, number of faucets, bath or kitchen faucets.

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 and number of faucets is unknown.

NOPF = 10 people / 3 faucets = 3.33

EPG = (8.34 lb/gal) x (1.0 Btu/lb°F) x (91°F – 49.0°F) / (0.98 x 3,412) = 0.105 kWh/gal

Unit kWh Savings per Year = ((1.39 gpm - 0.94 gpm) x (3 min/person/day) x (3.33) x (304.4 days) x 0.85) / 2.0 x 0.105 kWh/gal = 61.1 kWh Saved

Unit Peak kW Savings = 200.5 kWh / (24 hr/day 304.4 day/yr) = 0.008 kW*

Deemed Input Tables:

Table 1: 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
If location is unknown	49.0

Table 2: Faucet Characteristics (Ref. 2, 8)

Application	DF	GPMfactor
Kitchen	75%	1.0
Bath	90%	2.5
If application is unknown	85%	2.0

Table 3: Deemed Annual Hot Water Use by Building Type (Ref. 7)

Building Type	Days Per Year
Small Office	250
Large Office	250
Fast Food Restaurant	365.25
Sit-Down Restaurant	365.25
Retail	365.25
Grocery	365.25
Warehouse	250
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Motel	365.25
Hotel	365.25
Other Commercial	250
If building type is unknown	304.4

Methodology and Assumptions:

Uses algorithms from IL TRM (Ref. 2)

(L), Usage time coincides with the middle of the range (6.74 min/per/day to 13.4 min/per/day) from multiple sources.

GPM_base is a representative baseline flow rate for kitchen and bathroom faucet aerators from multiple sources.

GPM_low is an average retrofit flow rate for kitchen and bathroom faucet aerators from multiple sources. This accounts for all throttling and differences from rated flow rates.

Notes:

The current standard for kitchen and bathroom aerators is 2.2 GPM, effective 1/1/1994. (Ref. 5)

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. State of Illinois Energy Efficiency Technical Reference Manual, Version 4.0, Page 647-655. February 13, 2015.

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 and Their Effective Dates. January 1, 2010

6. 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.

7. 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.

8. Assumes one kitchen faucet and two restroom faucets. Franklin Energy Services.

9. Connecticut UI and CLP Program Savings Documentation. September 29, 2009.

Documentation Revision History:

Version / Description	Author	Date
1. Created standalone spec from ResidentialElectricDHW_v03.2	Joe Plummer, DER	
2. Revised formatting and algorithms	Franklin Energy Services	7/27/2012
2. Update the measure life and measure cost	Franklin Energy Services	7/27/2012
3. 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 8760 to 8766 hours per year to be consistent with other measures, minor edits.	JP	3/13/2013
3.3 Changed “electric or gas water heater” to “confirmation of gas water heater” in Required Inputs	JP	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

Commercial Hot Water – Heat Pump Water Heater

Version No. 1.0

Measure Overview

Description: This measure includes replacement of failed or working storage-type electric resistance water heaters in commercial facilities with more efficient storage-type heat pump water heaters.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: DHW

Applicable to: Small commercial customers.

Algorithms

Unit kWh Savings per Year = EnergytoHeatWater x (1/EF_min – 1/EF_Eff) x ESAF / CF1

Unit Peak kW Savings = Unit kWh Savings per Year / 8,766 / ESAF

Unit Dth Savings per Year = Unit kWh Savings / ESAF * CF2 * GIF

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 3)

Unit Participant Incremental Cost = $784 (Ref. 5)

Where:

EnergyToHeatWater = SpecificHeat x Density x GalPer1000SqftPerDay x Area/1000 x Days x (Tset - Tcold)

SpecificHeat = 1.0 Btu / (lb x °F)

Density = 8.34 lbs / gal

GalPer1000SqftPerDay = Gallons per 1,000 ft^2/day based on building type per Table 2

Tset = 140 F (Ref. 7)

Tcold = Average groundwater temperature per Table 1

EF_min = Based on tank size; see Table 3.

EF_Eff = Efficiency (energy factor) of new water heater

ESAF = Electric Savings Adjustment Factor. 0.50 If electric space heat, 1.0 if gas space heat. (Ref. 8)

GIF = Gas Impact Factor. -0.65 if gas space heat, 0 if electric space heat. (Ref. 11)

Area = Minimum of:

- Floor area served by the water heater in ft^2, provided by customer/contractor

- Tank Size / (Min Storage Capacity per 1,000 sq ft, see Table 2) x 1000, the maximum floor area that could be served by the water heater in ft² based on tank size (not applicable for instantaneous units)
- (Input kW x 3.412) / (Min Heating Capacity per 1,000 sq ft, see Table 2) x 1000, the maximum floor area that could be served by the water heater in ft² based on heating capacity

CF1 = 3,412 Btu/kWh

CF2 = 0.003412 Dth/kWh

Required from Customer/Contractor: tank size in gallons, new water heater efficiency (EF), building type, project location (county), input power in kW, and space heat fuel source.

Example:

A 10,000 ft² small office in Zone 2 installed a new 50-gallon, heat pump water heater with an EF of 2.56 and input power of 3.5 kW. Space heat is electric.

The area used to calculate savings is the minimum of:
- o *10,000 ft²*
- o *50/2.3 x 1000 = 21,739 ft²*
- o *3.5x3.412/0.6 x 1000 = 19,903 ft²*

EF_Base = 0.960 - (0.0003 x 50 gallons) = 0.945

EnergyToHeatWater = (1 Btu/lb°F) x (8.34 lbs/gal) x (2.3 gal/1,000 ft²) x (10,000 ft²/1,000) x (250 day/yr) x (140°F - 49.1°F) = 4,359,110 Btu/yr

Unit kWh Savings per Year = (4,359,110 Btu/yr) x (1/0.945- 1/2.56) x 0.5 / (3,412 Btu/kWh) = 426 kWh

Unit Peak kW Savings = 426 kWh / 8,766 / 0.5 = 0.097 kW

*Unit Dth Savings per Year = 426 kWh / 0.5 * 0.003412 * 0 = 0 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
If location is unknown	49.0

Table 2: Deemed Annual Hot Water Use by Building Type (Ref. 2)

Building Type	Days Per Year	Gal per 1,000 Sqft Per Day	Minimum Heating Capacity (kBtu/hr per 1,000 Sq Ft)
Small Office	250	2.3	0.6

Large Office	250	2.3	0.6
Fast Food Restaurant	365.25	549.2	34.4
Sit-Down Restaurant	365.25	816.0	31.9
Retail	365.25	2.0	0.6
Grocery	365.25	2.2	0.6
Warehouse	250	1.0	0.3
Elementary School	200	5.7	4.0
Jr. High/High School/College	200	17.1	6.7
Health	365.25	342.0	27.8
Motel	365.25	100.0	21.1
Hotel	365.25	30.8	7.8
Other Commercial	250	0.7	0.2

Table 3: Baseline efficiency based federal minimum efficiency standards (Ref. 4)

Equipment Type	Category	Minimum Efficiency	Efficiency Metric
Electric Storage Water Heaters	Storage ≤ 55 gal	0.960 - (0.0003 x gal)	Energy Factor
	Storage > 55 gal	2.057 - (0.00113 x gal)	Energy Factor

Methodology and Assumptions:

Assumes water heaters are installed in conditioned space.

Notes:

Table 4: Equipment Standards, effective for products manufactured on or after April 16, 2015 (Ref. 4)

Type of Equipment	Energy Factor
Electric Storage Water Heaters, ≤ 55 gallons	0.960 - (0.0003 x Rated Storage Volume in gallons)
Electric Storage Water Heaters, > 55 gallons	2.057 - (0.00113 x Rated Storage Volume in gallons)

References:

1. US DOE Building America Program. Building America Analysis Spreadsheet, Standard Benchmark DHW Schedules. http://energy.gov/eere/buildings/building-america-analysis-spreadsheets Accessed 12/19/2014.

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. 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.

4. Energy Conservation standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters: Final Rule, Federal Register, 75 FR 20112, April 16, 2010.

5. 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.

6. Interpolated values from Table 38, Ohio Technical Reference Manual. October 15, 2009. Page 52.

7. 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

8. This factor accounts for the water heater location (assumes all are located in conditioned space) and that no electric savings will occur in the heating season (50% of the year) if the space heat is electric. 0.5 = 1 - (100% * 50%).

9. 2011 Residential Building Stock Assessment: Single-Family Characteristics and Energy Use. Page 83. http://neea.org/docs/reports/residential-building-stock-assessment-single-family-characteristics-and-energy-use.pdf.

10. Heating system usage assumed to be 24 hours x 182.5 days/year = 4,380. Based on MN TRM v2.0 Electronic Ignition Hearth measure.

11. 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*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. From The Impact of Heat Pump Water Heaters on Whole-House Energy Consumption, Canadian Mortgage and Housing Corporation.

Documentation Revision History:

Version / Description	Author	Date
1. Created standalone measure	FES	11/10/15

Commercial Hot Water - Pre-Rinse Sprayers (1.6 gpm) with Electric Water Heater

Version No.

3.0

Measure Overview

Description: This measure includes retrofit of working standard pre-rinse sprayers with low-flow, 1.6 gpm pre-rinse sprayers in commercial kitchen applications.

Actions: Replace Working
Target Market Segments: Commercial
Target End Uses: DHW

Applicable to: Commercial facilities with kitchens: restaurants, large office buildings, etc, with electric water heaters.

Algorithms

Unit kWh Savings per Year = EPG x WaterSaved / EF_electric / ConversionFactor

Unit Peak kW Savings = (Unit kWh Savings per Year) / 8,766 hours

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 5 (Ref. 1)

Unit Participant Incremental Cost = $100 (Ref. 3)

Where:

EPG = SpecificHeat x Density x (Tmix - Tcold)

WaterSaved = (Flow_base x Hours_base - Flow_eff x Hours_eff) x 60 min/hr x Days

SpecificHeat = 1.0 Btu / (lb x °F)

Density = 8.34 lbs / gal

Flow_base = 2.23 gal/min (Ref. 1)

Flow_eff = 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

Tmix = 110 °F; spray water temperature (Ref. 8)

Tcold = Average groundwater temperature per Table 1 (Ref. 2)

EF_electric = 0.98 (Ref. 3)

ConversionFactor = 3,412 Btu/kWh

Required from Customer/Contractor: Confirmation of electric water heater, building type, project location (county)

Example:

A direct install crew has installed a low-flow pre-rinse spray valve 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 365.25 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 * 6,776 gal/yr / 0.98 / (3,412 Btu/kWh) = 1,031 kWh/yr*

Unit Peak kW Savings = 1,031 kWh / 8,766 hours = 0.118 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
If location is unknown	49.0

Table 2: Deemed Annual Hot Water Use by Building Type (Ref. 6)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365.25
Sit-Down Restaurant	365.25
Grocery	365.25
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Hotel	365.25
Other Commercial	250
Senior Living	365.25

Methodology and Assumptions:

The following building types were considered not to apply to this measure: Small Office, Retail, Warehouse and Motel

Notes:

The current flow standard for Pre-Rinse Sprayers is 1.6 GPM (Ref. 4)

The Federal Energy Management Program (FEMP) requires the federal government purchase and install pre-rinse spray valves with 1.25 gpm in federal buildings. (Ref.7)

References:

1. IMPACT AND PROCESS EVALUATION FINAL REPORT for CALIFORNIA URBAN WATER CONSERVATION COUNCIL 2004-5 PRE-RINSE SPRAY VALVE INSTALLATION PROGRAM (PHASE 2)

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. State of Illinois Energy Efficiency Technical Reference Manual, June 1st, 2012. Pages 109-113.

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.

5. No demand savings are claimed for this measure since there is insufficient peak coincident data.

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. FEMP Designated Product: Pre-Rinse Spray Valves, Purchasing Specification for Energy Efficient Products, FEMP, December 2008.

8. 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

Documentation Revision History:

Version / Description	Author	Date
1. Put measure together	Franklin Energy Services	7/23/2012
2.0 Add building types and Days variable	Franklin Energy Services	8/6/2012
2.1 Add Flow rate as a variable	Franklin Energy Services	8/6/2012
2.2 Changed the hot water set point from 120°F to 105°F	Franklin Energy Services	8/28/2012
2.3 Added building type to customer/contractor inputs, changed Applicable text	JP	3/25/2013
2.4 Renamed Tset to Tmix, reformulated savings algorithms for consistency with aerators, changed annual hours from 8760 to	JP	3/27/2013

8766 and days/yr from 365 to 365.25 for consistency with other measures, changed example accordingly		
2.5 Electric water heater recovery efficiency changed from 0.97 to 0.98 per FES recommendation, updated example accordingly	JP	4/5/2013
2.6 Updated to clarify that spec applies to installation of 1.6 gpm sprayers, removed ability to use flow rate of new sprayer as 1.12 gpm is actual average flow rate in field measured as part of evaluation study in Ref. 1	JP	4/8/2014
2.6 Added federal government purchase requirements and reference.	Franklin Energy Services	8/1/2014
3.0 Added Senior Living building type andunknown location to the Table 1. The average 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

Commercial HVAC - Programmable Thermostats with Electric Heating

Version No. 1.0

Measure Overview

Description: This measure includes replacement of failed or working manual thermostats in existing commercial businesses with programmable thermostats. New units must have the capability to adjust temperature setpoints according to a schedule without manual intervention. An estimate is provided for reduced heating energy consumption through temperature set-back during unoccupied or reduced demand times. Savings are provided for heating only as a literature review has not shown conclusive cooling savings. 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.

Actions: Replace on Fail, Replace Working
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.

Algorithms

Unit kWh Savings per Year = HCelec x HSF x ISR

Unit Peak kW Savings = 0

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 8 (Ref. 1)

Unit Participant Incremental Cost: $181 (Ref. 2)

Where:

HCelec = Heating consumption for electrically heated businesses

Where:

HCelel = $EFLH_{Heat}$ x Size x Load_Factor x EFF

Where:

$EFLH_{Heat}$ = Equivalent Full Load Hours heating, See Table #1. (Ref. 3)

Size = Nominal Cooling 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. (Ref. 4)

Load_Factor = boiler load factor, assumed to be 77% (Ref. 5)

EFF = equipment efficiency:

For less than 5.5 tons:

Eff = 12 / HSPF

Where HSPF = Heating system performance factor of existing equipment, provided by customer/contractor or use = 7.7 if unknown (Ref. 6)

For 5.5 tons or greater:

EFF = 3.52 / COP

Where COP = Heating system performance factor of baseline or existing ASHP, provided by customer/contractor. 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)

ISR = In-Service Rate, the percentage of units installed and programmed effectively, Table 2. (Ref. 9)

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)

Examples:

Retrofit a manual thermostat with a programmable thermostat in an electrically heated strip mall retail store in Climate Zone 1, via a direct installation program delivery.

HCelec = 1701 x 5 x 0.77 x 12 / 7.7 = 10,206 kWh

Unit kWh Savings per Year = 10,206 x 0.05 x 1.0 = 510.3 kWh

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: In-Service Rates (Ref. 9)

Program Delivery	ISR
Direct Install	1.0
Other, or unknown	0.56

Table 3: Deemed baseline efficiency for heating 5.5 tons and greater

Equipment	COP_base (Ref. 10)
ASHP Units 5.5-11.3 tons*	3.3
ASHP Units 11.4-19.9 tons*	3.2
ASHP Units 20-63.3 tons*	3.2
GSHP Units (closed loop)**	3.1
GWSHP Units (open loop)**	3.6

*HSPF and COP based upon 17°F DB and 15°F WB Outdoor air temperature.
** Heating efficiencies based upon ASHRAE 90.1-2010.

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.

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. 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, Subpart F - Commercial Air Conditioners and Heat Pumps. January 1, 2010.

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

9. "Programmable Thermostats. Report to KeySpan Energy Delivery on Energy and Cost Effectiveness," GDS Associates, Marietta, GA. 2002

10. ASHRAE 90.1-2010 based upon 17°F DB and 15°F WB Outdoor air temperature.

Documentation Revision History:

Version/Description	Autho	Date
1) New Measure	FES	11/12/2015

Industrial Compressed Air - No Loss Drains

Version No.

2.0

Measure Overview

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.

Actions: Replace Working, Replace on Fail
Target Market Segments: Industrial
Target End Uses: Industrial Process

Applicable to: Industrial and Commercial Customers

Algorithms

Unit kWh Savings per Year = kW_100_CFM*Hours*Drain_CFM/100

Unit Peak kW Savings = kW_100_CFM*Drain_CFM*CF/100

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 13 (Reference 5)

Unit Participant Incremental Cost =$450/drain (reference 4)

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

Required from Customer/Contractor: CAGI Data Sheet for Air Compressor, Annual Hours of Operation.

Example:

Install a no loss drain on a 40hp 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.

Documentation Revision History:

Version / Description	Author	Date
1.0 Original Issue	Franklin Energy	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	JP	9/12/2013

Industrial Compressed Air - Variable Speed Drive Air Compressors < 50hp

Version No.

2.0

Measure Overview

Description: This measure includes replacement of a inlet modulated, variable displacement, or load/no load controlled air compressor units < 50hp with variable speed drive (VSD) controlled units. Base load units do not qualify.

Actions: Replace Working, Replace on Fail, New Construction
Target Market Segments: Industrial
Target End Uses: Industrial Process

Applicable to: Industrial and commercial customers

Algorithms

Unit kWh Savings per Year = hp * SF * C * Hours

Unit Peak kW Savings = hp * SF * C * CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 (reference 1)

Unit Participant Incremental Cost =$428/hp (Replace Working) or $100/hp (Replace on Fail or New Construction)

Where:

hp =nominal horsepower of VSD air compressor motor

SF =Savings Factor: reference Table 1

Hours =annual facility hours where compressed air is required, default 4024 (reference 2)

C =conversion constant = 0.746 kW/hp

CF =coincidence factor, Default = 0.95

Required from Customer/Contractor: CAGI Data sheet (new), CAGI Data sheet (existing) or nameplate data

Optional inputs from customer/contractor: Annual facility hours where compressed air is required

Example:

Replace an a inlet modulated 25hp air compressor with a 25 hp VSD air compressor

*Unit kWh Savings per Year = 25 * 18% * 0.746 * 4024 = 13,509 kWh*

*Unit kW Savings per Year = 25 * 18% * 0.746 * 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.

Documentation Revision History:

Version / Description	Author	Date
1.0 Original Issue	Franklin Energy	8/28/2012
1.1 Specified that hp corresponds to VSD compressor, added optional input for facility hours, minor fixes	JP-DER	3/4/2013

Industrial Compressed Air – Compressed Air Leak Detection

Version No. 1.1

Measure Overview

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 manufacturing environments where they are used for blow off, pneumatic tools, and manufacturing processes of many varieties.

The incremental cost is associated with base equipment cost and does not include any installation costs.

Actions: Operation and Maintenance
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.

Algorithms

Unit kWh Savings per Year = N_leaks * CFM_leaks * C_aircomp * t * Control_factor

Unit Peak kW Savings = (unit kWh Savings per Year * CF)/t

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 1 year (ref .1)

Unit Participant Incremental Cost = $8 per horsepower (ref .2)

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)

Required from Customer/Contractor: Number of Leaks <u>Repaired</u>, 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.

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*0.41*.23*6,240*.31 = 1,824 kWh/year*

*Unit Peak KW Savings per Year = (1,824 * 0.845)/6,240 = 0.247 KW*

Deemed Input Tables:

Table 1 CFM per Leak Size for Compressed Air Leaks (ref. 7)

	Orifice Diameter (inches)					
Pressure (psig)	**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.

3. Compressed Air Challenge "Fundamentals of Compressed Air Systems" Pg 28-32

4. Compressed Air Challenge "Fundementals of Compressed Air Systems" Pg 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

Documentation Revision History:

Version/Description	Autho	Date
1) New Measure	FES	11/12/2015

Public - LED Traffic Signal

Version No.
1.6

Measure Overview

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%.

Actions: Replace working, Replace on Fail, New Construction
Target Market Segments: Public
Target End Uses: Lighting

Applicable to: Exterior traffic signals

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hrs

Unit Peak kW Savings = (kW_Base - kW_EE) X DF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years): See Table 1

Unit Participant Incremental Cost: See Table 3

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)

Required from Customer/Contractor: Efficient lamp type/quantity

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)*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
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

Document Revision History:

Version / Description	Author	Date
1) New version replacing LEDTrafficSignalPedestrian_V01,LEDTrafficSignalRedArrow_v01, LEDTrafficSignalRed_v01, LEDTrafficSignalGreen_v01	JP	
1.1) Changed to deemed wattages and incremental costs	JP	3/23/2012
1.2) Updated costs, format	FES	8/31/2012
1.3) Updated CF	FES	11/15/2012
1.4) Minor revisions	JP	2/7/2013
1.5) Added Yellow ball, Yellow Arrow, and Green Arrow signals	FES	2/27/2014
1.6) Minor formatting revisions	JP	5/15/2014
1.7) Sample calculation updated	FES	1/13/2016

Residential Appliances - ENERGY STAR Clothes Washers

Version No.

2.4

Measure Overview

Description: This measure includes replacement of failed or working clothes washer in existing homes with ENERGY STAR clothes washers, or installation of an ENERGY STAR clothes washer in a new home.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Residential
Target End Uses: Plug Loads

Applicable to: Residential customers in single-family homes and multi-family housing of 2 or more units (including 3- and 4-family homes, duplexes, townhomes and apartment complexes)

Algorithms

Unit kWh Savings per Year = [(Cap x 1/IMEF_base x N) x (CW_base + (DHW_base x %Elec_DHW) + (Dry_base x %Elec_dry))] - [(Cap x 1/IMEF_prop x N) x (CW_prop + (DHW_prop x %Elec_DHW) + (Dry_prop x %Elec_dry))]

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

Unit Dth Savings per Year = [[(Cap x 1/IMEF_base x N) x (DHW_base x (1 - %Elec_DHW) x R_eff + Dry_base x (1 - %Elec_dry))] - [(Cap x 1/IMEF_prop x N) x (DHW_prop x (1- %Elec_DHW) x R_eff + Dry_prop x (1 - %Elec_dry))]] x ConversionFactor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 11 (Ref. 1)

Unit Participant Incremental Cost = $119.46 (Ref. 10)

Where:

Cap = Clothes washer capacity (ft^3); If unknown, assume 3.5 ft^3 (Ref. 7)

IMEF_base = 1.57 (See Table 1); Integrated Modified Energy Factor (ft^3/kWh/cycle)

IMEF_prop = See Table 2

N = 307 cycles/yr (Ref. 4)

CW_base = 7% (Ref. 4); Percentage of total energy consumption for clothes washer operation

CW_prop = 6% (See Table 3)

DHW_base = 33% (Ref. 4); Percentage of total energy consumption for water heating

DHW_prop = See Table 3

%Elec_DHW = See Table 4; Percentage of DHW savings assumed to be electric

Dry_base = 59% (Ref. 4); Percentage of total energy consumption for dryer operation

Dry_prop = 62% (See Table 3)

%Elec_dry = See Table 4; Percentage of dryer savings assumed to be electric

R_eff = 1.26 (Ref. 11); Recovery efficiency factor

ConversionFactor = 0.003412 Dth/kWh

Hours = 307 hrs; Assumes 1 hour per cycle.

CF = 0.038 (Ref. 8)

Required from Customer/Contractor: washer capacity in ft^3, electric or gas water heating, electric or gas drying, confirmation of ENERGY STAR rating

Example:

A residential customer installed a new ENERGY STAR clothes washer (unknown capacity) in a home with an electric water heater and electric dryer.

Unit kWh Savings per Year = [(3.5 x 1/1.57 x 307) x (7% + (33% x 100%) + (59% x 100%))] - [(3.5 x 1/2.22 x 307) x (6% + (31% x 100%) + (62% x 100%))] = 198 kWh

Unit Peak kW Savings = 198 / 307 x 0.038 = 0.025 kW

Deemed Input Tables:

Table 1: Baseline Clothes Washer Performance Characteristics (Ref. 3)

Unit Type	IMEF_base
Federal Minimum Front-Loading Unit, > 1.6 ft^3	1.84
Federal Minimum Top-Loading Unit, > 1.6 ft^3	1.29
Federal Minimum Top & Front-Load Average	**1.57**

Table 2: Proposed Clothes Washer Performance Characteristics (Ref. 9)

Unit Type	IMEF_prop
ENERGY STAR Front-Loading Unit, > 2.5 ft^3	2.38
ENERGY STAR Top-Loading Unit, > 2.5 ft^3	2.06
ENERGY STAR Top & Front-Load Average	**2.22**

Table 3: Distribution of Energy Use (Ref. 4)

Baseline/ Proposed	Clothes Washer Operation (CW)	Domestic Hot Water Heating (DHW)	Dryer Operation (Dry)
Base	7%	33%	59%
Prop	6%	31%	62%

Table 4: Fuel Type Factors

Fuel Type	%Elec_DHW	%Elec_dry
Electric	100%	100%
Gas	0%	0%
Unknown (Ref. 5 and 6)	39%	81%

Table 5: Incremental Costs (Ref. 10)

Unit Type	Incremental Cost
Top-Loading Clothes Washer	$28.79
Front-Loading Clothes Washer	$210.12
Average for Top & Front-Load Unit	**$119.46**

Notes:

Table 5: Summarized Savings Values, 3.5 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	198	123	95	19	132
Demand Savings, kW	0.025	0.015	0.012	0.002	0.016
Gas Savings, Dth	0	0.33	0.35	0.68	0.27

Table 6: Determination of Annual Loads

Clothes Washer Use	IA, MN, ND, SD (millions of housing units) (Ref. 4)	Average Loads per Week
Use a Clothes Washer……………………….	3.3	
1 Load or Less Each Week……………….	0.2	.5
2 to 4 Loads Each Week………………….	1.4	3
5 to 9 Loads Each Week………………….	1.2	7
10 to 15 Loads Each Week……………….	0.3	12.5
More than 15 Loads Each Week………..	Q	15
Do Not Use a Clothes Washer At Home…	0.7	
	Weighted Average	5.89
	Estimated Annual Loads	307

Current Federal Standards require top-loading clothes washers have an IMEF ≥ 1.29 and an IWF ≤ 8.4 (Ref. 3)

Current Federal Standards require front-loading clothes washers have an IMEF ≥ 1.84 and an IWF ≤ 4.7 (Ref. 3)

ENERGY STAR requires top-loading clothes washers (> 2.5 ft3) have a IMEF ≥ 2.06 and an IWF ≤ 4.3 (Ref. 9)

ENERGY STAR requires front-loading clothes washers (> 2.5 ft3) have a IMEF ≥ 2.38 and an IWF ≤ 3.7 (Ref. 9)

References:

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.

2. Weighted average of 307 clothes washer cycles per year (based on 2009 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section, state of MN http://www.eia.gov/consumption/residential/data/2009/xls/HC3.9%20Appliances%20in%20Midwest%20Region.xls

3. 10 CFR Parts 429 and 430 [Docket Number EERE–2008–BT–STD– 0019] RIN 1904–AB90 Energy Conservation Program: Energy Conservation Standards for Residential Clothes Washers. http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0019-0041

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.html.

5. Percentage of total (gas and electric fuel types) water heating units that are electric calculated from Residential Energy Consumption Survey (RECS) "Table HC8.9. Water Heating in U.S. Homes in Midwest Region, Divisions, and States, 2009".

6. Percentage of total (gas and electric fuel types) dryer units that are electric calculated from Residential Energy Consumption Survey (RECS) "Table HC3.9. Appliances in U.S. Homes in Midwest Region, Divisions, and States, 2009".

7. To account for the different efficiency of electric and Natural Gas hot water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.78 used), and electric water heater with 0.98 recovery efficiency

8. Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren. Reference is from Illinois Technical Reference Manual June 1, 2012. Page 303.

9. Clothes Washer Program Requirements Version 7.0. https://www.energystar.gov/certified-products/sites/products/uploads/files/ENERGY%20STAR%20Final%20Version%207_0%20Clothes%20Washer%20Program%20Requirements.pdf?2c89-939f. Accessed 7/9/14.

10. 2010-2012 WO017 Ex Ante Measure Cost Study Draft Report, Itron Inc., Page 3-13. February 24, 2014.

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/15/2012
2. Used algorithm from IL TRM	Franklin Energy Services	8/16/2012
2.1 Added text to clarify that Tables 3-5 are for 3.5 ft3 washers	JP	4/2/2013
2.1 Changed End Use from HVAC to Plug Load	JP	4/2/2013
2.2 Added new ENERGY STAR standards to notes	Franklin Energy Services	8/1/2014
2.3 Updated algorithm and savings to new ENERGY STAR standard, updated loads per week, and cost.	Franklin Energy Services	12/18/2014
2.4 Corrected example, added unknown DHW, Dryer to summarized savings values, rearranged tables, corrected gas algorithm, corrected typos.	JP	1/6/2015

Residential Appliances - ENERGY STAR Dishwashers

Version No.

1.1

Measure Overview

Description: This measure includes replacement of failed or working dishwashers in existing homes with ENERGY STAR dishwashers, or installation of ENERGY STAR dishwashers in new homes.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Residential
Target End Uses: Plug Loads

Applicable to: Residential customers in single-family homes and multi-family housing of 2 or more units (including 3- and 4-family homes, duplexes, townhomes and apartment complexes)

Algorithms

Unit kWh Savings per Year = (kWh_base - kWh_prop) x (%kWh_op + (%kWh_heat x %Elec_DHW))

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

Unit Dth Savings per Year = (kWh_base - kWh_prop) x %kWh_heat x (1 - %Elec_DHW) x R_eff x ConversionFactor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $50 (Ref. 2)

Where:

kWh_prop = 268 kWh; Energy consumed by efficient dishwasher (Ref. 7)

kWh_base = 355 kWh; Energy consumed by baseline dishwasher (Ref. 7)

%kWh_op = 44%; The percentage of dishwasher energy consumption used for unit operation (Ref. 3)

%kWh_heat = 56%; The percentage of dishwasher energy consumption used for water heating (Ref. 3)

%Elec_DHW = 100% (electric water heating)

= 0% (gas water heating)

= 39% (if unknown) (Ref. 4)

R_eff = 1.26; Recovery efficiency factor

Hours = 269 hours (Ref. 5)

CF = 0.10 (Ref. 6)

ConversionFactor = 0.003412 kWh/Dth

Required from Customer/Contractor: electric or gas water heating

Example:

A residential customer installed a new ENERGY STAR dishwasher in a home with electric water heat.

Unit kWh Savings per Year = (355 kWh - 268 kWh) x (44% + (56% x 100%)) = 87 kWh

Unit Peak kW Savings = 87 kWh / 269 hours x 0.10 = 0.032 kW

Notes (Ref. 7):

Federal Standard requires standard sized dishwashers manufactured before 5/30/2013 use ≤ 355 kWh/yr and ≤ 6.5 gallons of water/cycle

Federal Standard requires standard sized dishwashers manufactured after 5/29/2013 use ≤ 307 kWh/yr and ≤ 5.0 gallons of water/cycle

Federal Standard requires compact sized dishwashers manufactured before 5/30/2013 use ≤ 260 kWh/yr and ≤ 4.5 gallons of water/cycle

Federal Standard requires compact sized dishwashers manufactured after 5/29/2013 use ≤ 222 kWh/yr and ≤ 3.5 gallons of water/cycle

ENERGY STAR requires standard sized dishwashers use ≤ 295 kWh/yr and ≤ 4.25 gallons of water/cycle

ENERGY STAR requires compact sized dishwashers use ≤ 222 kWh/yr and ≤ 3.50 gallons of water/cycle

Table 1: Summarized Savings Values, impact per unit

Water Heater	Peak Demand Savings (kW)	Annual Energy Savings (kWh)	Annual Gas Savings (therms)
Electric	0.032	87	0.000
Gas	0.014	38	2.095
Unknown	0.021	57	1.278

References:

1. Focus on Energy Evaluation "business Programs: Measure Life Study" Final Report, August 25, 2009. Page 53.

2. State of Illinois Energy Efficiency Technical Reference Manual, June 1, 2012. Page 313.

3. ENERGY STAR Appliance Savings Calculator. http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?e75f-ded1&e75f-ded1. Accessed August 15, 2012.

4. Percentage of total (gas and electric fuel types) water heating units that are electric calculated from Residential Energy Consumption Survey (RECS) "Table HC8.9. Water Heating in U.S. Homes in Midwest Region, Divisions, and States, 2009". http://www.eia.gov/consumption/residential/data/2009/xls/HC8.9%20Water%20Heating%20in%20Midwest%20Region.xls Accessed on August 15, 2012.

5. Assuming one and a half hours per cycle and 179 cycles per year therefore 269 operating hours per year; 179 cycles per year is based on a weighted average of dishwasher usage in MN http://www.eia.gov/consumption/residential/data/2009/xls/HC3.9%20Appliances%20in%20Midwest%20Region.xls

6. Franklin Energy Services internal standard value

7. *Dishwashers Key Product Criteria,* http://www.energystar.gov/index.cfm?c=dishwash.pr_crit_dishwashers. Accessed August, 15, 2012.

8. To account for the different efficiency of electric and Natural Gas hot water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.78 used), and electric water heater with 0.98 recovery efficiency (http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/Waste_Water_Heat_Recovery_Guidelines.pdf). Therefore a factor of 0.98/0.78 (1.26) is applied.

9. Average energy use of qualified standard-sized ENERGY STAR qualified dishwashers

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/15/2012
1.1 Corrected kWh_base and kWh_prop (values were reversed)	JP	4/2/2013
1.1 Changed Target End Use from HVAC to Plug Load	JP	4/2/2013

Residential Appliances - ENERGY STAR Refrigerators and Freezers

Version No.

2.1

Measure Overview

Description: This measure includes the replacement of failed or refrigerators or freezers in residential homes, as well as installation of high efficiency refrigerators and freezers in new homes.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Residential
Target End Uses: Plug Loads

Applicable to: Residential customers in single-family homes and multi-family homes, including duplexes and townhomes

Algorithms

Unit kWh Savings per Year = kWh_base - kWh_EE

Unit Peak kW Savings = (Unit kWh Savings per Year) x CF / 8,766

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 14 years for refrigerators, 11 years for freezers (Ref. 1)

Unit Participant Incremental Cost = $40 (Ref. 2)

Where:

kWh_base = Annual energy consumption of the baseline efficiency unit (Refer to Table 1 for refrigerators and Table 2 for freezers)

kWh_EE = Annual energy consumption of the energy efficient unit (Refer to Table 1 for refrigerators and Table 2 for freezers)

8,766 = Assumed annual operating hours per year.

CF = Peak coincidence factor = 1.0 (Ref. 3)

Required from Customer/Contractor: Appliance (refrigerator or freezer), product class (see Tables 1 and
2)

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) = 641 - 500 = 141 kWh

*Electric Peak Demand Savings (kW) = 141 kWh / 8,766 * 1.0 = 0.016 peak kW*

Deemed Input Tables:

Table 1: High Efficiency and Conventional Refrigerator Energy Use (kWh). (Ref. 3)

Product Class	ENERGY STAR Rated Model (kWh/year)	Conventional Model (kWh/year)
Refrigerator-freezer or refrigerator only (manual or partial-auto defrost)	380.8	488.3
Top-mounted freezer or refrigerator only (automatic defrost)	423.2	542.5
Side-by-side (automatic defrost)	500.0	641.0
Side-by-side with through-the-door ice (automatic defrost)	530.9	680.7
Bottom-mounted freezer (automatic defrost)	455.6	584.1
Bottom-mounted freezer with through-the-door ice (automatic defrost)	526.5	675.0

Table 2: High Efficiency and Conventional Freezer Energy Use (kWh). (Ref. 3)

Product Class	ENERGY STAR Rated Model (kWh/year)	Conventional Model (kWh/year)
Chest	358.0	407.0
Compact chest	331.0	430.0
Compact upright (manual defrost)	394.0	511.0
Compact upright (auto defrost)	535.0	695.0
Upright (manual defrost)	404.0	459.0
Upright (auto defrost)	578.0	657.0

Notes:

The Federal efficiency standards in place for residential refrigerators and freezers are as follows:

Table 3: Efficiency Standards for Residential Refrigerators and Freezers (Ref. 5)

Product Class	Maximum Energy Use (kWh)
Refrigerator-freezers, partial automatic defrost	8.82AV + 248.4
Refrigerator-freezers, automatic defrost with top-mounted freezer without through-the-door ice service and all refrigerators, automatic defrost	9.80AV + 276.0
Refrigerator-freezers, automatic defrost with side-mounted freezer without through-the-door ice service	4.91AV + 507.5
Refrigerator-freezers, automatic defrost with bottom-mounted freezer without through-the-door ice service	4.60AV + 459.0
Refrigerator freezers, automatic defrost with top-mounted freezer with through-the-door ice service	10.20AV + 356.0
Refrigerator-freezers, automatic defrost with side-mounted freezer with through-the-door ice service	10.10AV + 406.0
Effective for products manufactured on or after July 1, 2001. Standards do not apply to refrigerators and refrigerator-freezers with total refrigerated volume exceeding 39 cubic feet or freezers with total refrigerated volume exceeding 30 cubic feet. AV = total adjusted volume (ft^3)	

References:

1. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values, October 10, 2008

2. Incremental cost from ENERGY STAR Appliance Savings Calculator: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx. Vendor research shows that this value is typical, but that incremental costs vary greatly for this measure.

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. 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. January 1, 2010.

Documentation Revision History:

Version / Description	Author	Date
1. New standalone spec for Refrigerators and Freezers extracted from ResidentialElecAppliancesPlugloads_v02.xlsx (Nexant spec)	JP	
1. Corrected measure life: Nexant had listed 15 years even though the source comments say 14 years	JP	
2. Added to the measure description and algorithms sections.	FES	8/1/2012
2. Changed savings algorithm. Added annual consumption tables.	FES	8/1/2012
2. Added an example.	FES	8/1/2012
2. Changed source for measure life.	FES	8/1/2012
2. Changed incremental costs.	FES	8/1/2012
2. Added federal efficiency standards.	FES	8/1/2012
2.1 Changed Target End Use to Plug Load	JP	4/2/2013
2.2 Changed text of kWh formula for clarify, changed annual hours from 8,760 to 8,766, added coincidence factor of 1 to kW calculation in example, corrected Required Inputs	JP	1/2/2014

Residential Appliances - Secondary Refrigerator/Freezer Removal

Version No.

2.1

Measure Overview

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.

Actions: Remove
Target Market Segments: Residential
Target End Uses: Appliances

Applicable to: Residential customers in single-family homes, duplexes, and townhomes

Algorithms (Ref. 1)

Unit kWh Savings per Year = Gross_Annual_kWh

Unit Peak kW Savings = Gross_kW x PUF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 8 (Ref. 3)

Unit Participant Incremental Cost = $92.20 (Ref. 4)

Where:

Gross_Annual_kWh = the assumed gross savings from removing and recycling a refrigerator or freezer (Refer to Table 1).

PUF = Part-Use Factor, to account for units that may not have been plugged in before being recycled. Assumed to be 0.865 (Ref. 2)

Required from Customer/Contractor: equipment type being recycled (freezer or refrigerator), confirmation of working unit, confirmation of secondary unit

Example:

A secondary refrigerator used limitedly is retired and properly recycled.

Unit kWh Savings per Year = 915

Unit Peak kW Savings = 0.159 x 0.865 = 0.138

Deemed Input Tables:

Table 1: Gross Annual kWh, kW Savings per Unit

Appliance Type	Annual kWh	Gross kW
Refrigerator or Combo Unit	915	0.159
Freezer Only	1,134	0.159

Methodology and Assumptions:

Energy savings are based on a linear regression, using metered data and modeling.

References:

1. Observed average annual kWh consumption for refrigerators and freezers, from the memo: Fridge & Freezer Recycle Rewards Program PY4 Metering Study:
Preliminary Savings Results, May 4, 2012. Prepared for ComEd by Itron and Navigant.

2. PY4 Appliance Recycling Program PJM Post Install M&V Demand Analysis Report Draft, Prepared for Commonwealth Edison Company by Opinion Dynamics Corporation, April 20, 2012.

3. KEMA, “Residential Refrigerator Recycling Ninth Year Retention Study,” July 22, 2004

4. 2008 Database for Energy-Efficient Resources, "Revised DEER Measure Cost Summary," June 2, 2008. This source assumes a $47.00 material cost and a $45.20 installation or labor cost.

Documentation Revision History:

Version / Description	Author	Date
1. New specification based on Nexant version	JP	
2. Added measure description	FES	7/30/2012
2. Changed algorithm and source for algorithm for energy savings and demand savings	FES	7/30/2012
2. Added sources for default values	FES	7/30/2012
2. Added required information from customer/contractor	FES	7/30/2012
2. Changed measure life and EUL source	FES	7/30/2012
2. Changed measure incremental cost and cost source	FES	7/30/2012
2. Added example	FES	7/30/2012
2.1 Added confirmation of working unit, secondary unit to Required Inputs, revised appliance descriptions for clarity	JP	3/29/14

Residential HVAC - Central AC/ASHP

Version No. 3.0

Measure Overview

Description: This measure includes replacement of failed or working central AC system or ASHP in existing homes with high efficiency units, as well as installation of high efficiency AC systems in new homes. Savings for replacement of working units are in reference to existing unit.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: Residential customers in single-family homes, duplexes, townhomes, and multi-family homes (including 3- and 4-family homes) with residential type AC systems

Algorithms

Unit kWh Savings per Year for AC system = Size x $EFLH_{Cool}$ x (12/SEER_Base - 12/SEER_Eff)

Unit kWh Savings per Year for ASHP = Size x $EFLH_{Cool}$ x (12/SEER_Base - 12/SEER_Eff) + (Size x $EFLH_{Heat}$) x (12/HSPF_base - 12/HSPF_eff)

Unit Peak kW Savings = CF x Size x (12/EER_Base - 12/EER_Eff)

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 18 years (Ref. 1)

Unit Participant Incremental Cost = See Table 3, 4. Incremental equipment cost only, labor is not included

Where:

Size = Unit capacity in tons (1 ton = 12,000 btu/h)

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

SEER_Base = SEER of baseline or existing unit provided by customer/contractor if Replace Working, or use SEER = EER / 0.875 if EER is provided. (ref. 4), (SEER_Base = 13 if unknown, Replace on Fail or New Construction)

EER_Base = EER of baseline or existing unit provided by customer/contractor, or use EER = SEER x 0.875 if SEER is provided (ref. 4), (EER_Base = 13 X 0.875 = 11.4 if unknown, Replace on Fail or New Construction)

SEER_Eff = SEER of new high efficiency unit provided by customer/contractor, or use SEER = EER / 0.875 if EER is provided. (ref. 4)

EER_Eff = EER of new high efficiency unit provided by customer/contractor, or use EER = SEER x 0.875 if SEER is provided (ref. 4)
CF = Coincidence factor = 0.9 (ref. 5)

HSPF_base = Heating system performance factor of baseline or existing ASHP, provided by customer/contractor or use HSPF_base = 7.7 if unknown, Replace on Fail or New Construction (ref. 6)

HSPF_eff = Heating system performance factor of efficient ASHP, provided by customer/contractor

$EFLH_{Heat}$ = Equivalent Full Load Hours Heating. See Table 2.

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 (ASHP only), HSPF of existing equipment (ASHP only, if program includes early replacements), existing equipment condition (working or failed, if program includes early replacements), building type (single family/multifamily*), project location (county)

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

Example:

Retrofit AC System in single family home, 3-ton with SEER rating 14.5, Climate Zone 3.
Unit kWh Savings per Year = 3 x 520 x (12/13-12/14.5) = 149 kWh
EER_Eff = 14.5 x 0.875 = 12.7
Unit Peak kW Savings = 0.9 x 3 x (12/11.4 - 12/12.7) = 0.29 kW

Retrofit ASHP in single family home, 3-ton with SEER rating 15, HSPF rating 9, Climate Zone 2.
Unit kWh Savings per Year = 3 x 379 x (12/13-12/15) + (3 x 2099) x (12/7.7 - 12/9) = 1557 kWh
EER_Eff = 15 x 0.875 = 13.125
Unit Peak kW Savings = 0.9 x 3 x (12/11.4 - 12/13.125) = 0.373 kW

Deemed Input Tables:

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

Zone	Equivalent Full Load Cooling Hours	
	Single Family	Multifamily*
Zone 1 (Northern MN)	213	228
Zone 2 (Central MN)	379	473
Zone 3 (Southern MN/Twin Cities)	520	616

**Includes duplex, townhome, and multifamily buildings with 3 or more units*

Table 2. Equivalent Full Load Heating Hours ($EFLH_{Heat}$) by Climate Zone (ref. 7)

Zone	Equivalent Full Load Heating Hours
Zone 1 (Northern MN)	2280
Zone 2 (Central MN)	2099
Zone 3 (Southern MN/Twin Cities)	1932

**Includes duplex, townhome, and multifamily buildings with 3 or more units*

Table 3. AC Incremental cost (ref. 2)

Efficiency Level	Cost per Ton
SEER 14	$119
SEER 14.5	$178
SEER 15	$238
SEER 16	$357
SEER 17	$476
SEER 18	$596
SEER 19	$715
SEER 20	$834
SEER 21	$908
Average	$530

Table 4. ASHP Incremental cost (ref. 2)

Efficiency Level	Cost per Ton
SEER 14	$137
SEER 15	$274
SEER 16	$411
SEER 17	$548
SEER 18	$685

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 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: $EFLH_{MN} = EFLH_{IL} \times HDD_{65,MN} / HDD_{65,IL} \times DTD_{IL} / DTD_{MN}$, where DTD is the design temperature difference.

Geography	HDD65	DTD
Chicago, IL	6,339	73.5
MN Zone 1	9,833	92
MN Zone 2	8,512	86.5
MN Zone 3	7,651	84.5

Notes:

The prior national standards for central air conditioners and heat pumps, which raised the minimum Seasonal Energy Efficiency Ratio (SEER) requirement from 10 to 13, became effective in 2006. In January 2010, HVAC manufacturer representatives and efficiency advocates presented a negotiated consensus agreement to DOE to increase efficiency standards for central air conditioners and heat pumps. The consensus agreement included regional standards for

three regions: the South, the Southwest, and the North, reflecting varying HVAC needs for each climate. DOE issued a direct final rule (DFR) in June 2011 based on the standard levels in the consensus agreement. These DFR became effective on October 25, 2011. The new standards increase the minimum cooling efficiency requirement to SEER 14 for split system central air conditioners in the South and the SW while maintaining the SEER 13 standard for the North. The new standards also include EER (Energy Efficiency Ratio) requirements for the SW region to ensure efficient operation at high outdoor temperatures. For heat pumps, the standards raise

the cooling efficiency requirement to SEER 14 for all three regions and also increase the heating efficiency requirements. The standards will became effective on January 1, 2015.

The requirement pertains to the manufacture of units with an 18 month grace period allowed for the sale AC units and a similar period expected for ASHP units.

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. 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. ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment

5. 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.

6. Based on Minimum Federal Standard; http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_cac_hp.ht ml.

7. FES scaled annual heating loads from those provided in the Illinois Technical Reference Manual based on Minnesota weather data.

Documentation Revision History:

Version / Description	Author	Date
1 New spec to reflect standalone QI measure in DER Smart Measure Library	JP	
1.1 Added wording to clarify how EER and SEER are calculated	JP	
2.1 Changed energy savings equations arrangement	Franklin Energy	7/25/2012
2.2 Changed measure life	Franklin Energy	7/25/2012
2.3 Changed incremental cost	Franklin Energy	7/25/2012
2.4 Changed references	Franklin Energy	7/25/2012
2.5 Added incremental cost table	Franklin Energy	7/25/2012
2.6 Added to description, added missing customer/contractor Inputs	JP	3/25/2013
2.7 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.)	JP	3/12/2014
2.8 Federal standard grace period note added	Franklin Energy	07/31/2014

3.0	Changed to $EFLH_{Heat}$ algorithm.	FES	11/12/2015

Residential HVAC – Central AC/ASHP Quality Install Additional Savings

Version 3.0

Measure Overview

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 Central A/C-ASHP measure which represents the estimated savings that would be achieved without a Quality Installation program.

Actions: O&M
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: Residential customers in single-family homes, duplexes, multi-family homes (including 3- and 4-family homes), and townhomes

Algorithms

Unit kWh Savings per Year for AC system = (Size x EFLCH x (12/SEER_Eff) x (1/(1-Loss_No_QI) - 1/(1-Loss_QI)))

Unit kWh Savings per Year for ASHP = (Size x EFLCH x (12/SEER_Eff) x (1/(1-Loss_No_QI) - 1/(1-Loss_QI))) + (Size x EFLHH x (12/HSPF_eff) x (1/(1-Loss_No_QI) - 1/(1-Loss_QI)))

Unit Peak kW Savings = CF x Size x (12/EER_Eff) x (1 - ((1-Loss_No_QI) / (1-Loss_QI)))

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 18 years (ref. 1)

Unit Participant Incremental Cost = $250/unit (ref. 2)

Where:

Size_cool = Unit capacity in tons (1 ton = 12,000 btu/h)

EFLCH = Effective Full Load Cooling Hours. See Table 1 (ref. 3)

SEER_Eff = SEER of new high efficiency unit provided by customer/contractor, or use SEER = EER / 0.875 if EER is provided. (ref. 4)

EER_Eff = EER of new high efficiency unit provided by customer/contractor, or use EER = SEER*0.875 if SEER is provided (ref. 4)

Loss_No_QI = Efficiency loss of average unit due to improper installation = 25 %. Estimated savings potential with QI ranges from 18% to 36% for air conditioners (ref. 5, 6, 7)

Loss_QI = Efficiency loss of average quality installation = 3.75% in existing homes and 0% in new construction (ref. 8)

CF = Coincidence factor = 0.9 (ref. 9)

EFLHH = Effective Full Load Heating Hours. See Table 2 (ref. 10)

HSPF_eff = Heating system performance factor of efficient ASHP, provided by customer/contractor.

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)

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

Example:

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

Additional kWh Savings per Year = 3 x 520 x (12/14.5) x (1/ (1-0.25)-1/ (1-0.0375)) = 380

Additional Peak kW Savings = 0.9x3x(12/12.7)x(1-((1-0.25)/(1-0.0375)))= 0.56

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

Additional kWh Savings per Year = (3 x 379 x (12/15) x (1/ (1-0.25)-1/ (1-0.0375))) + (3 x 2099 x (12/9) x (1/ (1-0.25)-1/ (1-0.0375))) = 2739

Additional Peak kW Savings = 0.9x3x(12/13)x(1-((1-0.25)/(1-0.0375))) = 0.55

Deemed Input Tables:

Table 1. Effective Full Load Cooling Hours (EFLCH) by Climate Zone (ref. 3)

Zone	Equivalent Full Load Cooling Hours	
	Single Family	Multifamily*
Zone 1 (Northern MN)	213	228
Zone 2 (Central MN)	379	473
Zone 3 (Southern MN/Twin Cities)	520	616

Table 2. Equivalent Full Load Heating Hours (EFLHH) by Climate Zone (ref. 10)

Zone	Equivalent Full Load Heating Hours
Zone 1 (Northern MN)	2280
Zone 2 (Central MN)	2099
Zone 3 (Southern MN/Twin Cities)	1932

Methodology and Assumptions:

Savings with QI consist of four measures: equipment sizing, air flow, refrigerant charge, and duct leakage. The savings for each of four measures 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 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).

Notes:

The prior national standards for central air conditioners and heat pumps, which raised the minimum Seasonal Energy Efficiency Ratio (SEER) requirement from 10 to 13, became effective in 2006. In January 2010, HVAC manufacturer representatives and efficiency advocates presented a negotiated consensus agreement to DOE to increase efficiency standards for central air conditioners and heat pumps. The consensus agreement included regional standards for three regions: the South, the Southwest, and the North, reflecting varying HVAC needs for each climate. DOE issued a direct final rule (DFR) in June 2011 based on the standard levels in the consensus agreement. These DFR became effective on October 25, 2011 . The new standards increase the minimum cooling efficiency requirement to SEER 14 for split system central air conditioners in the South and the Southwest while maintaining the SEER 13 standard for the North. The new standards also include EER (Energy Efficiency Ratio) requirements for the Southwest region to ensure efficient operation at high outdoor temperatures. For heat pumps, the standards raise the cooling efficiency requirement to SEER 14 for all three regions and also increase the heating efficiency requirements. The standards will become effective on January 1, 2015.The requirement pertains to the manufacture of units with an 18 month grace period allowed for the sale AC units and a similar period expected for ASHP units.

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. Calculated through energy modeling be FES 2012

4. ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment

5. http://www.energystar.gov/index.cfm?c=hvac_install.hvac_install_index

6. New Jersey Residential HVAC Baseline Study, XENERGY, Inc. November 16, 2001

7. Energy saving Potential From Addressing Residential Air Conditioner And Heat Pump Installation Problems, Chris Neme, Fabruary 1999

8. 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.

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.

10 FES scaled annual heating loads from those provided in the Illinois Technical Reference Manual based on Minnesota weather data.

11. 2009 ASHRAE Fundamentals Handbook Table 1A Heating and Wind Design Conditions, Heating DB 99.6%

Documentation Revision History:

Version / Description	Author	Date
2.9 Federal standard grace period note added	Franklin Energy	07/31/2014
3.0 Changed heating savings approach and changed from HDD to EFLH	FES	1/13/2016

Residential HVAC - Central AC/ASHP Tune-up

Version No.

3.0

Measure Overview

Description: Residential split-system air conditioning tune-up involves inspection of mechanical/electrical components operation, refrigerant charge, airflow, and coils cleaning.

Actions: O&M
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: This measure assumes that the existing unit has not been serviced for at least 2 years for residential customers in single-family homes, duplexes, multi-family homes (including 3- and 4-unit buildings), and townhomes.

Algorithms

Unit kWh Savings per Year = ($EFLH_{Cool}$*CAP*(1/SEER))/1000*Mfe

Unit Peak kW Savings = CAP*(1/EER)/1000*MFd*CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 2 (Ref. 4)

Unit Participant Incremental Cost = $175 (default/planning figure; Use actual cost of tune-up) (ref. 4)

Where:

$EFLH_{Cool}$ = Full Load Cooling Hours, in hr. Depended on location. See table 1 below

CAP = Cooling capacity of AC system or ASHP in BTU/h. Note 1 ton=12000 BTU/h, default = 2.5-ton (for units with unknown capacity)

SEER = Nameplate efficiency of equipment, default = 11.5 (for units with unknown efficiency) (Ref. 6)

EER = Efficiency of equipment (ref. 5), EER = SEER*0.875, default=10.1 (for units with unknown efficiency) (Ref. 6)

CF = Coincidence factor = 0.9

MFe = Maintenance energy saving factor, MFe = 5 % (ref. 2)

MFd = Maintenance demand saving factor, MFd = 2 % (ref. 2)

Required from Customer/Contractor: Project location (county), tons, SEER, actual cost of tune-up, building type (single family or multifamily*)

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

Example:

Tune-up of a central AC unit in a single family house in Zone 3:

*Unit kWh Savings per Year = (520*2.5*12000*(1/11.5))/1000*0.05 = 67.8*

*Unit Peak kW Savings = 2.5*12000*(1/10.1)/1000*0.02*0.9 = 0.053*

Deemed Input Tables:

Table 1. Equivalent Full Load Cooling Hours ($EFLH_{Cool}$) by Climate Zone (ref. 3)

Zone	Effective Full Load Cooling Hours	
	Single Family	Multifamily*
Zone 1 (Northern MN)	213	228
Zone 2 (Central MN)	379	473
Zone 3 (Southern MN/Twin Cities)	520	616

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

Methodology and Assumptions:

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

$EFLH_{Cool}$ 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. 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, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."

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. 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. Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."

Documentation Revision History:

Version/Description	Author	Date
1 Initial version based on Nexant's original specification	JP	
1.1 Increased default tune-up cost to $200	JP	
2.1 Changed energy savings equations arrangement	Franklin Energy	7/25/2012
2.2 Changed measure life	Franklin Energy	7/25/2012
2.3 Changed incremental cost	Franklin Energy	7/25/2012
2.4 Changed references	Franklin Energy	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	JP	3/25/2013
2.6 Added explanation of multifamily buildings	JP	3/12/14
3.0 Made EFLH terminology consistent with other measures, added to description of source	FES	11/12/15

Residential HVAC - ECM Circulators

Version No. 1.0

Measure Overview

Description: Electronically commutated (EC) circulators (pumps) are high-efficiency brushless DC motors. They are typically fractional horsepower motors that enjoy several benefits over the more common permanent split capacitor (PSC) fractional horsepower motor.

Actions: Replace Working, Replace on Fail, New Construction
Target Market Segments: Residential and Multi-family
Target End Uses: Pumps

Applicable to: Residential and multi-family customers.

Algorithms

Unit kWh Savings per Year = kWbase x tbase - kWECM x tproposed

Unit Peak kW Savings = (kWbase - kWECM) x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 (Ref. 1)

Unit Participant Incremental Cost = $6 per Watt (Ref. 2)

Where:

kWbase = kWECM / 18% (Ref. 3)

kWECM = 0.050 kW, 0.250 kW, 0.700 kW (Ref. 4)

tbase = See Table 1

tproposed = See Table 1

CF_DHW = 1.0 (Ref. 5)

CF_CW = 0.299 (Ref. 6)

CF_HW = 0

Required from Customer/Contractor: Motor wattage, motor application.

Example:

A customer installed a new 250W ECM pump on their domestic hot water heater.

Unit kWh Savings per Year = 0.250 kW / 18% x 4,000 hours - 0.250 kW x 2,190 hours = 5,008 kWh

Unit Peak kW Savings = (0.250 kW / 18% - 0.250 kW) x 1.0 = 1.140 kW

Deemed Input Tables:

Table 1: Annual Operating Hours

Annual Hours	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: Coincident Peak Impact

EC Motor Size	DHW Circulator	Heating Water Circulator	Cooling Water Circulator
< 100 W	0.228 kW	0.000 kW	0.068 kW
100 - 500 W	1.139 kW	0.000 kW	0.341 kW
500 - 750 W	3.189 kW	0.000 kW	0.953 kW

Table 3: Estimated Energy Savings

EC Motor Size	DHW Circulator	Heating Water Circulator	Cooling Water Circulator
< 100 W	1,002 kWh	588 kWh	271 kWh
100 - 500 W	5,008 kWh	2,941 kWh	1,356 kWh
500 - 750 W	14,023 kWh	8,234 kWh	3,798 kWh

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. General sizes chosen to represent given size ranges.

5. Assumes baseline pump would be operating during the peak period. Franklin Energy Services.

6. Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 2.0, June 7, 2013, page 235.

7. Estimate based on EPRI Report Assessment of New Energy Efficient Circulator Pump Technology (40%*8,760 hr = 3,504 hr) and recommendation by Grundfos representatives (60%*8,760 hr = 5,256 hr).

8. Hours of use for pumps with an aqua-stat control in multi-family applications (6 hr/d * 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*24/(70°F-Design Temps).

10. Estimated based on an average of CDD65. Hours = CDD65*24/(Design Temps-70°F).

Documentation Revision History:

Version / Description	Author	Date
1. Measure created	FES	11/10/2015

Residential HVAC - ECM Blower Motors

Version No. 2.0

Measure Overview

Description:

A new furnace with an Electronically Commutated Motor (ECM) or Brushless Permanent Magnet (BPM) blower motor is installed instead of a new furnace with a lower efficiency motor, or retrofit of a less efficient (PCS) motor to a 2 stage BPM or ECM motor in an existing furnace. For retrofits, the target age range for existing furnaces is 10-12 years.

This measure characterizes only the electric savings associated with the fan and could be coupled with gas savings associated with a more efficient furnace.

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.

Actions: Replace on Fail, Replace Working, New Construction, Modify
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: Residential customers in single-family/multi-family homes, duplexes, and townhomes

Algorithms

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

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

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

Unit Gallons Fuel Oil and Propane Savings per Year = 0

Measure Lifetime = 20 years if installed with new furnace (Ref. 1), 9 years for blower retrofit (Ref. 11)

Unit Participant Incremental Cost = $250 if installed as part of new furnace (Ref. 2), $475 for blower retrofit (Ref. 7)

Where:

Heating Savings = See Table 1

Cooling Savings = See Table 1

Shoulder Season Savings = See Table 1

Cooling Watts Savings = Cooling Watts Saved = 237 if installed as part of new furnace (Ref. 3), 220 if retrofit of single speed PSC motor (Ref. 7)

CF = Coincidence factor = 0.9 (Ref. 5)

0.003412 = Converts kWH to Dth

AFUE = Efficiency of Furnace provided by customer. If unknown assume 80% (Ref. 13)

Required from Customer/Contractor: For ECMs as part of new furnaces: Central AC present (yes/no/new central AC installed with furnace, furnace AFUE)

Example:

An ECM blower is installed as part of a new furnace in a home where central AC presence and AFUE of furnace are unknown.

Unit kWh Savings per Year = 418 + 231 + 51 = 700 kWh

Unit Peak kW Savings = 231 x 0.9/1000 = 0.208 kW

Unit Dth Savings = -418 x 0.003412 / .8 = -1.78 Dth

Deemed Input Tables:

Table 1: kWh savings by season for ECM installed as part of new furnace and ECM installed as retrofit of single speed PSC motor

Season	New furnace	Retrofit of single speed PSC motor
Heating	418 (Ref. 3)	126 (Ref. 9)
Shoulder	51 (Ref. 3)	54 (Ref. 12)
Cooling	263 if Central AC (Ref.3), 175 if no Central AC (Ref. 3), 231 if Central AC unknown (Ref. 4), 0 if Central AC also installed (Ref. 6)	68 (Ref. 10)

Table 2: Summarized Savings (impacts per unit)

Description	Peak Demand Savings (kW)	Annual Energy Savings (kWh)	Dth Heating Savings
New Furnace & New CAC	0.213	469	-1.78
New Furnace & Existing CAC	0.213	732	-1.78
New Furnace & no CAC	0.213	644	-1.78
New Furnace & unknown CAC	0.213	700	-1.78
Retrofit & New CAC	0.198	248	-0.54
Retrofit & Existing CAC	0.198	248	-0.54
Retrofit & no CAC	0.198	248	-0.54
Retrofit & unknown CAC	0.198	248	-0.54

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. 3) and the values were adapted for Minnesota.

References:

1. Consistent with assumed life of a new gas furnace. Table 8.3.3 The Technical support documents for federal residential appliance standards:
http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/chapter_8.pdf

2. Appliance Standards Technical Support Documents

http://www1.eere.energy.gov/buildings/appliance_standards/residential/fb_tsd_0907.html

3. PA Consulting Group/Patrick Engineering Residential Deemed Savings Review for Focus on Energy, 2009

4. 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. 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.

6. Energy use of blower motor during cooling season is reflected in the SEER of the new central AC.

7. "Evaluation of Retrofit Variable-Speed Furnace Fan Motors", R. Aldrich and J. Williamson, Consortium for Advanced Residential Buildings, January 2014

9. 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* 1000 hrs / 1000 W/KW = 126 KWh.

10. 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* 310 hrs / 1000 W/KW = 68 KWh.

11. 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.

12. Modified by the ratio of Watt savings 422 watts (Ref. 8) / 400 watts (Ref. 3) x 51 KWh = 54 KWh.

13. US Department of Energy (http://buildingsdatabook.eere.energy.gov/ChapterIntro7.aspx). Though the federal minimum efficiency is 78% there are very few models available at this efficient; a review of AHRI shows that most low efficiency units are 80%.

Documentation Revision History:

Version / Description	Author	Date
1. New measure	Franklin Energy	7/31/2012
1.1. Added additional output to Cooling Savings input that cooling savings = 0 if central AC installed as part of project.	JP	4/1/2013
1.2 Removed project location and AFUE from required inputs from customer/contractor, removed Table 1 (EFLH by zone- not needed)	JP	3/2/2014
1.3 Added retrofit option. Corrected cooling watt savings and calculations.	Franklin Energy	12/23/2014
1.4 Moved seasonal savings into a deemed input table, updated example description	JP	2/2/2015
2.0 Included interactive effect of negative Dth gas savings and aligned % of homes with CAC with lighting measure assumptions	Franklin Energy	11/12/2015

Residential HVAC - ENERGY STAR Room A/C

Version No. 2.4

Measure Overview

Description: This measure includes the replacement of failed or working room air conditioners in residential homes, as well as installation of high efficiency room air conditioners in new homes.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: Residential customers in single-family homes and multi-family homes (including 3- and 4-unit buildings), including duplexes and townhomes

Algorithms

Unit kWh Savings per Year = ΔkW x Hrs

Unit Peak kW Savings = CF x ΔkW

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 9 years (Ref. 1)

Unit Participant Incremental Cost: See Table 3

Where:

ΔkW = Btuh x (1/EER_base - 1/EER_eff) / 1000

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

EER_base = Federal minimum standard energy efficiency ratio (EER) of air-conditioner. Refer to Table 1.

EER_eff = EER of new A/C. Refer to Table 1 for ENERGY STAR standards.

Hrs = Equivalent full load cooling hours. Refer to Table 2.

CF = Peak coincidence factor = 0.9 (Ref. 2)

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)

** Multifamily includes duplexes, townhomes, and 3 or more unit buildings*

Example:

A 1-ton (12,000 Btuh), 11.3 EER ENERGY STAR rated window air conditioner is installed in a Climate Zone 1 Single-Family home.

EER_Base = 10.9

ΔkW = 12,000 x (1/10.9 - 1/11.3) / 1000 = 0.039 kW

Electric Energy Savings (kWh/yr) = 0.039 x 228 = 8.89 kWh

Electric Peak Demand Savings (kW) = 0.039 x 0.9 = 0.035 kW

Deemed Input Tables:

Table 1: Baseline and high efficiency EER ratings. (Ref. 3, 6)

<table>
<tr><th></th><th colspan="2">Window Units (w/ louvered sides)</th><th colspan="2">Sleeve Units (w/o louvered sides)</th></tr>
<tr><th>Capacity (Btu/h)</th><th>Federal Minimum Efficiency, EER</th><th>ENERGY STAR Efficiency, EER</th><th>Federal Minimum Efficiency, EER</th><th>ENERGY STAR Efficiency, EER</th></tr>
<tr><td>< 6,000</td><td>11.0</td><td rowspan="2">11.2</td><td rowspan="2">10.0</td><td rowspan="2">10.4</td></tr>
<tr><td>6,000 to 7,999</td><td>11.0</td></tr>
<tr><td>8,000 to 10,999</td><td>10.9</td><td rowspan="2">11.3</td><td>9.6</td><td rowspan="5">9.8</td></tr>
<tr><td>11,000 to 13,999</td><td>10.9</td><td>9.5</td></tr>
<tr><td>14,000 to 19,999</td><td>10.7</td><td>11.2</td><td>9.3</td></tr>
<tr><td>20,000 to 24,999</td><td>9.4</td><td rowspan="2">9.8</td><td rowspan="2">9.4</td></tr>
<tr><td>≥ 25,000</td><td>9.0</td></tr>
</table>

Table 2: Effective full load cooling hours (Ref. 4)

Building Type	Zone 1	Zone 2	Zone 3
Single Family	213	379	520
Multi Family*	228	473	616

** Multifamily includes duplexes, townhomes, and 3 or more unit buildings*

Table 3: Incremental Cost by Capacity (Ref. 5)

Capacity (Btu/h)	Incremental Cost
< 6,000	$19.00
6,000 to 7,999	$27.00
8,000 to 13,999	$43.00
14,000 to 19,999	$66.00
>= 20,000	$85.00

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).

Notes:

There are currently federal efficiency standards in place for room air conditioners. See Table 1 above for details.

References:

1. 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values, October 10, 2008

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. ENERGY STAR® Program Requirements, Product Specification for Room Air Conditioners, Version 3.0, June 22, 2010

4. Calculated through energy modeling by FES 2012

5. Costs are averaged from vendor pricing for typical models meeting these criteria.

6. Federal Minimum Efficiency Standards, http://www.regulations.gov/#!documentDetail;D=EERE-2007-BT-STD-0010-0066. Accessed 7/9/14.

Documentation Revision History:

Version / Description	Author	Date
1. Original (derived from ResidentialRoomAC_CentralACTuneup_v02.xls)	JP	
2. Added to the measure description and algorithms sections.	FES	7/30/2012
2. Added an example.	FES	7/31/2012
2. Changed source for measure life.	FES	8/1/2012
2. Changed incremental costs.	FES	8/1/2012
2.1 Added building type to required inputs from customer	JP	4/2/2013
2.2 Added explanation of multifamily buildings	JP	3/12/2014
2.3 Updated to new Federal and ENERGY STAR standards, updated incremental costs	FES	7/31/2014
2.4 Removed mention of existing unit in example, adding EER_Eff to Required Inputs	JP	7/31/2014

Residential HVAC - ENERGY STAR Dehumidifiers

Version No.

3.0

Measure Overview

Description: This measure includes installation of a new ENERGY STAR Dehumidifier or replacement of an old dehumidifier with an ENERGY STAR unit.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: Residential customers

Algorithms

Unit kWh Savings per Year = (CAP*(Conversion Factor/24)*Hours)*(1/(L/kWhb)-1/(L/kWheff))

Unit Peak kW Savings = Unit kWh Savings per Year/Hours*CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $ 20 (Ref.1)

Where:

CAP = Capacity of the unit in pints/day. CAP = 50 pints/day if unknown

Conversion Factor = 0.473 liters/pints, Constant to convert pints to liters

Hours = 1620 hours/year, Run hours per year (ref. 1)

L/kWhb = Liters of water per kWh removed by baseline unit, as provided in tables below

L/kWheff = Liters of water per kWh removed by new unit, as provided in tables below

CF = 0.37, Coincidence Factor (ref.2)

Required from Customer/Contractor: Unit size

Example:

Install ENERGY STAR humidifier, capacity 50 pints/day,

Unit kWh Savings per Year = (50(0.473/24)*1620)*(1/1.23-1/1.6) = 300*

*Unit Peak kW Savings = 300/1620*0.37 = 0.5*

Deemed Input Tables:

Table 1: Dehumidifiers' baseline efficiency, per Federal Standard efficiency standards
As of 10/1/2012:

Capacity (pints/day)	Federal Standard Criteria (L/kWh)
≤ 35	≥ 1.35
> 35 to ≤45	≥ 1.50
> 45 to ≤ 54	≥ 1.60
> 54 to ≤ 75	≥ 1.70
> 75	≥ 2.5

Table 2: Dehumidifiers' ENERGY STAR standards
As of 10/1/2012 (V 3.0)

Capacity (pints/day)	ENERGY STAR Criteria (L/kWh)
< 75	≥ 1.85
75 to ≤185	≥ 2.80

Methodology and Assumptions:

A dehumidifier meeting the minimum qualifying efficiency standard established by the current ENERGY STAR (Version 2.1 or 3.0) is purchased and installed in a residential setting in place of a unit that meets the minimum federal standard efficiency.

Notes:

To qualify for this measure, the new dehumidifier must meet the ENERGY STAR standards.

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

References:

1. ENERGY STAR website

http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=DE

2. Assume usage is evenly distributed day vs. night, weekend vs. weekday and is used between April through the end of September (4392 possible hours). 1620 operating hours from ENERGY STAR calculator for dehumidifiers[1]. Coincidence peak during summer peak is therefore 1620/4392 = 36.9%

Documentation Revision History:

Version / Description	Author	Date
1 New standalone spec sheet, based on March 2009 evaluation report for Focus on Energy as noted in references	JP	
2.1 Changed energy savings equations arrangement	Franklin Energy	7/25/2012
2.2 Added Example	Franklin Energy	7/25/2012
2.3 Added input tables	Franklin Energy	7/25/2012
2.4 Added Notes	Franklin Energy	7/25/2012
2.5 Added Methodology and Assumption	Franklin Energy	7/25/2012
2.6 Spelling fixes, minor wording changes	JP	3/26/2013
3.0 Removed old federal efficiency criteria tables.	Franklin Energy Services	1/6/2016

Residential HVAC - Ground Source Heat Pump Systems

Version No. 1.0

Description:

This measure includes replacement of non-working and working ground source heat pump (GSHP) equipment and replacement of non-working and working furnace and air conditioner equipment with ground source heat pump systems (GSHP)

Actions: Replace on Fail, Replace Working, New Construction

Target Market Segments: Residential

Target End Uses: HVAC

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more where ground source heat pump equipment can be installed.

Algorithms

Baseline Heating, Existing GSHP:

Unit Heating kWh Baseline (GSHP) per Year = Size x (3.52 / Rated_COP_Base) x COP_Adjust x $EFLH_{Heat}$

Baseline Cooling, Existing GSHP:

Unit Cooling kWh Baseline (GSHP) per Year = Size x (12 / Rated_EER_Base) x EER_Adjust x $EFLH_{cool}$

Baseline Heating, Gas Furnace:

Unit Heating Dth Baseline (Furnace) per Year = Btuh_input / 1,000,000 x (1 / AFUE_Base) x $EFLH_{Heat}$

Baseline Cooling, Split System A/C:

Unit Cooling kWh Baseline (Split A/C) per Year = Size x (12 / SEER_Base) x $EFLH_{cool}$

Proposed Heating, GSHP:

Unit Heating Proposed kWh per Year = Size x (3.52 / Rated_COP_Proposed) x COP_Adjust x $EFLH_{Heat}$

Proposed Cooling, GSHP:

Unit Cooling Proposed kWh per Year = Size x (12 / Rated_EER_Proposed) x EER_Adjust x $EFLH_{cool}$

Savings, Existing GSHP:

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

Unit Peak kW Savings = (Unit Cooling kWh Baseline (GSHP) per Year - Unit Cooling Proposed kWh per Year) / $EFLH_{cool}$ x CF

Savings, Gas Furnace with Split System A/C:

Unit Dth Savings per Year = Unit Heating Dth Baseline (Furnace) per Year

Unit kWh Savings per Year = Unit Cooling kWh Baseline (Split A/C) per Year - (Unit Heating Proposed kWh per Year + Unit Cooling Proposed kWh per Year)

Unit Peak kW Savings = (Unit Cooling kWh Baseline (Split A/C) per Year - Unit Cooling Proposed kWh per Year) / $EFLH_{cool}$ x CF

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 18 years (Ref. 1)

Unit Participant Incremental Cost = $150/ton incremental cost when replacing existing ground source heat pump (Ref. 2)

$900/ton cost when installing new ground source heat pump, i.e., replacing a furnace / split system air conditioner (Ref. 3, 4)

Where:

Size = Heat pump or split system A/C capacity in tons (1 ton = 12,000 btu/h)

Btuh_input = furnace capacity in Btu/hr

3.52 = unit conversion, tons to kW

1,000,000 = unit conversion, BTU per Dtherm

Rated_COP_Base = 3.1, rated COP in heating mode for the baseline ground source heat pump (Ref. 5)

Rated_COP_Proposed = actual rated COP in heating mode for the proposed ground source heat pump

Rated_EER_Base = 13.4, rated EER in cooling mode for the baseline ground source heat pump (Ref. 5)

Rated_EER_Proposed = actual rated EER in cooling mode for the proposed ground source heat pump

SEER_Base = 13.0, baseline split system A/C SEER (Ref. 6)

AFUE_Base = AFUE rating of baseline furnace: 80% if replace existing furnace, 90% if new construction (Ref. 7)

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

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

CF = 0.90, deemed coincidence factor (Ref. 10)

Table 1. Equivalent Full Load Heating Hours ($EFLH_{Heat}$) by Climate Zone (ref. 8)

Zone	Equivalent Full Load Heating Hours
Zone 1 (Northern MN)	2280
Zone 2 (Central MN)	2099
Zone 3 (Southern MN/Twin Cities)	1932

**Includes duplex, townhome, and multifamily buildings with 3 or more units*

Table 2. Equivalent Full Load Cooling Hours ($EFLH_{Cool}$) by Climate Zone (ref. 9)

Zone	Equivalent Full Load Cooling Hours	
	Single Family	Multifamily*
Zone 1 (Northern MN)	213	228
Zone 2 (Central MN)	379	473
Zone 3 (Southern MN/Twin Cities)	520	616

**Includes duplex, townhome, and multifamily buildings with 3 or more units*

Required inputs from customer/contractor:

1. Existing HVAC system type (furnace with split system A/C, ground source heat pump, electric heat with split system A/C)
2. Existing system size
3. Proposed system size
4. Proposed system heating COP
5. Proposed system cooling EER

Example:

A low efficiency ground source heat pump is being replaced by a high efficiency 2.5 ton model with COP of 4.2 and EER of 18 in a single37 family residential home in zone 2:

Heating savings = 2.5 tons x 2099 hours x 3.52 x (1 / 3.1 – 1 / 4.2) x 81.6% = 1273 kWh

Cooling savings = 2.5 tons x 379 hours x 12 x (1 / 13.4 - 1 / 18) x 89.1% = 193 kWh

Demand savings = 193 kWh / 379 hours x 0.9 = 0.459 kW

Notes

For baseline heating system = electric resistance, use 'Baseline Heating, Existing GSHP' formula with COP = 1.0 and omit the COP_Adjust input.

Proposed heat pump should meet Energy Star minimum requirements

For multi-stage ground source heat pumps, average the highest and lowest EER and COP, per Energy Star guidelines (www.energystar.gov/index.cfm?c=geo_heat.pr_crit_geo_heat_pumps)

$EFLH_{Cool}$ 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 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: $EFLH_{MN} = EFLH_{IL} \times HDD_{65,MN} / HDD_{65,IL} \times DTD_{IL} / DTD_{MN}$, where DTD is the design temperature difference.

Geography	HDD65	DTD
Chicago, IL	6,339	73.5
MN Zone 1	9,833	92
MN Zone 2	8,512	86.5
MN Zone 3	7,651	84.5

References

1. Measure Life Report - Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.
http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf

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. Performance, Emissions, Economic Analysis of Minnesota Geothermal Heat Pumps, Michaels Energy for Minnesota Department of Commerce, April 2008.
http://www.michaelsenergy.com/PDFs/Minnesota%20GHP.pdf

4. Personal communication with Eric O'Neil of Michaels Energy, 7/30/15. Eric provided HVAC capacity for the building types modeled in Ref. 3.

5. ASHRAE Standard 90.1-2010, Energy Standard for Buildings Except Low-Rise Residential Buildings, Table 6.8.1B, Ground Source Heat Pump 32°F entering water for heating, 77°F entering water for cooling.

6. Title 10, Code of Federal Regulations, Part 430 - Energy Conservation Program for Consumer Products, Subpart C, Section 430.32. January 1, 2013.
http://www.gpo.gov/fdsys/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-sec430-32.pdf

7. US Department of Energy. Though the federal minimum efficiency is 78% there are very few models available at this efficient; a review of AHRI shows that most low efficiency units are 80%.
http://buildingsdatabook.eere.energy.gov/ChapterIntro7.aspx

8. FES scaled annual heating loads from those provided in the Illinois Technical Reference Manual based on Minnesota weather data.

9. 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

10. 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.

Version / Description	Author	Date
1.0 Initial draft, new workpaper	Franklin Energy Services	7/31/2015

Residential HVAC - Mini Split Ductless Systems A/C only and Heat Pump

Version No. 1.0

Description: This measure includes replacement of non-working and working air source heat pump (ASHP) equipment, furnaces with split system air conditioning systems, and electric mini split ductless A/C or heat pump systems.

Actions: Replace on Fail, Replace Working, New Construction

Target Market Segments: Residential

Target End Uses: HVAC

Applicable to: Residential customers with < 65,000 Btu/hr cooling systems where mini-split ductless equipment (both cooling-only and heat pump versions) can be installed.

Algorithms:

Baseline Heating, Existing ASHP or Electric Resistance:

Unit Heating Baseline kWh per Year = Size x 12 / HSPF_Base x $EFLH_{Heat}$

Baseline Heating, Gas Furnace:

Unit Heating Dth BaseliYne per Year = Btuh_input / 1,000,000 x (1 / AFUE_Base) x $EFLH_{Heat}$

Baseline Cooling, Split System A/C:

Unit Cooling kWh Baseline per Year = Size x 12 / SEER_Base x EFLH_cool

Proposed Heating:

Unit Heating Proposed kWh per Year = Size x 12 / HSPF_Proposed x $EFLH_{Heat}$

Proposed Cooling:

Unit Cooling Proposed kWh per Year = Size x 12 / SEER_Proposed x EFLH_cool

Savings, A/C Only:

Unit kWh Savings per Year = Unit Cooling kWh Baseline per Year - Unit Cooling Proposed kWh per Year

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

Savings, Existing ASHP or Electric Resistance:

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) / EFLH_cool x CF

Savings, Gas Furnace with Split System A/C:

Unit Dth Savings per Year = Unit Heating Dth Baseline (Furnace) per Year

Unit kWh Savings 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) / EFLH_cool x CF

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 18 years for residential (Ref. 1)

Unit Participant Incremental Cost (Ref. 2) = Actual costs should be used, for planning purposes an averaged full installed cost was determined to be $2,500/ton.

Where:

Size = mini split ductless cooling capacity in tons (1 ton = 12,000 btu/h)

Btuh_input = furnace capacity in Btu/hr

12 = unit conversion, EER to kW/ton

1,000,000 = unit conversion, BTU per Dtherm

HSPF_Base = HSPF in heating mode for the baseline HVAC system, select from table below:

Baseline Heating System	HSPF_Base	Reference
Residential ASHP	7.7	Ref. 3
Electric Resistance	3.412	Assumed (=100% efficient)

HSPF_Proposed = actual HSPF in heating mode for the proposed heat pump

SEER_Base = SEER in cooling mode for the baseline HVAC system, select from the table below:

Baseline Cooling System	SEER_Base	Reference
Residential ASHP	13.0	Ref. 3
Residential Split System A/C	13.0	Ref. 3
Thru-the-wall A/C	10.6	Ref. 3

SEER_Proposed = actual SEER of the mini split ductless system

AFUE_Base = AFUE rating of baseline furnace: 80% if replace existing furnace, 90% if new construction (Ref. 4)

$EFLH_{cool}$ = Effective Full Load Hours for cooling, see table below (Ref. 5):

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

Zone	Equivalent Full Load Cooling Hours	
	Single Family	Multifamily*
Zone 1 (Northern MN)	213	228
Zone 2 (Central MN)	379	473
Zone 3 (Southern MN/Twin Cities)	520	616

**Includes duplex, townhome, and multifamily buildings with 3 or more units*

$EFLH_{heat}$ = Effective Full Load Hours for cooling, see table below (Ref. 6):

Table 2. Equivalent Full Load Heating Hours ($EFLH_{Heat}$) by Climate Zone (ref. 6)

Zone	Equivalent Full Load Heating Hours
Zone 1 (Northern MN)	2280
Zone 2 (Central MN)	2099
Zone 3 (Southern MN/Twin Cities)	1932

**Includes duplex, townhome, and multifamily buildings with 3 or more units*

CF = 0.90, deemed coincidence factor (Ref. 7)

Required inputs from customer/contractor:

1. Existing HVAC system type (furnace with split system A/C, air source heat pump, electric heat with split system or other thru-the-wall A/C)
2. mini split system size
3. furnace system size (if applicable)
4. proposed system heating AFUE or HSPF
5. proposed system cooling SEER

Example:

Assume a 2.5 ton air source heat pump is being replaced by a mini-split system in a single family home in zone 1. Assuming that 2 1 ton mini splits, and one ½ ton mini split will be installed.

Cooling savings:

2.5 tons x 12 x 213 hours x (1/13 SEER – 1/20 SEER) = 172 kWh

Heating Savings:

2.5 tons x 12 x 2280 hours x (1 / 7.7 – 1/11) = 2665 kWh

Notes:

Proposed mini split ductless should meet Energy Star minimum requirements (14.5 SEER, 8.2 HSPF)

For multi-head systems, system capacity is the minimum of the: total indoor unit capacity and outdoor unit capacity.

$EFLH_{Cool}$ 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 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: $EFLH_{MN} = EFLH_{IL} \times HDD_{65,MN} / HDD_{65,IL} \times DTD_{IL} / DTD_{MN}$, where DTD is the design temperature difference.

Geography	HDD65	DTD
Chicago, IL	6,339	73.5
MN Zone 1	9,833	92
MN Zone 2	8,512	86.5
MN Zone 3	7,651	84.5

References

1. Measure Life Report - Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.

http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf

2. Based upon review of Ductless Heat Pumps for Residential Customers in Connecticut, Swift, Joseph R, and Rebecca A. Meyer, The Connecticut Light and Power Company, 2010 ACEEE Summer Study on Energy Efficiency in Buildings (2-292). Also supported by findings in 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. January 1, 2013.

http://www.gpo.gov/fdsys/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-sec430-32.pdf

4. US Department of Energy. Though the federal minimum efficiency is 78% there are very few models available at this efficient; a review of AHRI shows that most low efficiency units are 80%. http://buildingsdatabook.eere.energy.gov/ChapterIntro7.aspx

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. FES scaled annual heating loads from those provided in the Illinois Technical Reference Manual based on Minnesota weather data.

7. 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.

Documentation Revision History

Version / Description	Author	Date
1.0 Initial draft, new workpaper	Franklin Energy Services	7/31/2015

Residential HVAC – Thermostats with Electric Heating

Version No. 2.0

Measure Overview

Description: This measure includes installation of a programmable (Tier I), communicating (Tier II), or analytics capable (Tier III) thermostat in existing homes, or a communicating or analytics capable thermostat in new homes.

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

Caution is advised in using this measure as few large scale pilots have been completed to date and results have varied significantly.

Actions: Replace on Fail, Replace Working, New Construction

Target Market Segments: Residential

Target End Uses: HVAC

Applicable to: Residential customers in single-family homes, duplexes, townhomes, and multi-family homes (including 3- and 4- family homes).

Algorithms:

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

Unit Peak kW Savings = 0 unless Tier III device with demand response program. See Notes.

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 1, 2)

Unit Participant Cost = See Table 2 or use actual device costs plus installation cost if available.

Where:

Cooling kWh = Baseline cooling energy for residences in pilot area. Default = 760 kWh/yr (Ref. 9)

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, and 4,900 kWh for ground source heat pump (Ref. 9)

HSF = Heating savings factor, assumed fraction of heating energy saved by thermostat, see Table 1.

CSF = Cooling savings factor, assumed fraction of cooling energy saved by thermostat, see Table 1.

Required from Customer/Contractor: Confirmation of heating type, existing or new home

Example:

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

Heating kWh Savings per Year = 0.089 x 16,200 = 1,442 kWh
Cooling kWh Savings per Year = 0.089 x 760 = 67.6 kWh
Unit kW Savings = 0

Deemed Input Tables:

Table 1: Heating and cooling savings factors (Ref. 2, 3), incremental costs (Ref. 2, 8)

	Tier I	Tier II	Tier III
Heating (HSF)	3.6%/0%[3]	5.4%	8.9%
Cooling (CSF)	0.0%	5.4%	8.9%
Incremental Cost[1,2]	$30	$110	$200

[1]Tier III devices often require a monthly fee for software updates and data management. These fees should be factored into cost-benefit analyses. A typical fee is $3 per month (Ref.)

[2]Does not include installation costs.

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

Methodology and Assumptions:

A Tier I (programmable) thermostat is assumed to replace a manual thermostat. 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.

As a result, the savings factors may require adjustment as more pilot programs are completed.

Notes:

Few large scale pilot programs have been completed as of the drafting of this measure and results vary significantly.

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.

ENERGY STAR proposed a new specification for connected (Tier II) thermostats on June 17, 2015.

The specification will be based on demonstrated savings with aggregate data.

This measure could be modified to reference the new ENERGY STAR specification when finalized.

References:

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc. June 2007.
2. DTE Residential Thermostats, Market Assessment of Advanced Residential Programmable Thermostats, Navigant. December 2014.

   Midpoint of device cost ranges used for Tier II, Tier III incremental costs.

3. Tier I savings factor of 3.6% is based on the following sources: Ref. 2, 2.0%; Ref. 4, 6.6%, Ref. 5, 3.9%; Ref 6., 3.6%. If ISR of 56% is assumed for non-direct installs (Ref. 7), Ref. 4 savings are 3.7%.
4. Validating the Impacts of Programmable Thermostats, Final Report, RWL Analytics. 2007
5. CenterPoint Energy 2013-2015 Triennial CIP Plan, Docket No. G008/CIP-12-564. CPE estimated a reduction of 2.8 Dth for programmable thermostats, equivalent to 3.9% of the average heating load in its territory based on a 1.4F/18 hour average setback.

   The 1.4F average setback accounts for customers that do not program a schedule or manually override the schedule.

6. Xcel Energy 2013-2015 Triennial CIP Plan, Docket No. E,G002/CIP-12-447. Energy savings for the thermostat setback were calculated in RemRate modeling using a baseline model home calibrated to typical home size and characteristics for the Minneapolis/St.Paul area. Natural gas savings = 74.4 - 71.8 = 2.6 Dth/yr, equivalent to about 3.6% savings.
7. Programmable Thermostats. Report to KeySpan Energy Delivery on Energy and Cost Effectiveness, GDS Associates, Marietta, GA. 2002
8. Market price vary significantly for this product, the basic functions required are available on units readily available in the market for the listed price. (Illinois Statewide Technical Reference Manual for Energy Efficiency Version 3.0, 2014)
9. Baseline heating and cooling energy are derived from monthly sales information included in the 2015 jurisdictional annual reports filed by CenterPoint Energy and Xcel Energy (docket no. E,G999/PR-15-4) for calendar year 2014.

   The gas heating figure is based on weather-normalized sales. The cooling figure is based on non-weather normalized sales. The gas heating figure was convered to kWh for electric resistance heating assuming an average gas efficiency of 0.8 and electric efficiency of 100%.

   The electric resistance heating figure was used to derive average heating kWh for air source and ground source heat pumps assuming efficiencies of 7.7 HSPF and 3.3 COP, respectively.

Document Revision History:

Version / Description	Author	Date
1.0 Measure Created	Franklin Energy	2/28/2014
1.1 Added duplex to multifamily category	JP	3/11/2014
1.2 Added IECC 2012 note	Franklin Energy	7/31/2014
1.3 In Methodology and Assumption, changed “solely” to”primarily” regarding gas heating for consistency with Description.	JP	7/31/2014
2.0 Expanded measure to three Tiers of Thermostats	FES	11/12/2015

Residential Lighting – Lighting End Use

Version No. 2.0

Measure Overview

Description: The residential lighting measures use a standard set of variables for hours of use, HVAC cooling interaction effects, In Services Rates, 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 ISR

Unit Peak kW Savings = (kW_Base - kW_EE) x CF x HVAC_cooling_kWsavings_factor x ISR

Unit Dth Savings per Year = (kW_Base - kW_EE) x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = See each technology section.

Unit Participant Incremental Cost: See each technology section.

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, See Table 3.

Required from Customer/Contractor: Existing fixtures and quatities (retrofits only), Installed fixtures and quantities, space type (interior living quarters, multifamily* common areas, or exterior/unconditioned space), HVAC System (heating only, heating & cooling, exterior/unconditioned)

** Multifamily includes 3+ unit residential buildings*

Example Calculation:

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

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

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

Deemed Input Tables:

Table 1: HVAC Interactive Factors by HVAC System

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)	
Space Type	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only	HVAC System: Heating & Cooling	HVAC System: Heating Only or Heating & Cooling	Reference
Interior Living Quarters	1.00	1.248	1.00	1.075	-0.0029	1
Multifamily Common Areas	1.00	1.248	1.00	1.075	-0.0029	1
Exterior/Unconditioned Space	1.00	1.00	1.00	1.00	0	1
Interior Living Quarters - Cooling Unknown	1.16		1.048		-0.0029	1
Multifamily Common Areas - Cooling Unknown	1.11		1.034		-0.0029	1

*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 (see table for references)

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: In Service Rate

Delivery Method	ISR	Reference
Direct Install	97%	6
Retail/Time of Sale	73%	7
School Kits	61%	8
Direct Mail Kits	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 be 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 5 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. 1st year in service rate 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

Residential Lighting - CFLs and ENERGY STAR Torchieres

Version No. 3.0

Measure Overview

Description: CFLs and ENERGY STAR qualified torchieres provide an energy efficient alternative to traditional incandescent and halogen lamps.

Actions: Replace on Failure, Replace Working, New Construction
Target Market Segments: Residential, Commercial
Target End Uses: Lighting
Delivery Methods: Direct Install, Coupon, Giveaway, Upstream, Kits

Applicable to: Single family, duplex, townhome, and multifamily (3+ units) customers

Algorithm:

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

Deemed Input Tables:

Table 1: Fixture Wattage (Ref. 1 and 2) and Costs (Ref. 3 and 4)

Equipment Type	kW_base	kW_EE	Incremental Cost
CFL (non Direct Install)	0.0467	0.0190	$1.32
CFL (Direct Install)*	Actual Existing	0.0190	$1.32
ENERGY STAR Torchiere	0.1900	0.0485	$41.97

*Where actual existing base wattage is not available in direct install delivery, use the non-Direct Install wattage.

Table 2: Measure Life

Equipment Type	Measure life	Source
CFL	9.4	5
ENERGY STAR Torchiere	9.4	6

Methodology and Assumptions:

The baseline wattages in Table 1 were derived from extrapolating the approved baseline wattages for Xcel Energy's Home Lighting program for 2012- 2014 in a February 14, 2012 Order (Docket No. E,G002/CIP-09-198), shown below, and using the market share of each wattage range shown in Table 4. The wattages reflect the gradual depletion of traditional incandescent lighting from the market and were derived from the following report:

United States Environmental Protection Agency, October 2011. *Next Generation Lighting Programs: Opportunities to Advance Efficient Lighting for a Cleaner Environment.*

Table 3: Approved Baseline Wattages for Xcel Energy's Home Lighting Program, 2012-2014, with Extrapolation to 2015 and 2016

Lumen Bin	Typical Incandescent Wattage	EISA-Compliant Halogen Wattage	2012	2013	2014	2015	2016+
1490-2600	100W	72W	90.5 W	80.5 W	76.0 W	72.0W	72.0W
1050-1489	75W	53W	72.0 W	64.0 W	57.5 W	53.0W	53.0W
750-1049	60W	43W	58.5 W	55.0 W	48.5 W	46.1W	43.0W
310-749	40W	29W	39.0 W	37.0 W	33.0 W	31.4W	29.0W

Tables 4-5: Composite wattages and costs for CFLs and baseline incandescents. Source: CFL METERING STUDY FINAL REPORT, Prepared for: Pacific Gas & Electric Company, San Diego Gas & Electric Company, Southern California Edison Company, 2005. Incandescent wattages updated for EISA 2007 new wattages and include market lag effect for gradual depletion of traditional incandescent wattages from the market per February 14, 2012 Order for Xcel Energy (Docket No. E,G002/CIP-09-198).

CFL Wattage Range Avg	Percent of Total Res CFLs	Composite CFL Wattage	Comparable Incandescent and Halogen Wattage 2016+	Composite Baseline Wattage 2016+
11	12.0%	1.32	29.0	2.8
17	57.0%	9.69	43.0	24.5
25	19.0%	4.75	53.0	10.1
27	12.0%	3.24	72.0	8.6
	Weighted Average	19.0		46.7

CFL Wattage Range Avg	CFL Cost	Incandescent cost	Composite CFL Cost	Composite Incandescent Cost	Incremental
11	$2.23	$0.50	$0.27	$0.06	$0.21
17	$2.00	$0.75	$1.14	$0.43	$0.71
25	$1.87	$0.85	$0.36	$0.16	$0.19
27	$2.25	$0.50	$0.27	$0.06	$0.21
			$2.03	$0.71	$1.32

Table 6: Composite Wattages calculated from ENERGY STAR Qualified Product list accessed 10/27/2015

Brand	Model Number	Intended Use	Light Output	Total Input Power (Watts)
Kadium Lighting	VL-ET-41-01 X	Residential	1200	41.0
Maxlite	ML1G4523xxxx	Residential	3230	44.0
Maxlite	ML1G7033xxxx	Residential	3230	44.0
AutoCell Electronics, Inc.	57W-TOR-27KYN	Residential	1300	57.0
AutoCell Electronics, Inc.	57W-TOR-41KYN	Residential	1300	57.0
Cordelia Lighting Inc.	HBP1042P-x	Residential	3200	48.0
			Average	48.5

Notes:

Baseline incandescent lamp wattages are decreased through 2014 based on EISA 2007 legislation. Torchieres. Section 135(c) of EPACT 2005 amends section 325 of EPCA to add subsection (x) setting standards for torchieres. Torchieres manufactured on or after January 1, 2006, shall consume not more than 190 watts of power, and shall not be capable of operating with lamps that total more than 190 watts.

References:

1. CFL Wattage and baseline are from the CFL METERING STUDY FINAL REPORT, Prepared for: Pacific Gas & Electric Company, San Diego Gas & Electric Company, Southern California Edison Company, 2005. Incandescent wattages are updated for EISA 2007 and reflective of the full phase in.

2. Torchiere ENERGY STAR Light Fixtures Product List - accessed 10/27/2015

3. 2006 MEEA Change A Light Change the World Program for 15W and 26W lamps.

4. Costs are based on a survey of manufacturers and Midwest program data.

5. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08 (range from 2-10, 9.4 years was selected)

6. Measure life: 9.4 years (calculated), based on 10,000 hour average lamp life

Residential Lighting – ENERGY STAR LED Lamps and Fixtures

Version No . 1.4

Measure Overview

Description: ENERGY STAR LED lamps and fixtures provide an energy efficient alternative to traditional incandescent and halogen lamps. The ENERGY STAR program began labeling qualified LED products in the latter half of 2010. LED A-line lamps are used as efficient replacements of general service incandescent lamps and more efficient halogen lamps. LED Globes are commonly used in restroom vanity fixtures and offer an efficient alternative to incandescent lamps. LED PAR/Flood lamps are commonly used in downlights and track lighting and replace less efficient incandescent and halogen lamps. Recessed downlight fixtures are common in living rooms, bedrooms, and rec rooms and are typically incandescent lamps. LED recessed downlight fixtures offer an efficient alternative to the incandescent fixtures.

Actions: Replace on Failure, Replace Working, New Construction
Target Market Segments: Residential, Commercial
Target End Uses: Lighting
Delivery Methods: Direct Install, Coupon, Giveaway, Upstream, Kits

Applicable to: Single family, duplex, townhome, and multifamily (3+ units) customers

Algorithm:

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

Deemed Input Tables:

Table 3: Fixture Wattage (Ref. 3) and Costs (Ref. 9)

LED Lamp or Fixture	kW_base	kW_EE	Incremental Cost
17W LED A-Line Lamp	0.072	0.017	$11.50
13W LED A-Line Lamp	0.053	0.013	$8.15
10W LED A-Line Lamp	0.043	0.010	$11.25
7W LED A-Line Lamp	0.029	0.007	$6.50
3W LED Globe Lamp	0.025	0.003	$11.00
8W LED Globe Lamp	0.050	0.008	$13.00
14W LED PAR/Flood Lamp	0.078	0.014	$15.00
12W LED Downlight Fixture	0.065	0.012	$85.00

Methodology and Assumptions:

The baseline wattages in Table 3 reflect the approved baseline wattages for Xcel Energy's Home Lighting program in a February 14, 2012 Order (Docket No. E,G002/CIP-09-198), shown below. The wattages reflect the gradual depletion of traditional incandescent lighting from the market and were derived from the following report:

United States Environmental Protection Agency, October 2011. *Next Generation Lighting Programs: Opportunities to Advance Efficient Lighting for a Cleaner Environment.*

Table 4: Approved Baseline Wattages, Xcel Energy's Home Lighting Program

Lumen Bin	Typical Incandescent Wattage	EISA-Compliant Halogen Wattage	2015	2016+
1490-2600	100W	72W	72.0 W	72.0 W
1050-1489	75W	53W	53.0 W	53.0 W
750-1049	60W	43W	46.1 W	43.0 W
310-749	40W	29W	33.0 W	29.0 W

Codes and Standards:

The following tables indicate the effective phase out dates of incandescent lamps under the Energy Independence and Security Act of 2007 (EISA 2007) and technical information.

Wattage and Lumen Ranges for General Service Incandescent Types				
Incandescent Lamp Wattage	Rated Lumen Range	Replacement Maximum Rated Wattage	Minimum Rated Lamp Life	Effective Phase-Out Date Products Manufactured on or after:
100	1490-2600	72	1,000 hrs	1/1/2012
75	1050-1489	53	1,000 hrs	1/1/2013
60	750-1049	43	1,000 hrs	1/1/2014
40	310-749	29	1,000 hrs	1/1/2014

Incandescent reflector lamps (IRLs) are common cone-shaped light bulbs most typically used in track lighting and "recessed can" light fixtures. The table below shows lumen ranges and incandescent equivalents for LED reflector lamps based on EISA 2007 amendment for reflector lamps in residential settings.

Minimum Lumens	Maximum Lumens	Incandescent Equivalent Wattage
2340	3075	150
1682	2339	120
1204	1681	100
838	1203	75
561	837	60
420	560	45

Requirements and Qualifications:

All LED lamps and fixtures must 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.

References:

1. NEEP EMV Emerging Technologies Research Report (December 2011) – measure life capped at 10 years due to persistence.

2. Focus on Energy Evaluation “Business Programs: Measure Life Study” August 25, 2009

3. Baseline wattages are from EISA 2007 phase out table for general service incandescents. Baseline wattages for PAR/Floods were averaged based on available products. Baseline for downlights is based on the average downlight fixture. ENERGY STAR efficient wattages are from product information and available qualified products.

4. Costs are based on manufacturer product surveys and Midwest program data.

Revisions:

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

Residential Lighting - ENERGY STAR CFL Fixtures

Version No. 2.3

Measure Overview

Description: ENERGY STAR CFL Fixtures replace less efficient incandescent fixtures in retrofits or new construction. Fixtures are hardwired and use pin-based lamps.

Actions: Replace on Failure, Replace Working, New Construction
Target Market Segments: Residential, Commercial
Target End Uses: Lighting
Delivery Methods: Direct Install, Coupon, Giveaway, Upstream

Applicable to: Single family, duplex, townhome, and multifamily (3+ units) customers

Algorithm:

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

Deemed Input Tables:

Table 3: Measure Life (Ref. 1), Fixture Wattage (Ref. 2 and 3) and Costs (Ref. 4)

Retrofit Category	Existing Device	Replacement Device	Measure Life	kW_base	kW_EE	Incremental Cost
Residential CFL Fixture	Average Incandescent fixture	Average ENERGY STAR replacement fixture	9.4	0.106	0.034	$40

Methodology and Assumptions:

The baseline wattage is assumed to be approximately 4 times the efficient wattage of the fixture.

The option to collect the existing wattage and efficient wattage is available to input customer specific values in the algorithm. Use the average values provided if the existing and/or efficient wattages were not provided.

Requirements:

Efficient fixtures should appear on the current ENERGY STAR Qualified Product List available at www.energystar.gov.

References:

1. Measure life: 9.4 years (calculated), based on 10,000 hour average lamp life

2. ENERGY STAR Light Fixtures Product List - accessed 8/29/2012 and summarized in the

Assumptions tab.
http://downloads.energystar.gov/bi/qplist/Lamps_Qualified_Product_List.xls?1c46-c682

3. Study of costs for both incandescent and fluorescent 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 Gas & Electric Company, Southern California Edison Company, 2005

Residential Lighting - ENERGY STAR Outdoor Fixtures

Version No. 1.0

Measure Overview

Description: ENERGY STAR Outdoor Fixtures replace less efficient incandescent fixtures in retrofits or new construction. Fixtures are hardwired and use either pin based or screw in lamps.

Actions: Replace on Failure, Replace Working, New Construction
Target Market Segments: Residential, Commercial
Target End Uses: Lighting
Delivery Methods: Direct Install, Coupon, Giveaway, Upstream

Applicable to: Single family, duplex, townhome, and multifamily (3+ units) customers

Algorithm:

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

Deemed Input Tables:

Table 3: Measure Life (Ref. 1 and 5), Fixture Wattage (Ref. 2 and 3) and Costs (Ref. 4)

Retrofit Category	Existing Device	Replacement Device	Measure Life	kW_base	kW_EE	Incremental Cost
Residential Outdoor CFL Fixture	Average Incandescent fixture	Average ENERGY STAR replacement fixture	5.5	0.106	0.034	$40
Residential Outdoor LED Fixture	Average Incandescent fixture	Average ENERGY STAR replacement fixture	19	0.106	0.034	$40

Methodology and Assumptions:

The baseline wattage is assumed to be approximately 4 times the efficient wattage of the fixture.

The option to collect the existing wattage and efficient wattage is available to input customer specific values in the algorithm. Use the average values provided if the existing and/or efficient wattages were not provided.

Requirements:

Efficient fixtures should appear on the current ENERGY STAR Qualified Product List available at www.energystar.gov.

References:

1. Measure life: 5.5 years (calculated), based on 10,000 hour average lamp life.

2. ENERGY STAR Light Fixtures Product List, outdoor category - accessed 11/3/2015 www.energystar.gov

3. Study of costs for both incandescent and fluorescent 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 Gas & Electric Company, Southern California Edison Company, 2005

5. Measure life: 15 years (capped for persistence), based on 35,000 hour average fixture life.

Residential Lighting - ENERGY STAR Ceiling Fan

Version No. 2.1

Measure Overview

Description:

ENERGY STAR qualified ceiling fan/light combination units are over 50% more efficient than conventional fan/light units. They also use improved motors and blade designs.

Includes fan-only and fan + light options

Actions: Replace on Failure, Replace Working, New Construction
Target Market Segments: Residential, Multi-Family
Target End Uses: Lighting

Applicable to: Residential and multifamily customers

Algorithms

Unit kWh Savings per Year = (($Fan_{kW\ base}$ + $Fixture_{kW\ base}$) - ($Fan_{kW\ EE}$ + $Fixture_{kW\ EE}$)) x Hrs x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings per Year = Electric Peak Demand Savings (kW) = CF x (($Fan_{kW\ base}$ + $Fixture_{kW\ base}$) - ($Fan_{kW\ EE}$ + $Fixture_{kW\ EE}$)) x HVAC_cooling_kWsavings_factor

Unit Dth Savings per Year = Natural Gas Savings (Dth/yr) =(($Fan_{kW\ base}$ + $Fixture_{kW\ base}$) - ($Fan_{kW\ EE}$ + $Fixture_{kW\ EE}$)) x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 years (Ref. 1)

Unit Participant Incremental Cost: See Table 3

Where:

$Fan_{kW\ base}$ = Baseline fan wattage (kW per fan) determined from Table 3

$Fixture_{kW\ base}$ = Baseline fixture wattage (kW per fixture) determined from Table 3

$Fan_{kW\ EE}$ = High Efficiency fan wattage (kW per fan) determined from Table 3

$Fixture_{kW\ EE}$ = High Efficiency fixture wattage (kW per fixture) determined from Table 3

Hrs = Deemed annual operating hours from Table 2 in Lighting End Use

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 in Lighting End Use.

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.

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.

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting (Ref. 2).

Required from Customer/Contractor: Space type (Single Family/Multi Family in Unit, Multi Family Common Area, Exterior/Unconditioned Space), HVAC System (Heating Only or Heating & Cooling)

Example:

Install an ENERGY STAR qualified ceiling fan with light kit in a single family

*home kWh = ((0.0345+0.180)-(0.0315+0.060)) * 938 *1.075 = 124.03 kWh*

*kW = 0.095 *((0.0345+0.180)-(0.0315+0.060)) * 1.248 = 0.015 kW*

*Dth/year = ((0.0345+0.180)-(0.0315+0.060)) * 938 * -0.0029 = -0.335 Dth/year*

Deemed Input Tables:

Table 3: Fixture Wattage and Costs (Ref. 2)

Retrofit Category	Existing Device	Replacement Device	kW_base	kW_EE	Incremental Cost
ENERGY STAR Ceiling Fan (Fan wattage)	Conventional Unit Fan Wattage	ENERGY STAR qualified unit Fan Wattage	0.0345	0.0315	$86.00
ENERGY STAR Ceiling Fan (Fixture wattage)	Conventional Unit Fixture Wattage	ENERGY STAR qualified unit Fixture Wattage	0.1800	0.0600	$86.00

Notes:

Effective January 1, 2007 (EPAct): Shall have the following features: fan speed controls separate from any lighting controls; adjustable speed controls; the capability of reversible fan action. Specific to ceiling fan light kits, (A) Light kits with medium screw based sockets shall be packaged with screw based lamps to fill each socket that: (i) meet the ENERGY STAR CFL V3.0; (ii) use light sources other than CFL that have lumens per watt performance at least equivalent
to the ENERGY STAR CFL V3.0 requirements. (B) Light kits with pin-based sockets for fluorescent lamps shall meet the ENERGY STAR RLF V4.0 and be packaged with lamps to fill all sockets. Packaging must include FTC energy information label.

Effective January 1, 2009: All other lamp types, maximum total wattage of 190 watts.

References:

1. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08 (range from 13-16 years, 15 years was selected)

2. ENERGY STAR Ceiling Fan calculator (Ceiling_Fan_Savings_Calculator_Consumer.xls) accessed 8/29/2012

Residential Lighting - Controls

Version No. 1.0

Measure Overview

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.

Actions: Modify
Target Market Segments: Residential, Multi-Family
Target End Uses: Lighting

Applicable to: Residential Single Family, Multi-Family

Algorithms

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

Unit Peak kW Savings = 0

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

Unit Gallons Fuel Oil/Propane Savings per Year = 0

Measure Lifetime (years) = 10 years (Ref 1)

Unit Participant Incremental Cost: $40 for wall mounted, $100 for ceiling mounted.

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.

Required from Customer/Contractor: Control type/quantity, connected load (kW) to each control, building type, HVAC system (heating only, heating & cooling, exterior/unconditioned)

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 * 40% * 938 * 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 average);
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
   “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
9. 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.

Residential Lighting – LED Holiday Lighting

Version No. 2.8

Measure Overview

Description: This measure includes replacement of failed or working incandescent holiday light strings with new LED holiday light strings

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Residential, Commercial
Target End Uses: Lighting

Applicable to: residential customers in single-family homes, duplexes, and townhomes. Also available to commercial customers.

Algorithms

Unit kWh Savings per Year = (kW_Base - kW_EE) x Q x N x Hrs

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (kW_Base - kW_EE) x Q x N x Hrs x HVAC_heating_penalty_factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 8 (Ref. 1)

Unit Participant Incremental Cost = $10 (Ref. 3)

Where:

kW_EE = Stipulated wattage per light (kW per light) for efficient light string. See Table 1.

kW_Base = Stipulated wattage per light (kW per light) from baseline light string. See Table 1.

Q = Number of light strings

N = Number of lights in string

Hrs = Estimated annual operational hours per year of the fixture = 150 (Ref. 4);

HVAC_heating_penalty_factor = Heating system penalty factor resulting from efficient lighting

Required from Customer/Contractor: Number of light strings, number of lights per string, type of each lighting string (C7, C9, mini).

Example:

A customer bought (4) 70-light LED mini holiday light strings.

Unit kWh Savings per Year = (0.00045 - 0.000043) x 70 x 4 x 150 = 17.1 kWh

Unit Peak kW Savings per Year = 0 kW

Deemed Input Tables:

Table 1: Post-and Pre-retrofit Wattages per Light (Ref. 2, 5)

Post-retrofit Fixture	kW_EE	Pre-retrofit Fixture	kW_Base
LED Mini Holiday Lights	0.000043	Incandescent Mini Holiday Lights	0.000450
LED C9 Holiday Lights	0.002000	Incandescent C9 Holiday Lights	0.007000
LED C7 Holiday Lights	0.000480	Incandescent C7 Holiday Lights	0.006000

Table 2: HVAC Interactive Factors by HVAC System

	HVAC Heating Penalty Factor (Dth/kWh)	
Space Type	HVAC System: Heating Only or Heating & Cooling	Reference
Interior Living Quarters	-0.0029	6
Multifamily Common Areas	-0.0029	6
Exterior/Uncond. Space	0	6
Interior Living Quarters - Cooling Unknown	-0.0029	7
Multifamily Common Areas - Cooling Unknown	-0.0029	8

Methodology and Assumptions:

Light strings are assumed to be operating during winter (HVAC cooling factors and kW savings ignored)

Any potential gas savings is assumed to be negligible; due to a number of installations being in unheated space.

Hours are based on 5 hours per day, 30 days per year.

Light strings are assumed to be operating during non-peak hours; CF = 0

Notes:

ENERGY STAR criteria for Decorative Light Strings is: "Products must meet stringent efficiency (under 0.2W per bulb) and quality (3-year warranty, protection against over-voltage, maintained light output) requirements.

If desired, the baseline and proposed wattages can be prorated for light strings of different lengths (i.e. 50-light and 100-light strings)

References:

1. Engineering judgment based on 50% of DEER measure life value (16 years).

2. Based on a 70-light string; Pacific Gas & Electric document "Light up the holidays and save", November 2009.

3. State of Ohio Energy Efficiency Technical Reference Manual (TRM) for Ohio State Senate Bill 221, October 2009. Page 59.

4. Holiday Lights: LED and Fiber Optics, November 2007. Energy Ideas Clearinghouse.

5. Technical Reference Manual State of Pennsylvania Act 129 Energy Efficiency and Conservation Program & Act 213 Alternative Energy Portfolio Standards, June 2014 page 174.

6. Calculated through energy modeling by FES 2012

7. 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"

8. 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 average);

Residential Hot Water – Electric Water Heater Jacket Insulation

Version No.

2.0

Measure Overview

Description: This measure includes installing a water heater blanket on an electric water storage water heater.

Actions: Retrofit
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family, duplexes and townhomes with electric water heaters

Algorithms

Unit kWh Savings per Year = ((U_base x A_base - U_insul x A_insul) x (T_hot - T_ambient) x Hours) / Eff / ConversionFactor

Unit Peak kW Savings = Unit kWh Savings Per Year / Hours

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 5 (Ref. 1)

Unit Participant Incremental Cost = $20 (Ref. 5)

Where:

U_base = R-12; heat transfer coefficient of water heater without insulation jacket (Ref. 1)

U_insul = R-18; heat transfer coefficient of water heater with insulation jacket (Ref. 6)

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. 7)

Eff = See Table 1; Minimum Energy Factor = 0.67 - 0.0019 x (Tank Size in Gallons)

Hours = 8,766 hours

ConversionFactor = 3,412 Btu/kWh

Required from Customer/Contractor: project location (county), water heater size in gal, water heater fuel type

Example:

A customer in Zone 2 installed an insulation jacket on their 50-gallon water heater.

Unit kWh Savings per Year = ((1/12 x 24.99 ft2 - 1/18 x 27.06 ft2) x (120°F - 60°F) x (8,766 hours)) / 0.90 EF / 3,412 Btu/kWh = 99.2 kWh

Unit Peak kW Savings= 99.2 kWh / 8,766 hours = 0.011 kW

Deemed Input Tables:

Table 1: Energy Factors and Surface Areas, ft^2 (Ref. 1)

Water Heater Size	Eff	A_bare	A_insul
40-gallon tank	0.92	23.18	25.31
50-gallon tank	0.90	24.99	27.06
80-gallon tank	0.86	31.84	34.14

Methodology and Assumptions:

The algorithm is based on the IL TRM, but assumes a 2", R-6 water heater blanket.

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.

New water heaters are required to meet Energy Factor requirements, but are not required to meet a specific insulation level.

References:

1. Illinois Technical Reference User Manual, 6/1/2012. Pages 429-432.

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. Recommended value on DOE website, http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13090. Consistent with other DHW measures.

4. Measure life source: California Measurement Advisory Committee (CALMAC) Protocols, Appendix F (www.calmac.org/events/protocol.asp).

5. Incremental cost: assumed same cost as water heater blanket; Assumed $20 based on online pricing search. Franklin Energy Services.

6. Assumed an R-6 water heater wrap (2" thickness); Most available according to internet research.

7. The ambient temperature is based on the water heaters being located in the basement.

Documentation Revision History:

Version / Description	Author	Date
1. Based on original from Nexant, cleaned up and reformatted	Joe Plummer	
2. Added algorithms based on IL TRM (Ref. 1)	Franklin Energy Services	7/31/2012
3.0. Updated hours from 8,760 to 8,766.	Franklin Energy Services	1/11/2016

Residential Hot Water - Drainpipe Heat Exchanger with Electric Water Heater

Version No.

2.5

Measure Overview

Description: This measure includes installing a drainpipe heat exchanger to a residential or multi-family building to recover heat from heated water going down the building's drain. The savings for this measure is "per living unit affected."

Actions: Modify
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size electric water heaters.

Algorithms

Unit kWh Savings per Year = EnergyToHeatWater / Eff x SavingsFactor / ConversionFactor

Unit Peak kW Savings = Unit kWh Savings per Year / 8,766

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 20 (Ref. 1)

Unit Participant Incremental Cost = $742 (Ref. 1)

Where:

EnergyToHeatWater = SpecificHeat x Density x Gal/Day x 365.25 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)

Eff = Recovery efficiency of electric water heater, 0.98.

SavingsFactor = 0.25 (Ref. 2)

ConversionFactor = 3,412 Btu/kWh

Required from Customer/Contractor: Confirmation of electric water heater, building type (single family or multi family*), project location (county).

** Includes buildings with 2+ units and townhomes*

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 (365.25 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 / 8,766 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
If location is 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
Multi-family	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

Documentation Revision History:

Version / Description	Author	Date
1. Derived from ResidentialElectricDHW_v03.2 and ResidentialGasDHW_v03.2 which were based on Nexant's original spec.	Joe Plummer, DER	
2. 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 to Modify, changed “electric or gas water heater” to “confirmation of electric water heater” under required inputs, changed annual hours from 8,760 to 8,766, updated example for electric instead of gas	JP	11/24/2013
2.4 Added building type to required inputs, added definition of multifamily	JP	3/18/2014
2.5 Added unknown location and removed gas information.	Frankin Energy Services	12/18/2015

Residential Hot Water – Electric Water Heater Setback

Version No.

3.2

Measure Overview

Description:

This measure involves turning the water heater set point temperature to 120°F on residential storage-type water heaters, both gas and electric. 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.

Actions: Operations and Maintenance
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size electric water heaters

Algorithms

Unit kWh Savings per Year = SpecificHeat x Density x Gal_Person x People x 365.25 x (Tset - Tin) x Savings_Factor/ Eff / ConversionFactor

Unit Peak kW Savings = Unit kWh Savings per Year / 8,766 hours

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 2 (Ref. 2)

Unit Participant Incremental Cost = $0

Where:

SpecificHeat = 1.0 btu / (lb x °F)

Density = 8.34 lbs / gal

Gal_Person = See Table 2; Daily hot water usage per person

People = See Table 3; Number of people per household

Tset1 = 130 °F (assumed average starting temperature)

Tin = Average groundwater temperature per Table 1

Eff = 0.92 (2004 Federal minimum Energy Factor for 40 gal tank = 0.97 - 0.00132 x 40)

ConversionFactor = 3,412 Btu/kWh (electric water heater) or 1,000,000 Btu/MMBtu (gas water heater)

Savings_Factor = 4% (Ref. 3)

Required from Customer/Contractor: confirmation of electric water heater, project location (county), single-family or multi-family*

** Includes buildings with 2+ units and townhomes*

Example:

A direct install team reduces the set point of an electric water heater in a single-family home in Zone 1.

kWh savings = (1.0 Btu/lb°F) x (8.34 lb/gal) x (20.4 gal/day/person) x (2.59 people) x (365.25 day/yr) x (130°F - 46.5°F) x 4% / (0.92) / (3,412 Btu/kWh) = 171 kWh

kW savings = (171 kWh) / 8,766 hours = 0.020 kW

Deemed Input Tables:

Table 1: 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

Table 2: Daily Hot Water Usage per Person (Ref. 6)

Location	Gal/day/person
Single-Family	20.4
Multi-Family*	18.7

** Includes buildings with 2+ units and townhomes*

Table 3: People per Household (Ref. 7)

Application	Num_People
Single-Family	2.59
Multi-Family*	2.17

** Includes buildings with 2+ units and townhomes*

Methodology and Assumptions:

The savings from lowering the temperature setpoint 10°F is 3% to 5% of the overall domestic hot water energy. (Ref. 3)

The existing temperature is assumed to be 130°F (Ref. 5)

Notes:

There are no current energy standards for this measure.

The previous algorithm assumed that all hot water uses are done at max temperature, when in reality only a few are (i.e. clothes washer, dishwasher, misc. cleaning, etc.). The result of this was that the savings was being overestimated (i.e. 446 kWh, resulting in ~13% overall DHW savings). The IL TRM however, only accounts for the aforementioned uses and ignores the reduction in standby losses by lowering the delta T. The result of this is that the savings is underestimated (i.e. 49 kWh). The DOE estimates a savings that is between these two values. The savings value given by DOE estimates are supported by Ref. 2 (Efficiency Vermont TRM).

The excel algorithms yield a savings of 158 kWh and 0.84 Dth, which is within 4% of the values for Zone 1-single-family applications. The difference in savings will increase in zones 2 and 3 and in multi-family applications.

References:

1. Daily hot water usage is based on CEE's tankless water heater field study in Mpls/St. Paul (2008-2010); Supported by Focus on Energy's Residential Deemed Savings Review, page 4.

2. Efficiency Vermont Technical Reference User Manual (TRM), 2/19/2010. Page 409. This value is supported by the Illinois Technical Reference User Manual, 2012.

3. Average of 3-5% savings values on DOE website, http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13090. Accessed 7/2

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. Franklin Energy Services internal value.

6. Interpolated values from Table 38, Ohio Technical Reference Manual. October 15, 2009. Page 52.

7. U.S. Census Bureau, *Selected Housing Characteristics 2010 American Commnity 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

Documentation Revision History:

Version / Description	Author	Date
1. 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, DER	
2.0 Updated algorithm to use Savings_Factor of 4%	Franklin Energy Services	7/26/2012
2.1 Updated measure lifetime per Ref. 2	Franklin Energy Services	7/27/2012
3.0 Updated the hot water usage to be consistent with the hot water heater measure algorithm	Franklin Energy Services	8/6/2012
3.1 Changed "electric or gas water heater" to "confirmation of electric water heater" under required inputs, changed annual hours from 8760 to 8766	JP	11/25/2013
3.2 Added footnotes clarifying multifamily definition. In kWh algorithm, replaced Gal/Day with Gal_Person x People. Corrected example calculation.	JP	3/18/2014

Residential Hot Water - Faucet Aerator (1.5 gpm) with Electric Water Heater

Version No.

4.0

Measure Overview

Description: This measure includes replacing an existing faucet aerator with low-flow aerator.

Actions: Replace Working
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size electric water heaters

Algorithms

Unit kWh Savings per Year = WaterSaved x Density x SpecificHeat x (Tfaucet – Tcold) / ReEff / ConversionFactor

Unit Peak kW Savings = Unit kWh Savings per Year / 8,766 hours

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 1)

Unit Participant Incremental Cost = $6.70 (Ref. 6)

Where:

WaterSaved = Flow_diff x Vmin x (Num_People) x 365.25 days/year

Flow_diff = 1.0 GPM (i.e. 2.5 GPM replaced with 1.5 GPM)

Vmin = 1.125 minutes; the number of minutes of faucet use per adjusted number of bedrooms per day (an average of the following values: 1.5 minutes (kitchen) and 0.75 minutes (bathroom)) (Ref. 2)

Num_People = Number of people per household per Table 2

SpecificHeat = 1.0 Btu / (lb x °F)

Density = 8.34 lb / gal

Tfaucet = 80°F; Temperature of typical faucet usage (Ref. 2)

Tcold = Average groundwater temperature per Table 1 (Ref. 4)

ReEff = 0.98; recovery efficiency (electric water heater) (Ref. 7)

ConversionFactor = 3,412 Btu/kWh (electric water heater)

Required from Customer/Contractor: confirmation of electric water heater, building type (single family or multi-family*), project location (county)

** Includes buildings with 2+ units and townhomes*

Example:

Direct installation of a 1.5 GPM faucet aerator in an apartment with electric water heat located in Zone 1.

WaterSaved (gal/yr) = (1.0 gal/min) x (1.125 min) x (2.17 people) x 365.25 days/year = 892 gallons saved per year

Unit kWh Savings per Year = (891 gal) x (8.34 lbs/gal) x (1.0 Btu/lb°F) x (80°F – 46.5°F) / 0.98 /3,412 Btu/kWh = 74. 5 kWh saved

Unit Peak kW Savings = 74.5 kWh / 8,766 h = 0.008 kW

Deemed Input Tables:

Table 1: 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
If location is unknown	49.0

Table 2: People per Household (Ref. 3).

Application	Num_People
Single-Family	2.59
Multi-Family*	2.17
If unknown	2.38

** Includes buildings with 2+ units and townhomes*

Methodology and Assumptions:

Uses algorithms from Efficiency Vermont TRM (Ref. 2)

The “BR + 1” from Ref. 2 is assumed to equal the number of people per household or unit; People per household will be used instead of BR + 1.

Notes:

If inputs are unknown, deemed savings is 75.6 kWh.

The current standard for kitchen and bathroom aerators is 2.2 GPM, effective 1/1/1994. (Ref. 5)

FOE uses 8 therms/187 kWh for Commercial applications

ActOnEnergy TRM has 82 kWh, 6.1 therms, and 15 years

IL TRM uses 1.89 therms/ 42 kWh

NY TRM has 314 kWh, 17 therms

Ohio TRM (VEIC) 2010 uses 24.5 kWh / .109 MMBtu

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. Efficiency Vermont Technical Reference User Manual, 2/19/2010.

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 and Their Effective Dates. January 1, 2010

6. 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.

7. State of Illinois Energy Efficiency Technical Reference Manual, Page 132-139. July 18, 2012.

Documentation Revision History:

Version / Description	Author	Date
1. Created standalone spec from ResidentialElectricDHW_v03.2	Joe Plummer, DER	
2. Revised formatting and algorithms	Franklin Energy Services	7/27/2012
2. Update the measure life and measure cost	Franklin Energy Services	7/27/2012
3. Corrected Energy Factor equations	Franklin Energy Services	3/20/2013
3.1 Changed action from Direct Install to Replace Working	Joe Plummer, DER	4/5/2013
3.2 Removed extra multiplication sign following Eff in savings algorithms	Joe Plummer, DER	8/28/2013
3.3 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 8,766	JP	11/25/13
3.4 Added residence type (single family or multi-family) to required inputs	JP	1/3/14
3.5 Removed “owner-occupied” from single-family and “renter-occupied” from multi-family categories in Tables 2 and 3, added footnotes clarifying multifamily definition.	JP	3/11/14
4.0 Added in average values and a deemed value for applications where the inputs are unknown.	Franklin Energy Services	10/20/15
4.1 All hours of use changed to 365.25 and commercial usage updated.	FES	1/13/2016

Residential Hot Water – Heat Pump Water Heater

Version No. 1.0

Measure Overview

Description: This measure includes replacement of failed or working storage-type electric resistance water heaters in residential and multifamily buildings with more efficient storage-type electric heat pump water heaters.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size electric water heaters.

Algorithms

Unit kWh Savings per Year = EnergyToHeatWater x (1/EF_min – 1/EF_eff) x ESAF / CF1

Unit Peak kW Savings = EnergyToHeat Water x (1/EF_min – 1/EF_eff) / CF1 / 8,766

Unit Dth Savings per Year = Unit kWh Savings / ESAF * CF2 * GIF

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 13 (Ref. 3)

Unit Participant Incremental Cost = $784 (Ref. 3)

Where:

EnergyToHeatWater = Specific Heat x Density x Gal_Person x People x 365.25 Days/Year x (Tset – Tcold)

SpecificHeat = 1.0 btu / (lb x °F)

Density = 8.34 lbs / gal

Gal_Person = See Table 2; Daily hot water usage per person

People = See Table 3; number of people per household

Tset = 120 F (Ref. 7)

Tcold = Average groundwater temperature per Table 1

EF_min = Based on tank size; see Table 4.

EF_Eff = Efficiency (energy factor) of new water heater

ESAF = Electric Savings Adjustment Factor. 0.68 if electric space heat, 1.0 if gas space heat. (Ref. 8)

GIF = Gas Impact Factor. -0.65 if gas space heat, 0 if electric space heat. (Ref. 11)

CF1 = 3,412 Btu/kWh

CF2 = 0.003412 Dth/kWh

Required from Customer/Contractor: tank size in gallons, new water heater efficiency (EF), single-family or multi-family*, project location (county), space heat fuel source.

Example:

A single-family customer in Zone 2 has installed a new 50-gallon heat pump water heater with an EF of 2.56 in their electrically heated home.

EF_Minimum = 0.960 – (0.0003 x 50 gallons) = .945

EnergyToHeatWater = (1 Btu/lb°F) x (8.34 lbs/gal) x (20.4 gal/person) x (2.59 people) x (365.25 d/yr) x (120°F - 49.1°F) = 11,411,230 Btu/yr

Unit kWh Savings per Year = (11,411,230 Btu/yr) x (1/0.945 - 1/2.56) x 0.68 / (3,412 Btu/kWh) = 1,518 kWh

Unit Peak kW Savings = (11,411,230 Btu/yr) x (1/0.945 - 1/2.56) / (3,412 Btu/kWh) / 8,766 hours = 0.255 kW

Unit Dth Savings per Year = 1,517 kWh / 0.68 * 0.003412 * 0 = 0 Dth

Deemed Input Tables:

Table 1: 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
If location is unknown	49.0

Table 2: Daily Hot Water Usage per Person (Ref. 6)

Application	(Gal/day)/person
Single-Family	20.4
Multi-Family*	18.7
If unknown	19.6

** Includes buildings with two or more units and townhomes*

Table 3: People per Household (Ref. 7)

Application	Num_People
Single-Family	2.59

Multi-Family*	2.17
If unknown	2.38

** Includes buildings with two or more units and townhomes*

Notes:

Table 4: Equipment Standards, effective for products manufactured on or after April 16, 2015 (Ref. 4)

Type of Equipment	Energy Factor
Electric Storage Water Heaters, ≤ 55 gallons	0.960 - (0.0003 x Rated Storage Volume in gallons)
Electric Storage Water Heaters, > 55 gallons	2.057 - (0.00113 x Rated Storage Volume in gallons)

References:

1. US DOE Building America Program. Building America Analysis Spreadsheet, Standard Benchmark DHW Schedules. http://energy.gov/eere/buildings/building-america-analysis-spreadsheets Accessed 12/19/2014.

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. 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.

4. Energy Conservation standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters: Final Rule, Federal Register, 75 FR 20112, April 16, 2010.

5. "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.

6. Interpolated values from Table 38, Ohio Technical Reference Manual. October 15, 2009. Page 52.

7. 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

8. 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% * 50%).

9. 2011 Residential Building Stock Assessment: Single-Family Characteristics and Energy Use. Page 83. http://neea.org/docs/reports/residential-building-stock-assessment-single-family-characteristics-and-energy-use.pdf.

10. Heating system usage assumed to be 24 hours x 182.5 days/year = 4,380. Based on MN TRM v2.0 Electronic Ignition Hearth measure.

11. 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*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. From The Impact of Heat Pump Water Heaters on Whole-House Energy Consumption, Canadian Mortgage and Housing Corporation.

Documentation Revision History:

Version / Description	Author	Date
1. Created standalone measure	Franklin Energy Services	11/10/13

Residential Hot Water - Low Flow Showerheads (1.5 gpm) with Electric Water Heater

Version No.

4.0

Measure Overview

Description: This measure involves replacing a standard showerhead with a low flow showerhead.

Actions: Replace Working
Target Market Segments: Residential: Single-family and Multi-family
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size electric water heaters

Algorithms

Unit kWh Savings per Year = WaterSaved x Density x SpecificHeat x (Tshower - Tcold) / ReEff / ConversionFactor

Unit Peak kW Savings = Unit kWh Savings per Year / 8,766 hours

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 5)

Unit Participant Incremental Cost = $12 (Ref. 4)

Where:

WaterSaved = Flow_reduction x ShowerWater x Num_People x SPCD x 365.25 days/year / SPH

Flow_reduction = 40% (i.e. 2.5 GPM replaced with 1.5 GPM; (2.5-1.5)/2.5 = 0.40)

ShowerWater = 17.2 gallons; daily hot water use per shower per person (Ref. 3)

Num_People = Number of people per household per Table 2

SPCD = 0.75; Showers per capita per day (Ref. 4)

SPH = Showerheads per Household per Table 3

SpecificHeat = 1.0 Btu/(lb°F)

Density = 8.34 lbs/gal

Tshower = 105°F; Temperature of typical shower usage (Ref. 2)

Tcold = Average groundwater temperature per Table 1

ReEff = 0.98; recovery efficiency (electric water heater) (Ref. 7)

ConversionFactor = 3,412 Btu/kWh (electric water heater)

Required from Customer/Contractor: confirmation of electric water heater, building type (single-family or multi-family*), project location (county)

** Includes buildings with 2+ units and townhomes*

Example:

Direct installation of a low-flow showerhead in an apartment with electric water heat located in Zone 3.

WaterSaved (gal/yr) = (40%) x (17.2 gal/person) x (2.17 people/household) x 0.75 SPCD x 365.25 days/year / 1.3 SPH = 3,146 gallons saved per year

Unit kWh Savings per Year = (3,146 gal) x (8.34lbs/gal) x (1 Btu/lb°F) x (105°F - 51.3°F) / 0.98 / 3,412 Btu/kWh = 421 kWh saved

Unit Peak kW Savings = 421 kWh / 8,766 hours = 0.048 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
If location is unknown	49.0

Table 2: People per Household (Ref. 1).

Application	Num_People
Single-Family	2.59
Multi-Family*	2.17
If unknown	2.38

** Includes buildings with 2+ units and townhomes*

Table 3: Showerheads per Household (Ref. 4).

Application	SPH
Single-Family	1.79
Multi-Family*	1.30
If unknown	1.545

** Includes buildings with 2+ units and townhomes*

Methodology and Assumptions:

Algorithm is based on the Illinois TRM (Ref. 4), but has been modified with regard to existing water usage estimation. The original IL TRM calculation was estimating fairly high pre-retrofit water usages, so 11.6 gal/day (Ref. 3) has been used in an effort to temper the results.

Notes:

If inputs are unknown, the deemed savings is 405.2 kWh and 0.046 kW.

The current flow standard for showerheads is 2.5 GPM (Ref. 6)

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. Mayer P., DeOreo W., et.al. 1999. Residential end Uses of Water, American water Works Association Research Foundation.

4. Illinois Technical Reference Manual, 6/1/12. Pages 419-426.

5. 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 Multi-Family,

http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf

6. 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. January 1, 2010

7. State of Illinois Energy Efficiency Technical Reference Manual, Page 132-139. July 18, 2012.

Documentation Revision History:

Version / Description	Author	Date
1. Created standalone spec from ResidentialElectricDHW_v03.2	Joe Plummer	
2. Changed algorithm per IL TRM and modified the HW usage estimates	Franklin Energy Services	7/31/2012
2. Changed Measure Lifetime from 7 to 10	Franklin Energy Services	7/31/2012
3. 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	Joe Plummer	4/8/2013
3.1 Added residence type to list of required inputs from customer/vendor	Joe Plummer	4/8/2013
3.1 Changed description of Tshower from "typical faucet usage" to "typical shower usage"	Joe Plummer	4/8/2013
3.1 Changed "Required Inputs from Direct Installer" to "Required Inputs from Customer/Contractor"	Joe Plummer	4/8/2013
3.2 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	JP	11/25/2013
3.3 Added footnotes clarifying multifamily definition	JP	3/18/2014
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	FES	1/13/2016

Residential Hot Water – Thermostatic Restriction Valve with Electric Water Heater

Version No. 1.1

Measure Overview

Description: This measure involves installing a thermostatically restricting shower valve that reduces the amount of excess hot shower water during warm-up periods.

Actions: Replace Working, Replace on Fail, New Construction
Target Market Segments: Residential: Single-family and Multi-family
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3- and 4-plexes and townhomes) with residential-size electric water heaters.

Algorithms

Unit kWh Savings per Year = GPM_base x t_valve x Num_People x SPCD x 365.25 / SPH x EPG

Unit Peak kW Savings = Unit kWh Savings per Year / 8,766 hours

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 1)

Unit Participant Incremental Cost = $30 (Ref. 2)

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)

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

Required from Customer/Contractor: Showerhead flow rate, zip code.

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 * 1.0 Btu/lb-°F * (105°F - 51.3°F) / (0.98 * 3,412 Btu/kWh) = 0.13378 kWh/gal*

*Unit kWh Savings per Year (kWh/yr) = 1.5 gal/min * 0.94 min * 2.21 * 0.75 * 365.25 days/yr / 1.3 x 0.13378 kWh/gal= 87.8 kWh*

Peak kW Saved (kW) = 87.8 kWh / 8,766 hours = 0.010 kW

Deemed Input Tables

Table 1: People per Household (Ref. 4).

Application	Num_People
Single-Family (owner-occupied)	2.59
Multi-Family (renter-occupied)	2.17
If unknown	2.38

Table 2: Showerheads per Household (Ref. 5).

Application	SPH
Single-Family	1.79
Multi-Family	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
If location is 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 foonote 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 * 30% * 40% = 0.94.

4. U.S. Census Bureau, Selected Housing Characteristics 2010 American Commnity 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.

Documentation Revision History:

Version / Description	Author	Date
1. Measure created	Franklin Energy Services	11/10/2015
1.1 Added conversion factor for gas	Franklin Energy Services	12/16/2015

Residential Load Management Technologies

Version No. 1.0

Measure Overview

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.

Actions: Modify, Replace Working, Replace on Fail, New Construction
Target Market Segments: Residential
Target End Uses: HVAC, DHW

Applicable to: Residential customers in single-family homes

Algorithms

Unit kWh Savings per Year = (average # of events) x (kWh savings per event)

Unit Peak kW Savings = kW savings per event

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 years (Ref. 2)

Unit Participant Incremental Cost = (Refer to Table 4)

Where:

Average # of events = 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.)

kW savings per event = modeled peak kW savings per load control event per installation (refer to Tables 1-3)

Required Inputs from Utility: Load control technology installed (A/C cycling, electric heat cycling, electric water heater curtailment, electric thermal storage for space heating), installation location (county), average number of load control events in a typical year

Optional Inputs from Utility: Cost of load control equipment, installation, and any metering costs

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

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

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

Table 4: Default Incremental Cost (Equipment plus Installation) by Technology

Technology	Incr. Cost	Ref.
A/C Cycling	$200	2
Electric Heat Cycling	$200	2
DHW Curtailment Summer	$200	2
DHW Curtailment Winter	$200	2
Electric Thermal Storage	$11,700	3, 4

Methodology and Assumptions

Current Smart Measure™ implementation of this measure on ESP® does not support winter kW savings at this time.

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. http://mn.gov/commerce/energy/topics/conservation/Applied-Research-Development/About-CARD.jsp, accessed February 11, 2014.
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.

Documentation Revision History

Ver.	Description	Author	Date
1.0	New measure	Joe Plummer, DER	2.11.14

Residential Hot Water - Pipe Insulation with Electric Water Heater

Version No. 3.0

Measure Overview

Description: This measure includes installing pipe insulation on un-insulated piping of an electric water heating system.

Actions: Modify
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family, duplexes and townhomes with electric water heaters.

Algorithms

Unit kWh Savings per Year = (Qloss_base - Qloss_insul) x Hours x Length / ConversionFactor / Eff

Unit Peak kW Savings = Unit kWh Savings per Year / 8,766 hours

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 13 (Ref. 3)

Unit Participant Incremental Cost = $3.63 per foot (Ref. 4)

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

Required from Customer/Contractor: length of pipe insulation (linear feet), confirmation of electric water heater

Example:

A customer 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 = 46.1 kWh

Unit Peak kW Savings= 46.1 kWh / 8,766 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

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 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) 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.

Document Revision History:

Version / Description	Author	Date
1. Based on original from Nexant, cleaned up and reformatted	Joe Plummer, DER	
2. 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	JP	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

Residential Plug Load – Advanced Tier 2 Power Strips

Version No. 1.0

Measure Overview

Description: Advanced power strips are power strips that contain a number of controlled sockets and at least one uncontrolled socket. When the appliance that is plugged into the uncontrolled socket is turned off, the power strips shuts off the appliances that are plugged into the controlled sockets. These have recently been renamed Tier 1 power strips. Tier 2 power strips expand on this functionality by using algorithms to monitor the power of all controlled devices, whereas Tier 1 power strips only monitor the master device and turns off peripheral devices accordingly. Tier 2 power strips use infrared (IR) sensing and Root Mean Squared (RMS) power sensing to detect energy consumption from connected devices; tier 1 power strips only use current sensing. After 1 hour of inactivity, energy savings are delivered by turning off power to inactive devices.

Actions: Modify
Target Market Segments: Residential
Target End Uses: Misc. Electric Loads

Applicable to: Residential customers in single-family homes, duplexes, townhomes, and multi-family homes (including 3- and 4-family homes) with audio-visual home entertainment systems.

Algorithms

Unit kWh Savings per Year = kWh_tv x ESR

Unit kW Savings per Year = CF x (ΔkWh / 8760)

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 8 years (Ref 1)

Unit Participant Incremental Cost = $70 (Ref 1)

Where:

kWh_tv = 602.08 (Ref 1)

ESR = 0.51 (Ref 2)

CF = 0.9 (Ref 3)

Example:

Installing an Advanced Tier 2 Powerstrip in a single-family home with one entertainment center

Unit kWH Savings per Year, ΔkWh = kWh_tv x ESR = 602.08 x 0.51 = 307.1 kWh

Unit kW Peak Savings, kW = CF x ΔkWh /8760 = 0.9 x 307.1 /8760 = 0.0316 kW

Unit Dth Savings per Year = 0

Methodology and Assumptions:

Energy Savings is determined by estimating typical annual energy consumption for home electronics and applying the Energy Reduction Percentage (ERP) determined from field evaluation. The most applicable source for base consumption was determined to be a recent Midwest study in Minnesota. The best source for Tier 2 savings, the ERPs, was determined to be the large study in California. This estimation applies only to residential home entertainment electronics.

References:

1. "Electricity Savings Opportunities for Home Electronics and Other Plug-In Devices in Minnesota Homes", Energy Center of Wisconsin, May 2010.
2. CF Values of Standby Losses for Entertainment Center and Home Office in Efficiency Vermont TRM, 2013, pg 16
3. Estimated based on CalPlug's findings of activity distribution by daytime from data collected between 2007-2011

Document Revision History:

Version / Description	Author	Date
1.0 Document Created	Franklin Energy Service	10/15/15

Residential – Variable Speed Pool Pumps

Version No. 1.0

Measure Overview

Description: This measure involves installation of variable speed pool pumps to replace single speed units.

Actions: Replace Working, Replace on Fail, New Construction
Target Market Segments: Residential
Target End Uses: Misc. Electric Loads

Applicable to: Residential customers.

Algorithms

Unit kWh Savings per Year = (V_pool x N_turnovers) * (1/EF_ss - 1/EF_vs) * Days / C1

Unit Peak kW Savings = Unit kWh Savings per Year / (Days * C2) x CF

Unit Dth Savings per Year = 0

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 1, Page 10)

Unit Participant Incremental Cost = $809 (Ref. 2, Page 18)

Where:

EF_ss = 2.0 gal/Wh. Energy Factor of single-speed (baseline) pool pump. (Ref. 2, Page 33)

EF_vs = 8.37 gal/Wh. Energy Factor of single-speed (baseline) pool pump. (Ref. 3)

V_pool = 22,000 gallons, if unknown. Volume of swimming pool. (Ref. 2, Page 33)

N_turnovers = 2 turnovers/day; (Ref. 2, Page 33)

Days = 122 days; Annual day pool is in operation. (Ref. 2, Page 33)

C1 = 1,000 W/kW

C2 = 24 hr/day

CF = 0.52 (Ref. 6)

Required from Customer/Contractor: Model number, Pool Size

Example:

A residential customer installed a new variable speed pool pump..

*Unit kWh Savings per Year = (22,000 gal * 2 turnovers/day) * (1/2.0 EF - 1/8.37 EF) * 122 days / (1000 W / kW) = 2,043 kWh*

*Unit Peak kW Savings = 2,043 kWh / (122 days * 24 hr/day) * 0.52 = 0.363 kW*

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. “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. http://library.cee1.org/sites/default/files/library/9986/cee_res_swimmingpoolinitiative_07dec2012_pdf_10557.pdf.

3. Average Energy Factor for variable speed pumps in the California Appliance Database. See 'CA Appliance Summary' tab. Accessed on 5/21/15. http://www.appliances.energy.ca.gov/SearchResults.aspx. .

4. Evaluation of Year 2001 Summer Initiatives Pool Pump Program, Pacific Gas & Electric Company. Page 3-1.

Documentation Revision History:

Version / Description	Author	Date
1. Measure created	Franklin Energy Services	11/10/2015

Gas Efficiency Measures

C/I Envelope – Loading Dock Door and Pit Seals

Version No. 1.0

Measure Overview

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.
Actions: Modify, New Construction
Target Market Segments: Commercial, Industrial, Public
Target End Uses: Envelope

Applicable to: Commercial and Industrial customer facilities with loading docks

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = C_1 x Average Infiltration CFM x HDD_{65} x C_2 x t_{week} / C_3 / Eff / C_4

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10

Unit Participant Incremental Cost = $ 2,857 Dock Door Seals, $780 for Pit/Ramp Seals

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, in^2

C_{stack} = Stack Coefficient, 0.0225 Assuming a 1.5 story building (Ref. 1)

T_{set} = Temperature Setpoint, typically 68°F

T_{ave} = Average Winter Temperature, see Table 1 for heating design 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_{65} = Heating Degree Days, see Table 1 for heating degree-days for the climate zone at a base of 65 degrees

t_{week} = 10 hours per week for dock doors, 168 hours per week for pit ramps

Eff = Heating System Efficiency, 80% for a typical heating system

C_1 = 1.04 Btu/CFM

C_2 = 24 hours/day

C_3 = 168 hours/week

C_4 = 1,000,000 Btu/Dth

Required from Customer/Contractor: Leak area of existing dock doors and pits, climate zone, HVAC system.

Example:

Door Seals: A single loading dock with leaks along the door measuring 20in² for a warehouse in Minneapolis is installing seals.

Average Infiltration CFM = 20 in² x √(0.0225 x (68 °F - -16.5 °F) + 0.0138 x ((10.3 mph)²)) = 36.7 CFM

Unit Dth Savings per Year = 1.04 Btu/CFM x 36.7 CFM x 8,512 HDD x 24 hr/day x 10 hours/week / 168 hours/week / 80% Efficiency / 1,000,000 Btu/Dth = 0.580 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 (Ref. 2)	9,833	8,512	7,651
Heating design temperature (°F) (Ref. 3)	-22.0 °F	-16.5 °F	-14.5 °F
Average wind speed (mph) (Ref. 4)	9.5	10.3	11.5

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. 2013 ASHRAE Handbook - Fundamentals, Climate Design Information Appendix Table, Minnesota Heating DB 99.6%

4. 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

Documentation Revision History:

Version / Description	Author	Date
1. Created standalone Specification Loading Dock Door and Pit Seals	FES	11/12/15

C/I HVAC - Destratification Fan

Version No. 1.2

Measure Overview

Description: This measure analyzes the heating savings potential of destratification fans in new and existing buildings. Includes High Volume Low Speed and High Volume High Speed fans.

Actions: New Construction (addition on new or existing building)

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.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (U x A x ΔT_C x HH x HrsPerDay/24) / η / 1,000,000

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 years (ref 1)

Unit Participant Incremental Cost = See Table 1 (ref 2)

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

Required from Customer/Contractor: Ceiling height, area being destratified, project location (county)

Optional from Customer/Contractor: Heat transfer coefficient for roof, area being destratisfied in square feet, hours per day of fan operation in heating season, heating system efficiency

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

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

Documentation Revision History:

Version	Description	Author	Date
1.	New savings specification for retrofit/incorporation of destratification fans.	FES	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	JP	2/12/2013
1.2	Corrected typos in algorithm, added heating system efficiency to optional inputs	JP	4/2/2014

C/I HVAC - Infrared Heater

Version No. 2.0

Measure Overview

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.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial, Industrial
Target End Uses: HVAC

Applicable to: Commercial customers with natural gas fired forced air heating systems

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = Pre_Annual_Consumption x (1 - Load_Reduction_Factor)

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years): 15 (Ref. 1)

Unit Participant Incremental Cost: $1,716 (Ref. 2)

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

Required from Customer/Contractor: New infrared heater input Btu/h, project location (county).

Example:

A 300 Mbtuh infrared heater is installed to replace a furnace of the same size in an existing Manfacturing 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

Minnesota	Zone 1	Zone 2	Zone 3
	(Northern MN)	(Central MN)	(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.

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 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. *2009 ASHRAE Fundamentals Handbook Table 1A Heating and Wind Design Conditions, Heating DB 99.6%*

Documentation Revision History

Version / Description	Author	Date
1. Original document.	FES	7/30/2012
1.1 Added Industrial to Market Segments, corrected use of Btu/Dth conversion factor in algorithm, changed measure name.	JP	2/12/2013

2.0	Changed from Heating Degree Days to $EFLH_{Heat}$. Updated Table 2 to include building types.	FES	11/12/2015

C/I HVAC - Steam Trap

Version No. 3.0

Measure Overview

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.

Actions: Replace on Fail
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

Measure Overview

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = Rate_Loss x h_fg x Loss_Factor x $EFLH_{Heat}$ x CCF_Space Heating / Heat_Eff / Conversion_Factor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 6 (Ref. 1)

Unit Participant Incremental Cost: Use actual or refer to Table 4 if unavailable

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 8760.

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%

Conversion_Factor = 1,000,000 Btu/Dth

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

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 Btu/hr

Dth Savings per Year = 9.2 Btu/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. 4)
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. 5)

Building Type - Application	Zone 1	Zone 2	Zone 3
Production End-use (Ref. 7)	4,567	4,567	4,567
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. 6)

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 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

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.

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. 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.

4. FES determined. 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

Documentation Revision History:

Version / Description	Author	Date
1. Original from Nexant with extraneous tabs hidden	Nexant	
1. Changed measure life and measure life source	FES	7/31/2012
1. Changed incremental cost and cost source	FES	7/31/2012
1. Updated HDD65 and design temperatures based on new 30-year averages.	FES	7/31/2012
1. The references for HDD65, design temperatures, and tune-up savings were changed.	FES	7/31/2012
1. Changed EFLH assumptions and sources	FES	7/31/2012
1. Changed algorithm	FES	7/31/2012
1. Added the variables Oversize_Factor, Conversion_Factor, and Loss_Factor	FES	7/31/2012

2. 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	JP	3/4/2013
3. Changed to $EFLH_{heat}$ algorithm. Added Table 1	FES	11/12/2015

Commercial HVAC - Boiler Modifications, Space Heating Only

Version No. 4.0

Measure Overview

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[2] 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.
- 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

Actions: Operations & Maintenance, Modify
Target Market Segments: Commercial, Industrial
Target End Uses: HVAC, Industrial Process

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[2] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up

Applicable to: Commercial and industrial customers with HVAC boilers

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (Percent Savings) x (Pre-Annual Consumption)

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years): See Table 2

Unit Participant Incremental Cost: Use actual cost of modification. Table 2 figures may be used for planning estimates.

Where:

Pre-Annual Consumption (Dth/yr) = BTUH_In x Load_Factor x $EFLH_{Heat}$ / ConversionFactor

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

Percent Savings = percent of the pre-modification annual consumption saved. See Table 2.

Required from Customer/Contractor: Modification type, nominal pre-modification Btu/h input, project location (county), facility type.

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	Percent 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	2% (Ref. 5)	$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.

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.

Documentation Revision History:

Version	Description	Author	Date
3.6	Changed to EFLH Heating and revised Boiler Tune-Up Efficiency	FES	11/12/15

Commercial HVAC - Boilers, Space Heating Only

Version No. 4.0

Measure Overview

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.

Actions: New Construction, Replace on Fail, Replace Working
Target Market Segments: Commercial
Target End Uses: HVAC

Applicable to: Commercial customers with HVAC boilers

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = BTUH_In x Load_Factor x $EFLH_{Heat}$ x Eff_High x (1/Eff_Base - 1/Eff_High) / ConversionFactor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years): 20 (Ref. 1)

Unit Participant Incremental Cost: See Table 2.

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 at actual operating conditions, as estimated by customer/contractor.

ConversionFactor = 1,000,000 Btu/Dth

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.

Example:

A 1,000 kBtuh 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)

High Efficiency Replacement Boiler Type	High Efficiency Boiler Efficiency Range*	Baseline Efficiency*	Incre-mental Cost ($ / kBtuh)
Steam, < 300 kBtu/h	82+% AFUE	75% 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	80% CE	$1.02
Steam, natural draft, > 2500 kBtu/h	83-85% CE	80% CE	$1.02
Mid-Efficiency Hot Water, < 300 kBtu/h	84.5-88% AFUE	80% 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	80% 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.

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 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	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 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. 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 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 Efficiency Program for Certain Commercial and Industrial Equipment, Subpart E - Commercial Packaged Boilers. January 1, 2010.

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)

Documentation Review History

Version / Description	Author	Date
4.0 Changed from Heating Degree Days to $EFLH_{Heat}$. Updated Table 2 to include building types.	FES	11/12/2015

Commercial HVAC – Condensing Unit Heaters

Version No. 1.0

Measure Overview

Description: This measure applies to a gas fired condensing unit heater installed in a commercial application.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: HVAC

Applicable to: Commercial Customers

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

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

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $676 (Ref. 2)

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

Required from Customer/Contractor: Input capacity of the new condensing unit heater, project location, thermal efficiency

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/Misc	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.

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%.

Documentation Revision History:

Version / Description	Author	Date
1. Created standalone Specifications for Condensing Unit Heaters	FES	11/10/15

Commercial HVAC - Energy Recovery Ventilator

Version No. 2.1

Measure Overview

Description: This measure includes replacement of existing unitary equipment or the optional addition of energy recovery on existing unitary equipment. This measure analyzes the heating savings potential of an energy recovery ventilator on unitary equipment. This measure is applicable to all gas-fired heated air systems.

Actions: Replace on Fail, Replace Working, Modify
Target Market Segments: Commercial & Industrial
Target End Uses: HVAC

Applicable to: Commercial & Industrial customers where air unitary equipment has been/could be installed.

Algorithms

Unit kWh Savings per Year = 0 (ref. 11)

Unit Peak kW Savings = ((((4.5 x CFM x Δh_cooling) / 12,000) x 12 / EER x ERV_E)– CFM x PD / 6356 / Eff_Motor / Eff_Fan x 0.746 x 2) x CF

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

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 years (ref. 1)

Unit Participant Incremental Cost = See Table 3 (ref. 2)

Where:

CF = Coincidence Factor = 0.9 (ref. 8)
CFM = Outside Air flow in cubic feet per minute

EER = Provided by customer. If SEER provided, SEER x 0.875 (ref. 10). If value not provided use default values in Table 2. (ref. 9).

Eff_Fan = Efficiency of Fan. Provided by customer. If value not provide assume 0.705 (Ref. 13)

Eff_Motor = Efficiency of Motor. Provided by customer. If value not provide 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 operation per day. 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. Provided by customer. If value is not provided see values in Table 3. (ref. 7)

T_indoor = Customer provided indoor conditioned space temperature in °F. See Table 1 for default values if not provided.

T_design = the equipment design temperature of the climate zone. See Table 1. (ref. 4)

η = Efficiency of heating equipment. Assume 0.8 (ref 6) 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 1 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

12,000 = Conversion factor for BTUH to Ton of Refrigeration

1,000,000 = Conversion factor for BTU to Dth

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)

*If heat recovery control strategy uses full air flow by-pass for operation at temperatures causing freezing of condensate, multiply ERE_E by 0.75 if not adjusted by manufacturer or customer.

Required from Customer/Contractor: ERV type, outside air cfm, building hours of operation, project location (county), facility age and type, cooling system type.

Example:

Install a 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 on average 12 hours per day. The cooling system utilizes an Air Cooled Chiller.

Unit peak kW Savings = (((4.5 x 1500 x (34.81– 22.75) / 12,000) x 12 / 15 x 0.647) - (1,500 x 0.00012 / 6356 / 0.705 / 0.855 x 0.746 x 2)) x 0.9 = 3.16 kW

Unit Dth Savings per Year = ((4.5 x 1500 x (22.75 – (-3.29)) / 0.8) x (7651 x 24) / (70.0 – (-14.5)) x (12 / 24) / 1,000,000 x 0.647 x 0.75 = 115.8 Dth

Deemed Input Tables:

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

	Design Day Heating Outside Air Conditions		Design Day Cooling Outside Air Properties	Return Air Conditions		HDD65
Zone #	Heating (°F) (Ref. 4)	Enthalpy (Btu/lb) (Ref. 12)	Enthalpy (Btu/lb) (Ref. 12)	Temp. (°F)	Enthalpy (Btu/lb) (Ref. 12)	(Ref. 9)
Northern: #1	-22.0	-5.16	31.49	70.00	22.75	9833
Central: #2	-16.5	-3.79	34.79	70.00	22.75	8512
Southern/ Twin Cities: #3	-14.5	-3.29	34.81	70.00	22.75	7651

Table 2: EER values for various equipment (ref.9).

Equipment Type#	EER
Air Cooled Air Conditioner	8.4
Air/Water Cooled Chiller	15.0
Air Cooled Heat Pumps	8.6

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

Energy Recover Type	Total Heating Effectiveness (Ref.7)	Pressure Drop /CFM Inches WC/CFM (Ref. 7)	Incremental Cost** /CFM (Ref. 2)
Fixed Plate – (Sensible Heat Only)	0.355	0.00035	$6
Fixed Plate – (Sensible and Latent Heat)	0.577	0.00074	$6
Fixed Plate - Unknown	0.466	0.00055	$6
Rotary Wheel	0.647	0.00012	$6
Heat Pipe	0.31	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 o

not include any savings from reduced energy for humidification.

Studies have shown that the cooling savings have been offset by the increased fan energy in all areas of MN.

Notes:

Table 4: Exhaust Energy Recovery Requirement

CLIMATE ZONE	PERCENT (%) OUTDOOR AIR AT FULL DESIGN AIRFLOW RATE					
	≥ 30% and < 40%	≥ 40% and < 50%	≥ 50% and < 60%	≥ 60% and < 70%	≥ 70% and < 80%	≥ 80%
	DESIGN SUPPLY FAN AIRFLOW RATE (cfm)					
6A (MN)	≥ 5500	≥ 4500	≥ 3500	≥ 2000	≥ 1000	> 0
7*	≥ 2500	≥ 1000	> 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 Trail, Pennington, Pine, Polk, Red Lake, Roseau, St. Louis, Wadena, Wilkin

Code requires Energy Recovery Ventilation for most applications based upon the table above.

The "green code" ASHRAE Standard 189 further reduces outdoor air thresholds requiring ERV and increases minimum ERV effectiveness to 60%.

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 75° F, FES

6. Assumed standard combustion efficiency of heating equipment, FES

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 1.0 with most being very close to 0.9, primary data has not been identified.

9. ASHRAE Standard 90.1-1989. FES assumed baseline.

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 = 0.875 x SEER for single stage equipment.

11. It is assumed cooling savings are equal to the increased fan energy usage.

12. Values calculated using Trane HDPsyChart Professional Edition, Version 3.1.61 assuming 50% relative humidity.

13. Average Fan efficiency for centrifugal fans from the Energy Efficiency Guide Book (2004), Chapter 5,

14. Assumed average 5 HP Nema EPAct Open Frame motor efficiency.

15. Franklin Energy Services estimate of operational hours.

Documentation 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.	FES	1/1/16
2.1	Changed to total (sensible and latent) energy savings.	FES	1/1/16

Commercial HVAC - Exhaust Energy Recovery

Version No. 2.1

Measure Overview

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.

Actions: Replace Working, New Construction, Modify
Target Market Segments: Commercial & Industrial
Target End Uses: HVAC

Applicable to: Commercial & Industrial customers where energy can be recovered from exhausted air.

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)

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 years (Ref. 1)

Unit Participant Incremental Cost = See Table 1 (Ref.

2)

Where:

CFM = Exhaust Air flow in cubic feet per minute

Eff_Fan = Efficiency of Fan. Provided by customer. If value not provide assume 0.69 (Ref. 10)

Eff_Motor = Efficiency of Motor. Provided by customer. If value not provide assume 0.855 (Ref. 11)

ERV_E = Sensible Energy Effectiveness of ERV. Provided by manufacturer/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.

Where:

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)

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.

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

5. Analysis of AHRI listed devices available 1/1/2016.

6. Laboratories for the 21st Century: Best Practices, Energy Recovery for Ventilation Air in Laboratories, Dept. of Energy, DOE/GO-102003-1774, October 2003.

7. 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.

8. Responsible Energy, Reheat for Commercial Buildings, Madison Gas & Electric, GS1889, 10/28/2015

9. Trane Engineering Newsletter Volume 36-2, Energy Savings Strategies for Water Source Heat Pump Systems, ADM-APN024-EN (May 2007)

10. Average Fan efficiency from the Energy Efficiency Guide Book (2004), Chapter 5, Bureau of Energy Efficiency, Government of India.

11. Assumed average 5 HP Nema EPAct Open Frame motor efficiency.

12. 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.

Documentation Revision History:

Version	Description	Author	Date
1	New savings specification for retrofit/incorporation of energy recovery.	FES	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	JP	3/13/2013
1.2	Added New Construction and Modify to Action Types	JP	11/24/13
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.	JP	8/1/2014
2.0	Corrected reference numbering. Changed equation format to be consistent with other measures.	FES	11/12/2014
2.1	Changed to sensible only based equation. Removed EFLH. Added kW and kWH penalties, corresponding references and heating application table.	FES	1/12/2016

Commercial HVAC - Forced-Air Heating Maintenance

Version No. 2.0

Measure Overview

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.

*Applies to heating equipment in space heating applications only.

Actions: Operations & Maintenance

Target Market Segments: Commercial

Target End Uses: HVAC

Applicable to: Commercial customers with natural gas fired, forced-air heating systems

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (Percent Savings) x (Pre-Annual Consumption)

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years): 2 (Ref. 1)

Unit Participant Incremental Cost: $0.83/MBtuh (Ref. 2) Where:

Pre-Annual Consumption (Dth/yr) = Btuh_In x Load_Factor x $EFLH_{Heat}$ / Conversion_Factor

Percent Savings = percent 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

Required from Customer/Contractor: Nominal Btu/h input of heating system, project location (county), building type

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.

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.

Documentation Revision History:

Version / Description	Author	Date
1. Original document.	FES	7/30/2012
1.1 Changed name	JP	2/11/2013
2.0 Changed from Heating Degree Days to $EFLH_{Heat}$. Updated Table 2 to include building types.	FES	11/12/2015

Commercial HVAC - Programmable Thermostats with Gas Heating

Version No. 1.0

Measure Overview

Description: This measure includes replacement of failed or working manual thermostats in existing commercial businesses with programmable thermostats. New units must have the capability to adjust temperature setpoints according to a schedule without manual intervention. An estimate is provided for reduced heating energy consumption through temperature set-back during unoccupied or reduced demand times. Savings are provided for heating only as a literature review has not shown conclusive cooling savings. 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.

Actions: Replace on Fail, Replace Working
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.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = HCgas x HSF x ISR

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 8 (Ref. 1)

Unit Participant Incremental Cost: $181 (Ref. 2)

Where:

HCgas = Heating consumption for gas heated businesses, see Table 1. (Ref. 3)

Where:

HCgas = $EFLH_{Heat}$ x BTUH_IN x Load_Factor / Conversion_Factor

Where:

$EFLH_{Heat}$ = Equivalent Full Load Hours heating, See Table #1. (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)

Load_Factor = the load factor, assumed to be 0.77 (implies 30% oversizing) (ref. 5)

Conversion_Factor = 1,000,000 Btu/Dth

HSF = Heating Savings Factor, assumed fraction reduction in heating energy consumption due to programmable thermostat, HSF = 0.05 (Ref. 6)

ISR = In-Service Rate, the percentage of units installed and programmed effectively, Table 2. (Ref. 7)

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)

Examples:

Retrofit a manual thermostat with a programmable thermostat in a gas heated strip mall retail store Climate Zone 1, via a direct installation program delivery.

HCgas = 1701 x 100,000 x 0.77 / 1,000,000 = 131.0 Dth

Unit Dth Savings per Year = 131.0 x 0.05 x 1.0 = 6.55 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	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: In-Service Rates (Ref. 7)

Program Delivery	ISR
Direct Install	1.0
Other, or unknown	0.56

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.

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. 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

7. “Programmable Thermostats. Report to KeySpan Energy Delivery on Energy and Cost Effectiveness,” GDS Associates, Marietta, GA. 2002

Documentation Revision History:

Version/Description	Author	Date
1) New Measure	FES	11/12/2015

Commercial Food Service – ENERGY STAR Gas Combination Oven

Version No.

1.3

Measure Overview

Description:

This measure includes the replacement of a gas combination oven with an ENERGY STAR gas combination oven, or installation of an ENERGY STAR combination oven in new construction.

ENERGY STAR combination ovens incorporate timesaving features via sophisticated control packages.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (Eday_base - Eday_prop) / Conversion Factor x Day

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $5,717 (Ref. 2)

Where:

Eday_base (Btu/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs - LBFood / PC_base - T_pre / 60] + E_pre_base

Eday_prop (Btu/day) = LBFood x Efood / Eff_prop + IdleRate_prop x [OpHrs - LBFood / PC_prop - T_pre / 60] + E_pre_prop

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 (Ref. 6)

Eff_prop = 48.5% (Ref. 6)

IdleRate_base = 28,000 Btu/hr; Idle Energy Rate (Ref. 2)

IdleRate_prop = 14,000 Btu/hr (Ref. 7)

OpHrs = 8 hrs/day; Daily operating hours (Ref. 5)

PC_base = 80 lbs/hr; Production Capacity (Ref. 2)

PC_prop = 120 lbs/hr (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = 18,000 Btu/day; Preheat energy (Ref. 2)

E_pre_prop = 13,000 Btu/day (Ref. 2)

Days = See Table 1

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: building type

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) / (48.5%) + [14,000 Btu/hr x (8 hrs/day - (200 lbs/day / 120 lb/hr) - (15 min / 60 min/hr))] + 13,000 Btu/day = 201,259 Btu/day

Unit Dth Savings per Year = (307,857 Btu/day - 201,259 Btu/day) / 1,000,000 Btu/Dth x 365.25 days/yr = 38.9 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:

Table 2: ENERGY STAR Gas Combination Oven Criteria (Ref. 6, 7)

Operation	Idle Rate, Btu/h	Cooking-Energy Efficiency, %
Steam Mode	≤ 200P+6,511	≥ 41
Convection Mode	≤ 150P+5,425	≥ 56
Average (assuming 6-pan unit)	**14,000**	**48.5**

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. Average of steam and convection cooking efficiencies listed in ENERGY STAR Commercial Ovens Key Product Criteria, Version 2.1. http://www.energystar.gov/index.cfm?c=ovens.pr_crit_comm_ovens. Accessed 7/9/14.

7. Sum of steam and convection oven idle rates (summed because they can be used simultaneously), assuming 6-pans to be conservative, rounded to nearest tenth. Ref. 5.

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/27/2012
1.1 Renamed measure	JP	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	JP	7/31/2014

Commercial Food Service – ENERGY STAR Gas Convection Oven

Version No. 2.0

Measure Overview

Description:

This measure includes installation of high efficiency ENERGY STAR gas convection ovens instead of standard efficiency units. Energy efficient commercial gas ovens reduce energy consumption primarily through sophisticated control package.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (Eday_base - Eday_prop) / Conversion Factor x Days

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $1,886 (Ref. 2)

Where:

Eday_base (Btu/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs - LBFood / PC_base - T_pre / 60] + E_pre_base

Eday_prop (Btu/day) = LBFood x Efood / Eff_prop + IdleRate_prop x [OpHrs - LBFood / PC_prop - T_pre / 60] + E_pre_prop

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 energy efficiency (Ref. 2)

Eff_prop = 46% (Ref. 4)

IdleRate_base = 18,000 Btu/hr; Idle Energy Rate (Ref. 2)

IdleRate_prop = 13,000 Btu/hr (Ref. 4)

OpHrs = 8 hrs/day; Daily operating hours (Ref. 5)

PC_base = 70 lbs/hr; Production Capacity (Ref. 2)

PC_prop = 80 lbs/hr (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = 19,000 Btu/day; Preheat energy (Ref. 2)

E_pre_prop = 11,000 Btu/day (Ref. 2)

Days = See Table 1

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: building type

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_prop (Btu/day) = (100 lbs/day) x (250 Btu/lb) / (46%) + [13,000 Btu/hr x (8 hrs/day - (100 lbs/day / 80 lb/hr) - (15 min / 60 min/hr))] + 11,000 Btu/day = 149,848 Btu/day

Unit Dth Savings per Year = (216,119 Btu/day – 149,848 Btu/day) / 1,000,000 Btu/Dth x 365.25 days/yr = 24.2 Dth

Deemed Input Tables:

Table 1: Operation Days by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365.25
Sit-Down Restaurant	365.25
Grocery	365.25
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Hotel	365.25
Other Commercial	250

Notes:

There is no code requirement for this technology.

ENERGY STAR requires that Full Size Gas Ovens have a cooking energy efficiency ≥ 44% and an idle energy rate ≤ 13,000 Btu/h (Ref. 4)

References:

1. 2008 Database for Energy Efficient Resources, Version 2008.2.05, EUL/RUL Values, October 10, 2008.

2. Commercial 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. Commercial Ovens Key Product Criteria, http://www.energystar.gov/index.cfm?c=ovens.pr_crit_comm_ovens. Accessed August, 15, 2012.

5. Technology Assessment: Ovens, Food Service Technology Center, 2002. Page 7-22. http://www.fishnick.com/equipment/techassessment/7_ovens.pdf

Documentation Revision History

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/14/2012
1.1 Renamed measure	JP	2/8/2013
2.0 Updated ENERGY STAR efficiency requirements	FES	11/11/2015

Commercial Food Service – ENERGY STAR Gas Fryer

Version No. 1.1

Measure Overview

Description: This measure includes installation of high efficiency ENERGY STAR gas fryers 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.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (Eday_base - Eday_prop) / Conversion Factor x Days

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $1,219 (Ref. 2)

Where:

Eday_base (Btu/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs - LBFood / PC_base - T_pre / 60] + E_pre_base

Eday_prop (Btu/day) = LBFood x Efood / Eff_prop + IdleRate_prop x [OpHrs - LBFood / PC_prop - T_pre / 60] + E_pre_prop

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%; Heavy load cooking energy efficiency (Ref. 2)

Eff_prop = 50% (Ref. 2)

IdleRate_base = 14,000 Btu/hr; Idle Energy Rate (Ref. 2)

IdleRate_prop = 9,000 Btu/hr (Ref. 2)

OpHrs = 12 hrs/day; Daily operating hours (Ref. 5)

PC_base = 60 lbs/hr; Production Capacity (Ref. 2)

PC_prop = 65 lbs/hr (Ref. 2)

T_pre = 15 min/day; Preheat Time (Ref. 2)

E_pre_base = 16,000 Btu/day; Preheat energy (Ref. 2)

E_pre_prop = 15,500 Btu/day (Ref. 2)

Days = See Table 1

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: building type

Example:

A grocery store installed a new ENERGY STAR Gas Fryer

Eday_base (Btu/day) = (150 lbs/day) x (570 Btu/lb) / (35%) + [14,000 Btu/hr x (12 hr/day - (150 lbs/day / 60 lb/hr) - (15 min / 60 min/hr))] + 16,000 Btu/day = 389,785 Btu/day

Eday_prop (Btu/day) = (150 lbs/day) x (570 Btu/lb) / (50%) + [9,000 Btu/hr x (12 hr/day - (150 lbs/day / 65 lb/hr) - (15 min / 60 min/hr))] + 15,500 Btu/day = 271,481 Btu/day

Unit Dth Savings per Year = (389,785 Btu/day - 271,481 Btu/day) / 1,000,000 Btu/Dth x 365.25 days/yr = 43.2 Dth

Deemed Input Tables:

Table 1: Operation Days by Building Type (Ref. 3)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365.25
Sit-Down Restaurant	365.25
Grocery	365.25
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Hotel	365.25
Other Commercial	250

Notes:

There is no code requirement for this technology.

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 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 Fryers Key Product Criteria,* http://www.energystar.gov/index.cfm?c=fryers.pr_crit_fryers. Accessed August, 15, 2012.

5. *Technology Assessment: Fryer,* Food Service Technology Center, 2002. Page 2-20. http://www.fishnick.com/equipment/techassessment/2_fryers.pdf

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/14/2012
1.1 Changed measure name	JP	2/8/2013

Commercial Food Service – ENERGY STAR Gas Griddle

Version No. 1.1

Measure Overview

Description: This measure includes installation of high efficiency ENERGY STAR gas griddles instead of standard efficiency units. Energy efficient commercial gas griddles reduce energy consumption primarily through advanced burner design and controls.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (Eday_base - Eday_prop) / Conversion Factor x Days

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $1,912 (Ref. 6)

Where:

Eday_base (Btu/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs - LBFood / PC_base - T_pre / 60] + E_pre_base

Eday_prop (Btu/day) = LBFood x Efood / Eff_prop + IdleRate_prop x [OpHrs - LBFood / PC_prop - T_pre / 60] + E_pre_prop

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_prop = 38% (Ref. 4)

IdleRate_base = 19,000 Btu/hr; Idle Energy Rate (Ref. 2)

IdleRate_prop = 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_prop = 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_heat = 15,000 Btu/day (Ref. 2)

Days = See Table 1

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: building type

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_base (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 365.25 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	365.25
Sit-Down Restaurant	365.25
Grocery	365.25
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Hotel	365.25
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.*

Documentation Revision History

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/14/2012
1.1 Renamed measure	JP	2/8/2013

Commercial Food Service – ENERGY STAR Gas Steamer

Version No. 1.0

Measure Overview

Description: This measure includes replacement of commercial gas steamers with new 5 or 6-pan ENERGY STAR gas steamers.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (Eday_base - Eday_prop) / Conversion Factor x Days

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $3,732 (Ref. 2)

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_prop (Btu/day) = LBFood x Efood / Eff_prop + (IdleRate_prop + Res_Rate_prop) x (OpHrs - LBFood / PC_prop - T_pre / 60) + E_pre_prop

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_prop = 38% (Ref. 2)

IdleRate_base = See Table 1; Idle Energy Rate (Ref. 2)

IdleRate_prop = See Table 1 (Ref. 2)

OpHrs = 12 hrs/day; Daily operating hours (Ref. 2)

PC_base = See Table 1; Production Capacity (Ref. 2)

PC_prop = See Table 1 (Ref. 2)

Res_Rate_base = 45,080 Btu/h; Residual Energy Rate (Ref. 2)

Res_Rate_prop = 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_prop = 9,000 Btu/day (Ref. 2)

Days = See Table 2

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: building type, number of pans (5 or 6)

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_prop (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 365.25 days/yr = 203.6 Dth

Deemed Input Tables:

Table 1: Steamer Characteristics

	5-Pan Steamer	6-Pan Steamer
LBFood (lbs/day)	83	100
Efood (Btu/lb)	105	105
Eff_base (%)	15%	15%
Eff_prop (%)	38%	38%
IdleRate_base (Btu/hr)	13,333	16,000
IdleRate_prop (Btu/hr)	10,400	12,500
OpHrs (hrs/day)	12	12
PC_base (lbs/hr)	117	140
PC_prop (lbs/hr)	100	120
Res_Rate_base (Btu/h)	45,080	45,080
Res_Rate_prop (Btu/h)	1,658	1,658
T_pre (minutes)	15	15
E_pre_base (Btu)	18,000	18,000
E_pre_prop (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	365.25
Sit-Down Restaurant	365.25
Grocery	365.25
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Hotel	365.25
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):

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.

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/27/2012

Commercial Food Service - Gas Conveyor Oven

Version No.

1.1

Measure Overview

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.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (Eday_base - Eday_prop) / Conversion Factor x Days

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $1,751 for small; $4,731 for large (Ref. 2)

Where:

Eday_base (Btu/day) = nPizza x Efood / Eff_base + IdleRate_base x [OpHrs - nPizza / PC_base - T_pre / 60] + E_pre_base

Eday_prop (Btu/day) = nPizza x Efood / Eff_prop + IdleRate_prop x [OpHrs - nPizza / PC_prop - T_pre / 60] + E_pre_prop

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_prop = 42% (Ref. 2)

IdleRate_base = See Table 1; Idle Energy Rate (Ref. 2)

IdleRate_prop = See Table 1 (Ref. 2)

OpHrs = 10 hrs/day; Daily operating hours (Ref. 4)

PC_base = See Table 1; Production Capacity (Ref. 2)

PC_prop = 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_prop = See Table 1 (Ref. 2)

Days = See Table 2

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: building type, width of conveyor (≤ 25"or > 25")

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_prop (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 365.25 days/yr = 61.7 Dth

Deemed Input Tables:

Table 1: Conveyor Characteristics

	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_prop (%)	42%	42%
IdleRate_base (Btu/hr)	45,000	70,000
IdleRate_prop (Btu/hr)	29,000	57,000
OpHrs (hrs/day)	10	10
PC_base (pizzas/hr)	55	150
PC_prop (pizzas/hr)	75	225
T_pre (minutes)	15	15
E_pre_base (Btu)	16,000	35,000
E_pre_prop (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	365.25
Sit-Down Restaurant	365.25
Grocery	365.25
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Hotel	365.25
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

Documentation Revision History:

Version / Description	Author	Date
1) Put together algorithm	Franklin Energy Services	8/27/2012
1.1) Replaced LBFood in algorithms with nPizza, changed measure name	JP	2/8/2013

Commercial Food Service - Gas Oven, Broiler, Pasta Cooker

Version No.

3.1

Measure Overview

Description: This measure includes replacement of failed or working gas food service equipment with new high efficiency food service equipment.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = HVAC_Savings_Factor x BTUH_In / 1,000 kWh/Wh

Unit Peak kW Savings = 0

Unit Dth Savings per Year = BTUH_In x BTU_Savings_Factor / 1,000,000

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 2)

Unit Participant Incremental Cost = See Table 1

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)

Required from Customer/Contractor: Input Btu/h of new equipment, new equipment type

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*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

Documentation Revision History:

Version / Description	Author	Date
1. Original from Nexant with extraneous tabs hidden	Nexant	
2. 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	JP	
2.1 Corrected algorithm to add conversion factor from Btu to MMBtu	JP	
2.2 Corrected algorithm to add conversion factor from Btu to kWh/yr (multiply by 1e-3 to divide by 1,000)	SK	
3. Removed measures per note above and reformatted	Franklin Energy Services	8/29/2012
3.1 Renamed measure	JP	2/8/2013

Commercial Food Service - Gas Rack Oven

Version No.

1.1

Measure Overview

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.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: Food Service

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (Eday_base - Eday_prop) / Conversion Factor x Days

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 12 (Ref. 1)

Unit Participant Incremental Cost = $4,933 for single-rack; $5,187 for double-rack (Ref. 2)

Where:

Eday_base (Btu/day) = LBFood x Efood / Eff_base + IdleRate_base x [OpHrs - LBFood / PC_base - T_pre / 60] + E_pre_base

Eday_prop (Btu/day) = LBFood x Efood / Eff_prop + IdleRate_prop x [OpHrs - LBFood / PC_prop - T_pre / 60] + E_pre_prop

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_prop = 50% (Ref. 2)

IdleRate_base = See Table 1; Idle Energy Rate (Ref. 2)

IdleRate_prop = See Table 1 (Ref. 2)

OpHrs = 8 hrs/day; Daily operating hours (Ref. 4)

PC_base = See Table 1; Production Capacity (Ref. 2)

PC_prop = 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_prop = See Table 1 (Ref. 2)

Days = See Table 2

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: building type, single or double rack

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_prop (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_prop (%)	50%	50%
IdleRate_base (Btu/hr)	43,000	65,000
IdleRate_prop (Btu/hr)	29,000	35,000
OpHrs (hrs/day)	8	8
PC_base (lbs/hr)	130	250
PC_prop (lbs/hr)	140	280
T_pre (minutes)	20	20
E_pre_base (Btu)	50,000	100,000
E_pre_prop (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	365.25
Sit-Down Restaurant	365.25
Grocery	365.25
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Hotel	365.25
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

Documentation Revision History:

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	8/27/2012
1.1 Changed measure name, added single or double rack as required input from customer/contractor	JP	9/12/2013

Commercial Hot Water - Faucet Aerator (1.5 gpm) with Gas Water Heater

Version No.

4.0

Measure Overview

Description: This measure includes replacing an existing faucet aerator with low-flow aerator.

Actions: Replace Working
Target Market Segments: Replace Working
Target End Uses: DHW

Applicable to: Commercial facilities with gas water heaters. Measure includes installation of 1.5 GPM aerators only.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = ((GPM_base - GPM_low) x L x NOPF x Days x DF / GPMfactor) x EPG

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 1)

Unit Participant Incremental Cost = $6.70 (Ref. 6)

Where:

EPG = Density x Specific Heat x (Tfaucet - Tcold) / (ReEff x ConversionFactor)

NOPF = People / Faucets

GPM_base = 1.39 gpm (Ref. 2); Flow rate of existing 2.2 GPM aerator, adjusted for throttled flow uses

GPM_low = 0.94 gpm (Ref. 2); Flow rate of proposed 1.5 GPM aerator, adjusted for throttled flow uses

L = 3 min/person/day; Usage time (Ref. 9)

People = Provided by customer; Number of people in facility. If unknown, assume 10 people.

Faucets = Provided by customer; Number of faucets in facility. If unknown, assume 3 faucets. (Ref. 8)

DF = See Table 2; Drain Factor that accounts for uses that are volumetric in nature and aren't affected by low-flow aerators

GPM Factor = See Table 2; Factor accounts for differences in use between commercial and residential applications

Days = See Table 3; Days of operation

Specific Heat = 1.0 Btu / (lb x °F); Specific heat of water

Density = 8.34 lbs / gal; Density of water

Tfaucet = 91°F; Temperature of typical faucet usage (Ref. 2)

Tcold = Average groundwater temperature per Table 1 (Ref. 4)

ReEff = Recovery Efficiency = 75% (gas water heater) (Ref. 2)

Conversion Factor = 1,000,000 Btu/Dth (gas water heater)

Required from Customer/Contractor: confirmation of gas water heater, project location (county), number of people, number of faucets, bath or kitchen faucets.

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 and number of faucets is unknown.

NOPF = 10 people / 3 faucets = 3.33

EPG = (8.34 lb/gal) x (1.0 Btu/lb°F) x (91°F – 49.0°F) / (0.75 x 1,000,000) = 0.000467 Dth/gal

Unit Dth Savings per Year = ((1.39 gpm - 0.94 gpm) x (3 min/person/day) x (3.33) x (304.4 days) x 0.85) / 2.0 x 0.000467 Dth/gal = 0.272 Dth Saved

Deemed Input Tables:

Table 1: 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
If location is unknown	49.0

Table 2: Faucet Characteristics (Ref. 2, 8)

Application	DF	GPMfactor
Kitchen	75%	1.0
Bath	90%	2.5
If application is unknown	85%	2.0

Table 3: Deemed Annual Hot Water Use by Building Type (Ref. 7)

Building Type	Days Per Year
Small Office	250
Large Office	250
Fast Food Restaurant	365.25
Sit-Down Restaurant	365.25
Retail	365.25
Grocery	365.25
Warehouse	250
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Motel	365.25
Hotel	365.25
Other Commercial	250
If building type is unknown	304.4

Methodology and Assumptions:

Uses algorithms from IL TRM (Ref. 2)

(L), Usage time coincides with the middle of the range (6.74 min/per/day to 13.4 min/per/day) from multiple sources.

GPM_base is a representative baseline flow rate for kitchen and bathroom faucet aerators from multiple sources.

GPM_low is an average retrofit flow rate for kitchen and bathroom faucet aerators from multiple sources. This accounts for all throttling and differences from rated flow rates.

Notes:

The current standard for kitchen and bathroom aerators is 2.2 GPM, effective 1/1/1994. (Ref. 5)

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. State of Illinois Energy Efficiency Technical Reference Manual, Version 4.0, Page 647-655. February 13, 2015.

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 and Their Effective Dates. January 1, 2010

6. 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.

7. 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.

8. Assumes one kitchen faucet and two restroom faucets. Franklin Energy Services.

9. Connecticut UI and CLP Program Savings Documentation. September 29, 2009.

Documentation Revision History:

Version / Description	Author	Date
1. Created standalone spec from ResidentialElectricDHW_v03.2	Joe Plummer, DER	
2. Revised formatting and algorithms	Franklin Energy Services	7/27/2012
2. Update the measure life and measure cost	Franklin Energy Services	7/27/2012
3. 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 8760 to 8766 hours per year to be consistent with other measures, minor edits.	JP	3/13/2013
3.3 Changed “electric or gas water heater” to “confirmation of gas water heater” in Required Inputs	JP	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

Commercial Hot Water - Pre-Rinse Sprayers (1.6 gpm) with Gas Water Heater

Version No.

3.0

Measure Overview

Description: This measure includes retrofit of working standard pre-rinse sprayers with low-flow, 1.6 gpm pre-rinse sprayers in commercial kitchen applications.

Actions: Replace Working
Target Market Segments: Commercial
Target End Uses: DHW

Applicable to: Commercial facilities with kitchens: restaurants, large office buildings, etc, with gas water heaters.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = EPG x WaterSaved / ReEff / ConversionFactor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 5 (Ref. 1)

Unit Participant Incremental Cost = $100 (Ref. 3)

Where:

EPG = SpecificHeat x Density x (Tmix - Tcold)

WaterSaved = (Flow_base x Hours_base - Flow_eff x Hours_eff) x 60 min/hr x Days

SpecificHeat = 1.0 Btu / (lb x °F)

Density = 8.34 lbs / gal

Flow_base = 2.23 gal/min (Ref. 1)

Flow_eff = 1.12 gal/min is default (Ref.1)

Hours_base = 0.44 hr/day (Ref. 1)

Hours_eff = 0.60 hr/day (Ref. 1)

Days = See Table 2

Tmix = 110 °F; spray water temperature (Ref. 8)

Tcold = Average groundwater temperature per Table 1 (Ref. 2)

ReEff = 0.75; recovery efficiency (gas water heater) (Ref. 3)

ConversionFactor = 1,000,000 Btu/Dth (gas water heater)

Required from Customer/Contractor: Confirmation of gas water heater, building type, project location (county)

Example:

A direct install crew has installed a low-flow pre-rinse spray valve 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 365.25 day/yr = 6,776 gal/yr

EPG = (1 Btu/lb°F) x (8.34 lbs/gal) x (110°F - 49.1°F) = 508.7 Btu/gal

*Savings per Year = 508.7 Btu/gal * 6,776 gal/yr / 0.75 / (1,000,000 Btu/Dth) = 4.60 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
If location is unknown	49.0

Table 2: Deemed Annual Hot Water Use by Building Type (Ref. 6)

Building Type	Days Per Year
Large Office	250
Fast Food Restaurant	365.25
Sit-Down Restaurant	365.25
Grocery	365.25
Elementary School	200
Jr. High/High School/College	200
Health	365.25
Hotel	365.25
Other Commercial	250
Senior Living	365.25

Methodology and Assumptions:

The following building types were considered not to apply to this measure: Small Office, Retail, Warehouse and Motel

Notes:

The current flow standard for Pre-Rinse Sprayers is 1.6 GPM (Ref. 4)

The Federal Energy Management Program (FEMP) requires the federal government purchase and install pre-rinse spray valves with 1.25 gpm in federal buildings. (Ref.7)

References:

1. IMPACT AND PROCESS EVALUATION FINAL REPORT for CALIFORNIA URBAN WATER CONSERVATION COUNCIL 2004-5 PRE-RINSE SPRAY VALVE INSTALLATION PROGRAM (PHASE 2)

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. State of Illinois Energy Efficiency Technical Reference Manual, June 1st, 2012. Pages 109-113.

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.

5. No demand savings are claimed for this measure since there is insufficient peak coincident data.

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. FEMP Designated Product: Pre-Rinse Spray Valves, Purchasing Specification for Energy Efficient Products, FEMP, December 2008.

8. 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

Documentation Revision History:

Version / Description	Author	Date
1. Put measure together	Franklin Energy Services	7/23/2012
2.0 Add building types and Days variable	Franklin Energy Services	8/6/2012
2.1 Add Flow rate as a variable	Franklin Energy Services	8/6/2012
2.2 Changed the hot water set point from 120°F to 105°F	Franklin Energy Services	8/28/2012
2.3 Added building type to customer/contractor inputs, changed Applicable text	JP	3/25/2013
2.4 Renamed Tset to Tmix, reformulated savings algorithms for consistency with aerators, changed annual hours from 8760 to 8766 and days/yr from 365 to 365.25 for consistency with other measures, changed example accordingly	JP	3/27/2013
2.5 Electric water heater recovery efficiency changed from 0.97 to 0.98 per FES recommendation	JP	4/5/2013
2.5 Example updated accordingly	JP	4/5/2013
2.6 Updated example from electric to gas savings, changed "electric or gas water heater" to "confirmation of gas water heater" in Required Inputs	JP	11/25/13
2.7 Updated to clarify that spec applies to installation of 1.6 gpm sprayers, removed ability to use flow rate of new sprayer as 1.12 gpm is actual average flow rate in field measured as part of evaluation study in Ref. 1. Corrected example to specify gas water heater.	JP	4/8/14
2.8 Added federal government purchase requirements and reference.	Franklin Energy Services	7/31/2014
3.0 Added the Senior Living building type and unknown location in Table 1.	Franklin Energy Services	12/1/2015

Commercial Hot Water – Gas Water Heater

Version No. 7.0

Measure Overview

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.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial
Target End Uses: DHW

Applicable to: Storage or instantaneous gas water heaters installed in commercial applications.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = EnergyToHeatWater x (1 / Eff_Base - 1 / Eff_High)/ConversionFactor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years): see Table 4

Unit Participant Incremental Cost: see Table 5

Where:

EnergyToHeatWater = SpecificHeat x Density x GalPer1000SqftPerDay x Area/1000 x DaysPerYear x (Tset - Tcold)

SpecificHeat = 1.0 btu / (lb x °F)

Density = 8.34 lbs / gal

GalPer1000SqftPerDay = Deemed gallons per 1,000 square foot per day based on building type per Table 2

DaysPerYear = Days per year of operation per Table 2

Area = Minimum of:

- Floor area served by the water heater in ft^2, provided by customer/contractor
- Tank Size / (Min Storage Capacity per 1,000 sq ft, see Table 2) x 1000, the maximum floor area that could be served by the water heater in ft^2 based on tank size (not applicable for instantaneous units)
- (Input Btu/h / 1000) / (Min Heating Capacity per 1,000 sq ft, see Table 2) x 1000, the maximum floor area that could be served by the water heater in ft^2 based on heating capacity

Tset = 140 °F (Ref. 8)

Tcold = Average groundwater temperature per Table 1

Eff_Base = Efficiency of standard water heater, expressed as Energy Factor (EF) or thermal efficiency per Table 3.

Eff_High = Efficiency of efficient water heater, expressed as Energy Factor (EF) or thermal efficiency consistent with Eff_Base.

ConversionFactor = 1,000,000 Btu/Dth (gas water heaters)

Required from Customer/Contractor: Water heater type (gas storage or gas instantaneous), input Btu/h, efficiency of new water heater, tank size in gallons, building type, square footage, project location (county)

Example:

A 1,300 ft^2 fast food restaurant in Zone 2 installed a new 60-gallon, 40,000 Btu/h gas storage water heater with an EF of 0.67

Max area based on tank size = 60/38.9 x 1000 = 1,542 ft^2
Max area based on heating capacity = (40000/1000)/34.4 x 1000 = 1,163 ft^2

Area = minimum (1300, 1542, 1163) = 1,163 ft^2

EnergyToHeatWater = 1 x 8.34 x 549.2 x 1163/1000 x 365.25 x (140 - 49.1) = 176,860,318 Btu/yr

Eff_Base = 0.67 – (0.0019 x 60) = 0.56

Unit Dth Savings per Year = 176,860,318 x (1/0.56 - 1/.67) /1,000,000 = 51.9 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
If location is unknown	49.0

Table 2: Deemed Annual Hot Water Use by Building Type, Minimum Storage Capacity and Heating Capacity (Ref. 2)

Building Type	Days Per Year	Annual Hot Water Load (Gal per 1,000 Sqft Per Day)	Minimum Storage Capacity (Gal per 1,000 Sqft)	Minimum Heating Capacity (kBtu/hr per 1,000 Sq Ft)
Small Office	250	2.3	0.7	0.6
Large Office	250	2.3	0.7	0.6
Fast Food Restaurant	365	549.2	38.9	34.4
Sit-Down Restaurant	365	816.0	36.0	31.9
Retail	365	2.0	0.6	0.6
Grocery	365	2.2	0.7	0.6
Warehouse	250	1.0	0.3	0.3
Elementary School	200	5.7	4.6	4.0
Jr. High/High School/College	200	17.1	7.6	6.7
Health	365	342.0	21.4	27.8
Motel	365	100.0	23.9	21.1
Hotel	365	30.8	8.8	7.8
Other Commercial	250	0.7	0.2	0.2

Table 3: Deemed baseline efficiency based on ASHRAE 90.1-2010, Table 7.8, as adopted by MN Commercial Energy Code (Ref. 3)

Equipment Type	Input Btu/h	Subcategory	Minimum Efficiency	Efficiency Metric
Gas Storage Water Heaters	≤75,000 Btu/h	≥ 20 gal	0.67 - (0.0019 x gal)	Energy Factor
	>75,000 Btu/h	< 4,000 (Btu/h)/gal	0.80	Thermal Efficiency
Gas Instantaneous Water Heaters*	>50,000 Btu/h and <200,000 Btu/h	≥4,000 (Btu/h)/gal and <2 gal	0.62 - (0.0019 x gal)	Energy Factor
	≥ 200,000 Btu/h	≥4,000 (Btu/h)/gal	0.80	Thermal Efficiency

** "gal" refers to volume of buffer tank in gallons*

Table 4: Measure Lifetime by Type (Ref. 4)

Equipment Type	Lifetime (years)
Gas Storage Water Heaters	11
Gas Instantaneous Water Heaters	20

Table 5: Incremental Cost by Type

Equipment Type	Input Btu/h	Incremental Cost	
Gas Storage Water Heaters	≤75,000 Btu/h	$0.00	(Ref. 5)
	>75,000 Btu/h	$1,350.00	(Ref. 6)
Gas Instantaneous Water Heaters*	>50,000 Btu/h and <200,000 Btu/h	$0.00	(Ref. 5)
	≥ 200,000 Btu/h	$1,800.00	(Ref. 6)

Notes:

Current water heater efficiency standards are given in Table 3

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. 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. Minnesota Commercial Energy Code, Minn. Rules ch. 1323.0780 Table 7.8, Performance Requirements for Water Heating Equipment.

4. 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, December 16, 2008

5. 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 measure worksheet.

6. ActOnEnergy Technical Resource Manual, Standard Measures, 5/31/2011. Pages 278, 284 and 286.

7. "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.

8. "To minimize the growth of Legionella in the system, domestic hot water should be stored at a minimum of 60°C (140°F) " http://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_7.html#5. Section III, Chapter 7; V.C.3.a

Documentation Revision History:

Version / Description	Author	Date
7.0 Corrected instantaneous water heater efficiency requirement	FES	11/11/15

Residential Hot Water - Drainpipe Heat Exchanger with Gas Water Heater

Version No.

2.5

Measure Overview

Description: This measure includes installing a drainpipe heat exchanger to a residential or multi-family building to recover heat from heated water going down the building's drain.

Actions: Modify
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size gas water heaters.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = EnergyToHeatWater / Eff x SavingsFactor / ConversionFactor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 20 (Ref. 1)

Unit Participant Incremental Cost = $742 (Ref. 1)

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)

Eff = Recover efficiency of gas water heater, 0.75.

SavingsFactor = 0.25 (Ref. 2)

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: confirmation of gas water heater, building type (single family or multi family*), project location (county).

** Includes buildings with 2+ units and townhomes*

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
If location is 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
Multi-family*	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

Documentation Revision History:

Version / Description	Author	Date
1. Derived from ResidentialElectricDHW_v03.2 and ResidentialGasDHW_v03.2 which were based on Nexant's original spec.	Joe Plummer, DER	
2. 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	JP	11/25/2013
2.4 Added building type to required inputs, added footnotes clarifying multifamily definition	JP	3/18/2014
2.5 Added unknown location and removed electric information.	Franklin Energy Services	12/18/2015

Residential Hot Water - Faucet Aerator (1.5 gpm) with Gas Water Heater

Version No.

4.0

Measure Overview

Description: This measure includes replacing an existing faucet aerator with low-flow aerator.

Actions: Replace Working
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size gas water heaters

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = WaterSaved x Density x SpecificHeat x (Tfaucet – Tcold) / ReEff / ConversionFactor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 1)

Unit Participant Incremental Cost = $6.70 (Ref. 6)

Where:

WaterSaved = Flow_diff x Vmin x (Num_People) x 365.25 days/year

Flow_diff = 1.0 GPM (i.e. 2.5 GPM replaced with 1.5 GPM)

Vmin = 1.125 minutes; the number of minutes of faucet use per adjusted number of bedrooms per day (an average of the following values: 1.5 minutes (kitchen) and 0.75 minutes (bathroom)) (Ref. 2)

Num_People = Number of people per household per Table 2

SpecificHeat = 1.0 Btu / (lb x °F)

Density = 8.34 lb / gal

Tfaucet = 80°F; Temperature of typical faucet usage (Ref. 2)

Tcold = Average groundwater temperature per Table 1 (Ref. 4)

ReEff = 0.75; recovery efficiency (gas water heater) (Ref. 7)

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: confirmation of gas water heater, building type (single family or multi-family*), project location (county)

** Includes buildings with 2+ units and townhomes*

Example:

Direct installation of a 1.5 GPM faucet aerator in an apartment with gas water heat located in Zone 1.

WaterSaved (gal/yr) = (1.0 gal/min) x (1.125 min) x (2.17 people) x 365 days/year = 891 gallons saved year

Unit Dth Savings per Year = (891 gal) x (8.34 lbs/gal) x (1.0 Btu/lb°F) x (80°F – 46.5°F) / 0.75 /1,000,000 Btu/Dth = 0.33 Dth saved

Deemed Input Tables:

Table 1: 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
If location is unknown	49.0

Table 2: People per Household (Ref. 3).

Application	Num_People
Single-Family	2.59
Multi-Family*	2.17
If unknown	2.38

** Includes buildings with 2+ units and townhomes*

Methodology and Assumptions:

Uses algorithms from Efficiency Vermont TRM (Ref. 2)

The “BR + 1” from Ref. 2 is assumed to equal the number of people per household or unit; People per household will be used instead of BR + 1.

Notes:

If inputs are unknown, deemed savings is 0.337 Dth.

The current standard for kitchen and bathroom aerators is 2.2 GPM, effective 1/1/1994. (Ref. 5)

FOE uses 8 therms/187 kWh for Commercial applications

ActOnEnergy TRM has 82 kWh, 6.1 therms, and 15 years

IL TRM uses 1.89 therms/ 42 kWh

NY TRM has 314 kWh, 17 therms

Ohio TRM (VEIC) 2010 uses 24.5 kWh / .109 MMBtu

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. Efficiency Vermont Technical Reference User Manual, 2/19/2010.

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 and Their Effective Dates. January 1, 2010

6. 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.

7. State of Illinois Energy Efficiency Technical Reference Manual, June 1st, 2012. Pages 109-113.

Documentation Revision History:

Version / Description	Author	Date
1. Created standalone spec from ResidentialElectricDHW_v03.2	Joe Plummer, DER	
2. Revised formatting and algorithms	Franklin Energy Services	7/27/2012
2. Update the measure life and measure cost	Franklin Energy Services	7/27/2012
3. Corrected Energy Factor equations	Franklin Energy Services	3/20/2013
3.1 Changed action from Direct Install to Replace Working	Joe Plummer, DER	4/5/2013
3.2 Removed extra multiplication sign following Eff in savings algorithms	Joe Plummer, DER	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	JP	11/25/13
3.4 Added residence type (single family or multi-family) to required inputs	JP	1/3/14
3.5 Removed “owner-occupied” from single-family and “renter-occupied” from multifamily in Table 2, added footnotes clarifying multifamily definition.	JP	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

Residential Hot Water – Gas Water Heater

Version No. 5.0

Measure Overview

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.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size gas water heaters

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = Energy to Heat Water x (1/EF_minimum – 1/EF_efficient) / ConversionFactor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 for storage models; 20 for tankless models (Ref. 3)

Unit Participant Incremental Cost = See Table 4

Where:

EnergyToHeatWater = Specific Heat x Density x Gal_Person x People x 365 Days/Year x (Tset – Tcold)

SpecificHeat = 1.0 btu / (lb x °F)

Density = 8.34 lbs / gal

Gal_Person = See Table 2; Daily hot water usage per person

People = See Table 3; number of people per household

Tset = 120 °F (Ref. 7)

Tcold = Average groundwater temperature per Table 1

EF_Minimum = 0.67 – 0.0019 x (Tank Size in Gallons): storage units

= 0.62 – 0.0019 x (Rated Storage Volume in gallons): instantaneous units

EF_Efficient = Efficiency (energy factor) of new water heater (0-1);

ConversionFactor = 1,000,000 Btu/Dth

Required from Customer/Contractor: confirmation of gas water heater, tank size in gallons, new water heater efficiency (EF), single-family or multifamily*, project location (county)

** Includes buildings with 2+ units and townhomes*

Example:

A single-family customer in Zone 2 has installed a new 50-gallon gas-fired water heater (EF = 0.7) to replace their previous gas-fired storage water heater.

EF_Minimum = 0.67 - 0.0019 x 50 gallons = 0.575

Energy To Heat Water = (1 Btu/lb°F) x (8.34 lbs/gal) x (20.4 gal/person) x (2.59 people) x (365 d/yr) x (120°F - 49.1°F) = 11,403,419 Btu/yr

Unit Dth Savings per Year = (11,403,419 Btu/yr) x (1/0.575 - 1/0.70) / (1,000,000 Btu/Dth) = 3.5 Dth

Deemed Input Tables:

Table 1: 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
If location is unknown	49.0

Table 2: Daily Hot Water Usage per Person (Ref. 8)

Application	(Gal/day)/person
Single-Family	20.4
Multi-Family*	18.7
If unknown	19.6

** Includes buildings with 2+ units and townhomes*

Table 3: People per Household (Ref. 9)

Application	Num_People
Single-Family	2.59
Multi-Family*	2.17
If unknown	2.38

** Includes buildings with 2+ units and townhomes*

Table 4: Incremental Cost by Type (Ref. 4)

Type of Water Heater	Incremental Cost
Power-Vented, Gas-Fired, Storage	$577.00
Condensing, Gas-Fired, Storage	$814.00
Instantaneous Gas	$1,096.60

Notes

Table 5: Current Equipment Standards, effective for products manufactured on or after April 16, 2015 (Ref. 6)

Type of Equipment	Energy Factor
Gas-Fired Storage Water Heaters, ≤ 55 gallons	0.675 - (0.0015 x Rated Storage Volume in gallons)
Gas-Fired Storage Water Heaters, > 55 gallons	0.8012 - (0.00078 x Rated Storage Volume in gallons)
Instantaneous Gas-Fired Water Heaters	0.82 - (0.0019 x Rated Storage Volume in gallons)

References

1. Daily hot water usage is based on CEE's tankless water heater field study in Mpls/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. Incremental water heater costs, water heater lifetime from NW Council-RTF Residential DHW-Efficient Tanks deemed savings, v 2.0

4. 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.

5. 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. January 1, 2010

6. Energy Conservation standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters: Final Rule, Federal Register, 75 FR 20112, April 16, 2010.

7. "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.

8. Interpolated values from Table 38, Ohio Technical Reference Manual. October 15, 2009. Page 52.

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

Documentation Revision History:

Version / Description	Author	Date
1. Created standalone spec from ResidentialElectricDHW_v03.2	Joe Plummer, DER	
2.0 Updated the groundwater temperatures	FES	7/23/2012
2.1 Added example	FES	7/23/2012
2.2 Amended description, measure requirements and EF_Efficient	FES	7/23/2012
2.3 Updated the incremental costs	FES	7/23/2012
3.0 Updated the hot water usage	FES	8/6/2012
4.0 Updated measure lifetimes for tankless water heaters	FES	3/20/13
4.1 Added footnotes clarifying multifamily definition, changed “tankless” to “instantaneous” since some instantaneous water heaters have small buffer tanks	JP	3/12/2014
5.0 Added unknown input values.	FES	11/11/15

Residential Hot Water – Gas Water Heater Setback

Version No. 3.2

Measure Overview

Description:

This measure involves turning the water heater set point temperature to 120°F on residential storage-type gas 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.

Actions: Operations and Maintenance
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size gas water heaters

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = SpecificHeat x Density x Gal_Person x People x 365.25 x (Tset - Tin) x Savings_Factor/ Eff / ConversionFactor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 2 (Ref. 2)

Unit Participant Incremental Cost = $0

Where:

SpecificHeat = 1.0 btu / (lb x °F)

Density = 8.34 lbs / gal

Gal_Person = See Table 2; Daily hot water usage per person

People = See Table 3; Number of people per household

Tset1 = 130 °F (assumed average starting temperature)

Tin = Average groundwater temperature per Table 1

Eff (gas) = 0.59 (2004 Federal minimum Energy Factor for 40 gal tank = 0.67 - 0.0019 x 40)

Eff (elec) = 0.92 (2004 Federal minimum Energy Factor for 40 gal tank = 0.97 - 0.00132 x 40)

ConversionFactor = 3,412 Btu/kWh (electric water heater) or 1,000,000 Btu/MMBtu (gas water heater)

Savings_Factor = 4% (Ref. 3)

Required from Customer/Contractor: confirmation of gas water heater, project location (county), building type (single family or multi-family*)

** Includes buildings with 2+ units and townhomes*

Example:

A direct install team reduces the set point of a gas water heater in a single-family home in Zone 1.

Unit Dth Savings per Year = (1.0 Btu/lb°F) x (8.34 lb/gal) x (20.4 gal/day/person) x (2.59 people) x (365.25 day/yr) x (130°F - 46.5°F) x 4% / (0.59) / (1,000,000 Btu/Dth) = 0.91 Dth saved

Deemed Input Tables:

Table 1: 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

Table 2: Daily Hot Water Usage per Person (Ref. 6)

Location	Gal/day/person
Single Family	20.4
Multi Family*	18.7

** Includes buildings with 2+ units and townhomes*

Table 3: People per Household (Ref. 7)

Application	Num_People
Single Family	2.59
Multi Family*	2.17

** Includes buildings with 2+ units and townhomes*

Methodology and Assumptions:

The savings from lowering the temperature setpoint 10°F is 3% to 5% of the overall domestic hot water energy. (Ref. 3)

The existing temperature is assumed to be 130°F (Ref. 5)

Notes:

There are no current energy standards for this measure.

The previous algorithm assumed that all hot water uses are done at max temperature, when in reality only a few are (i.e. clothes washer, dishwasher, misc. cleaning, etc.). The result of this was that the savings was being overestimated (i.e. 446 kWh, resulting in ~13% overall DHW savings). The IL TRM however, only accounts for the aforementioned uses and ignores the reduction in standby losses by lowering the delta T. The result of this is that the savings is underestimated (i.e. 49 kWh). The DOE estimates a savings that is between these two values. The savings value given by DOE estimates are supported by Ref. 2 (Efficiency Vermont TRM).

The excel algorithms yield a savings of 158 kWh and 0.84 Dth, which is within 4% of the values for Zone 1-single-family applications. The difference in savings will increase in zones 2 and 3 and in multi-family applications.

References:

1. Daily hot water usage is based on CEE's tankless water heater field study in Mpls/St. Paul (2008-2010); Supported by Focus on Energy's Residential Deemed Savings Review, page 4.

2. Efficiency Vermont Technical Reference User Manual (TRM), 2/19/2010. Page 409. This value is supported by the Illinois Technical Reference User Manual, 2012.

3. Average of 3-5% savings values on DOE website, http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13090. Accessed 7/2

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. Franklin Energy Services internal value.

6. Interpolated values from Table 38, Ohio Technical Reference Manual. October 15, 2009. Page 52.

7. U.S. Census Bureau, *Selected Housing Characteristics 2010 American Commnity 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

Documentation Revision History:

Version / Description	Author	Date
1. 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, DER	
2.0 Updated algorithm to use Savings_Factor of 4%	Franklin Energy Services	7/26/2012
2.1 Updated measure lifetime per Ref. 2	Franklin Energy Services	7/27/2012
3.0 Updated the hot water usage to be consistent with the hot water heater measure algorithm	Franklin Energy Services	8/6/2012
3.1 Changed action type to Modify, changed "electric or gas water heater" to "confirmation of gas water heater" in	JP	11/25/2013

Required Inputs, changed example to compute gas savings instead of electric		
3.2 Added footnotes clarifying multifamily definition. In Dth algorithm, replaced Gal/Day with Gal_Person x People.	JP	3/18/2014

Residential Hot Water - Low Flow Showerheads (1.5 gpm) with Gas Water Heater

Version No.

4.0

Measure Overview

Description: This measure involves replacing a standard showerhead with a low flow showerhead.

Actions: Replace Working
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3-, and 4-plexes and townhomes) with residential-size gas water heaters.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = WaterSaved x Density x SpecificHeat x (Tshower - Tcold) / ReEff / ConversionFactor

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 5)

Unit Participant Incremental Cost = $12 (Ref. 4)

Where:

WaterSaved = Flow_reduction x ShowerWater x Num_People x SPCD x 365 days/year / SPH

Flow_reduction = 40% (i.e. 2.5 GPM replaced with 1.5 GPM; (2.5-1.5)/2.5 = 0.40)

ShowerWater = 17.2 gallons; daily hot water use per shower per person (Ref. 3)

Num_People = Number of people per household per Table 2

SPCD = 0.75; Showers per capita per day (Ref. 4)

SPH = Showerheads per Household per Table 3

SpecificHeat = 1.0 Btu/(lb°F)

Density = 8.34 lbs / gal

Tshower = 105°F; Temperature of typical shower usage (Ref. 2)

Tcold = Average groundwater temperature per Table 1

ReEff = 0.75; recovery efficiency (gas water heater) (Ref. 7)

ConversionFactor = 1,000,000 Btu/Dth (gas water heater)

Required from Customer/Contractor: electric or gas water heater, residence type (single-family or multi-family*), project location (county)

** Includes buildings with 2+ units and townhomes*

Example:

Direct installation of a low-flow showerhead in an apartment with gas water heat located in Zone 3.

WaterSaved (gal/yr) = (40%) x (17.2 gal/person) x (2.17 people/household) x 0.75 SPCD x 365 days/year / 1.3 SPH = 3,144 gallons saved per year

Unit Dth Savings per Year = (3,144 gal) x (8.34 lbs/gal) x (1 Btu/lb°F) x (105°F - 51.3°F) / 0.75 / 1,000,000 Btu/Dth = 1.9 Dth saved

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
If location is unknown	49.0

Table 2: People per Household (Ref. 1).

Application	Num_People
Single Family	2.59
Multi Family*	2.17
If unknown	2.38

Includes buildings with 2+ units and townhomes

Table 3: Showerheads per Household (Ref. 4).

Application	SPH
Single Family	1.79
Multi Family*	1.30
If unknown	1.545

** Includes buildings with 2+ units and townhomes*

Methodology and Assumptions:

Algorithm is based on the Illinois TRM (Ref. 4), but has been modified with regard to existing water usage estimation. The original IL TRM calculation was estimating fairly high pre-retrofit water usages, so 11.6 gal/day (Ref. 3) has been used in an effort to temper the results.

Notes:

If inputs are unknown, the deemed savings is 1.807 Dth.

The current flow standard for showerheads is 2.5 GPM (Ref. 6)

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. Mayer P., DeOreo W., et.al. 1999. Residential end Uses of Water, American water Works Association Research Foundation.

4. Illinois Technical Reference Manual, 6/1/12. Pages 419-426.

5. 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 Multi-Family,

http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf

6. 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. January 1, 2010

7. State of Illinois Energy Efficiency Technical Reference Manual, June 1st, 2012. Pages 109-113.

Documentation Revision History:

Version / Description	Author	Date
1. Created standalone spec from ResidentialElectricDHW_v03.2	Joe Plummer	
2. Changed algorithm per IL TRM and modified the HW usage estimates	Franklin Energy Services	7/31/2012
2. Changed Measure Lifetime from 7 to 10	Franklin Energy Services	7/31/2012
3. 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	Joe Plummer	4/8/2013
3.1 Added residence type to list of required inputs from customer/vendor	Joe Plummer	4/8/2013
3.1 Changed description of Tshower from "typical faucet usage" to "typical shower usage"	Joe Plummer	4/8/2013
3.1 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	JP	11/25/2013
3.3 Added footnotes clarifying multifamily definition	JP	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

Residential Hot Water - Pipe Insulation with Gas Water Heater

Version No.

3.0

Measure Overview

Description: This measure includes installing pipe insulation on un-insulated piping of a gas water heating system.

Actions: Modify
Target Market Segments: Residential
Target End Uses: DHW

Applicable to: Residential customers in single-family, duplexes and townhomes with gas water heaters.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = (Qloss_base - Qloss_insul) x Hours x Length / ConversionFactor / Eff

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 13 (Ref. 3)

Unit Participant Incremental Cost = $3.63 (Ref. 4)

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

Required from Customer/Contractor: length of pipe insulation (linear feet), confirmation of gas water heater

Example:

A customer 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 = 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

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 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) 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.

Document Revision History:

Version / Description	Author	Date
1. Based on original from Nexant, cleaned up and reformatted	Joe Plummer, DER	
2. 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 gas water heater to required inputs	JP	11/24/13

Residential Hot Water – Thermostatic Restriction Valve with Gas Water Heater

Version No. 1.0

Measure Overview

Description: This measure involves installing a thermostatically restricting shower valve that reduces the amount of excess hot shower water during warm-up periods.

Actions: Replace Working, Replace on Fail, New Construction
Target Market Segments: Residential: Single-family and Multi-family
Target End Uses: DHW

Applicable to: Residential customers in single-family homes and multi-family homes consisting of 2 units or more (this includes 2-, 3- and 4-plexes and townhomes) with residential-size electric water heaters.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = GPM_base x t_valve x Num_People x SPCD x 365.25 / SPH x EPG

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 1)

Unit Participant Incremental Cost = $30 (Ref. 2)

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)

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

Required from Customer/Contractor: Showerhead flow rate, zip code.

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 * 1.0 Btu/lb-°F * (105°F - 51.3°F) / (0.76 * 1,000,000 Btu/Dth) = 0.000589 Dth/gal*

*Unit Dth Savings per Year (Dth/yr) = 1.5 gal/min * 0.89 min * 2.21 * 0.75 * 365.25 days/yr / 1.3 x 0.000589 Dth/gal = 0.366 Dth*

Methodology and Assumptions:

Notes:

Table 1: People per Household (Ref. 4).

Application	Num_People
Single-Family (owner-occupied)	2.59
Multi-Family (renter-occupied)	2.17
If unknown	2.38

Table 2: Showerheads per Household (Ref. 5).

Application	SPH
Single-Family	1.79
Multi-Family	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
If location is 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 foonote 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 * 30% * 40% = 0.94.

4. U.S. Census Bureau, Selected Housing Characteristics 2010 American Commnity 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.

Documentation Revision History:

Version / Description	Author	Date
1. Measure created	Franklin Energy Services	11/10/2015

Residential HVAC - Electronic Ignition Hearth

Version No.

1.2

Measure Overview

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

Actions: Replace on Fail, Replace Working
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: Residential customers in single-family homes, duplexes, townhomes, and multi-family homes (including 3- and 4-family homes) with residential type heating equipment

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = P/CF x t

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 (ref. 1)

Unit Participant Incremental Cost = $193 (ref. 1)

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

Required from Customer/Contractor:

none

Example:

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

*Unit Dth Savings per Year = 1000/1000000*24*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

Documentation Revision History:

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

Residential HVAC - Furnaces and Boilers

Version No. 3.0

Measure Overview

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 for furnaces with ECM blowers.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: Residential customers in single-family homes, duplexes, townhomes, and multi-family homes (including 3- and 4-family homes) with residential type heating equipment.

Algorithms

Unit kWh Savings per Year = Heating Savings + Cooling Savings + Shoulder Season Savings (for furnaces incorporating a Blower ECM motor)
= 0 (for furnaces not incorporating a Blower ECM motor)

Unit Peak kW Savings = Cooling Watts Savings x CF/1000 (for furnaces incorporating a Blower ECM motor)
= 0 (for furnaces not incorporating a Blower ECM motor)

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 - Heating Savings x 0.003142 / Eff_High

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 20 (Ref. 1)

Unit Participant Incremental Cost: See Table 3

Where:

Heating Savings = Blower ECM motor savings during heating season = 418 kWh (Ref 6.)

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 7.) If new central AC installed as part of the project, cooling savings equal 0 (Ref. 8).

Shoulder Season Savings = Blower ECM motor savings during shoulder season = 51 kWh (Ref 6.)

Cooling Watts Savings = ECM motor Cooling Watts Saved = 73 (Ref. 6)

CF = Coincidence factor = 0.9 (Ref. 9)

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 (Ref.3)

Eff_base = Efficiency of the baseline, i.e., standard replacement, equipment. Refer to Table 2. (Ref. 4)

Eff_high = Efficiency (AFUE) of the new furnace or boiler, supplied by customer/contractor.

Conversion_Factor = 1,000,000 Btu/Dth

0.003412 Converts kWh to Dth

Required from Customer/Contractor: Equipment type (furnace w/o ECM or boiler), Input Btu/h of new unit, project location (county), AFUE of the new equipment, Action Type (Replace on Fail, Replace Working, or New Construction), building type (single-family or duplex, multifamily*or townhome).

** Multifamily includes buildings with 3 or more units.*

Example:

Retrofit furnace installed in single family home, 94% AFUE furnace with a Blower ECM motor, 60,000 btu/h input, Climate
Zone 3.

Unit kWh Savings per Year = 418 + 251 + 51 = 720

*Unit Peak kW Savings = 73 * 0.9/1000 = 0.065*

Unit Dth Savings per Year = 60,000 x 0.77 x 1,932 x 0.94 x (1/0.80 - 1/0.94) / 1,000, - 418 kWh x 0.003412 / 0.94 = 14.1Dth

Deemed Input Tables:

Table 1. Equivalent Full Load Heating Hours ($EFLH_{Heat}$) by Climate Zone (Ref. 3)

Zone	Equivalent Full Load Heating Hours
Zone 1 (Northern MN)	2280
Zone 2 (Central MN)	2099
Zone 3 (Southern MN/Twin Cities)	1932

**Includes duplex, townhome, and multifamily buildings with 3 or more units*

Table 2: Deemed baseline efficiency (Ref. 4)

Equipment Type	Building Type*	Existing or New Construction	Baseline Efficiency
Furnace	1F/2F	Existing	80%
Furnace	1F/2F	New Construction	90%
Furnace	TH, MF	Existing	80%
Furnace	TH, MF	New Construction	90%
Boiler	1F/2F, MF or TH	Either	80%

** 1F = single family, 2F = two family, TH = townhomes, MF = multi-family*

Table 3: Incremental Costs (Ref. 5)

Equipment Type	Building Type	Existing or New Con-struction	Equip-ment Cost ($/unit)	Installation Only Cost ($/unit)	Total Installed Cost ($/unit)	Incre-mental Cost ($/unit)
Baseline furnace, 80%	1F/2F, MF or TH	Ex	$1,196	$815	$2,011	$0
New furnace, AFUE ≥ 90% and < 92%	1F/2F, MF or TH	Ex	$1,575	$1,066	$2,641	$630
New furnace, AFUE ≥ 92% and < 94%	1F/2F, MF or TH	Ex	$1,747	$1,066	$2,813	$802
New furnace, AFUE ≥ 94%	1F/2F, MF or TH	Ex	$2,383	$1,066	$3,449	$1,438
Baseline furnace, 80%	1F/2F	NC	$1,196	$815	$2,011	$0
New furnace, AFUE ≥ 90% and < 92%	1F/2F	NC	$1,575	$1,066	$2,641	$630
New furnace, AFUE ≥ 92% and < 94%	1F/2F	NC	$1,747	$1,066	$2,813	$802
New furnace, AFUE ≥ 94%	1F/2F	NC	$2,383	$1,066	$3,449	$1,438
Baseline furnace, 80%	TH	NC	$1,196	$815	$2,011	$0
New furnace, AFUE ≥ 90% and < 92%	TH	NC	$1,575	$1,066	$2,641	$630
New furnace, AFUE ≥ 92% and < 94%	TH	NC	$1,747	$1,066	$2,813	$802
New furnace, AFUE ≥ 94%	TH	NC	$2,383	$1,066	$3,449	$1,438
Baseline boiler, 80%	1F/2F, MF or TH	Either	$1,686	$1,648	$3,334	$0
New boiler, AFUE ≥ 84% and < 90%	1F/2F, MF or TH	Either	$1,937	$2,331	$4,268	$934
New boiler, AFUE ≥ 90%	1F/2F, MF or TH	Either	$2,525	$2,289	$4,814	$1,480

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.

$EFLH_{Heat}$ were determined from 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: $EFLH_{MN} = EFLH_{IL} \times HDD_{65,MN} / HDD_{65,IL} \times DTD_{IL} / DTD_{MN}$, where DTD is the design temperature difference.

Geography	HDD65	DTD
Chicago, IL	6,339	73.5
MN Zone 1	9,833	92
MN Zone 2	8,512	86.5
MN Zone 3	7,651	84.5

AFUE does not include any electrical power savings.

The baseline efficiency source is the Energy Independence and Security Act of 2007 with technical amendments from Federal Register, volume 73, Number 145, Monday, July 28, 2008 for boilers <300,000 Btu/h and is Final Rule, Federal Register, volume 74, Number 139, Wednesday, July 22, 2009 for boiler ≥300,000 Btu/h.

Year	AFUE or TE
Hot Water <300,000 Btu/h < Sept 1, 2012	80% AFUE
Hot Water <300,000 Btu/h ≥ Sept 1, 2012	82% AFUE
Hot Water ≥300,000 & ≤2,500,000 Btu/h	80% TE
Hot Water >2,500,000 Btu/h	82% Ec

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. FES scaled annual heating loads from those provided in the Illinois Technical Reference Manual based on Minnesota weather data.

4. US Department of Energy (http://buildingsdatabook.eere.energy.gov/ChapterIntro7.aspx). Though the federal minimum efficiency is 78% there are very few models available at this efficient; a review of AHRI shows that most low efficiency units are 80%.

5. Xcel Energy 2010-2012 CIP Triennial (Docket No. E,G002/CIP-09-198)

6. PA Consulting Group/Patrick Engineering Residential Deemed Savings Review for Focus on Energy, 2009

7. The weighted average value is based on assumption that 75% of homes installing BPM furnace blower motors have central AC.

8. Energy use of blower motor during cooling season is reflected in the SEER of the new central AC.

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.

Document Revision History:

Version / Description	Author	Date
1. Replaces ResidentialFurnaceMeasures_v01, moved furnace tune-ups to a separate measure, updated baseline efficiencies to reflect decisions in 2010-2012 gas utility triennials	Joe Plummer, DER	
1.1 Added specifications for actions and needed from customer/vendor	Joe Plummer, DER	
1.2 Added missing incremental cost categories	Joe Plummer, DER	
2.1 Changed savings equation	Franklin Energy	7/25/2012
2.2 Added Multi-family buildings to the measure	Franklin Energy	7/25/2012
2.3 Added efficiency standards	Franklin Energy	7/25/2012
2.4 Added references	Franklin Energy	7/25/2012
2.5 Updated equipment costs	Franklin Energy	8/1/2013
2.6 Updated baselines and Federal standard comments due to the postponing of the furnace efficiency standard	Franklin Energy	8/1/2013
2.7 Updated baselines from 78% to 80%	Franklin Energy	8/1/2013
2.8 Added Action Type as Required Input from Customer/Contractor (determines existing or new construction which is needed to determine baseline efficiency)	JP	1/13/14
2.9 Added equipment type to required inputs from customer/contractor. Corrected example to use baseline efficiency of 0.80 instead of 0.78.	JP	3/4/14
3.0 Changed to $EFLH_{Heat}$ algorithm and added kWh and kW savings and heating penalty factors.	FES	11/12/2015
3.1 Indicated fan savings are for furnaces with ECM motors only.	FES	1/15/2016

Residential HVAC - Furnaces & Boiler Tune-Up

Version No. 3.0

Measure Overview

Description: 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 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 per manufacturer's recommendations
- Combustion Chamber – verify condition is per manufacturer's recommendations
- Temperature Rise - verify operation 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 per manufacturer's recommendations
- Safety Locks - verify operation per manufacturer's recommendations
- Final Operation - verify operation per manufacturer's recommendations

Description: 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 per manufacturer's recommendations
- Combustion Chamber – verify condition is per manufacturer's recommendations
- Temperature Rise - verify operation 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 per manufacturer's recommendations
- Safety Locks - verify operation per manufacturer's recommendations
- Final Operation - verify operation per manufacturer's recommendations

Actions: O&M
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: Residential customers in single-family homes, duplexes, townhomes, and multi-family homes (including 3- and 4-family homes) with residential type furnace

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

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

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 2 (Ref. 1)

Unit Participant Incremental Cost = $175 (default/planning figure; OK to use actual cost of tune-up) (ref.2 TBD)

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. 3)

$EFLH_{Heat}$ = Equivalent Full Load Hours of Heating. (ref. 4)

Conversion_Factor = 1,000,000 Btu/Dth

MF= Maintenance saving factor. MF=2%. (ref. 5)

Required from Customer/Contractor: Input Btu/h, project location (county), heating equipment type, building type.

Example:

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

*Unit Dth Savings per Year = 60000 x 0.77 x 1932 / 1000000 * 0.02= 1.79 Dth*

Deemed Input Tables:

Table 1. Equivalent Full Load Heating Hours ($EFLH_{Heat}$) by Climate Zone (ref. 4)

Zone	Equivalent Full Load Heating Hours
Zone 1 (Northern MN)	2280
Zone 2 (Central MN)	2099
Zone 3 (Southern MN/Twin Cities)	1932

**Includes duplex, townhome, and multifamily buildings with 3 or more units*

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.

$EFLH_{Heat}$ were determined from 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: $EFLH_{MN} = EFLH_{IL} \times HDD_{65,MN} / HDD_{65,IL} \times DTD_{IL} / DTD_{MN}$, where DTD is the design temperature difference.

Geography	HDD65	DTD
Chicago, IL	6,339	73.5
MN Zone 1	9,833	92
MN Zone 2	8,512	86.5
MN Zone 3	7,651	84.5

Notes:

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. TBD

3. 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.

4. FES scaled annual heating loads from those provided in the Illinois Technical Reference Manual based on Minnesota weather data.

5. FES determined by collection of results from over 125 projects completed through a Midwest energy project.

Document Revision History:

Version / Description	Author	Date

1 Replaces furnace tune-up measure in ResidentialFurnaceMeasures_v01; changed algorithm to match commercial boiler tune-up	JP	
1.1 Specified action, removed modification type from list of inputs from customer/vendor	JP	
1.2 Corrected error so that cost of tune-up is an optional input, increased cost of tune-up to $200	JP	
2.1 Changed savings equation	Franklin Energy	8/14/2012
2.2 Added Multi-family buildings to the measure	Franklin Energy	8/14/2012
2.3 Added efficiency standards	Franklin Energy	8/14/2012
2.4 Added references	Franklin Energy	8/14/2012
2.5 Changed wording of Btuh_input description	JP	4/3/2013
3.0 Added Service Recommendations and changed algorithm format to EFLH and Boilers	FES	11/12/2015

Residential HVAC – Thermostats with Gas Heating

Version No. 2.0

Measure Overview

Description: This measure includes installation of a programmable (Tier I), communicating (Tier II), or analytics capable (Tier III) thermostat in existing homes, or a communicating or analytics capable thermostat in new homes.

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

Caution is advised in using this measure as few large scale pilots have been completed to date and results have varied significantly.

Actions: Replace on Fail, Replace Working, New Construction

Target Market Segments: Residential

Target End Uses: HVAC

Applicable to: Residential customers in single-family homes, duplexes, townhomes, and multi-family homes (including 3- and 4- family homes).

Algorithms:

Unit kWh Savings per Year = (CSF x Cooling kWh)

Unit Peak kW Savings = 0 unless Tier III device with demand response program. See Notes.

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

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 10 (Ref. 1, 2)

Unit Participant Cost = See Table 2 or use actual device costs plus installation cost if available.

Where:

Heating Dth = Baseline heating energy for natural gas-heated residences in pilot area. Default = 69 Dth/yr (Ref. 9)

Cooling kWh = Baseline cooling energy for residences in pilot area. Default = 760 kWh/yr (Ref. 9)

HSF = Heating savings factor, assumed fraction of heating energy saved by thermostat, see Table 1.

CSF = Cooling savings factor, assumed fraction of cooling energy saved by thermostat, see Table 1.

Required from Customer/Contractor: Confirmation of heating type, existing or new home

Example:

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

Unit kWh Savings per Year = 0.089 x 760 = 67.6
Unit kW Savings = 0
Unit Dth Savings = 0.089 x 69 = 6.1

Deemed Input Tables:

Table 1: Heating and cooling savings factors (Ref. 2, 3), incremental costs (Ref. 2, 8)

	Tier I	Tier II	Tier III
Heating (HSF)	3.6%/0%[3]	5.4%	8.9%
Cooling (CSF)	0.0%	5.4%	8.9%
Incremental Cost[1,2]	$30	$110	$200

[1]*Tier III devices often require a monthly fee for software updates and data management. These fees should be factored into cost-benefit analyses. A typical fee is $3 per month (Ref.)*

[2]*Does not include installation costs.*

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

Methodology and Assumptions:

A Tier I (programmable) thermostat is assumed to replace a manual thermostat. 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.

As a result, the savings factors may require adjustment as more pilot programs are completed.

Notes:

Few large scale pilot programs have been completed as of the drafting of this measure and results vary significantly.

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.

ENERGY STAR proposed a new specification for connected (Tier II) thermostats on June 17, 2015.

The specification will be based on demonstrated savings with aggregate data.

This measure could be modified to reference the new ENERGY STAR specification when finalized.

References:

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc. June 2007.
2. DTE Residential Thermostats, Market Assessment of Advanced Residential Programmable Thermostats, Navigant. December 2014.

   Midpoint of device cost ranges used for Tier II, Tier III incremental costs.

3. Tier I savings factor of 3.6% is based on the following sources: Ref. 2, 2.0%; Ref. 4, 6.6%, Ref. 5, 3.9%; Ref 6., 3.6%. If ISR of 56% is assumed for non-direct installs (Ref. 7), Ref. 4 savings are 3.7%.
4. Validating the Impacts of Programmable Thermostats, Final Report, RWL Analytics. 2007

5. CenterPoint Energy 2013-2015 Triennial CIP Plan, Docket No. G008/CIP-12-564. CPE estimated a reduction of 2.8 Dth for programmable thermostats, equivalent to 3.9% of the average heating load in its territory based on a 1.4F/18 hour average setback.

   The 1.4F average setback accounts for customers that do not program a schedule or manually override the schedule.

6. Xcel Energy 2013-2015 Triennial CIP Plan, Docket No. E,G002/CIP-12-447. Energy savings for the thermostat setback were calculated in RemRate modeling using a baseline model home calibrated to typical home size and characteristics for the Minneapolis/St.Paul area. Natural gas savings = 74.4 - 71.8 = 2.6 Dth/yr, equivalent to about 3.6% savings.
7. Programmable Thermostats. Report to KeySpan Energy Delivery on Energy and Cost Effectiveness, GDS Associates, Marietta, GA. 2002
8. Market price vary significantly for this product, the basic functions required are available on units readily available in the market for the listed price. (Illinois Statewide Technical Reference Manual for Energy Efficiency Version 3.0, 2014)
9. Baseline heating and cooling energy are derived from monthly sales information included in the 2015 jurisdictional annual reports filed by CenterPoint Energy and Xcel Energy (docket no. E,G999/PR-15-4) for calendar year 2014.

   The gas heating figure is based on weather-normalized sales. The cooling figure is based on non-weather normalized sales. The gas heating figure was convered to kWh for electric resistance heating assuming an average gas efficiency of 0.8 and electric efficiency of 100%.

   The electric resistance heating figure was used to derive average heating kWh for air source and ground source heat pumps assuming efficiencies of 7.7 HSPF and 3.3 COP, respectively.

Document Revision History:

Version / Description	Author	Date
1.0 Measure Created	Franklin Energy	2/28/2014
1.1 Added duplex to multifamily category	JP	3/11/2014
1.2 Added IECC 2012 note	Franklin Energy	7/31/2014
1.3 In Methodology and Assumption, changed “solely” to”primarily” regarding gas heating for consistency with Description.	JP	7/31/2014
2.0 Expanded measure to three Tiers of Thermostats,	FES	11/12/2015

Residential HVAC - Furnace Quality Installation/Maintenance

Version No. 1.1

Measure Overview

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).

1. For each tune-up or new installation, a contractor must perform the following actions in addition to a standard "clean and check":
2. Determine manufacturer's expected capacity based on current conditions. This includes determining the gas flow rate by clocking the gas meter.
3. With equipment running, measure the temperature difference across the heat exchanger. Adjust airflow to manufacturer's rated temperature range.
4. Measure dry bulb temperature at the equipment.
5. Measure dry bulb temperature at three grilles and registers.
6. 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.

Actions: O&M, Replace Working, Replace on Fail, New Construction
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: residential customers in single-family homes, duplexes, townhomes, and multi-family homes (including 3- and 4-family homes) with residential type furnaces.

Algorithms

Unit kWh Savings per Year = 0
Unit Peak kW Savings = 0
Unit Dth Savings per Year = Btuh_prop x LF x EFLH x AFUE_prop x (1/(AFUE_base x CEbase) - 1/(AFUE_prop x CEprop)) / C
Unit Gallons Fuel Oil Savings per Year = 0
Unit Gallons Propane Savings per Year = 0
Measure Lifetime = 20 years if Replace on Fail, New Construction, or Replace Working; 10 years if O&M (Ref. 3)

Unit Participant Incremental Cost = Field Testing/Verification Labor + Incremental Equipment/Installation Cost if new furnace installed. See Table 2a and 2b.

Where:

Btuh_prop = 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.
LF = the load factor, assumed to be 0.77 (implies 30% oversizing) (ref. 2)
AFUE_base = Nameplate efficiency of the existing furnace. If Replace on Fail = 80%. If New Construction baseline efficiency = 90% (Ref. 4).
AFUE_prop = Nameplate efficiency of the proposed furnace. If furnace is not being replaced, then AFUE_prop = AFUE_base.
CE_base = Test-in conversion efficiency of existing furnace. A formula for conversion efficiency is provided in Methodology and Assumptions.
CE_prop = Test-out conversion efficiency of proposed furnace. A formula for conversion efficiency is provided in Methodology and Assumptions.
EFLH = Effective full load heating hours. See Table 1.
C = conversion factor from Btu to Dth, 1,000,000 Btu/Dth.

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).

Examples:

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

Unit Dth Savings per Year = (60000 x 0.77 x 1956 x 0.80 x (1/(0.80 x 0.70) - 1/(0.80 x 0.90)))/1000000 = 28.7

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. 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 = 60000 x 0.77 x 2245 x 0.95 x (1/(0.80 x 0.75) - 1/(0.95 x 0.88))/1e6 = 46.4

Example 3: *Install a 60,000 Btu/h, 97% AFUE furnace in a new single-family home located in Climate Zone 2. The test-out conversion efficiency is calculated as 98%.*

Unit Dth Savings per Year = 60000 x 0.77 x 2099 x 0.97 x (1/(0.90 x 0.72) - 1/(0.97 x 0.98))/1000000 = 46.2

Deemed Input Tables

Table 1. Effective Full Load Heating Hours by Climate Zone (ref. 7)

Zone	Equivalent Full Load Heating Hours
Zone 1 (Northern MN)	2280
Zone 2 (Central MN)	2099
Zone 3 (Southern MN/Twin Cities)	1932

Table 2a. Estimated field testing and verification labor costs (Ref. 6)

Job Type	Labor
Tune-up (O&M)	$170
Replace Working	$170
Replace on Fail or New Construction	$78

Table 2b. Incremental Equipment and Installation Costs (Ref. 5)

New Furnace Efficiency	Existing Home	New Construction
AFUE ≥ 90% and < 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

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). 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).

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.

Values were scaled as follows: $EFLH_{MN} = EFLH_{IL} \times HDD_{65,MN} / HDD_{65,IL} \times DTD_{IL} / DTD_{MN}$, where DTD is the design temperature difference.

Geography	HDD65	DTD
Chicago, IL	6,339	73.5
MN Zone 1	9,833	92
MN Zone 2	8,512	86.5
MN Zone 3	7,651	84.5

References

1. Assumed baseline conversion efficiency is drawn from a sample of 507 homes in Iowa field tested in 2011 and 2012. Assumed proposed conversion efficiency is drawn from a sample of 588 homes that participated in the HVAC SAVE program in Iowa in 2014 and 2015 and based on in-field verification and testing. Conversion efficiencies higher than 100 were excluded from the calculation.
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. 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

   A measure life of 9 years for O&M assumes that on average, tune-ups are performed at the midpoint of the equipment's lifespan (18 years).

4. The US Code of Federal Regulations, 10 CFR 430.32(e)(1)(i) defines a minimum AFUE of 78% for residential non-weatherized gas furnaces manufactured before November 19, 2015. On this date, the minimum AFUE changes to 80%. A baseline of 80% is used for Replace Working because there are very few models available below this efficiency; a review of AHRI shows that most low efficiency units are 80%.

   A 90% AFUE baseline for new construction is based on a Minnesota Department of Commerce analysis from 2006 showing that the vast majority of furnaces installed in hew homes were 90% or higher.

5. Xcel Energy 2010-2012 CIP Triennial (Docket No. E,G002/CIP-09-198)

6. Incremental labor costs for QI/QM were derived from the following labor estimates.

Table 3. 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 4. Field Time Estimates (Replace Working, 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
		120
	Contractor Billable Rate	$85.00
	Measure Cost	$170.00

7. Calculated through energy modeling by FES

Document Revision History

Version / Description	Author	Date
1. New measure	FES	9/14/2015
2. Modified lifetime methodology	FES	10/30/2015

Residential Insulation and Air Sealing

Version No.
1.4

Measure Overview

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.

Actions: Modify
Target Market Segments: Residential, Commercial
Target End Uses: Envelope

Applicable to: Residential and small commercial customers with natural gas heating. For existing buildings only.

Algorithms

Unit kWh Savings per Year = 0

Unit Peak kW Savings = 0

Unit Dth Savings per Year = Wall Insulation Savings + Attic Insulation Savings + Air Sealing Savings

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years): 20 (Ref. 2)

Unit Participant Incremental Cost: See Table 3

Where:

Wall Insulation Savings (Dth) = ((1/(R1_w + R_wa) - 1/(R2_w+R_wa)) * A_w * (1-Framing_factor))*24*HDD*CF/ Eff)/1,000,000

Attic Insulation Savings (Dth) = ((1/(R1_a + R_aa) – 1/(R2_a+R_aa)) * A_a * (1-Framing_factor/2))*24*HDD*CF/Eff)/1,000,000

Air Sealing Savings (Dth) = ((1.08 x 24 x HDD x CFM50 x CF/ N_heat)/ Eff)/1,000,000 (Ref. 3)

R1_w = Initial R-value of wall insulation

R2_w = Final R-value of wall insulation

R_wa = R-value of uninsulated wall assembly including air films = 2.73. See Methodology and Assumptions for derivation.

R1_a = Initial R-value of attic insulation

R2_a = Final R-value of attic insulation

R_aa = R-value of uninsulated attic assembly including air films = 2.37. See Methodology and Assumptions for derivation.

A_w = Total area of insulated wall (square feet)

A_a = Total area of insulated ceiling/attic (square feet)

Framing_factor = 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.

Eff = Efficiency of Heating System. Assume 80% if unknown.

CFM50 = Total reduction in Infiltration at 50 Pascals as measured by blower door. If unknown, use 1000.

CF = 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: 1,000,000 Btu/Dth

Required from Customer/Contractor: Pre and postR-values of attic insulation (if applicable); pre and post R-values of wall insulation (if applicable); confirmation of gas heating, relative exposure of building (well-shielded, normal, or exposed, if air sealing), no. of stories (if air sealing), project location (county).

Optional from Customer/Contractor: Efficiency of heating system, Infiltration before and after sealing as measured by blower door testing at 50 Pascals (if applicable). Blower door testing is recommended to measure effectiveness of air sealing.

Example:

A two-story single-family house with 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.

Wall Insulation Savings = 0

*Attic Insulation Savings = ((1/(11+2.37) - 1/(50+2.37) * 1,000 * (1 - 0.15/2) * 24 * 9,833 *0.7 / 0.80) / 1,000,000 = 10.6 Dth*

*Air Sealing Savings = ((1.08 * 24 * 9,833 * 500 * 0.7 / 12.4) / 0.8) / 1,000,000 = 9.0 Dth*

Unit Dth Savings per Year = 0+10.6+9.0 = 19.6 Dth

Deemed Input Tables:

Table 1: Heating Degrees Days (HDD) per zone in Minnesota

Minnesota	Zone 1	Zone 2	Zone 3
	(Northern MN)	(Central MN)	(Southern MN / Twin Cities)
HDD65 (Ref. 5)	9,833	8,512	7,651

Table 2: N_heat for Minnesota, based on relative Wind Shielding Correction Factors and Height Correction Factors (Ref. 2)

Relative Exposure	Building Height (Stories)		
(see definitions below)	1	2	3
Well Shielded	18.6	14.9	13.0
Normal	15.5	12.4	10.9
Exposed	14.0	11.2	9.8

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: Incremental Costs of Insulation (Ref. 6)

Insulation Type	Incremental Cost ($ / Square Foot)
Roof/Ceiling Insulation	$1.36
Wall Insulation	$0.94

Methodology and Assumptions:

The potential summer cooling electric savings from this measure is ignored, as the cooling hours in this area are limited, and customers may not use central cooling.

The assumed R-value of an uninsulated wall assembly was derived from the following inputs:

Table 4. 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 5. 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:

There are statewide energy codes related to minimum insulation values of newly constructed and renovated commercial and residential buildings. There may also local building codes in place. Energy codes pertaining to insulation, air sealing, and ventilation should be verified for each utility or location.

Minnesota is expected to adopt a new residential energy codes in 2014 referencing the 2012 International Energy Conservation Code.

References:

1. All insulation algorithms in this work paper come from the Illinois Statewide Technical Reference Manual, Sections 7.6.1 and 7.6.4, July 18, 2012

2. 2008 Database for Energy-Efficient Resources, Version 2008.2.04 October 30, 2008, EUL/RUL (Effective/Remaining Useful Life) Values

3. Air sealing algorithms from Building Energy Solutions, Inc., Explanation of Blower Door Terms and Results. This source cites another document: TECTITE BUILDING AIRTIGHTNESS TEST by The Energy Conservatory, which is not publicly available.

4. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

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. 2008 Database for Energy-Efficient Resources, Revised DEER Measure Cost Summary, June 2, 2008

7. The correction factor corrects heating usage as building balance points are below 65F, and setback schedules are common. A typical heating degree day correction factor is 0.7. Assuming a typical building balance point temperature of 55F if was found that for a sampling of Minnesota cities HDD55 = 0.7 x HDD65.

8. 2006 International Residential Code Section N1101 as amended by Minnesota Residential Energy Code (Minn. Rules chapter 1322.1101.)

9. 2006 International Residential Code Section R303, as incorporated by Minnesota Residential Energy Code (Minn. Rules chapter 1322).

10. 2006 International Residential Code Section N1104 as amended by Minnesota Residential Energy Code (Minn. Rules chapter 1322.1104.)

Documentation Revision History :

Version/Description	Author	Date
1. Original Document	FES	7/31/2012
1.1 Changed Action to Modify	JP	11/24/13
1.2 Added “confirmation of gas heating system” to Required Inputs	JP	11/25/2013
1.3 Corrected required and optional inputs from customer/contractor, changed example to include air sealing, reformatted algorithm for clarity, modified description, added Commercial to market segment since also applicable to small commercial customers. Added definitions of shielding categories from FES.	JP	2/14/2014
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 algorithms	FES	12/18/15

Combined Electric and Gas Efficiency Measures

Commercial Food Service - ENERGY STAR® Dishwasher

Version No. 1.1

Measure Overview

Description:

This measure involves the installation of an ENERGY STAR commercial dishwasher.

Actions: Replace on Fail, Replace Working, New Construction
Target Market Segments: Commercial, Restaurants, Schools
Target End Uses: Other

Applicable to: Commercial kitchens

Algorithms

Unit kWh Savings per Year = kWh_dhw + kWh_boost + kWh_idle

Unit Peak kW Savings = Unit kWh Savings per Year / t_annual * CF

Unit Dth Savings per Year = therms_dhw + therms_boost

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = See Table 3 (See Ref. 1)

Unit Participant Incremental Cost = See Table 4 (Ref. 1)

Where:

kWh_dhw = (Cp * ρH2O * ΔT_dhw / η_electric / C1) * (RPD * (GPR_base - GPR_ES) * Days)

kWh_boost = (Cp * ρH2O * ΔT_boost / η_electric / C1) * (RPD * (GPR_base - GPR_ES) * Days)

kW_idle = (kW_idle_base - kW_idle_ES) * (t_annual - (Days * RPD * t_rack / C2)

therms_dhw = (Cp * ρH2O * ΔT_dhw / η_gas / C1) * (RPD * (GPR_base - GPR_ES) * Days)

therms_boost = (Cp * ρH2O * ΔT_boost / η_gas / C1) * (RPD * (GPR_base - GPR_ES) * Days)

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 whole building water heaters.

ΔT_boost = 40°F. Inlet water temperature rise for booster heaters.

η_gas = 80%. Gas water heater efficiency.

η_electric = 98%. Electric water heater efficiency.

RPD = racks per day. See Table 1 or 2 (Ref. 1)

GPR_base = gallons per rack of baseline dishwasher. See Table 1 (Ref. 1)

GPR_ES = gallons per rack of baseline dishwasher. See Table 1 (Ref. 1)

Days = 360 days/year. Annual days of operation. (Ref. 2)

kW_idle_base = Idle power draw of baseline dishwasher. See Table 1 (Ref. 1)

kW_idle_ES = idle power draw of ENERGY STAR dishwasher. See Table 2 (Ref. 1)

t_annual = 6,570 hours. Annual hours of dishwasher operation. (Ref. 1)

t_rack = See Table 1. Cleaning time per rack. (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.

CF = 1.0. Coincidence factor.

Required from Customer/Contractor: Dishwasher type, water heater fuel, booster water heater fuel

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 * 8.34 lb/gal * 70°F / 98% / 3,413 Btu/kWh) * (280 racks/day * (1.29 gal/rack - 0.89 gal/rack) * 360 day/yr) = 7,038 kWh*

*kWh_boost = (1 Btu/lb-°F * 8.34 lb/gal * 40°F / 98% / 3,413 Btu/kWh) * (280 racks/day * (1.29 gal/rack - 0.89 gal/rack) * 360 day/yr) = 4,021 kWh*

*kWh_idle = (0.87 kW - 0.70 kW) * (6,570 hrs - (360 day/yr * 280 rack/day * 1.0 min/rack / 60 min/hr)) = 831 kWh*

Unit kWh Savings per Year = 7,038 kWh + 4,021 kWh + 862 kWh = 11,890 kWh

*Unit Peak kW Savings = 11,921 kWh / 6,570 hrs * 1.0 = 1.810 kW*

Deemed Input Tables:

Table 1: Baseline Dishwasher Characteristics

Dishwasher Type	RPD	GPR	kW_Idle	t_rack
High Temp Door Type	280	1.29	0.87	1.0
High Temp Multi Tank Conveyor	600	0.97	2.59	0.2
High Temp Single Tank Conveyor	400	0.87	1.93	0.3
High Temp Under Counter	75	1.09	0.76	2.0
Low Temp Door Type	280	2.10	0.60	1.5
Low Temp Multi Tank Conveyor	600	1.04	2.00	0.3
Low Temp Single Tank Conveyor	400	1.31	1.60	0.3
Low Temp Under Counter	75	1.73	0.50	2.0

Table 2: ENERGY STAR Dishwasher Characteristics

Dishwasher Type	RPD	GPR	kW_Idle	t_rack
High Temp Door Type	280	0.89	0.70	1.0
High Temp Multi Tank Conveyor	600	0.54	2.25	0.2
High Temp Single Tank Conveyor	400	0.70	1.50	0.3
High Temp Under Counter	75	0.86	0.50	2.0
Low Temp Door Type	280	1.18	0.60	1.5
Low Temp Multi Tank Conveyor	600	0.54	2.00	0.3
Low Temp Single Tank Conveyor	400	0.79	1.50	0.3
Low Temp Under Counter	75	1.19	0.50	2.0

Table 3: Equipment Lifetime

Equipment Lifetime (Years)	
Under Counter	10
Door Type	15
Single Tank Conveyor	20
Multi Tank Conveyor	20

Table 4: Incremental Costs

Incremental Cost	
Low Temp - Under Counter	$50
Low Temp - Door Type	$0
Low Temp - Single Tank Conveyor	$0
Low Temp - Multi Tank Conveyor	$970
High Temp - Under Counter	$120
High Temp - Door Type	$770
High Temp - Single Tank Conveyor	$2,050
High Temp - Multi Tank Conveyor	$970

Table 5: ENERGY STAR Criteria

ENERGY STAR Efficiency Requirements for Commercial Dishwashers				
Machine Type	High Temp Efficiency Requirements		Low Temp Efficiency Requirements	
	Idle Energy Rate*	Water Consumption**	Idle Energy Rate*	Water Consumption
Under Counter	≤ 0.50 kW	≤ 0.86 gal/rack	≤ 0.50 kW	≤ 1.19 gal/rack
Stationary Single Tank Door	≤ 0.70 kW	≤ 0.89 gal/rack	≤ 0.60 kW	≤ 1.18 gal/rack
Single Tank Conveyor	≤ 1.50 kW	≤ 0.70 gal/rack	≤ 1.50 kW	≤ 0.79 gal/rack
Multiple Tank Conveyor	≤ 2.25 kW	≤ 0.54 gal/rack	≤ 2.00 kW	≤ 0.54 gal/rack

From: http://www.energystar.gov/index.cfm?c=comm_dishwashers.pr_crit_comm_dishwashers , accessed 02/07/13.
*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 6: Calculated Savings Values

Dishwasher System Description	Annual Savings		
	kW	kWh	therms
High Temp, Electric Heat, Electric Booster, Door Type	1.8098	11,890	-
High Temp, Electric Heat, Electric Booster, Multi Tank Conveyor	4.1803	27,464	-
High Temp, Electric Heat, Electric Booster, Single Tank Conveyor	1.4049	9,230	-
High Temp, Electric Heat, Electric Booster, Under Counter	0.4836	3,177	-
High Temp, Gas Heat, Electric Booster, Door Type	0.7386	4,853	168
High Temp, Gas Heat, Electric Booster, Multi Tank Conveyor	1.7127	11,253	387
High Temp, Gas Heat, Electric Booster, Single Tank Conveyor	0.7545	4,957	102
High Temp, Gas Heat, Electric Booster, Under Counter	0.3187	2,094	26
High Temp, Gas Heat, Gas Booster, Door Type	0.1265	831	194
High Temp, Gas Heat, Gas Booster, Multi Tank Conveyor	0.3027	1,989	438
High Temp, Gas Heat, Gas Booster, Single Tank Conveyor	0.3829	2,516	270
High Temp, Gas Heat, Gas Booster, Under Counter	0.2244	1,474	413
Low Temp, Electric Heat, Door Type	2.4637	16,186	-
Low Temp, Electric Heat, Multi Tank Conveyor	2.8692	18,851	-
Low Temp, Electric Heat, Single Tank Conveyor	2.0783	13,655	-
Low Temp, Electric Heat, Under Counter	0.3873	2,545	-
Low Temp, Gas Heat, Door Type	-	-	387
Low Temp, Gas Heat, Multi Tank Conveyor	-	-	450
Low Temp, Gas Heat, Single Tank Conveyor	0.0889	584	312
Low Temp, Gas Heat, Under Counter	-	-	61

References:

1. Commercial Kitchen Equipment Savings Calculator, ENERGY STAR. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx. Accessed 07/17/15.

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 Efficiency Requirements for Commercial Dishwashers, Version 2.0. ENERGY STAR. http://www.energystar.gov/sites/default/files/specs//private/Commercial_Dishwasher_Program_Requirements%20v2_0.pdf. Accessed 7/17/15.

Documentation Revision History

Version / Description	Author	Date
1. Put together algorithm	Franklin Energy Services	7/15/2015
1.1 Updated savings example	Franklin Energy Services	7/20/2015

Commercial HVAC - Demand Control Ventilation

Version No. 2.0

Measure Overview

Description: This measure includes the retro-fit of existing equipment or the optional addition of demand control ventilation. This measure analyzes the cooling savings potential of the installation of demand control ventilation on unitary equipment. This measure is applicable to DX and water cooled air systems.

The incremental cost is associated with CO2 sensor equipment cost and programming, the incremental cost does not include any damper actuator installation costs.

Actions: Replace Working (addition on working equipment)
Target Market Segments: Commercial & Industrial
Target End Uses: HVAC

Applicable to: Commercial & Industrial customers where air unitary equipment has been/could be installed.

Algorithms

Unit kWh Savings per Year = (4.5 x CFM x Δh) x ($EFLH_{Cool}$ x 12 / SEER) x SF_C / 3412

Unit Peak kW Savings = 0

Unit Dth Savings per Year = [(1.08 x CFM)/η x HDD65 x Hours] / 1,000,000 x

SF_H Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 years (Ref. 1)

Unit Participant Incremental Cost= See Table 2 (Ref.

2) Where:

CFM = Outside Air flow in cubic feet per minute. Provided by customer.

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. If unknown, use SEER = EER/0.875 (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)

ΔT = Difference in temperature (°F) between the return air conditions (Ref. 10) and the design day outside air conditions (Ref. 11). See Table 1 for default values if not provided.

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

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).

Example:

Install a CO2 senor in the return duct for a 10.5 EER 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 (36.3 - 28.8)) x (446 x 12 / (10.5/.875)) x 0.15 / 3412= 990 KWh

Unit Dth Savings per Year = ((1.08 x 1500) / 0.8 x 7651 x 12) / 1,000,000 x 0.18= 33 Dth

Deemed Input Tables:

Table 1: Enthalpies, heating degree days and incremental costs.

	Design Cooling	Cooling Return	HDD65	Incremental
Zone #	h (Btu/lbm) (Ref. 3)	h (Btu/lbm) (Ref. 4)	(°F-days) (Ref. 8)	Cost (Ref. 2)
Northern: #1	28.8	32.1	9883	$0.60/CFM
Central: #2	28.8	35.1	8512	$0.60/CFM
Southern: #3	28.8	36.3	7651	$0.60/CFM

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)	EFLH - Zone 1	EFLH - Zone 2	EFLH - Zone 3
Convenience Store	0.3	0.40	647	825	986
Education - Community College /University	0.3	0.40	682	782	785
Education - Primary	0.3	0.40	289	338	408
Education - Secondary	0.3	0.40	484	473	563
Health/Medical - Clinic	0.2	0.34	558	738	865
Health/Medical - Hospital	0.3	0.40	663	1089	1298
Lodging	0.1	0.18*	401	606	754
Manufacturing	0.2	0.34	347	472	589
Office-Low Rise	0.1	0.18	257	359	446
Office-Mid Rise	0.1	0.18	373	529	651
Office-High Rise	0.1	0.18	669	1061	1263
Restaurant	0.3	0.40	347	535	652
Retail - Large Department Store	0.3	0.40	462	588	686
Retail - Strip Mall	0.3	0.40	307	441	574
Warehouse	0.3	0.36	164	343	409
Other/Miscellaneous	0.3	0.33	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 / Eff. x Equivalent full load hours x conversion

Where: Design Heating Load = (1.08 x CFM x ΔT), Equivalent full load hours = 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)/η x HDD65 x Hours) / 1,000,000 x SF_H

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 Chart at Barometric Pressure 29.921 Inches of Mercury", by Trane and ASHRAE
2009 Fundamentals Cooling DB/MCWB @ 0.4% averaged across zones

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

Documentation Revision History:

Version	Description	Author	Date
2.0	Added 2015 Minnesota Energy Code Information. Updated $EFLH_{Cool}$ format and description and added other category.	FES	11.12.15

Commercial HVAC - Guest Room Energy Management Controls

Version No. 1.0

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.

Actions: Modify, Replace Working (retrofit), New Construction
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.

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

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 years (Ref. 1)

Unit Participant Incremental Cost = $260 (Ref. 2)

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 = The heating equivalent full load hours, select from table below: (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 = The cooling equivalent full load hours, select from table below: (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 the table below:

HVAC Cooling System	EER	Reference
PTAC, < 7,000 BTU	11.7	Ref. 5
PTAC, 7,000-15,000 BTU	13.8 - (0.300 x Cap/1000)	Ref. 5
PTAC, > 15,000 BTU	9.3	Ref. 5
PTHP, < 7,000 BTU	11.9	Ref. 5
PTHP, 7,000-15,000 BTU	14.0 - (0.300 x Cap/1000)	Ref. 5
PTHP, > 15,000 BTU	9.5	Ref. 5
Chilled Water Fan Coil Unit	12.5	Ref. 6

Where 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 the table below:

HVAC Heating System	COP	Reference
PTAC, All Sizes	1.0	Assumed for elec. resistance heat
PTHP, < 7,000 BTU	3.3	Ref. 5
PTHP, 7,000-15,000 BTU	3.7 - (0.052 x Cap/1000)	Ref. 5
PTHP, > 15,000 BTU	2.9	Ref. 5

Hot Water PTAC or Fan Coil Unit	0.8	Ref. 7

Where 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 decatherm

CF = 0.90, deemed coincidence factor (Ref. 9)

Required inputs 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

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 PTHP in climate zone 3.

*Cooling_Eff = 14.0 - (0.300 * Cap/1,000) = 14.0 - (0.300 * 9,000/1,000) = 11.3*

Coolng Savings = (9,000 / 1,000) x 754 x (1 / 11.3) x 18.4% = 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 * Cap/1,000) = 3.7 - (0.052 * 9,000/1,000) = 3.23*

Heating Savings = (9,000 / 3412) 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 * Cap/1,000) = 14.0 - (0.300 * 9,000/1,000) = 11.3*

Cooling Savings = (9,000 / 1,000) x 606 x (1 / 11.3) x 18.4% =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:

EFLHCool 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.

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. 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.
http://www.ecfr.gov/cgi-bin/text-idx?SID=683dd820ec02f5e7beaa862cd5239790&mc=true&node=pt10.3.431&rgn=div5

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. http://www.ecfr.gov/cgi-bin/text idx?SID=683dd820ec02f5e7beaa862cd5239790&mc=true&node=pt10.3.431&rgn=div5

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.

Documentation Revision History

Version / Description	Author	Date
1.0 Initial draft, new work papers	Franklin Energy Services	7/30/2015
1.1 Updating NG savings method to EFLH method	Franklin Energy Services	11/16/2015

C/I HVAC– Parking Garage Exhaust Fan CO Control and Heating

Version No. 1.1

Measure Overview

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).

Actions: Modify, New Construction
Target Market Segments: We envision this measure to be used by Assembly, Big Box Retail, Grocery, Large Office, and Industrial customers. This measure applies to both Commercial and Industrial retrofit projects.
Target End Uses: HVAC

Applicable to: Commercial and Industrial Customers

Algorithms

Unit kWh Savings per Year = (HP x LF x UF x C_1 x t x SF) / η_{motor}

Unit Peak kW Savings = (HP x LF x UF x C_1 x CF) / η_{motor}

Heating kWh Savings per Year (if Electric) = (HP x C_2 x $t_{heating}$ x (T_{set} – T_{cold}) x C_3 x SF) / (C_4 x $\eta_{heating}$)

Unit Dth Savings per Year = (HP x C2 x $t_{heating}$ x (T_{set} – T_{cold}) x C_3 x SF) / (C_4 x $\eta_{heating}$)

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 15 (Ref. 1)

Unit Participant Incremental Cost = $800/HP (Ref. 2)

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 8766

SF = Annual reduction in operating hours, 33% (Ref. 3)

CF = Coincidence Factor of 0.88[3] (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)

Required from Customer/Contractor: motor size, efficiency, heating type

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 8766 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:

a. Garages less than 30,000 ft2 with ventilation systems that do not utilize mechanical cooling or mechanical heating.
b. 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.
c. Where not permitted by the authority have jurisdiction. (Ref. 9)

[3] Comparing Ref. 3 with 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

Documentation Revision History:

Version / Description	Author	Date
1. Created standalone specifications for parking garage exhaust fan CO controls and heating	FES	11/12/15
1.1 Corrected constant in Dth Savings algorithm	FES	11/30/15

C/I - Building Operator Certification

Version No.
1.0

Measure Overview

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.

Actions: Modify
Target Market Segments: Commercial, Industrial, Public
Target End Uses: HVAC, Lighting

Applicable to: Commercial, Industrial, and Public Buildings

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

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 5 years (See Ref. 2)

Unit Participant Incremental Cost = $1,200 per participant (Ref. 3)

Where:

Rebate Factor = 0 for incentivized projects, 1 for no incentive paid

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

Required from Customer/Contractor: Completion of Level I of Level II BOC training

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. * 0.121 kWh/sq. ft.= 29,040 kWh/yr.*

*Building therm savings per year = 240,000 sq. ft. * 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:

Building Operator Certification (Electric/Gas), 2012. Prepared by Consumers Energy Business Solutions, pages 1-9

The Impact and Process Evaluation Building Operator Training and Certification (BOC) Program Final Report, Section 1.4, page 4

The 2010 Building Operator Certification Pilot Summary Report, Section 2, page 3

Document Revision History:

Version / Description	Author	Date
1) Document created	Franklin Energy Services	11/12/2015

Residential HVAC – Duct Sealing

Version No. 1.0

Measure Overview

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.

Actions: O&M
Target Market Segments: Residential
Target End Uses: HVAC

Applicable to: Residential customers in single-family homes, duplexes, townhomes, and multi-family homes (including 3- and 4-family homes) with residential type ducted heating or cooling systems.

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

Unit Gallons Fuel Oil Savings per Year = 0

Unit Gallons Propane Savings per Year = 0

Measure Lifetime (years) = 20 (Ref. 1)

Unit Participant Incremental Cost = $5 per CFM reduction (ΔCFM25DL) (Ref. 2)

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) / 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 = SEER x 0.875 (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

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

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 4. (Ref. 11)

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. 13)

CF = electric peak coincidence factor = 0.9 (Ref. 14)

Required from Customer/Contractor: ΔCFM25 as measured in pressurized duct test, Cooling System SEER, Heating System HSPF, Duct Location, project location (county).

Example:

Duct sealing in single family home Climate Zone 3 crawl space with 2.5 ton SEER 14 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 520 x 2.5 x 12,000 x 1.0 / (0.89 x 14) / 1000 + 38.3 x 0.0297 x 293 = 709 kWh

Unit kW Peak Savings = 300 / (2.5 x 400) x 2.5 x 12,000 x 1.0 / 1000 / (0.89 x 14 x

0.875) x 0.9 = 0.743 kW

Unit Dth Savings per Year = 300 / (60,000 x 0.017) x 1932 x 60,000 / 0.89 x 1.0 / 1,000,000 = 38.3 Dth

Deemed Input Tables:

Table 1. Equivalent Full Load Cooling Hours ($EFLH_{Cool}$) by Climate Zone (Ref. 4)

Zone	Equivalent Full Load Cooling Hours	
	Single Family	Multifamily*
Zone 1 (Northern MN)	213	228
Zone 2 (Central MN)	379	473
Zone 3 (Southern MN/Twin Cities)	520	616

**Includes duplex, townhome, and multifamily buildings with 3 or more units*

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

Table 4. Equivalent Full Load Heating Hours ($EFLH_{Heat}$) by Climate Zone (Ref. 12)

Zone	Equivalent Full Load Heating Hours
Zone 1 (Northern MN)	2280
Zone 2 (Central MN)	2099
Zone 3 (Southern MN/Twin Cities)	1932

**Includes duplex, townhome, and multifamily buildings with 3 or more units for in unit furnaces.*

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.

$EFLH_{Cool}$ 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 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: $EFLH_{MN} = EFLH_{IL} \times HDD_{65,MN} / HDD_{65,IL} \times DTD_{IL} / DTD_{MN}$, where DTD is the design temperature difference.

Geography	HDD65	DTD
Chicago, IL	6,339	73.5
MN Zone 1	9,833	92
MN Zone 2	8,512	86.5
MN Zone 3	7,651	84.5

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.

Notes:

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

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. 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. 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 = 0.875 x SEER

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. US Department of Energy (http://buildingsdatabook.eere.energy.gov/ChapterIntro7.aspx). Though the federal minimum efficiency is 78% there are very few models available at this efficient; a review of AHRI shows that most low efficiency units are 80%.

13. Building Performance Institute, Inc., 11/20/2007, Distribution Efficiency look- Up Table, Building Performance Institute Technical Standards for the Heating Professional.

14. 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.

Document Revision History:

Version / Description	Author	Date
1.0 New Measure	FES	11/12/2015

Appendix A – Climate Zones

Weather-dependent measures in the Minnesota TRM reference three different climate zones which are illustrated 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.

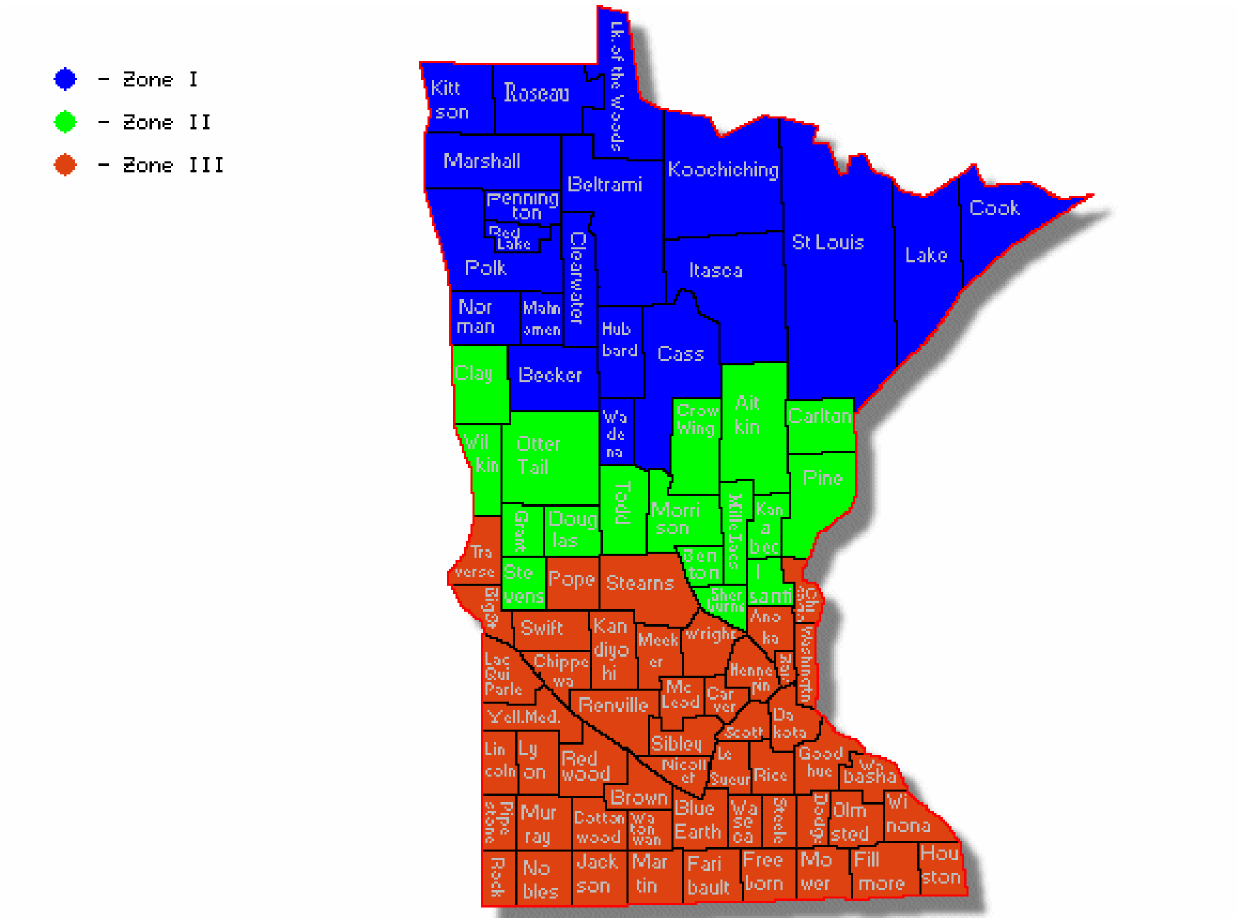

Figure A-1. Minnesota counties by climate zone (1, 2, and 3)

Table A-1. Minnesota counties by climate zone

	Zone 1	Zone 2	Zone 3	
Counties	Becker, Beltrami, Cass, Clearwater, Cook, Hubbard, Itasca, Kittson, Koochiching, Lake, Lake of the Woods, Mahnomen, Marshall, Norman, Pennington, Polk, Red Lake, Roseau, St. Louis, Wadena	Aitkin, Benton, Carlton, Clay, Crow Wing, Douglas, Grant, Isanti, Kanabec, Mille Lacs, Morrison, Otter Tail, Pine, Sherburne, Stevens, Todd, Wilkin	Anoka, Big Stone, Blue Earth, Brown, Carver, Chippewa, Chisago, Cottonwood, Dakota, Dodge, Faribault, Fillmore, Freeborn, Goodhue, Hennepin, Houston, Jackson, Kandiyohi, Lac qui Parle, Le Sueur, Lincoln, Lyon, McLeod, Martin, Meeker	Mower, Murray, Nicollet, Nobles, Olmsted, Pipestone, Pope, Ramsey, Redwood, Renville, Rice, Rock, Scott, Sibley, Stearns, Steele, Swift, Traverse, Wabasha, Waseca, Washington, Watonwan, Winona, Wright, 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. From the DER website, (http://mn.gov/commerce/energy/), please navigate to the ESP/TRM page under Conservation Improvement Program->Design Resources.

Appendix C – C/I Motor Tables

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	1	80.00%	82.50%	83.50%	$826.86	$311.97	$1,138.83
1200	ODP	1.5	84.00%	86.50%	87.50%	$821.85	$308.62	$1,130.47
1200	ODP	2	85.50%	87.50%	88.50%	$907.18	$365.64	$1,272.82
1200	ODP	3	86.50%	88.50%	89.50%	$953.05	$396.29	$1,349.34
1200	ODP	5	87.50%	89.50%	90.50%	$976.06	$411.67	$1,387.72
1200	ODP	7.5	88.50%	90.20%	91.20%	$1,323.26	$643.67	$1,966.93
1200	ODP	10	90.20%	91.70%	92.70%	$1,475.12	$745.15	$2,220.27
1200	ODP	15	90.20%	91.70%	92.70%	$2,541.29	$976.47	$3,517.75
1200	ODP	20	91.00%	92.40%	93.40%	$2,861.24	$1,190.27	$4,051.52
1200	ODP	25	91.70%	93.00%	94.00%	$3,261.14	$1,457.50	$4,718.64
1200	ODP	30	92.40%	93.60%	94.60%	$3,513.58	$1,626.18	$5,139.75
1200	ODP	40	93.00%	94.10%	95.10%	$4,222.09	$2,099.62	$6,321.70
1200	ODP	50	93.00%	94.10%	95.10%	$4,628.91	$2,371.47	$7,000.39
1200	ODP	60	93.60%	94.50%	95.50%	$5,831.16	$3,174.84	$9,006.00
1200	ODP	75	93.60%	94.50%	95.50%	$6,697.92	$3,754.03	$10,451.95
1200	ODP	100	94.10%	95.00%	96.00%	$8,402.69	$4,412.08	$12,814.77
1200	ODP	125	94.10%	95.00%	96.00%	$10,323.06	$5,695.32	$16,018.38
1200	ODP	150	94.50%	95.40%	96.40%	$10,693.62	$5,942.94	$16,636.56
1200	ODP	200	94.50%	95.40%	96.40%	$12,801.47	$7,351.45	$20,152.92
1200	ODP	250	95.40%	95.40%	96.40%	$15,888.00	$9,413.95	$25,301.95
1200	ODP	300	95.40%	95.40%	96.40%	$20,204.33	$12,298.23	$32,502.56
1200	ODP	350	95.40%	95.40%	96.40%	$29,220.28	$18,322.91	$47,543.19

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	400	95.80%	95.80%	96.80%	$32,992.47	$20,843.58	$53,836.05
1200	ODP	450	96.20%	96.20%	97.20%	$56,915.81	$36,829.75	$93,745.56
1200	ODP	500	96.20%	96.20%	97.20%	$59,663.64	$38,665.92	$98,329.55
1200	TEFC	1	80.00%	82.50%	83.50%	$826.86	$311.97	$1,138.83
1200	TEFC	1.5	85.50%	87.50%	88.50%	$821.85	$308.62	$1,130.47
1200	TEFC	2	86.50%	88.50%	89.50%	$907.18	$365.64	$1,272.82
1200	TEFC	3	87.50%	89.50%	90.50%	$953.05	$396.29	$1,349.34
1200	TEFC	5	87.50%	89.50%	90.50%	$976.06	$411.67	$1,387.72
1200	TEFC	7.5	89.50%	91.00%	92.00%	$1,323.26	$643.67	$1,966.93
1200	TEFC	10	89.50%	91.00%	92.00%	$1,475.12	$745.15	$2,220.27
1200	TEFC	15	90.20%	91.70%	92.70%	$2,541.29	$976.47	$3,517.75
1200	TEFC	20	90.20%	91.70%	92.70%	$2,861.24	$1,190.27	$4,051.52
1200	TEFC	25	91.70%	93.00%	94.00%	$3,261.14	$1,457.50	$4,718.64
1200	TEFC	30	91.70%	93.00%	94.00%	$3,513.58	$1,626.18	$5,139.75
1200	TEFC	40	93.00%	94.10%	95.10%	$4,222.09	$2,099.62	$6,321.70
1200	TEFC	50	93.00%	94.10%	95.10%	$4,628.91	$2,371.47	$7,000.39
1200	TEFC	60	93.60%	94.50%	95.50%	$5,831.16	$3,174.84	$9,006.00
1200	TEFC	75	93.60%	94.50%	95.50%	$6,697.92	$3,754.03	$10,451.95
1200	TEFC	100	94.10%	95.00%	96.00%	$8,402.69	$4,412.08	$12,814.77
1200	TEFC	125	94.10%	95.00%	96.00%	$10,323.06	$5,695.32	$16,018.38
1200	TEFC	150	95.00%	95.80%	96.80%	$10,693.62	$5,942.94	$16,636.56
1200	TEFC	200	95.00%	95.80%	96.80%	$12,801.47	$7,351.45	$20,152.92
1200	TEFC	250	95.00%	95.80%	96.80%	$15,888.00	$9,413.95	$25,301.95
1200	TEFC	300	95.00%	95.80%	96.80%	$20,204.33	$12,298.23	$32,502.56

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	350	95.00%	95.80%	96.80%	$29,220.28	$18,322.91	$47,543.19
1200	TEFC	400	95.00%	95.80%	96.80%	$32,992.47	$20,843.58	$53,836.05
1200	TEFC	450	95.00%	95.80%	96.80%	$56,915.81	$36,829.75	$93,745.56
1200	TEFC	500	95.00%	95.80%	96.80%	$59,663.64	$38,665.92	$98,329.55
1800	ODP	1	82.50%	85.50%	86.50%	$826.86	$311.97	$1,138.83
1800	ODP	1.5	84.00%	86.50%	87.50%	$821.85	$308.62	$1,130.47
1800	ODP	2	84.00%	86.50%	87.50%	$907.18	$365.64	$1,272.82
1800	ODP	3	86.50%	89.50%	90.50%	$953.05	$396.29	$1,349.34
1800	ODP	5	87.50%	89.50%	90.50%	$976.06	$411.67	$1,387.72
1800	ODP	7.5	88.50%	91.00%	92.00%	$1,323.26	$643.67	$1,966.93
1800	ODP	10	89.50%	91.70%	92.70%	$1,475.12	$745.15	$2,220.27
1800	ODP	15	91.00%	93.00%	94.00%	$2,541.29	$976.47	$3,517.75
1800	ODP	20	91.00%	93.00%	94.00%	$2,861.24	$1,190.27	$4,051.52
1800	ODP	25	91.70%	93.60%	94.60%	$3,261.14	$1,457.50	$4,718.64
1800	ODP	30	92.40%	94.10%	95.10%	$3,513.58	$1,626.18	$5,139.75
1800	ODP	40	93.00%	94.10%	95.10%	$4,222.09	$2,099.62	$6,321.70
1800	ODP	50	93.00%	94.50%	95.50%	$4,628.91	$2,371.47	$7,000.39
1800	ODP	60	93.60%	95.00%	96.00%	$5,831.16	$3,174.84	$9,006.00
1800	ODP	75	94.10%	95.00%	96.00%	$6,697.92	$3,754.03	$10,451.95
1800	ODP	100	94.10%	95.40%	96.40%	$8,402.69	$4,412.08	$12,814.77
1800	ODP	125	94.50%	95.40%	96.40%	$10,323.06	$5,695.32	$16,018.38
1800	ODP	150	95.00%	95.80%	96.80%	$10,693.62	$5,942.94	$16,636.56
1800	ODP	200	95.00%	95.80%	96.80%	$12,801.47	$7,351.45	$20,152.92

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	250	95.40%	95.80%	96.80%	$15,888.00	$9,413.95	$25,301.95
1800	ODP	300	95.40%	95.80%	96.80%	$20,204.33	$12,298.23	$32,502.56
1800	ODP	350	95.40%	95.80%	96.80%	$29,220.28	$18,322.91	$47,543.19
1800	ODP	400	95.40%	95.80%	96.80%	$32,992.47	$20,843.58	$53,836.05
1800	ODP	450	95.80%	96.20%	97.20%	$56,915.81	$36,829.75	$93,745.56
1800	ODP	500	95.80%	96.20%	97.20%	$59,663.64	$38,665.92	$98,329.55
1800	TEFC	1	82.50%	85.50%	86.50%	$826.86	$311.97	$1,138.83
1800	TEFC	1.5	84.00%	86.50%	87.50%	$821.85	$308.62	$1,130.47
1800	TEFC	2	84.00%	86.50%	87.50%	$907.18	$365.64	$1,272.82
1800	TEFC	3	87.50%	89.50%	90.50%	$953.05	$396.29	$1,349.34
1800	TEFC	5	87.50%	89.50%	90.50%	$976.06	$411.67	$1,387.72
1800	TEFC	7.5	89.50%	91.70%	92.70%	$1,323.26	$643.67	$1,966.93
1800	TEFC	10	89.50%	91.70%	92.70%	$1,475.12	$745.15	$2,220.27
1800	TEFC	15	91.00%	92.40%	93.40%	$2,541.29	$976.47	$3,517.75
1800	TEFC	20	91.00%	93.00%	94.00%	$2,861.24	$1,190.27	$4,051.52
1800	TEFC	25	92.40%	93.60%	94.60%	$3,261.14	$1,457.50	$4,718.64
1800	TEFC	30	92.40%	93.60%	94.60%	$3,513.58	$1,626.18	$5,139.75
1800	TEFC	40	93.00%	94.10%	95.10%	$4,222.09	$2,099.62	$6,321.70
1800	TEFC	50	93.00%	94.50%	95.50%	$4,628.91	$2,371.47	$7,000.39
1800	TEFC	60	93.60%	95.00%	96.00%	$5,831.16	$3,174.84	$9,006.00
1800	TEFC	75	94.10%	95.40%	96.40%	$6,697.92	$3,754.03	$10,451.95
1800	TEFC	100	94.50%	95.40%	96.40%	$8,402.69	$4,412.08	$12,814.77
1800	TEFC	125	94.50%	95.40%	96.40%	$10,323.06	$5,695.32	$16,018.38
1800	TEFC	150	95.00%	95.80%	96.80%	$10,693.62	$5,942.94	$16,636.56

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	200	95.00%	96.20%	97.20%	$12,801.47	$7,351.45	$20,152.92
1800	TEFC	250	95.00%	96.20%	97.20%	$15,888.00	$9,413.95	$25,301.95
1800	TEFC	300	95.40%	96.20%	97.20%	$20,204.33	$12,298.23	$32,502.56
1800	TEFC	350	95.40%	96.20%	97.20%	$29,220.28	$18,322.91	$47,543.19
1800	TEFC	400	95.40%	96.20%	97.20%	$32,992.47	$20,843.58	$53,836.05
1800	TEFC	450	95.40%	96.20%	97.20%	$56,915.81	$36,829.75	$93,745.56
1800	TEFC	500	95.80%	96.20%	97.20%	$59,663.64	$38,665.92	$98,329.55
3600	ODP	1	76.30%	77.00%	78.00%	$826.86	$311.97	$1,138.83
3600	ODP	1.5	82.50%	84.00%	85.00%	$821.85	$308.62	$1,130.47
3600	ODP	2	84.00%	85.50%	86.50%	$907.18	$365.64	$1,272.82
3600	ODP	3	84.00%	85.50%	86.50%	$953.05	$396.29	$1,349.34
3600	ODP	5	85.50%	86.50%	87.50%	$976.06	$411.67	$1,387.72
3600	ODP	7.5	87.50%	88.50%	89.50%	$1,323.26	$643.67	$1,966.93
3600	ODP	10	88.50%	89.50%	90.50%	$1,475.12	$745.15	$2,220.27
3600	ODP	15	89.50%	90.20%	91.20%	$2,541.29	$976.47	$3,517.75
3600	ODP	20	90.20%	91.00%	92.00%	$2,861.24	$1,190.27	$4,051.52
3600	ODP	25	91.00%	91.70%	92.70%	$3,261.14	$1,457.50	$4,718.64
3600	ODP	30	91.00%	91.70%	92.70%	$3,513.58	$1,626.18	$5,139.75
3600	ODP	40	91.70%	92.40%	93.40%	$4,222.09	$2,099.62	$6,321.70
3600	ODP	50	92.40%	93.00%	94.00%	$4,628.91	$2,371.47	$7,000.39
3600	ODP	60	93.00%	93.60%	94.60%	$5,831.16	$3,174.84	$9,006.00
3600	ODP	75	93.00%	93.60%	94.60%	$6,697.92	$3,754.03	$10,451.95
3600	ODP	100	93.00%	93.60%	94.60%	$8,402.69	$4,412.08	$12,814.77
3600	ODP	125	93.60%	94.10%	95.10%	$10,323.06	$5,695.32	$16,018.38

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	150	93.60%	94.10%	95.10%	$10,693.62	$5,942.94	$16,636.56
3600	ODP	200	94.50%	95.00%	96.00%	$12,801.47	$7,351.45	$20,152.92
3600	ODP	250	94.50%	95.00%	96.00%	$15,888.00	$9,413.95	$25,301.95
3600	ODP	300	95.00%	95.40%	96.40%	$20,204.33	$12,298.23	$32,502.56
3600	ODP	350	95.00%	95.40%	96.40%	$29,220.28	$18,322.91	$47,543.19
3600	ODP	400	95.40%	95.80%	96.80%	$32,992.47	$20,843.58	$53,836.05
3600	ODP	450	95.80%	95.80%	96.80%	$56,915.81	$36,829.75	$93,745.56
3600	ODP	500	95.80%	95.80%	96.80%	$59,663.64	$38,665.92	$98,329.55
3600	TEFC	1	75.50%	77.00%	78.00%	$826.86	$311.97	$1,138.83
3600	TEFC	1.5	82.50%	84.00%	85.00%	$821.85	$308.62	$1,130.47
3600	TEFC	2	84.00%	85.50%	86.50%	$907.18	$365.64	$1,272.82
3600	TEFC	3	85.50%	86.50%	87.50%	$953.05	$396.29	$1,349.34
3600	TEFC	5	87.50%	88.50%	89.50%	$976.06	$411.67	$1,387.72
3600	TEFC	7.5	88.50%	89.50%	90.50%	$1,323.26	$643.67	$1,966.93
3600	TEFC	10	89.50%	90.20%	91.20%	$1,475.12	$745.15	$2,220.27
3600	TEFC	15	90.20%	91.00%	92.00%	$2,541.29	$976.47	$3,517.75
3600	TEFC	20	90.20%	91.00%	92.00%	$2,861.24	$1,190.27	$4,051.52
3600	TEFC	25	91.00%	91.70%	92.70%	$3,261.14	$1,457.50	$4,718.64
3600	TEFC	30	91.00%	91.70%	92.70%	$3,513.58	$1,626.18	$5,139.75
3600	TEFC	40	91.70%	92.40%	93.40%	$4,222.09	$2,099.62	$6,321.70
3600	TEFC	50	92.40%	93.00%	94.00%	$4,628.91	$2,371.47	$7,000.39
3600	TEFC	60	93.00%	93.60%	94.60%	$5,831.16	$3,174.84	$9,006.00
3600	TEFC	75	93.00%	93.60%	94.60%	$6,697.92	$3,754.03	$10,451.95

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	100	93.60%	94.10%	95.10%	$8,402.69	$4,412.08	$12,814.77
3600	TEFC	125	94.50%	95.00%	96.00%	$10,323.06	$5,695.32	$16,018.38
3600	TEFC	150	94.50%	95.00%	96.00%	$10,693.62	$5,942.94	$16,636.56
3600	TEFC	200	95.00%	95.40%	96.40%	$12,801.47	$7,351.45	$20,152.92
3600	TEFC	250	95.40%	95.80%	96.80%	$15,888.00	$9,413.95	$25,301.95
3600	TEFC	300	95.40%	95.80%	96.80%	$20,204.33	$12,298.23	$32,502.56
3600	TEFC	350	95.40%	95.80%	96.80%	$29,220.28	$18,322.91	$47,543.19
3600	TEFC	400	95.40%	95.80%	96.80%	$32,992.47	$20,843.58	$53,836.05
3600	TEFC	450	95.40%	95.80%	96.80%	$56,915.81	$36,829.75	$93,745.56
3600	TEFC	500	95.40%	95.80%	96.80%	$59,663.64	$38,665.92	$98,329.55

Appendix D – Commercial Building Models

The following table defines the characteristics of the models used for the C/I measures by Franklin Energy Services.

	Building Characteristics			General Occupancy Schedule				HVAC Equipment		
Building Type	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 Occupany 40%)	7am-7pm	10am-Noon	10am-Noon	Variable Air Volume (VAV), [constant volume packaged rooftop unit, kitchen]	Centrifigal 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
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

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
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