4.4.31 Small Business Furnace Tune-Up

DESCRIPTION

This measure is for a natural gas Small Business furnace that provides space heating. The tune-up will improve furnace performance by inspecting, cleaning and adjusting the furnace and appurtenances for correct and efficient operation. Additional savings maybe realized through a complete system tune-up.

This measure was developed to be applicable to the following program types: Small business.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure an approved technician must complete the tune-up requirements[455] listed below:

- Measure combustion efficiency using an electronic flue gas analyzer
- Check and clean blower assembly and components per manufacturer's recommendations
- Where applicable Lubricate motor and inspect and replace fan belt if required
- Inspect for gas leaks
- Clean burner per manufacturer's recommendations and adjust as needed
- Check ignition system and safety systems and clean and adjust as needed
- Check and clean heat exchanger per manufacturer's recommendations
- Inspect exhaust/flue for proper attachment and operation
- Inspect control box, wiring and controls for proper connections and performance
- Check air filter and clean or replace per manufacturer's
- Inspect duct work connected to furnace for leaks or blockages
- Measure temperature rise and adjust flow as needed
- Check for correct line and load volts/amps
- Check thermostat operation is per manufacturer's recommendations (if adjustments made, refer to 'Small Commercial Programmable Thermostat Adjustment' measure for savings estimate)
- Perform Carbon Monoxide test and adjust heating system until results are within standard industry acceptable limits

DEFINITION OF BASELINE EQUIPMENT

The baseline is furnace assumed not to have had a tune-up in the past 2 years.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for the tune up is 2 years.[456]

DEEMED MEASURE COST

The incremental cost for this measure should be the actual cost of tune up.

[455] American Standard Maintenance for Indoor Units: http://www.americanstandardair.com/owner-support/maintenance.html
[456]Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.3 Gas Forced-Air Furnace Tune-up.

DEEMED O&M COST ADJUSTMENTS

There are no expected O&M savings associated with this measure.

LOADSHAPE

Loadshape C04 - Commercial Electric Heating

COINCIDENCE FACTOR

N/A

Algorithms

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$\Delta kWh = \Delta Therms * F_e * 29.3$

Where:

ΔTherms = as calculated below

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[457]

29.3 = kWh per therm

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

ΔTherms = (Capacity * EFLH * (((Effbefore + Ei)/ Effbefore) – 1)) / 100,000

Where:

Capacity = Furnace gas input size (Btu/hr)

= Actual

EFLH = Equivalent Full Load Hours for heating are provided

[457] F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% F_e. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

in section 4.4 HVAC End Use

Effbefore = Efficiency of the furnace before the tune-up

= Actual

Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the heating season and take readings at a consistent firing rate for pre and post tune-up.

EI = Efficiency Improvement of the furnace tune-up measure

= Actual

100,000 = Converts Btu to therms

EXAMPLE

A 200 kBtu furnace in a Rockford low rise office records an efficiency prior to tune up of 82% AFUE and a 1.8% improvement in efficiency are tune up:

Δtherms = (200,000 * 1428 * (((0.82 + 0.018)/ 0.82) – 1)) /100,000

= 62.3 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-FTUN-V02-160601

4.4.32 Combined Heat and Power

DESCRIPTION

The Combined Heat and Power (CHP) measure can provide energy savings within the State of Illinois through the development and operation of CHP projects. This measure is applicable for Conventional or Topping Cycle CHP systems, as well as Waste Heat-to-Power (WHP) or Bottoming Cycle CHP systems. The measure will reduce the total Btu's of energy required to meet the end use needs of the facility.

It is recognized that CHP system design and configuration may be complex, and as such the calculation of energy savings may not be reducible to the equations within this measure. In such cases a more comprehensive engineering and financial analysis may be developed that more accurately incorporates the attributes of complex CHP configurations such as variable-capacity systems, and partial combined-cycle CHP systems. Where noted, the use of values that are determined through an external engineering analysis may be substituted by agreement between the participant, the program administrator and independent evaluator. This substitution of values does not eliminate ex post evaluation risk (retroactive adjustments to savings claims) that exists when using custom inputs.

This measure was developed to be applicable to the following program types: Retrofit (RF), New Construction (NC). If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

Conventional or Topping Cycle CHP is defined as an integrated system that is located at or near the building or facility (on-site, on the customer side of the meter) that utilizes a prime mover (reciprocating engine, gas turbine, micro-turbine, fuel cell, boiler/steam turbine combination) for the purpose of generating electricity and useful thermal energy (such as steam, hot water, or chilled water) where the primary function of the facility where the CHP is located is not to generate electricity for use on the grid. An eligible system must demonstrate a minimum total system efficiency of 60% (HHV)[458] with at least 20% of the system's total useful energy output in the form of useful thermal energy on an annual basis.

Measuring and Calculating Conventional CHP Total System Efficiency:

CHP efficiency is calculated using the following equation:

$$CHP_{\ Efficiency}(HHV) = \frac{\left[CHP_{thermal}\ \left(\frac{kBtu}{yr}\right) + E_{CHP}\ \left(\frac{kWh}{yr}\right) * 3.412\ \left(\frac{kBtu}{kWh}\right)\right]}{F_{totalCHP}\left(\frac{kBtu}{yr}\right)}$$

Where:

$CHP_{thermal}$ = Useful annual thermal energy output from the CHP system, defined as the annual thermal energy output of the CHP system that is actually recovered and utilized in the facility/process.

E_{CHP} = Useful annual electricity output produced by the CHP system, defined as the annual electric energy output of the CHP system that is actually utilized to replace purchased electricity required to meet the requirements of the facility/process.

$F_{totalCHP}$ = Total annual fuel consumed by the CHP system

For further definition of the terms, please see "Calculation of Energy Savings" Section below.

[458] Higher Heating Value (HHV): refers to the heating value of the fuel and is defined as the total thermal energy available, including the heat of condensation of water vapors,resulting from complete combustion of the fuel versus the Lower Heating Value (LHV) which assumes the heat of condensation is not available

Waste Heat-to-Power or Bottoming Cycle CHP is defined as an integrated system that is located at or near the building or facility (on-site, on the customer side of the meter) that does one of the following:

- Utilizes exhaust heat from an industrial/commercial process to generate electricity (except for exhaust heat from a facility whose primary purpose is the generation of electricity for use on the grid); or
- Utilizes the pressure drop in an industrial/commercial facility to generate electricity through a backpressure steam turbine where the facility normally uses a pressure reducing valve (PRV) to reduce the pressure in their facility; or
- Utilizes the pressure reduction in natural gas pipelines (located at natural gas compressor stations) before the gas is distributed through the pipeline to generate electricity, provided that the conversion of energy to electricity is achieved without using additional fossil fuels.

Since these types of systems utilize waste heat as their fuel, they do not have to meet any specific total system efficiency level (assuming they use no additional fossil fuel in their operation) If additional fuel is used onsite, it should be accounted for using the following methodology:

- Treat the portion of Waste-Heat-to-Power that does not require any additional fuel using the Waste-Heat-to-Power methodology outlined in this document.
- Treat the portion of Waste-Heat-to-Power that requires additional fuel (if natural gas) using the Conventional CHP methodology outlined in this document. If the additional fuel is not natural gas, custom carbon equivalency calculations would be needed – refer to section "Calculation of Energy Savings" for more details.
- Add the energy savings together.

These systems may export power to the grid.

DEFINITION OF BASELINE EQUIPMENT

Electric Baseline: The baseline facility would be a facility that purchases its electric power from the grid.

Heating Baseline (for CHP applications that displace onsite heat): The baseline equipment would be the boiler/furnace operating onsite, or a boiler/furnace meeting the baseline equipment defined in the High Efficiency Boiler (Section 4.4.10)/Furnace (Section 4.4.11) measures of this TRM.

Cooling Baseline (for CHP applications that displace onsite cooling demands): The baseline equipment would be the chiller (or chillers) operating onsite, or a chiller (or chillers) meeting the definition of baseline equipment defined in the Electric Chiller (Section 4.4.6) measure of this TRM.

Facilities that use biogas or waste gas: Facilities that use (but are not purchasing) biogas or waste gas that is not otherwise used, whether they are using biogas or waste gas only or a combination of biogas or waste gas and natural gas to meet their energy demands are also eligible for this measure. If additional fuel is purchased to power the CHP system, then the additional natural gas should be taken into account using the following methodology:

- Treat the portion of CHP system that does not require any additional fuel, or that requires additional fuel that would otherwise be wasted (e.g. flared), using the Waste-Heat-to-Power methodology outlined in this document.
- Treat the portion of CHP that requires additional fuel (if natural gas) using the Conventional CHP methodology outlined in this document. If the additional fuel is not natural gas, custom carbon equivalency calculations would be needed – refer to section "Calculation of Energy Savings" for more details.
- Add the energy savings together.

Consumption of any biogas or waste gas that would not otherwise being wasted (*e.g.,* flared) will be accounted for in the overall net BTU savings calculations the same as for purchased natural gas.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

Measure life is a custom assumption, dependent on the technology selected and the system installation.

DEEMED MEASURE COST

Custom installation and equipment cost will be used. These costs should include the cost of the equipment and the cost of installing the equipment. Equipment costs include, but are not limited to: prime mover, heat recovery system(s), exhaust gas treatment system(s), controls, and any interconnection/electrical connection costs.

The installations costs include labor and material costs such as, but not limited to: labor costs, materials such as ductwork, piping, and wiring, project and construction management, engineering costs, commissioning costs, and other fees.

Measure costs will also include the present value of expected maintenance costs over the life of the CHP system.

LOADSHAPE

Use Custom Loadshape. The loadshape should be obtained from the actual CHP operation strategy, based on the On-Peak and Off-Peak Energy definitions specified in Table 3.3 of "Section 3.5 Electrical Loadshapes" of the TRM.

COINCIDENCE FACTOR

Custom coincidence factor will be used. Actual value based on the CHP operation strategy will be used.

Algorithm

CALCULATION OF ENERGY SAVINGS

i) Conventional or Topping Cycle CHP Systems:

<u>Step 1: (Calculating Total Annual Source Fuel Savings in Btus)</u>

The first step is to calculate the total annual source fuel savings associated with the CHP installation, in order to ensure the CHP project produces positive total annual source fuel savings (i.e. reduction in source Btus):

$S_{FuelCHP}$ = Annual fuel savings (Btu) associated with the use of a Conventional CHP system to generate the useful electricity output (kWh, converted to Btu) and useful thermal energy output (Btu) versus the use of the equivalent electricity generated and delivered by the local grid and the equivalent thermal energy provided by the onsite boiler/furnace.

$= (F_{grid} + F_{thermalCHP}) - F_{total\ CHP}$

Where:

F_{grid} = Annual fuel in Btu that would have been used to generate the useful electricity output of the CHP system if that useful electricity output was provided by the local utility grid.

$= E_{CHP} * H_{grid}$

Where:

E_{CHP} = Useful annual electricity output produced by the CHP system, defined as the annual electric energy output of the CHP system that is actually utilized to replace purchased electricity required to meet the requirements of the facility/process. [459]

= ($CHP_{capacity}$ * Hours) - $E_{Parasitic}$

$CHP_{capacity}$ = CHP nameplate capacity

= Custom input

Hours = Annual operating hours of the system

= Custom input

$E_{parasitic}$ = The electricity required to operate the CHP system that would otherwise not be required by the facility/process

= Custom input

H_{grid} = Heat rate of the grid in Btu/kWh, based on the average fossil heat rate for the EPA eGRID subregion, adjusted to take into account T&D losses.

For systems operating less than 6,500 hrs per year:

Use the Non-baseload heat rate provided by EPA eGRID for RFC West region for ComEd territory (including independent providers connected to RFC West), and SERC Midwest region for Ameren territory (including independent providers connected to SERC Midwest)[460]. Also include any line losses.

For systems operating more than 6,500 hrs per year:

Use the All Fossil Average heat rate provided by EPA eGRID for RFC West region for ComEd territory (including independent providers connected to RFC West), and SERC Midwest region for Ameren territory (including independent providers connected to SERC Midwest). Also include any line losses.

$F_{thermalCHP}$ = Annual fuel in Btu that would have been used on-site by a boiler/furnace to provide the useful thermal energy output of the CHP system. [461]

= $CHP_{thermal}$ / $Boiler_{eff}$ (or $CHP_{thermal}$ / $Furnace_{eff}$)

$CHP_{thermal}$ = Useful annual thermal energy output from the CHP system, defined as the annual thermal energy output of the CHP system that is actually recovered and utilized in the facility/process.

[459] For complex systems this value may be obtained from a CHP System design/financial analysis study.

[460] Refer to EPA eGRID data http://www.epa.gov/chp/documents/fuel_and_co2_savings.pdf, page 24 and http://www.epa.gov/cleanenergy/documents/egridzips/eGRID_9th_edition_V1-0_year_2010_Summary_Tables.pdf, page 9. Current values are:

- Non-Baseload RFC West: 9,811 Btu/kWh * (1 + Line Losses)
- Non-Baseload SERC Midwest: 10,511 Btu/kWh * (1 + Line Losses)
- All Fossil Average RFC West: 10,038 Btu/kWh * (1 + Line Losses)
- All Fossil Average SERC Midwest: 10,364 Btu/kWh * (1 + Line Losses)

[461] For complex systems this value may be obtained from a CHP System design/financial analysis study.

= Custom input

$Boiler_{eff}$ /$Furnace_{eff}$= Efficiency of the on-site Boiler/Furnace that is displaced by the CHP system or if unknown, the baseline equipment value stated in the High Efficiency Boiler (Section 4.4.10) measure or High Efficiency Furnace (Section 4.4.11) measure in this TRM. .

= Custom input

$F_{total\ CHP}$ = Total fuel in Btus consumed by the CHP system

= Custom input

Step 2: (Savings Allocation to Program Administrators for Purposes of Assessing Compliance with Energy Savings Goals (Not for Use in Load Reduction Forecasting))

Savings claims are a function of the electric output of the CHP system (E_{CHP}), the used thermal output of the CHP system ($F_{thermalCHP}$), and the CHP system efficiency (CHP_{Eff}(HHV)). The percentages of electric output and used thermal output that can be claimed also differ slightly depending on whether the project was included in both electric[462] and gas[463] Energy Efficiency Portfolio Standard (EEPS)[464] efficiency programs, only an electric EEPS program or only a gas EEPS program. The tables below provide the specific percentages of electric and/or thermal output that can be claimed under each of those three scenarios. These percentages apply only to cases in which natural gas is the fuel used by the CHP system. Saving estimates for systems using other fuels should be calculated on a custom basis. If the waste heat recovered from the CHP system is offsetting electric equipment, such as an absorption chiller offsetting an electric chiller, then the net change in electricity consumption associated with the electric equipment should be added to the allocated electric savings.

1) For systems participating in both electric EEPS and gas EEPS programs:

CHP Annual System Efficiency (HHV)	Allocated Electric Savings	Allocated Gas Savings
60%	65% of E_{CHP} (kWh)	No gas savings
>60% to 65%	65% of E_{CHP} (kWh) + one percentage point increase for every one percentage point increase in CHP system efficiency (max 70% of E_{CHP} in kWh)	No gas Savings
>65%	70% of E_{chp} (kWh)	2.5% of $F_{thermal}$ (useful thermal output of the CHP system) for every one percentage point increase in CHP system efficiency above 65%.

[462] 220 ILCS 5/8-103; 220 ILCS 5/16-111.5B

[463] 220 ILCS 5/8-104

[464] As used in this measure characterization, EEPS programs are defined as those energy efficiency programs implemented pursuant to Sections 8-103, 8-104, and 16-111.5B of the Illinois Public Utilities Act. Technically, EEPS programs pertain to energy efficiency programs implemented pursuant to 220 ILCS 5/8-103 and 220 ILCS 5/8-104. However, for simplicity in presentation, this measure defines EEPS programs as also including those programs implemented pursuant to 220 ILCS 5/16-111.5B (these programs are funded through the same energy efficiency riders established pursuant to Section 8-103).

Example: System with measured annual system efficiency (HHV) of 70%: Electric savings (kWh) = 70% of E_{CHP} measured over 12 months, and Gas savings (therms) = 12.5% of $F_{thermal}$ measured over 12 months (70% - 65% = 5 X 2.5% = 12.5%)

2) For systems participating in only an electric EEPS program:

CHP Annual System Efficiency (HHV)	Allocated Electric Savings	Allocated Gas Savings
60%	65% of E_{CHP} (useful electric output of CHP system in kWh)	No gas Savings
Greater than 60%	65% + one percentage point increase for every one percentage point increase in CHP system efficiency (no max)	No gas Savings

Example: System with measured annual fuel use efficiency of 75%: Electric savings (kWh) = 65% + 15% = 80% of E_{CHP} measured over 12 months (15% = 1% for every 1% increase in system efficiency). No gas savings (therms).

3) For systems participating in only a gas EEPS program:

CHP Annual System Efficiency (HHV)	Allocated Electric Savings	Allocated Gas Savings
60% or greater	No electric savings	2.5% of Fthermal (useful thermal output of the CHP system) for every one percentage point increase in CHP system efficiency above 60%.

Example: System with measured annual system efficiency (HHV) of 70%: No Electric savings (kWh). Gas savings (therms) = 25% of $F_{thermal}$ measured over 12 months (70% - 60% = 10 X 2.5% = 25%)

Conventional or topping cycle CHP systems virtually always require an increase in the use of fuel on-site in order to produce electricity. Different jurisdictions and experts across the country have employed and/or put forward a variety of approaches[465] to address how increased on-site fuel consumption should be reflected in the attribution of electric savings to CHP systems. The approach reflected in the tables above is generally consistent – for CHP systems consuming natural gas – with approaches recently put forward by the Southwest Energy Efficiency Project (SWEEP) and Institute for Industrial Productivity (IIP) that determine reduced electric savings based on the equivalent amount of carbon dioxide generated from the increased fuel used[466].

[465] Approaches range from ignoring the increased gas use entirely (i.e., no "penalty") to applying approximately 40-60% "penalties", depending on the CHP efficiency and based on the equivalent grid kWh that the increased gas use represents.

[466] Consider, for example, a hypothetical CHP system that produces 5 million kWh annually, consumes 50 million kBtu of gas annual to generate that electricity (i.e. electric efficiency of approximately 34.8% HHV), reduces on-site gas use for space heating by 26 million kBtu of gas (i.e. equivalent to approximately 81.5% CHP thermal output utilization displacing gas used in a 70% efficient space heating boiler) and has a total annual CHP efficiency of 70.6% HHV. In this example, the net increase in on-site gas use is 24 million kBtu. At a carbon dioxide emission rate of 53.06 kg/MMBtu for burning natural gas, that translates to an increase in on-site carbon dioxide emissions of 1404 tons per year. At an estimated marginal emission rate of 1.098 tons of carbon dioxide per MWh in Illinois, that is equivalent to electric grid production of approximately 1.28 million kWh, or penalty of about 25.6% of the CHP system's electrical output if a precise calculation of carbon equivalency was utilitized to assign savings. In comparison, the simplified table above would entitle an electric utility to claim savings equal to 75.6% of the electric output (i.e. a penalty of 24.4% of electrical output) if it was the only utility promoting the system. In a gas and electric example, the electric savings claimed would be 70% of the production (a penalty of 30% of the CHP system's electrical output) and 12.5%

There are a variety of ways one could treat the potential for gas utilities to claim savings from CHP projects in their EEPS portfolios. For projects in which a natural gas EEPS program is involved, the tables above treat savings from CHP installations in two steps: (1) a fuel-switch from electricity to natural gas (i.e. using more natural gas to eliminate the need to generate as much electricity on the grid); and (2) possible increases in CHP efficiency above a "benchmark" level. When both electric EEPS and natural gas EEPS programs are involved in a project, the program administrator claims all the electricity savings associated with a fuel-switch up to a "benchmark" 65% efficient CHP system. All the savings associated with increasing CHP efficiencies above that benchmark level are allocated to natural gas (e.g. if the CHP efficiency is 75%, the natural gas savings associated with an increase in CHP efficiency from 65% to 75% are allocated to natural gas). That is consistent with the notion that CHP efficiency typically increases primarily by increasing the use of the thermal output of the system (increasing the displacement of baseline gas use). For projects that involve only a natural gas EEPS program, the "benchmark" above which the gas utility can claim savings is lowered to 60%.

ii) Waste-Heat-to-Power CHP Systems :

ELECTRIC ENERGY SAVINGS:

$$\Delta kWh = E_{CHP}$$

Where:

E_{CHP} = Useful annual electricity output produced by the CHP system, defined as the annual electric energy output of the CHP system that is actually utilized to replace purchased electricity required to meet the requirements of the facility/process.

= Custom input

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = CF * CHP_{capacity}$$

Where:

CF = Summer Coincidence factor. This factor should also consider any displaced chiller capacity[467]

= Custom input

$CHP_{Capacity}$ = CHP nameplate capacity

= Custom input

NATURAL GAS ENERGY SAVINGS:

$$\Delta Therms = F_{thermalCHP} \div 100{,}000$$

Where:

$F_{thermalCHP}$ = Net savings in annual purchased fuel in Btu, if any, that would have been used on-site by a boiler/furnace to provide some or all of the useful thermal energy output of the CHP system[468].

of the recovered thermal output, equivalent to 2.23 million kBtu. The difference between the electric only scenario and the electric and gas, on the electric side, is 5% of the electric output or 250,000 kWh, which would require 2.45 million kBtu input at an efficiency of 34.8% HHV.

[467] If some or all of the existing electric chiller peak demand is no longer needed due to new waste heat powered chillers (e.g., absorption), the coincidence factor should be adjusted appropriately.

[468] In most cases, it is expected that waste-heat-to-power systems will not provide any new net useful thermal energy output, since the CHP system will be driven by thermal energy that was otherwise being wasted. If additional natural gas or other purchased energy is used onsite, it should be properly accounted for.

100,000 = Conversion factor for Btu to therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Custom estimates of maintenance costs that will be incurred for the life of the measure will be used**.** Maintenance costs vary with type and size of the prime mover. These costs include, but are not limited to:

- Maintenance labor
- Engine parts and materials such as oil filters, air filters, spark plugs, gaskets, valves, piston rings, electronic components, etc. and consumables such as oil
- Minor and major overhauls

For screening purposes, the US EPA has published resource guides that provide average maintenance costs based on CHP technology and system size[469].

COST-EFFECTIVENESS SCREENING AND LOAD REDUCTION FORECASTING

For the purposes of forecasting load reductions due to CHP projects per Section 16-111.5B, changes in site energy use at the customer's meter – reduced consumption of utility provided electricity – adjusted for utility line losses (at-the-busbar savings), customer switching estimates, NTG, and any other adjustment factors deemed appropriate, should be used.

For the purposes of screening a CHP measure application for cost-effectiveness, changes in site energy use – reduced consumption of utility provided electricity and the net change in consumption of fuel – should be used. In general, the benefit and cost components used in evaluating the cost-effectiveness of a CHP project would include at least the following terms:

Benefits: $E_{CHP} + \Delta kW + F_{thermal_CHP}$

Costs: $F_{total_CHP} + CHP_{COSTS} + O\&M_{COSTS}$

Where:

CHP_{Costs} = CHP equipment and installation costs as defined in the "Deemed Measure Costs" section

$O\&M_{Costs}$ = CHP operations and maintenance costs as defined in the "Deemed O&M Cost Adjustment Calculation" section

MEASURE CODE: CI-HVC-CHAP-V01-150601

[469] "EPA Combined Heat and Power Partnership Resources" Oct 07, 2014, http://www.epa.gov/chp/resources.html in the document "Catalog of CHP technologies" http://www.epa.gov/chp/documents/catalog_chptech_full.pdf pages 2-16, 3-14, 4-14, 5-14, and 6-16.

4.4.33 Industrial Air Curtain

DESCRIPTION

This measure applies to buildings with exterior entryways that utilize overhead doors. All other air curtain applications, such as through sliding door entryways or conventional foot-traffic entryways, require custom analysis as air curtain designs must often accommodate other factors that may change their effectiveness.

The use of overhead doors within exterior entryways during the heating season leads to the exfiltration of warm air from the upper portion of the door opening and the infiltration of colder air from the lower portion of the door opening. This results in increase heating energy use to compensate for heat losses every time a door is opened. By reducing heat losses, air curtains can also enhance the physical comfort of employees or customers near the entryway as there will be reduced temperature fluctuations when the door is opened and closed. In addition, in some cases excess heating capacity may be installed in buildings to meet this larger heating load. The addition of air curtains to exterior entryways that currently utilize overhead doors will result in energy savings and enhanced personal comfort, and also possibly in reduced equipment sizing and corresponding costs.

The primary markets for this measure are commercial and industrial facilities with overhead doors in exterior entryways, including but not limited to the following building types: retail, manufacturing, and warehouse (non-refrigerated).

Limitations

- For use in conditioned spaces with an overhead door in an exterior entryway. This measure does include other door types such doorways to commercial spaces such as retail.
- This measure should only be applied to spaces in which the overhead door separates a conditioned space and an unconditioned space.
- Installation must follow manufacturer recommendations to attain proper air velocity, discharge angle down to the floor level, and unit position.
- Certain heating systems may not be a good fit for air curtains, such as locations with undersized heating capacity. In these cases, the installation of an air curtain may not effectively reduce heating system cycling given the inappropriately sized heating capacity.
- Buildings with slightly positive to slightly negative (~5 Pa to -10 Pa). For all other scenarios, custom analysis is recommended.
- Measure assumes that wind speeds at near ground level are less than or equal to 12 mph for 90% of the heating or cooling season. For areas with more extreme weather, custom analysis is necessary.
- Note: for cost effectiveness, it is recommended that minimum door open times should be approximately 15 hours per week.[470]

This measure was developed to be applicable to the following program types: NC, RF. If applied to other program types, the measure savings should be verified.

The following methodology is highly complex and requires significant data collection. It is hoped that simplifying steps can be made in future iterations based on continued metering and evaluation of installations. Also the data collected through implementing the measure in the way currently drafted will aid in simplifying efforts at a future date.

DEFINITION OF EFFICIENT EQUIPMENT

Overhead air curtains designed for commercial and industrial applications that have been tested and certified in

[470] Spentzas, Steve, et. al, "1009: Commercial and Industrial Air Curtains – Public Project Report," Nicor Gas Emerging Technology Program (Oct 2014): 9

accordance with ANSI/AMCA 220 and installed following manufacturer guidelines. Measure is for standard models without added heating.

DEFINITION OF BASELINE EQUIPMENT

No air curtain or other currently installed means to effectively reduce heat loss and air mixing during door openings, such as a vestibule or strip curtain.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[471]

DEEMED MEASURE COST

The incremental capital cost for overhead air curtains for exterior entryways are as follows, with an added average installation cost approximately equal to the capital cost.[472]

Door Size	Capital Cost
8'w x 8'h	$3,600
10'w x 10'h	$4,500
10'w x 12'h	$5,400
12'w x 14'h	$8,000
16'w x 16'h	$13,300

LOADSHAPE

Heating Season: If electric heating, use Commercial Electric Heating Loadshape: C04. Otherwise, N/A

Cooling Season: Commercial Cooling Loadshape C03. Or, if applicable, use Commercial Electric Heating and Cooling Loadshape C05.

COINCIDENCE FACTOR

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3%[473]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8%[474]

Algorithm

[471] Navigant Consulting Inc, Measures and Assumptions for Demand Side Management (DSM) Planning: Appendix C: Substantiation Sheets, "Air Curtains – Single Door," Ontario Energy Board, (April 2009): C-137.
2014 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values, February 4, 2014.
[472] Based on manufacturer interviews and air curtain specification sheets.
[473] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.
[474]Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

CALCULATION OF ENERGY SAVINGS

The following formulas provide a methodology for estimating cooling load (kWh) and heating load (therm) savings associated with the installation of air curtains on exterior entryways such as a single door or loading bay. This algorithm is based on the assumption that therm savings are directly related to the difference in cooling or heating losses due to infiltration or exfiltration through an entryway before and after the installation of an AMCA certified air curtain. Energy savings are assumed to be the result of a reduction of natural infiltration effects due to wind and thermal forces and follow the calculation methodology outlined by the ASHRAE Handbook.[475] The calculation assumes that the air curtain is appropriately sized and commissioned to be effective in mitigating infiltration of winds of up to 12 mph for at a least 90% of the year (based on manufacturer literature and TMY3 wind speed ranges at near ground level for Illinois).[476] Additionally, this measure assumes the HVAC systems are appropriately balanced such that the maximum pressure differential between indoor air and outdoor air is within the range of 5 Pa < ΔP < -10 Pa.[477] Custom analysis is necessary if building pressurization exceeds this range. However, while effectiveness decreases, some studies suggest that air curtains outperform vestibules and single door construction for negatively pressurized buildings with a ΔP of above -30 Pa.[478]

This algorithm allows either actual inputs or provides estimates if actual data is not available. All weather dependent values are derived from TMY3 data for the closest weather station to those locations defined elsewhere in the Illinois TRM (which are based on 30 year climate normals). If TMY3 weather station data was not available for the data used in the Illinois TRM, the next closest weather station was used. It is assumed that weather variations are negligible between the weather stations located within the same region. This approach was followed as the air curtain algorithm has a number of weather dependent variables which are all calculated in relation to the heating season or cooling season as defined by the balance point temperature deemed appropriate for the facility. All weather dependent data is based on TMY3 data and is listed in tables by both climate zone and balance point temperature, which is then normalized to the Illinois TRM climate zoned HDD/CDD definitions unless otherwise noted.

ELECTRIC ENERGY SAVINGS

$$\Delta kWhcooling = [(Q_{tbc} - Q_{tac}) / EER - (HP * 0.7457)] * t_{open} * CD$$

$$\Delta kWhHPheating = [(Q_{tbc} - Q_{tac}) / HSPF - (HP * 0.7457)] * t_{open} * HD$$

$$\Delta kWhGasheating = - (HP * 0.7457) * t_{open} * HD$$

Where:

Q_{tbc} = rate of total heat transfer through the open entryway, before air curtain (kBtu/hr)

Q_{tac} = rate of total heat transfer through the open entryway, after air curtain (kBtu/hr)

(see calculation in 'Heat Transfer Through Open Entryway with/without Air Curtain' sections below)

EER = energy efficiency ratio of the cooling equipment (kBtu/kWh)

= Actual. If unknown, use the table C403.2.3(2) in IECC 2012 (or IECC 2015 if through new

[475] ASHRAE, "Ventilation and Infiltration," in 2013 ASHRAE Handbook – Fundamentals (2013): Ch 16.1 - 16.37

[476] National Solar Radiation Data Base – 1991 – 2005 Update: Typical Meteorological year 3. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html

[477] Spentzas, Steve, et. al, "1009: Commercial and Industrial Air Curtains – Public Project Report," Nicor Gas Emerging Technology Program (Oct 2014): 10

Wang, Liangzhu, "Investigation of the Impact of Building Entrance Air Curtain on Whole Building Energy Use," Air Movement and Control International, Inc. (2013). 4

[478] Wang, Liangzhu, "Investigation of the Impact of Building Entrance Air Curtain on Whole Building Energy Use," Air Movement and Control International, Inc. (2013). 4

construction) to assume values based on code estimates

HP = Input power for air curtain (hp)

= Actual value. If actual value not available, use the following estimates based on manufacturer specs

Door Size	Fan HP
8'w x 8'h	1
10'w x 10'h	1.5
10'w x 12'h	4
12'w x 14'h	6
16'w x 16'h	12

0.7457 = unit conversion factor, brake horsepower to electric power (kW/HP)

t_{open} = average hours per day the door is open (hr/day)

= Actual or user defined estimated value.

CD = cooling days per year, total days in year above balance point temperature (day)

= use table below to select the best value for location[479]

	CD (Balance Point Temperature)				
Climate Zone - Weather Station/City	45 °F	50 °F	55 °F	60 °F	65 °F
1 -Rockford AP / Rockford	194	168	148	124	97
2 - Chicago O'Hare AP / Chicago	194	173	153	127	95
3 - Springfield #2 / Springfield	214	194	174	148	114
4 - Belleville SIU RSCH / Belleville	258	229	208	174	138
5 - Carbondale Southern IL AP / Marion	222	201	181	158	130

HSPF = Heating System Performance Factor of heat pump equipment

[479] National Solar Radiation Data Base – 1991 – 2005 Update: Typical Meteorological year 3. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html
Note that cooling days (CD) are calculated by first determining its value from the TMY3 data associated with the appropriate weather station as defined by and used elsewhere in the Illinois TRM. Using the TMY3 outdoor air dry bulb hourly data, Error! Reference source not found. the annual hours are totaled for every hour that the outdoor air dry bulb temperature is above a designated zero heat loss balance point temperature or base temperature for cooling. For commercial and industrial (C&I) buildings, a base temperature for heating of 55 °F is designated in the Illinois TRM, but building specific base temperatures are recommended for large C&I projects. Additionally, the TRM uses a 30-year normal data for degree-days while the CD calculation was based on TMY3 data; in order to account for this, calculations of CD were also normalized by the ratio of CDD to align the calculated values more closely with the TRM.

= Actual. If unknown, use the table C403.2.3(2) in IECC 2012 (or IECC 2015 if through new construction) to assume values based on code estimates

HD = heating days per year, total days in year above balance point temperature (day)

= use table below to select an appropriate value[480]:

	HD				
Climate Zone - Weather Station/City	45 °F	50 °F	55 °F	60 °F	65 °F
1 -Rockford AP / Rockford	142	160	183	204	228
2 - Chicago O'Hare AP / Chicago	150	166	192	219	253
3 - Springfield #2 / Springfield	125	142	167	194	230
4 - Belleville SIU RSCH / Belleville	101	115	134	156	180
5 - Carbondale Southern IL AP / Marion	103	123	148	174	205

Heat Transfer Through Open Entryway without Air Curtain (Cooling Season)

Q_{tbc} = 4.5 * CFM_{tot} *(h_{oc} – h_{ic}) / (1,000 Btu/kBtu)

Where:

4.5 = unit conversion factor with density of air: 60 min/hr * 0.075 lbm/ft3 (lb*min/(ft*hr))

CFM_{tot} = Total air flow through entryway (cfm), see calculation below

h_{oc} = average enthalpy of outside air during the cooling season (Btu/lb)

= use the below table to determine the approximate outdoor air enthalpy associated with an indoor temperature setpoint and climate zone.[481]

	h_{oc}		
Climate Zone - Weather Station/City	67 °F	72 °F	77 °F
1 -Rockford AP / Rockford	31.6	33.0	35.3
2 - Chicago O'Hare AP / Chicago	32.0	33.6	35.4
3 - Springfield #2 / Springfield	32.9	34.6	36.6
4 - Belleville SIU RSCH / Belleville	33.5	35.0	36.4
5 - Carbondale Southern IL AP / Marion	34.6	36.2	37.7

h_{ic} = average enthalpy of indoor air, cooling season (Btu/lb)

= use the below table to determine the approximate indoor air enthalpy associated with an indoor temperature setpoint in indoor relative humidity.

	h_{ic}		
Relative Humidity (%)	67 °F	72 °F	77 °F

[480] Note that Heating Days (HD) are calculated following the same approach outlined in the Cooling Days section.

[481] Average enthalpies were estimated following ASHRAE guidelines for perfect gas relationships for dry air associated with hourly TMY3 data.Error! Reference source not found. Enthalpies were then averaged for all values associated with a dry-bulb outdoor air temperature that exceeded the indoor air temperature setpoint. Other enthalpy values may be interpolated for indoor air temperature setpoints not represented in the table. Note that while outdoor air enthalpies increase with higher temperature setpoints, the change in enthalpy from indoor to outdoor will decrease.

	h_{ic}		
Relative Humidity (%)	67 °F	72 °F	77 °F
60	25.5	28.5	31.8
50	23.9	26.6	29.5
40	22.3	24.7	27.3

= an estimate 26.6 Btu/lb associated with the 72 °F and 50% indoor relative humidity case can be used as an approximation if no other data is available. For other indoor temperature setpoints and RH, enthalpies may be interpolated.

The total airflow through the entryway, CFM_{tot}, includes both infiltration due to wind as well as thermal forces, as follows:

CFM_{tot} = sqrt[$(CFM_w)^2 + (CFM_t^2)$]

Where:

CFM_w = Infiltration due to the wind (cfm)

CFM_t = Infiltration due to thermal forces (cfm)

The infiltration due to the wind is calculated as follows:

CFM_w = $(v_{wc} * C_{wc}) * C_v * A_d$ * (88 fpm/mph)

Where:

v_{wc} = average wind speed during the cooling season based on entryway orientation (mph)

= use the below table to for the wind speed effects based on climate zone and entryway orientation[482]:

	Entryway Orientation			
Climate Zone -Weather Station /City	N	E	S	W
1 -Rockford AP / Rockford	4.2	4.1	4.7	4.8
2 - Chicago O'Hare AP / Chicago	4.7	4.5	5.4	4.6
3 - Springfield #2 / Springfield	4.1	3.7	6.0	5.0
4 - Belleville SIU RSCH / Belleville	3.3	2.7	3.8	4.2
5 - Carbondale Southern IL AP / Marion	3.1	2.9	4.4	3.8

C_{wc} = wind speed correction factor due to wind direction in cooling season, (%)

= because wind direction is not constant, a wind speed correction factor is used to adjust for the amount of time during the cooling season prevailing winds can be expected to impact the entryway. Use the following table to determine the correct wind speed correction factor for cooling applications.

	Entryway Orientation			
Climate Zone -Weather Station/City	N	E	S	W
1 -Rockford AP / Rockford	0.18	0.13	0.30	0.31

[482] Average wind speeds are calculated based on the TMY3 wind speed data. Because this data is collected at an altitude of 33 ft, wind speed is approximated for a 5 ft level based on ASHRAE Handbook guidelines using the urban/suburban parameters for adjusting wind speed based on altitude (⍰ = 1200, ⍰ = 0.22).
ASHRAE, "Airflow Around Buildings," in 2013 ASHRAE Handbook – Fundamentals (2013): p 24.3

	Entryway Orientation			
Climate Zone -Weather Station/City	N	E	S	W
2 - Chicago O'Hare AP / Chicago	0.18	0.17	0.36	0.26
3 - Springfield #2 / Springfield	0.17	0.12	0.46	0.21
4 - Belleville SIU RSCH / Belleville	0.21	0.15	0.35	0.16
5 - Carbondale Southern IL AP / Marion	0.18	0.15	0.37	0.11

Note that correction factors do not add up to 1 (100%). This is attributed to periods of calm winds.

C_v = effectiveness of openings,

= 0.3, assumes diagonal wind[20]

A_d = area of the doorway (ft^2)

= user defined

The infiltration due to thermal forces is calculated as follows:

CFM_t = A_d * C_{dc} * (60 sec/min) * sqrt[2 * g * H/2 * (T_{oc} - T_{ic}) / (459.7 + T_{oc})]

Where:

C_{dc} = the discharge coefficient during the cooling season[483]

= 0.4 + 0.0025 * |T_{ic} – T_{oc}|

= 0.42, Illinois average at indoor air temp of 72°F

Note, values for C_{dc} show little variation due to balance point temperature, indoor air temperature, and climate zone. As such, if estimating results, the Illinois average value may be used as a simplification.

g = acceleration due to gravity

= 32.2 ft/sec^2

H = the height of the entryway (ft)

= user input

T_{ic} = Average indoor air temperature during cooling season

= User input, can assume indoor cooling temperature set-point

T_{oc} = Average outdoor temp during cooling season (°F)

= the average outdoor temperature is dependent on the CD period and zone. As such, the following table may be used for average outdoor temperature during the cooling period[484]:

	T_{oc}				
Climate Zone - Weather Station/City	62 °F	67 °F	72 °F	77 °F	82 °F
1 -Rockford AP / Rockford	72.9	76.0	79.2	82.5	85.5
2 - Chicago O'Hare AP / Chicago	72.9	76.0	79.4	82.8	85.5
3 - Springfield #2 / Springfield	73.7	76.7	79.9	83.4	86.4
4 - Belleville SIU RSCH / Belleville	74.9	77.7	81.0	84.3	86.9
5 - Carbondale Southern IL AP / Marion	75.1	77.7	80.9	84.7	87.4

[483] ASHRAE, "Ventilation and Infiltration," in 2013 ASHRAE Handbook – Fundamentals (2013): p 16.13

[484] Based on binned data from TMY3 & adjusted bracketed thermostat setpoint temperatures. Interpolate other values as needed.

459.7 = conversion factor from °F to °R

= calculation requires absolute temperature for values not calculated as a difference of temperatures.

Heat Transfer Through Open Entryway with Air Curtain (Cooling Season)

Q_{tac} = Q_{tbc} * (1 – E)

Where:

E = the effectiveness of the air curtain (%)

= 0.60[485]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ($\Delta kWh_{cooling}$ / (CD *24)) * CF

Where:

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3%[486]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8%[487]

NATURAL GAS SAVINGS

Natural gas savings, Δtherms, associated with reduced infiltration through an entryway during the heating season are calculated by determining the difference between heat loss through the entryway before and after the installation of the air curtain.

Δtherms = (Q_{bc} - Q_{ac}) * t_{open} * HD / η

Where:

Q_{bc} = rate of sensible heat transfer through the open entryway, before air curtain (therm/hr)

Q_{ac} = rate of sensible heat transfer through the open entryway, after air curtain (therm/hr)

t_{open} = average hours per day the door is open (hr/day)

= Actual or estimated user input value

HD = heating days per year, total days in year above balance point temperature (day)

= use table below to select an appropriate value[488]:

[485] Assumed conservative estimate based on referenced study results and ASHRAE 2004 effectiveness range of 60-80% for air curtains. Jaramillo, Julian, et. Al. "Application of Air Curtains in Refrigerated Chambers," International Refrigeration and Air-Conditioning Conference, Purdue University e-Pubs (July 14-17, 2008): http://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1972&context=iracc
ASHRAE, "Room Air Distribution Equipment," in 2004 ASHRAE Handbook – HVAC Systems and Equipment (2004): p 17.8

[486] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[487] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

[488] Note that Heating Days (HD) are calculated following the same approach outlined in the Cooling Days section.

	HD				
Climate Zone - Weather Station/City	45 °F	50 °F	55 °F	60 °F	65 °F
1 -Rockford AP / Rockford	142	160	183	204	228
2 - Chicago O'Hare AP / Chicago	150	166	192	219	253
3 - Springfield #2 / Springfield	125	142	167	194	230
4 - Belleville SIU RSCH / Belleville	101	115	134	156	180
5 - Carbondale Southern IL AP / Marion	103	123	148	174	205

η = efficiency of heating equipment

= Actual. If unknown, assume 0.8

Heat Transfer Through Open Entryway without Air Curtain (Heating Season)

Q_{bc} = (1.08 Btu/(hr*°F*cfm)) * CFM_{tot} * (T_{ih} – T_{oh}) / (100,000 Btu/therm)

Where:

1.08 = sensible heat transfer coefficient (specific heat of air and unit conversions)

CFM_{tot} = Total air flow through entryway (cfm)

T_{ih} = Average indoor air temperature during heating season

= User input, can assume indoor heating temperature set-point

T_{oh} = Average outdoor temp during heating season (°F)

= use table below, based on binned data from TMY3 & balance point temperature

	Avg Outdoor Air Temp - Heating Season				
Climate Zone - Weather Station/City	45 °F	50 °F	55 °F	60 °F	65 °F
1 -Rockford AP / Rockford	26.3	28.8	31.6	34.2	37.3
2 - Chicago O'Hare AP / Chicago	29.4	31.2	34.0	36.8	40.3
3 - Springfield #2 / Springfield	29.4	31.5	34.6	37.7	41.6
4 - Belleville SIU RSCH / Belleville	31.7	33.6	36.2	39.2	42.3
5 - Carbondale Southern IL AP / Marion	32.5	34.9	37.8	40.7	44.0

The total airflow through the entryway, CFM_{tot}, includes both infiltration due to wind as well as thermal forces, as follows:

CFM_{tot} = sqrt[$(CFM_w)^2 + (CFM_t^2)$]

Where:

CFM_w = Infiltration due to the wind (cfm)

CFM_t = Infiltration due to thermal forces (cfm)

The infiltration due to the wind is calculated as follows:

CFM_w = $(v_{wh} * C_{wh}) * C_v * A_d$ * (88 fpm/mph)

Where:

v_{wh} = average wind speed during the heating season (mph)

= similar to cooling season wind speed assumptions, use the following table to determined average wind speed based on entryway orientation:

	Entryway Orientation			
Climate Zone -Weather Station/ City	N	E	S	W
1 -Rockford AP / Rockford	5.0	4.6	4.9	5.6
2 - Chicago O'Hare AP / Chicago	5.5	5.2	4.9	5.1
3 - Springfield #2 / Springfield	5.0	4.9	5.3	5.1
4 - Belleville SIU RSCH / Belleville	4.3	3.4	3.5	5.3
5 - Carbondale Southern IL AP / Marion	4.6	3.2	4.2	4.4

C_{wh} = wind speed correction factor due to wind direction in heating season, (%)

= because wind direction is not constant, a wind speed correction factor is used to adjust for the amount of time during the heating season prevailing winds can be expected to impact the entryway. Use the following table to determine the correct wind speed correction factor for the heating applications.

	Entryway Orientation			
Climate Zone -Weather Station/ City	N	E	S	W
1 -Rockford AP / Rockford	0.18	0.13	0.30	0.31
2 - Chicago O'Hare AP / Chicago	0.21	0.10	0.26	0.39
3 - Springfield #2 / Springfield	0.21	0.14	0.27	0.34
4 - Belleville SIU RSCH / Belleville	0.31	0.15	0.22	0.29
5 - Carbondale Southern IL AP / Marion	0.31	0.11	0.27	0.18

Note that correction factors do not add up to 1 (100%). This is attributed to periods of calm winds.

C_v = effectiveness of openings,

= 0.3, assumes diagonal wind[24]

A_d = area of the doorway (ft^2)

= user input

The infiltration due to thermal forces is calculated as follows:

CFM_t = $A_d * C_{dh} * (60\ sec/min) * sqrt[2 * g * H/2 * (T_{ih} – T_{oh}) / (459.7 + T_{ih})]$

Where:

C_{dh} = the discharge coefficient during the heating season

= $0.4 + 0.0025 * |T_{ih} – T_{oh}|$

= 0.49, Illinois average at indoor air temp of 72°F

Note, values for C_{dh} show little variation due to balance point temperature, indoor air temperature, and climate zone. As such, if estimating results, the Illinois average value may be used as a simplification.

g = acceleration due to gravity

= 32.2 ft/sec^2

H = the height of the entryway (ft)

= user defined

Heat Transfer Through Open Entryway without Air Curtain (Heating Season)

Q_{ac} = Q_{bc} * (1 – E)

Where:

E = the effectiveness of the air curtain (%)

= 0.60[489]

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The air curtain would need to be regularly serviced and commissioned to ensure that it is appropriately operating. This is estimated at a cost of $150[490].

MEASURE CODE: CI-MSC-AIRC-V01-160601

[489] Assumed conservative estimate based on referenced study results and ASHRAE 2004 effectiveness range of 60-80% for air curtains. Jaramillo, Julian, et. Al. "Application of Air Curtains in Refrigerated Chambers," International Refrigeration and Air-Conditioning Conference, Purdue University e-Pubs (July 14-17, 2008): http://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1972&context=iracc
ASHRAE, "Room Air Distribution Equipment," in 2004 ASHRAE Handbook – HVAC Systems and Equipment (2004): p 17.8

[490] Assumes approximately 1 hour of maintenance (include cleaning out filters, greasing, and checking that the designed angle of attack on the blower nozzle is at the designed position) based on manufacturer inpur and product spec sheets.

4.4.34 Destratification Fan

DESCRIPTION

This measure applies to buildings with high bay ceiling construction without fans currently installed for the purpose of destratifying air. There is also a separate measure for destratification fans as applied to agricultural settings ("High Volume Low Speed Fans"). All other destratification fan applications require custom analysis.

Air stratification leads to higher temperatures at the ceiling and lower temperatures at the ground. During the heating season, destratification fans improve air temperature distribution in a space by circulating warmer air from the ceiling back down to the floor level, thereby enhancing comfort and saving energy. Energy savings are realized by a reduction of heat loss through the roof-deck and walls as a result of a smaller temperature differential between indoor temperature and outdoor air.

Note that further, but limited, empirical evidence suggests that improved air mixing due to destratification would also result in shorter heating system runtimes due to warmer air reaching the thermostat level sooner, and possibly even allow a facility to lower the thermostat set point while maintaining a similar level of occupant comfort. This is supported by measured data in which an increase in temperatures was observed at the thermostat (5 foot level) level when air is destratified, resulting in an approximate temperature increase at the 5 foot level in the range of 1 - 3°F[491]. This measure does not currently attempt to quantify the potential impacts of air mixing from destratification; however, it should be noted that additional therms savings may be possible.

This measure was developed to be applicable to the following program types: NC, RF. If applied to other program types, the measure savings should be verified.

Limitations

- For use in conditioned, high bay structures. Recommended minimum ceiling height of 20 ft.
- This measure should only be applied to spaces in which the ceiling is subject to heat loss to outdoor air (i.e., single story or top floor spaces) and where there is sufficient space to allow for appropriate spacing of the fans. Other applications require custom analysis.
- Installation must follow manufacturer recommendations sufficient to effectively destratify the entire space. Please see calculation of effective area, A_{eff}, in the therms savings algorithm as a check if this criteria is met. Otherwise, custom calculation is necessary.
- Measure does not currently support facilities with night setbacks on heating equipment. Custom analysis is needed in this case.
- Certain heating systems may not be a good fit for destratification fans, such as locations with: high velocity vertical throw unit heaters, radiant heaters, and centralized forced air systems. In these cases, measured evidence of stratification should be confirmed and custom analysis may be necessary.

DEFINITION OF EFFICIENT EQUIPMENT

High Volume, Low Speed (HVLS) fans with a minimum diameter of 14 ft with Variable Speed Drive (VSD) installed[492].

Note that bell-shaped fans are currently excluded from this measure due to limited validation of the technology available. Further verification of effectiveness compared to HVLS is needed. A manufacturer of bell shaped fans indicates that four bell-shaped fans provide an equivalent effective area as a typical HVLS fan. However, there is a need for further review of bell shaped fan field test data supporting manufacturer claims regarding comparable

[491] Kosar, Doug, "1026: Destratification Fans – Public Project Report," Nicor Gas, Emerging Technology Program (Oct 2014): 16
[492] Kosar, Doug, "1026: Destratification Fans – Public Project Report," Nicor Gas, Emerging Technology Program (Oct 2014): 16

effectiveness to HVLS technologies.

DEFINITION OF BASELINE EQUIPMENT

No destratification fans or other means to effectively mix indoor air.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years[493]

DEEMED MEASURE COST

Measure cost = [incremental cost of HVLS fans] + [installation costs (including materials and labor)]

The incremental capital cost for HVLS fans are as follows[494]:

Fan Diameter (ft)	Incremental Cost
14	$6,600
16	$6,650
18	$6,700
20	$6,750
22	$6,800
24	$6,850

Since installation cost is depended on a variety of factors, this is a custom entry. Actual costs should be used.

LOADSHAPE

Loadshape C04: Commercial Electric Heating.

COINCIDENCE FACTOR

N/A due to no savings attributable to cooling during the summer peak period.

Algorithm

CALCULATION OF SAVINGS

The following formulas provide a methodology for estimating heating load savings associated with destratification fan use. This algorithm is based on the assumption that savings are directly related to the difference in heat loss through the envelope before and after destratification.

ELECTRIC ENERGY SAVINGS

The algorithm for this measure was developed for natural gas heating applications, however, for electric heating

[493] Consistent with both 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values, October 10, 2008 and GDS Associates, Inc, "Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures," New England Stat Program Working Group (June 2007), p30.

[494] Costs were obtained from manufacturer interviews and are based off of average or typical prices for base model HVLS fans. Costs include materials and labor to install the fans and tie fans into an existing electrical supply located near the fan.

applications, the same methodology presented in the Natural Gas Savings Section may be used with the standard conversion factor from therms to kWh of 29.31 kWh/therm and an equipment efficiency as follows:

System Type	Age of Equipment	HSPF Estimate	η (Effective COP Estimate) (HSPF/3.413)
Heat Pump	Before 2006	6.8	2.0
	2006 - 2014	7.7	2.3
	2015 on	8.2	2.40
Resistance	N/A	N/A	1

Regardless of how the building is heated, the energy consumption of the fans must be accounted for. If the building is electrically heated, fan energy shall be subtracted from the savings as calculated above. If the building is heated with natural gas, this shall represent an electric penalty, i.e., an increase in consumption. This is calculated as follows:

$\Delta kWh = - (W_{fan} * N_{fan}) * t_{eff}$

W_{fan} = fan input power (kW)

N_{fan} = number of fans

t_{eff} = effective annual operation time, based on balance point temperature (hr)

= see table below in Natural Gas Savings section for further detail

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

$\Delta Therms = [(\Delta Q_r + \Delta Q_w) * t_{eff}] / (100{,}000 * \eta)$

Where:

ΔQ_r = the heat loss reduction through the roof due to the destratification fan (Btu/hr)

= See calculation section below

ΔQ_w = the heat loss reduction through the exterior walls due to destratification fan (Btu/hr)

= See calculation section below

t_{eff} = effective annual operation time, based on balance point temperature (hr)

= use table below to select an appropriate value[495]:

Climate Zone - Weather Station/City	t_{eff}				
	45 °F	50 °F	55 °F	60 °F	65 °F
1 -Rockford AP / Rockford	3810	4226	4880	5571	6436
2 - Chicago O'Hare AP / Chicago	3593	3986	4603	5254	6070

[495] These were calculated at various base temperatures using TMY3 data and adjusted to make consistent with the 30 year normal data used elsewhere. For more information see 'Destratification Fan Workpaper'; Robert Irmiger, Gas Technology Institute, 9/6/2015.

Climate Zone - Weather Station/City	t_{eff}				
	45 °F	50 °F	55 °F	60 °F	65 °F
3 - Springfield #2 / Springfield	3038	3370	3891	4442	5131
4 - Belleville SIU RSCH / Belleville	2243	2488	2873	3280	3789
5 - Carbondale Southern IL AP / Marion	2271	2519	2909	3320	3836

100,000 = conversion factor (1 therm = 100,000 Btu)

η = thermal efficiency of heating equipment

= Actual. If unknown assume 0.8.

EXAMPLE:

For a warehouse facility located in Rockford, IL, installing destratification fans could reduce heat loss through the roof of 95,000 Btu/hr and a reduced heat loss through the wall of 51,2282 Btu/hr. Assuming a balance point of 55°F the therms savings for the facility would be estimated as:

ΔTherms = $[(\Delta Q_r + \Delta Q_w) * t_{eff}] / (100{,}000 * \eta)$

= [(95,000 Btu/hr + 51,282 Btu/hr) * 4880 hr] / [(100,000 Btu/therm) * 0.8)]

= 8,923 therms

Heat loss reduction through the roof

$\Delta Q_r = Q_{r,s} - Q_{r,d}$

$= (1/R_r) * A_r * [(T_{r,s} - T_{oa}) - (T_{r,d} - T_{oa})]$

$= (1/R_r) * A_r * (T_{r,s} - T_{r,d})$

Where:

$Q_{r,s}$ = roof heat loss for stratified space

$Q_{r,d}$ = roof heat loss for destratified space

R_r = overall thermal resistance through the roof (hr * ft^2 * °F / Btu)

= Actual or estimated based on construction type. If unknown, assume the following:

Thermal Resistance Factor (R-Factor) for Roof	Retrofit[496]	New Construction[497] (2010 or newer)
R_r	10.0 (hr * ft^2 * °F / Btu)	20.0 (hr * ft^2 * °F / Btu)

[496] ANSI/ASHRAE/IESNA 100-1995, "Energy Conservation in Existing Buildings," ASHRAE Standard (1995). Additionally, professional judgement was used to address older vintage structure prior to adoption of the 1995 standard and an estimate of 50% of current code standard was used.

[497] ANSI/ASHRAE/IESNA Standard 90.1-2007, "Energy Standard for Buildings Except Low-Rise Residential Buildings," ASHRAE Standard (2007): Table 5.5-4 and Table 5.5-5

A_r = roof area (ft^2)

= user input

= can be approximated with floor area

T_{oa} = outside air temperature, note: therm savings calculations are actually independent of outside air because this term drops out of the heat loss reduction equation

$T_{r,s}$ = indoor temperature at roof deck, stratified case (°F)

= Actual. If unknown, use the following equation

= $m_s * h_r + T_{f,s}$

h_r = ceiling height/roof deck (ft)

m_s = estimated heat gain per foot elevation, stratified case (°F/ft)

= 0.8 °F/ft

= Professional judgement used to define value based on result from a Nicor Gas ETP Pilot field testing results and the Ansley article[498,499]. Estimates from these sources fall on the conservative side of the industry rule of thumb range of 1-2 °F/ft heat gain.

$T_{f,s}$ = estimated floor temperature, stratified case (°F)

= $T_{tstat} – m_s * h_{tstat}$

= T_{tstat} – 4 °F

T_{tstat} = temperature set point at the thermostat

h_{tstat} = vertical distance between the floor and the thermostat, assumed 5ft

$T_{r,d}$ = indoor temp at roof, destratified case

= actual value, or may be estimated using the following:[500,501]

= T_{tstat} + 1 °F

[498] Kosar, Doug, "1026: Destratification Fans – Public Project Report," Nicor Gas, Emerging Technology Program (Oct 2014): 10-11. Field testing results indicated approximately 0.6 oF/ft for a garden center.
[499] Aynsley, Richard, "Saving Heating Costs in Warehouses," ASHRAE Journal (Dec 2005): 48. Identifies a 0.8 oF/ft gain.
[500] 12. Kosar, Doug, "1026: Destratification Fans – Public Project Report," Nicor Gas, Emerging Technology Program (Oct 2014): 10-11. Field testing results indicated approximately 0.6 oF/ft for a garden center.
[501] 13. Aynsley, Richard, "Saving Heating Costs in Warehouses," ASHRAE Journal (Dec 2005): 48.

EXAMPLE:

For a 50,000 ft^2 warehouse built in 1997 with 30 ft ceilings and a thermostat set point of 65 °F. No further measured values available.

$$\Delta Q_r = (1/R_r) * A_r * (T_{r,s} - T_{r,d}) = (1/R_r) * A_r * [(m_s * h_r + T_{tstat} - 4\ ^oF) - (T_{tstat} + 1\ ^oF)]$$

$$= (1/R_r) * A_r * [(0.8^oF/ft * h_r) - 5\ ^oF]$$

$$= 1/(10\ hr * ft^2 * {}^oF / Btu) * (50{,}000\ ft^2) * [(0.8^oF/ft * 30\ ft) - 5\ ^oF]$$

$$= 95{,}000\ Btu/hr$$

Heat loss reduction through exterior walls

Note: a conservative estimate for therms savings would neglect the impact of heat loss through the walls. However, Ansley suggests that estimates based on the roof deck losses alone underestimate actual savings by up to 46%.[502]

$$\Delta Q_w = Q_{w,s} - Q_{w,d}$$

$$= (1/R_w) * A_w * (T_{w,s} - T_{w,d})$$

Where:

R_w = overall thermal resistance through the exterior walls (hr * ft^2* °F / Btu)

= Actual or estimated based on construction type[503]. If unknown, assume the following

Thermal Resistance Factor (R-Factor) for Wall	Retrofit[504]	New Construction[505] (2010 or newer)
R_w	6.5 (hr * ft^2 * °F / Btu)	13.0 (hr * ft^2 * °F / Btu)

A_w = area of exterior walls (ft^2)

= user input

$T_{w,s}$ = average indoor air temperature for wall heat loss, stratified case

[502] Aynsley, Richard, "Saving Heating Costs in Warehouses," ASHRAE Journal (Dec 2005): 51

[503] Because heat loss through the walls is estimated using the average space temperature pre- and post- destratification. There are a number of factors that can impact the average space temperature causing deviations from estimates of many degrees in some cases. As such, it is recommended that a conservative value for the thermal resistance through the walls, R_w, be used. A recommended method for determining R_w would be to use the highest R-value for the wall space, neglecting lower R-values associated with windows, thermal bridges, etc.

[504]ANSI/ASHRAE/IESNA 100-1995, "Energy Conservation in Existing Buildings," ASHRAE Standard (1995). Additionally, professional judgement was used to address older vintage structure prior to adoption of the 1995 standard and an estimate of 50% of current code standard was used.

[505]ANSI/ASHRAE/IESNA Standard 90.1-2007, "Energy Standard for Buildings Except Low-Rise Residential Buildings," ASHRAE Standard (2007): Table 5.5-4 and Table 5.5-5

= If actual $T_{r,s}$ measurement is available[506]

= $[(T_{r,s} * h_a) + (T_{tstat} * h_b)] / h_r$

h_a = vertical distance between the heat source and the ceiling

h_b = vertical distance between the floor and the heat source

= Otherwise, use the linear stratification equation at average space height, see definition above.

= $m_s * (h_r / 2) + T_{f,s}$

= $m_s * (h_r / 2) + (T_{tstat} – 4)$

$T_{w,d}$ = average indoor air temperature for wall heat loss, destratified case

= $T_{tstat} + 0.5$

= conservative estimate using engineering judgment based on the same assumption used for $T_{r,f}$ estimate.

EXAMPLE:

For a 50,000 ft^2 warehouse built in 1997 with 30 ft ceilings and a thermostat set point of 65 °F and a measured temperature at the ceiling of 85 °F and unit heaters located 10 feet from the roof:

ΔQ_w = $(1/R_w) * A_w * (T_{w,s} – T_{w,d})$

= $(1/R_w) * A_w$ w* $[([(T_{r,s} * h_a) + (T_{tstat} * h_b)] / h_r) – (T_{tstat} + 0.5\ ^oF)]$

= $1/(6.5\ hr*ft^2*^oF/Btu) * (50{,}000ft^2) * [([(85^oF * 10ft) + (65\ ^oF * 20ft)] / 30ft) – (65 + 0.5\ ^oF)]$

= $1/(6.5\ hr*ft^2*^oF/Btu) * (50{,}000ft^2) * (71.7\ ^oF – 65.5\ ^oF)$

= 51,282 Btu/hr

Measure eligibility check

Use the following algorithm to verify a fan system is sufficiently sized to destratify air across the entire area.

Effective area, A_{eff}, is the area over which a fan or a group of fans can be expected to effectively destratify a space. If A_{eff} is less than the roof area, A_r, a custom analysis approach should be followed to account for the change in the effectiveness of the system. In lieu of more detailed studies, effective area is defined based on the measured results from an Enbridge Gas field study in which the area a fan was expected to effectively destratify was equal to 5 times the fan diameter[507]. Effective area, is calculated as follows:

A_{eff} = $[\pi * (5*D_{fan})^2) / 4] * N_{fan}$

= $6.25 * \pi * D_{fan}^2 * N_{fan}$

Where:

A_{eff} = the effective area fan area on the floor (ft^2)

D_{fan} = fan diameter

[506] Aynsley, Richard, "Saving Heating Costs in Warehouses," ASHRAE Journal (Dec 2005): 48

[507] Enbridge Gas Distribution, Inc., "Big Fans Deliver Big Bonus," (Aug 2007) https://www.enbridgegas.com/businesses/assets/docs/hunter_douglas_case_study.pdf. Additionally, multiple utilities have adopted this definition in their programs in including Enbridge Gas and Consumers Energy.

N_{fan} = the number of fans

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-DSFN-V01-160601

4.4.35 Economizer Repair and Optimization

DESCRIPTION

Economizers are designed to use unconditioned outside air (OSA) instead of mechanical cooling to provide cooling when exterior conditions permit. When the OSA temperature is less than the changeover temperature (determined by a static setpoint or a reference return air sensor) up to 100% OSA is supplied to help meet the facility's cooling needs, thus reducing mechanical cooling energy and saving energy. An economizer that is not working or is not properly adjusted can waste energy and cause comfort issues. This HVAC Economizer Optimization measure involves the repair and optimization of common economizer problems such as adjusting changeover setpoint, repairing damper motors & linkages and replacing non-working sensors and/or controllers. These repairs and adjustments result in proper operation which maximizes both occupant comfort and energy savings.

This measure is only appropriate for single zone packaged rooftop units. Custom calculations are required for savings for multi-zone systems.

In general the HVAC Economizer Optimization measure may involve both repair and/or optimization;

Economizer Repair – The Economizer repair work is preformed to ensure that the existing economizer is working properly. This allows the system to take advantage of free cooling and ensure that the system is not supplying an excess amount of outside air (OSA) during non-economizing periods.

- **Replace Damper Motor** – If the existing damper motor is not operational, the unit will be replaced with a functioning motor to allow proper damper modulation.
- **Repair Damper linkage** – If the existing linkage is broken or not adjusted properly, the unit will be replaced or adjusted to allow proper damper modulation.
- **Repair Economizer Wiring** – If the existing economizer is not operational due to a wiring issue, the issue will be repaired to allow proper economizer operation.
- **Reduce Over Ventilation** – If the unit is supplying excess OSA, the OSA damper position will be adjusted to meet minimum ventilation requirements.
- **Economizer Sensor Replacement** – If the unit is equipped with a nonadjustable dry bulb (i.e. snapdisk) or malfunctioning analog sensor, the sensor is replaced with a new selectable sensor.
- **Economizer Control Replacement** – If the existing economizer controller is not operational, the unit will be replaced or upgraded to allow for proper economizer operation.

Economizer Optimization- The economizer optimization work is preformed to ensure that the existing economizer system is set up properly to maximize use of free cooling for units located in a particular climate zone.

- **Economizer Changeover Setpoint Adjustment** – If the unit is equipped with a fully operational economizer, the controller is adjusted to the appropriate changeover setpoint based on ASHRAE 90.1 (Figure 1 - *Table 6.5.1.1.3 High-Limit Shutoff Control Settings for Air Economizers)* for the corresponding climate zone.
- **Enable Integrated Operation** – If the unit is equipped with a fully operational economizer and is not set up to allow a minimum of two stages of cooling (1st stage – Economizer Only & 2nd Stage – Economizer & Mechanical cooling), the unit will be wired to allow two stage cooling

This measure was developed to be applicable to the following program types: RF, DI.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment condition is defined by fully functional economizer that is programmed to meet ASHRAE 90.1 economizer changeover setpoint requirements for the facility's climate zone and changeover control type

(Figure 1 - Table 6.5.1.1.3 High-Limit Shutoff Control Settings for Air Economizers)[508].

Figure 1 – Baseline ASHRAE High-Limit Shutoff Control Settings

TABLE 6.5.1.1.3 High-Limit Shutoff Control Settings for Air Economizers[b]

Control Type	Allowed Only in Climate Zone at Listed Setpoint	Required High-Limit Setpoints (Economizer Off When):	
		Equation	Description
Fixed dry-bulb temperature	1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8	$T_{OA} > 75°F$	Outdoor air temperature exceeds 75°F
	5a, 6a	$T_{OA} > 70°F$	Outdoor air temperature exceeds 70°F
	1a, 2a, 3a, 4a,	$T_{OA} > 65°F$	Outdoor air temperature exceeds 65°F
Differential dry-bulb temperature	1b, 2b, 3b, 3c, 4b, 4c, 5a, 5b, 5c, 6a, 6b, 7, 8	$T_{OA} > T_{RA}$	Outdoor air temperature exceeds return air temperature
Fixed enthalpy with fixed dry-bulb temperature	All	$h_{OA} > 28$ Btu/lb[a] or $T_{OA} > 75°F$	Outdoor air enthalpy exceeds 28 Btu/lb[a] of dry air[a] or outdoor air temperature exceeds 75°F
Differential enthalpy with fixed dry-bulb temperature	All	$h_{OA} > h_{RA}$ or $T_{OA} > 75°F$	Outdoor air enthalpy exceeds return air enthalpy or outdoor air temperature exceeds 75°F

a. At altitudes substantially different than sea level, the fixed enthalpy limit shall be set to the enthalpy value at 75°F and 50% RH. As an example, at approximately 6000 ft elevation, the fixed enthalpy limit is approximately 30.7 Btu/lb.
b. Devices with selectable rather than adjustable setpoints shall be capable of being set to within 2°F and 2 Btu/lb of the setpoint listed.

Figure 2 – ASHRAE Climate Zone Map

NORMATIVE APPENDIX B
CLIMATE ZONES FOR U.S. STATES AND COUNTIES

This normative appendix provides the climate zones for U.S. states and counties. Figure B-1 contains the county-level climate zone map for the United States. Table B-1 lists each state and major counties within the state and shows the climate number and letter for each county listed.

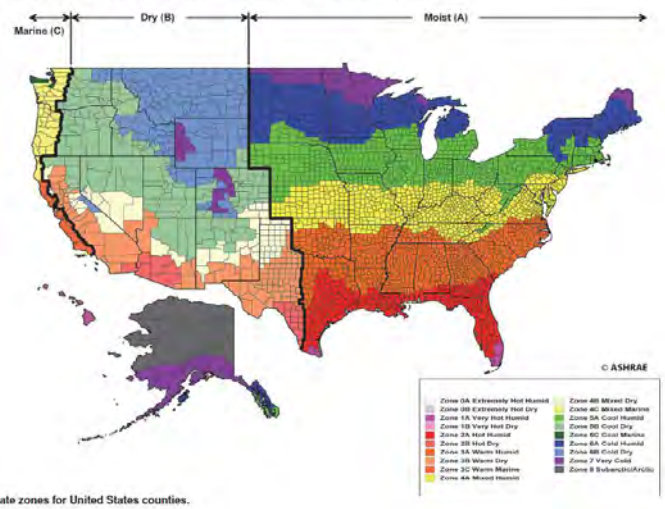

FIGURE B-1 Climate zones for United States counties.

Definition of Baseline Equipment

The baseline for this measure is an existing economizer installed on a packaged single zone rooftop HVAC unit. The existing economizer system is currently not operating as designed due to mechanical and/or control problems, and/or is not optimally adjusted.

Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 5 years[509].

Deemed Measure Cost

The cost for this measure can vary considerably depending upon the existing condition of the economizer and the

[508] ASHRAE, Standard 90.1-2013 - https://www.ashrae.org/resources--publications/bookstore/standard-90-1
[509] California Public Utilities Commission, DEER 2014 EUL Table D08 v2.05

work required to achieve the required efficiency levels. Measure cost should be determined on a site-specific basis.

LOADSHAPE

Loadshape C03 - Commercial Cooling

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

The savings calculation methodology uses a regression equation to calculate the energy savings for a variety of common situations[510].

ELECTRIC ENERGY SAVINGS

ΔkWh = [Baseline Energy Use (kWh/Ton) – Proposed Energy Use (kWh/Ton)] * Cooling Capacity (Tons)

The following equations are used to calculate baseline and proposed electric energy use[511].

Electric Energy Use Equations (kWh / ton)

Building Type	Changeover Type	Equation
Assembly	Fixed Dry-Bulb (DB)	cz+CSP*-2.021+EL*-16.362+OAn*1.665+OAx*-3.13
	Dual Temperature Dry-Bulb (DTDB)	cz+EL*-11.5+OAn*1.635+OAx*-2.817
	Dual Temperature Enthalpy (DTEnth)	cz+EL*-17.772+OAn*1.853+OAx*-3.044
	Fixed Enthalpy (Enth)	cz+CSP*-5.228+EL*-17.475+OAn*1.765+OAx*-3.003
	Analog ABCD Economizers (ABCD)	cz+CSP*-2.234+EL*-16.394+OAn*1.744+OAx*-3.01
Convenience Store	DB	cz+CSP*-2.021+EL*-16.362+OAn*1.665+OAx*-3.13
	DTDB	cz+EL*-11.5+OAn*1.635+OAx*-2.817
	DTEnth	cz+EL*-17.772+OAn*1.853+OAx*-3.044
	Enth	cz+CSP*-5.228+EL*-17.475+OAn*1.765+OAx*-3.003
	ABCD	cz+CSP*-2.234+EL*-16.394+OAn*1.744+OAx*-3.01
Office - Low Rise	DB	cz+CSP*-3.982+EL*-27.508+OAn*2.486+OAx*-4.684
	DTDB	cz+EL*-20.798+OAn*2.365+OAx*-3.773
	DTEnth	cz+EL*-30.655+OAn*2.938+OAx*-4.461
	Enth	cz+CSP*-8.648+EL*-25.678+OAn*2.092+OAx*-3.754
	ABCD	cz+CSP*-3.64+EL*-24.927+OAn*2.09+OAx*-3.788
Religious Facility	DB	cz+CSP*-0.967+EL*-6.327+OAn*2.87+OAx*-1.047
	DTDB	cz+OAn*2.968+OAx*-0.943
	DTEnth	cz+EL*-9.799+OAn*3.106+OAx*-1.085

[510] For more information on methodology, please refer to workpaper submitted by CLEAResult titled "CLEAResult_Economizer Repair_151020_Finalv2.doc". Note that the original ComEd eQuest models were used in the analysis, rather than the VEIC developed models used elsewhere. VEIC do not consider this a significant issue as adjustments from the ComEd models were focused on calibrating EFLH values, not to overall energy use metrics. We also believe using the ComEd models is likely more conservative. It may be appropriate to update the analysis with the updated models at a later time.

[511] This approach allows the savings estimate to account for the operational attributes of the baseline as well as the proposed case, yielding a better estimate than an approach that assumes a particular baseline or proposed energy use to determine savings.

Building Type	Changeover Type	Equation
	Enth	cz+CSP*-2.773+EL*-7.392+OAn*2.941+OAx*-0.974
	ABCD	cz+CSP*-1.234+EL*-7.229+OAn*2.936+OAx*-0.995
Restaurant	DB	cz+CSP*-1.131+OAn*3.542+OAx*-1.01
	DTDB	cz+EL*-10.198+OAn*4.056+OAx*-1.279
	DTEnth	cz+OAn*3.775+OAx*-1.031
	Enth	cz+CSP*-2.13+OAn*3.317+OAx*-0.629
	ABCD	cz+CSP*-0.95+OAn*3.313+OAx*-0.647
Retail - Department Store	DB	cz+CSP*-2.243+EL*-21.523+OAx*-1.909
	DTDB	cz+EL*-14.427+OAn*0.295+OAx*-1.451
	DTEnth	cz+EL*-25.99+OAn*0.852+OAx*-1.951
	Enth	cz+CSP*-4.962+EL*-16.868+OAn*-0.12+OAx*-1.418
	ABCD	cz+CSP*-2.115+EL*-16.15+OAn*-0.125+OAx*-1.432
Retail - Strip Mall	DB	cz+CSP*-1.003+OAn*3.765+OAx*-0.938
	DTDB	cz+OAn*3.688+OAx*-0.676
	DTEnth	cz+OAn*4.081+OAx*-1.072
	Enth	cz+CSP*-2.545+OAn*3.725+OAx*-0.788
	ABCD	cz+CSP*-1.175+OAn*3.708+OAx*-0.809

Where:

CZ = Climate Zone Coefficient

= Depends on Building Type and Changover Type (see table below)

		Electric Climate Zone Coefficients				
Building Type	Changeover Type	CZ1 (Rockford)	CZ2 (Chicago)	CZ3 (Springfield)	CZ4 (Belleville)	CZ5 (Marion)
Assembly	DB	874.07	886.73	1043.38	1071.48	1072.20
	DTDB	698.45	711.89	870.13	899.51	903.10
	DTEnth	702.06	715.42	873.43	902.76	906.50
	Enth	851.95	865.43	1020.65	1047.10	1053.32
	ABCD	884.19	897.63	1053.12	1080.58	1086.35
Convenience Store	DB	1739.12	1787.09	2128.78	2206.65	2245.93
	DTDB	1389.28	1436.30	1780.99	1863.45	1904.89
	DTEnth	1398.42	1446.82	1789.71	1869.89	1912.59
	Enth	1643.51	1691.34	2032.83	2112.21	2157.63
	ABCD	1692.80	1740.62	2082.35	2162.73	2207.68
Office - Low Rise	DB	674.06	687.17	899.17	993.84	989.16
	DTDB	583.62	597.02	811.39	907.61	903.58
	DTEnth	588.94	602.11	816.02	912.49	908.26
	Enth	668.83	682.23	893.61	987.52	986.59
	ABCD	690.27	703.52	915.27	1009.94	1008.59
Religious Facility	DB	613.26	630.50	853.53	923.99	931.74
	DTDB	518.40	535.45	760.76	832.57	840.72
	DTEnth	513.59	531.20	756.26	829.13	837.26
	Enth	576.94	594.17	817.64	888.37	897.18
	ABCD	593.78	611.04	834.69	905.83	914.27
Restaurant	DB	1397.27	1430.45	1763.21	1837.63	1872.18

		Electric Climate Zone Coefficients				
Building Type	Changeover Type	CZ1 (Rockford)	CZ2 (Chicago)	CZ3 (Springfield)	CZ4 (Belleville)	CZ5 (Marion)
	DTDB	1191.82	1225.12	1558.32	1633.95	1669.13
	DTEnth	1192.84	1226.77	1559.41	1635.13	1671.11
	Enth	1343.56	1377.52	1710.11	1783.66	1821.67
	ABCD	1373.72	1407.70	1740.43	1814.74	1852.55
Retail - Department Store	DB	717.89	730.07	968.85	1034.78	1035.06
	DTDB	628.83	641.70	883.37	951.09	951.33
	DTEnth	629.35	641.90	882.84	951.33	951.44
	Enth	705.06	717.99	956.42	1020.57	1024.45
	ABCD	728.60	741.47	980.19	1045.30	1048.57
Retail - Strip Mall	DB	800.69	818.68	1070.39	1129.87	1133.84
	DTDB	692.97	711.31	965.63	1026.68	1030.41
	DTEnth	698.12	716.34	970.06	1031.78	1035.72
	Enth	784.54	803.35	1054.37	1112.72	1120.74
	ABCD	810.10	828.86	1080.11	1139.39	1146.95

CSP = Economizer Changeover Setpoint (°F or Btu/lb) (actual in ranges below)

Economizer Control Type		Economizer Changeover Setpoint
Dry-Bulb		60°F - 80°F
Dual Temperature Dry-Bulb		0°F -5°F delta
Dual Temperature Enthalpy		0 Btu/lb -5 Btu/lb delta
Enthalpy		18 Btu/lb – 28 Btu/lb
Analog ABCD Economizers	A	73°F
	B	70°F
	C	67°F
	D	63°F
	E	55°F

EL = Integrated Economizer Operation (Economizer Lockout)

= 0 for Economizer w/ Integrated Operation (Two Stage Cooling)

= 1 for Economizer w/ out Integrated Operation fan that runs intermittently (One Stage Cooling)

Oan = Minimum Outside Air (% OSA)[512]

= Actual. Must be between 15% -70%. If unknown assume

Functional Economizer – 30%
Non functional Economizer (Damper failed closed) – 15%
Non functional Economizer (Damper failed open) - 30% (Assume Minimum Ventilation (Three Fingers)[513])

Oax = Maximum Outside Air (%)[i]

= Actual. Must be between 15% -70%. If unknown assume

Functional Economizer – 70%

[512] DNV GL, "HVAC Impact Evaluation Final Report WO32 HVAC – Volume 1: Report," California Public Utilities Commission, Energy Division, HVAC Commercial Quality Maintenance (CQM) (1/28/14)
[513] Technician rule of thumb taken from CPUC 'HVAC Impact Evaluation Final Report', WO32, 28Jan 2015, p18.

Non functional Economizer (Damper failed closed) – 15%
Non functional Economizer (Damper failed open) — 30% (Assume Minimum Ventilation (Three Fingers))

EXAMPLE
A low rise office building in Rockford (Climate Zone 1) is heated and cooled with a packaged Gas (92 kBtu output) / DX (5 Ton) RTU. The RTU is equipped with a fixed dry-bulb outside air economizer and is programed for integrated operation. When the technician inspects the RTU they find that the changeover setpoint is programmed to 62°F, which does not meet ASHRAE economizer high limit shut off air economizer recommendations. After further investigation it is found that the OSA damper motor is not operational and is providing 30% outside air.

The technician replaces the damper motor and allow for proper OSA damper modulation (30% Min OSA & 70% Max OSA). They also adjust the fixed dry-bulb changeover setpoint to meet the ASHRAE economizer high limit shut off air economizer recommendation of 70°F.

ΔkWh = [Baseline Energy Use (kWh/Ton) – Proposed Energy Use (kWh/Ton)] * Cooling Capacity (Tons)

Baseline Energy Use (kWh/Ton) = Equation for Office Low Rise
= cz+CSP*-0.967+EL*-6.327+OAn*2.87+OAx*-1.047
= 674.06+62*-0.967+0*-6.327+30*2.87+30*-1.047
= 668.8 kWh/Ton

Proposed Energy Use (kWh/Ton) = Equation for Office Low Rise
= cz+CSP*-0.967+EL*-6.327+OAn*2.87+OAx*-1.047
= 674.06+70*-0.967+0*-6.327+ 30*2.87+70*-1.047
= 619.2 kWh/Ton

ΔkWh = [668.8 (kWh/Ton) – 619.2 (kWh/Ton)] * 5 Tons
= 49.6 kWh/Ton * 5 Tons
= 248.08 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A - It is assumed that repair or optimization of the economizer will not typically have a significant impact summer peak demand.

NATURAL GAS SAVINGS

ΔTherms = [Baseline Energy Use (Therms/kBtuh) – Proposed Energy Use (Therms/kBtuh)] * Output Heating Capacity (kBtuh)

The following equations are used to calculate baseline and proposed electric energy use.

Natural Gas Energy Use Equations (therms / kbtu output)

Building Type	Changeover Type	Equation
Assembly	Fixed Dry-Bulb (DB)	cz+OAn*0.0853
	Dual Temperature Dry-Bulb (DTDB)	cz+OAn*0.0866

Building Type	Changeover Type	Equation
	Dual Temperature Enthalpy (DTEnth)	cz+OAn*0.0866
	Fixed Enthalpy (Enth)	cz+OAn*0.0855
	Analog ABCD Economizers (ABCD)	cz+OAn*0.0855
Convenience Store	DB	cz+OAn*0.26
	DTDB	cz+OAn*0.263
	DTEnth	cz+OAn*0.263
	Enth	cz+OAn*0.261
	ABCD	cz+OAn*0.261
Office - Low Rise	DB	cz+OAn*0.3
	DTDB	cz+OAn*0.301
	DTEnth	cz+OAn*0.301
	Enth	cz+OAn*0.3
	ABCD	cz+OAn*0.3
Religious Facility	DB	cz+OAn*0.35
	DTDB	cz+OAn*0.348
	DTEnth	cz+OAn*0.348
	Enth	cz+OAn*0.349
	ABCD	cz+OAn*0.349
Restaurant	DB	cz+OAn*0.0867
	DTDB	cz+OAx*-0.038+OAn*OAx*0.00149
	DTEnth	cz+OAx*-0.038+OAn*OAx*0.00149
	Enth	cz+OAn*0.0878
	ABCD	cz+OAn*0.0878
Retail - Department Store	DB	cz+OAn*0.319
	DTDB	cz+OAn*0.318
	DTEnth	cz+OAn*0.318
	Enth	cz+OAn*0.318
	ABCD	cz+OAn*0.318
Retail - Strip Mall	DB	cz+OAn*0.215
	DTDB	cz+OAn*0.216
	DTEnth	cz+OAn*0.216
	Enth	cz+OAn*0.215
	ABCD	cz+OAn*0.215

Where:

CZ = Climate Zone Coefficient

= Depends on Building Type and Changover Type (see table below)

		Natural Gas Climate Zone Coefficients				
Building Type	Changeover Type	CZ1 (Rockford)	CZ2 (Chicago)	CZ3 (Springfield)	CZ4 (Belleville)	CZ5 (Marion)
Assembly	DB	-0.03	-0.55	-1.06	-1.28	-1.71
	DTDB	-0.02	-0.57	-1.11	-1.34	-1.79
	DTEnth	-0.02	-0.57	-1.11	-1.34	-1.79
	Enth	-0.03	-0.55	-1.06	-1.29	-1.72

		Natural Gas Climate Zone Coefficients				
Building Type	Changeover Type	CZ1 (Rockford)	CZ2 (Chicago)	CZ3 (Springfield)	CZ4 (Belleville)	CZ5 (Marion)
	ABCD	-0.03	-0.55	-1.06	-1.29	-1.72
Convenience Store	DB	2.95	0.50	-1.48	-2.96	-5.56
	DTDB	3.06	0.52	-1.56	-3.11	-5.81
	DTEnth	3.06	0.52	-1.56	-3.11	-5.81
	Enth	2.96	0.50	-1.49	-2.98	-5.59
	ABCD	2.96	0.50	-1.49	-2.98	-5.59
Office - Low Rise	DB	5.83	3.02	0.46	-0.92	-4.13
	DTDB	5.98	3.08	0.41	-1.03	-4.36
	DTEnth	5.98	3.08	0.41	-1.03	-4.36
	Enth	5.85	3.03	0.46	-0.93	-4.16
	ABCD	5.85	3.03	0.46	-0.93	-4.16
Religious Facility	DB	9.23	6.71	3.75	2.40	-0.80
	DTDB	9.41	6.83	3.77	2.39	-0.86
	DTEnth	9.41	6.83	3.77	2.39	-0.86
	Enth	9.25	6.73	3.75	2.40	-0.80
	ABCD	9.25	6.73	3.75	2.40	-0.80
Restaurant	DB	8.30	6.54	4.94	4.00	1.95
	DTDB	10.51	8.71	7.07	6.10	4.00
	DTEnth	10.51	8.71	7.07	6.10	4.00
	Enth	8.28	6.51	4.91	3.96	1.90
	ABCD	8.28	6.51	4.91	3.96	1.90
Retail - Department Store	DB	8.20	5.86	3.19	1.25	-2.59
	DTDB	8.35	5.94	3.18	1.18	-2.75
	DTEnth	8.35	5.94	3.18	1.18	-2.75
	Enth	8.21	5.87	3.18	1.24	-2.61
	ABCD	8.21	5.87	3.18	1.24	-2.61
Retail - Strip Mall	DB	6.40	4.35	2.07	0.49	-2.18
	DTDB	6.51	4.38	2.03	0.39	-2.34
	DTEnth	6.51	4.38	2.03	0.39	-2.34
	Enth	6.41	4.35	2.06	0.48	-2.20
	ABCD	6.41	4.35	2.06	0.48	-2.20

EXAMPLE

A low rise office building in Rockford (Climate Zone 1) is heated and cooled with a packaged Gas (92 kBtu output) / DX (5 Ton) RTU. The RTU is equipped with a fixed dry-bulb outside air economizer and is programed for integrated operation. When the technician inspects the RTU they find that the changeover setpoint is programmed to 62°F, which does not meet ASHRAE economizer high limit shut off air economizer recommendations. After further investigation it is found the OSA damper motor is not operational and is providing 30% outside air.

The technician replaces the damper motor and allow for proper OSA damper modulation (30% Min OSA & 70% Max OSA). They also adjust the fixed dry-bulb changeover setpoint to meet the ASHRAE economizer high limit shut off air economizer recommendation of 70°F.

ΔTherms = [Baseline Energy Use (Therms/kBtuh) – Proposed Energy Use(Therms/kBtuh)] * Output Heating Capacity (kBtuh)

Baseline Energy Use (Therms/kBtuh) = Equation for Office Low Rise
= cz+OAn*0.3
= 5.83+30*.3
=14.8 Therms/kBtuh output

Proposed Energy Use (Therms/kBtuh) = Equation for Office Low Rise
= cz+OAn*0.3
= 5.83+30*.3
=14.8 Therms/kBtuh output

ΔTherms = [14.8(Therms/kBtuh output) – 14.8 (Therms/kBtuh output)] * 92kBtuh output
= 0.0 (Therms/kBtuh output) * 92kBtuh output
= 0 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-ECRP-V01-160601

4.4.36 Multi-Family Space Heating Steam Boiler Averaging Controls

DESCRIPTION

This measure covers multi-family space heating boiler averaging controls. Temperature sensors are placed in interior spaces to monitor the average temperature of the building. At minimum a sensor must be placed at each corner and at one central location. Additionally, a temperature sensor must monitor the outside air temperature. These sensors shall provide data to the averaging controls. The averaging controls will adjust the boiler operation based upon an average of the indoor sensors and the outside air temperature. These controls shall also incorporate a night-time setback capability. Buildings utilizing thermostatic radiator valves, or other modulating control valves or sequences to control the temperature in individual spaces are not eligible.

This measure was developed to be applicable to the following program types: RF.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify the boiler(s) must incorporate an averaging control system utilizing at least 5 indoor sensors and 1 outdoor sensor. The controls shall have the capability to incorporate a nighttime setback throughout the building.

DEFINITION OF BASELINE EQUIPMENT

The baseline is a boiler system without averaging controls or other steam supply modulating controls. Current boiler control system can utilize a single thermostat or aquastat and timer.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for the domestic hot water boilers is 20 years.[514]

DEEMED MEASURE COST

As a retrofit measure, the actual installed cost should be used for screening purposes.

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

[514] The Brooklyn Union Gas Company, High Efficiency Heating and Water and Controls, Gas Energy Efficiency Program Implementation Plan.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = Capacity \times EFLH \times SF / 100{,}000$$

Where:

Capacity	= Boiler gas input size (Btu/h)
	= Actual
EFLH	= Effective Full Load Hours for heating are provided in section 4.4. HVAC End Use
SF	= Savings Factor
	= 5%[515] or custom if savings can be substantiated
100,000	= converts Btu/h to therm

For Example:

A 1,000,000 btu/h steam boiler in a Mid-Rise Multi-Family building in Chicago has averaging controls installed.

$$\Delta Therms = 1{,}000{,}000 \times 1{,}685 \times 0.05 / 100{,}000$$

$$= 843 \text{ therms}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-SBAC-V01-160601

[515] A conservative estimate considering only setback savings, with DOE estimates as much as 1% per degree per 8 hours of setback. http://energy.gov/energysaver/thermostats

4.4.37 Unitary HVAC Condensing Furnace

DESCRIPTION

Condensing furnaces recover energy in combustion exhaust flue gasses that would otherwise simply be vented to the atmosphere, making them more efficient than non-condensing furnaces. This measure applies to a constant volume (CV), dedicated outside air system (DOAS), make-up air system (MUAS), or any unitary HVAC system that is utilizing an indirect gas fired process to heat 100% OA to provide ventilation or make-up air to commercial and industrial (C&I) building spaces. The unitary package must contain an indirect gas-fired, warm air furnace section, but the unitary package can be with or without an electric air conditioning section. The unitary package can be either a single package or split system that is applied indoors (non-weatherized) or outdoors (weatherized).

This measure excludes demand control ventilation, condensing unit heaters, and high efficiency (condensing) furnaces with annual fuel utilization efficiency (AFUE) ratings (for furnaces with less than 225,000 Btu/hr input capacity), which are covered by other measures for the C&I sector in the Technical Reference Manual (TRM)[516].

This measure was developed to be applicable to the following program types: TOS, NC. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the efficient unitary equipment must contain a condensing, warm air furnace with a natural gas thermal efficiency (TE) rating of 90% or higher, or alternatively, the unitary package must have equipment nameplate information for natural gas that identifies a heating output and heating input rating that has an output over input ratio of 0.90 or higher. These ratings must be certified by a recognized testing laboratory in accordance with American National Standards Institute (ANSI) Standard Z21.47 for Gas-Fired Central Furnaces[517]. The furnace must be vented and condensate disposed of in accordance with the equipment manufacturer installation instructions and applicable codes.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is expected to be unitary equipment that contains a non-condensing, warm air furnace with a natural gas thermal efficiency (TE) rating of 80%, or alternatively, the unitary package will have equipment nameplate information for natural gas that identifies a heating output and heating input rating that has an output over input ratio of 0.80. These ratings must be certified by a recognized testing laboratory in accordance with American National Standards Institute (ANSI) Standard Z21.47 for Gas-Fired Central Furnaces.

Note the current Department of Energy (DOE) federal minimum efficiency standard is 80% for 225,000 Btu/hr and higher input capacity furnaces per the Energy Conservation Standard for Commercial Warm Air Furnaces[518]. In the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings[519] that minimum TE requirement is extended below 225,000 Btu/hr input capacity to require all commercial warm air furnaces and combination warm air furnace/air conditioning units to meet the minimum 80% TE.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years, which is consistent with the established TRM measure life for

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[516] Illinois Statewide Technical Reference Manual (TRM), Version 4.0 (effective June 1, 2015), 2015. http://www.ilsag.info/technical-reference-manual.html (Accessed September 25, 2015).

[517] American National Standards Institute (ANSI), ANSI Z21.47 Standard for Central Gas-Fired Central Furnaces, 2012. http://www.techstreet.com/products/1837013#product (Accessed September 25, 2015).

[518] Department of Energy (DOE), Commercial Warm Air Furnace Standard DOE 10 CFR, Part 431, Subpart D – Commercial Warm Air Furnaces, 2004. https://www.law.cornell.edu/cfr/text/10/part-431/subpart-D (Accessed September 25, 2015).

[519] American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), ASHRAE Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings, 2013. https://www.ashrae.org/resources-- publications/bookstore /standard-90-1 (Accessed September 25, 2015).

single-package and split system unitary air conditioners, since in colder climates these unitary packages typically contain a gas-fired, warm air furnace section, with an electric air conditioning section.

DEEMED MEASURE COST

The actual incremental equipment and installation costs should be used, if available. If not, the incremental cost of $5.42 per 1000 Btu/hr of output capacity should be used for the condensing furnace equipment (as part of a unitary package) and its installation (including the combustion condensate drainage and disposal system). This incremental cost is from the DOE Technical Support Document for the Notice of Proposed Rulemaking (NOPR) for the Commercial Warm Air Furnace Standard[520]. Per the DOE documentation, it is based on their representative 250,000 Btu/hr input capacity furnace at a 92% TE.

LOADSHAPE

Loadshape C23 - Commercial Ventilation

COINCIDENCE FACTOR

The coincidence factor is assumed to be 1.0 – that is, building ventilation will always be provided during peak periods.

Algorithm

CALCULATION OF SAVINGS

The following methodology provides formulas for estimating gas heating savings associated with condensing furnaces in unitary HVAC packages when applied as a CV, DOAS, MUAS, or any RTU that is indirectly heating 100% outside air (OA). These types of HVAC systems typically run continuously during the HVAC operating schedule to provide building ventilation and maintain indoor air quality or to compensate for exhaust and maintain neutral or slightly positive building pressurization. The algorithm estimates the gas use reduction resulting from utilizing condensing heating of 90% or higher thermal efficiency (TE) in place of the federal minimum TE of 80% (or other user defined baseline TE) for commercial warm air furnaces.

The methodology provides a representative group of operating schedules for the market sector applications highlighted earlier based on DOE commercial reference building models[521]. Heating loads during the operating schedule are determined based on hourly differences between a range of supply air (SA) heated to temperatures and the OA temperature using Typical Meteorological Year (TMY3)[522] weather data. These hourly heating loads are generated for all hours when the OA temperature is below the base temperature of 55 ^{o}F for heating in C&I settings per the TRM. To accommodate the variability in heating base temperatures in C&I settings, these hourly heating loads are also generated for base temperatures of 45 ^{o}F and 65 ^{o}F for heating. The hourly heating loads are then summed for the entire year. The annual heating loads are calculated in this manner for the climate zone 2 weather station (Chicago O'Hare Airport), which is then normalized to its National Climatic Data Center (NCDC)[523] 30 year (1981-2010) weather average by multiplying by the heating degree day (HDD) ratio of the NCDC/TRM HDD55 over the TMY3 HDD55 (HDD at base temperature of 55 ^{o}F), and likewise for the annual heating loads for HDD45 (HDD at base temperature of 45 ^{o}F) and HDD65 (HDD at base temperature of 65 ^{o}F), using the values in Table 1 and Table 2. Since detailed hourly weather data is not available for all 5 of the TRM climate zone weather

[520] Department of Energy (DOE), Rulemaking for Commercial Warm Air Furnace Standard, Technical Support Document 2015. https://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/70 (Accessed September 25, 2015).
[521] Department of Energy (DOE) National Renewable Energy Laboratory, Commercial Reference Building Models of the National Building Stock, 2011. http://www.nrel.gov/docs/fy11osti/46861.pdf (Accessed September 25, 2015).
[522] Department of Energy (DOE) National Renewable Energy Laboratory, Users Manual for TMY3 Data Sets, 2008. http://www.nrel.gov/docs/fy08osti/43156.pdf (Accessed September 25, 2015).
[523] National Climatic Data Center, 1981-2010 Climate Normals, 2015. https://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/climate-normals/1981-2010-normals-data (Accessed November 4, 2015).

stations, the annual heating loads for the other climate zones are determined by multiplying the climate zone 2 annual heating loads by the ratio of the other climate zone NCDC HDD over the climate zone 2 NCDC HDD, using the values in Table 1.

These annual heating loads on a per unit airflow basis are then used in conjunction with the actual airflow of the 100% OA system and its condensing efficiency to calculate the gas heating savings versus the baseline (non-condensing) heating efficiency. This measure results in additional electric use by the unitary HVAC package due to the additional pressure drop of the condensing heat exchanger of the warm air furnace section.

Table 1. NCDC/TRM HDD Values for All Climate Zones

Climate Zone - Weather Station/City	NCDC 30 Year Average HDD45[8]	NCDC 30 Year Average HDD55[1,8]	NCDC 30 Year Average HDD65[8]
1 - Rockford AP / Rockford	2495	4272	6569
2 - Chicago O'Hare AP / Chicago	2263	4029	6340
3 - Springfield #2 / Springfield	1812	3406	5495
4 - Belleville SIU RSCH / Belleville	1197	2515	4379
5 - Carbondale Southern IL AP / Marion	1183	2546	4477

Table 2. TMY3 HDD Values for Climate Zone 2

Climate Zone - Weather Station/City	TMY3 HDD45[7]	TMY3 HDD55[7]	TMY3 HDD65[7]
2 - Chicago O'Hare AP / Chicago	2422	4188	6497

ELECTRIC ENERGY SAVINGS

As noted previously, this measure results in additional SA fan electric use by the unitary HVAC system due to the additional pressure drop of the condensing heat exchanger of the warm air furnace section.

$$\Delta kWh = -(t_{FAN} * cfm * \Delta P) / (\eta_{FAN/MOTOR} * 8520)$$

Where:

t_{FAN} = annual fan runtime (hr), refer to Tables 1 through 4

cfm = airflow (cfm), use actual or rated system airflow

ΔP = incremental pressure drop (inch W.G.), assume 0.15 if actual value not known

$\eta_{FAN/MOTOR}$ = combined fan and motor efficiency, assume 0.60 if actual value not known

8520 = conversion factor (fan horsepower – HP – calculation constant of 6356 for standard air conditions adjusted by 1 HP = 0.746 kW, or 6356/ 0.746 = 8520 for this kW calculation)

EXAMPLE:

For a "big box" retail store operating 24 hours a day and 7 days a week (8760 hours per year) with a 5000 cfm DOAS that has an incremental pressure drop of 0.15 inch W.G. and a combined fan and motor efficiency of 0.6 has annual kWh savings of:

$$\Delta kWh = -(t_{FAN} * cfm * \Delta P) / (\eta_{FAN/MOTOR} * 8520)$$

$$= -(8760 * 5000 * 0.15) / (0.6 * 8520)$$

$$= -1285 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

The additional SA fan electric use by the unitary HVAC system will typically result in a modest electric demand increase.

$\Delta kW = (\Delta kWh / t_{FAN}) * CF$

Where:

CF = 1.0

EXAMPLE:

Continuing the previous example:

$\Delta kW = (\Delta kWh / t_{FAN}) * CF$

$= (- 1285 / 8760) * 1.0$

$= - 0.15$ kW

NATURAL GAS ENERGY SAVINGS

$\Delta Therms = [Q_{OA} * cfm * (1/TE_{NC} - 1/TE_{C})]/ 100{,}000$

Where:

Q_{OA} = annual outside air (OA) heating load per cfm of OA (Btu/cfm)

First, select the most representative operating schedule for the application from among the four (4) scenarios listed below and its set of three (3) applicable tables. Second, select the table in that set with the most representative HDD base temperature – the base temperature for OA below which heating is required. If that base temperature is not readily determined, select the TRM default base temperature of 55 °F (HDD55) for heating in C&I settings. Third, select the climate zone within that table. Fourth, select an appropriate heated to supply air (SA) temperature within that table. Use the resulting Q_{OA} value, with linear interpolation allowed between SA temperatures.

The four (4) scenarios available are indicative of the following building applications and operating schedules:

1. 24 hour a day and 7 day a week (24/7) operation, with HVAC operating schedule of 8760 hours per year, typical of large retail stores with DOAS, hotel/multifamily buildings with corridor MUAS, and healthcare facilities with DOAS. Use Table 3 through Table 5.

2. 6:00 AM to 1:00 AM every day operation, with HVAC operating schedule of 7300 hours per year, typical of full service and quick service restaurants with kitchen MUAS. Use Table 6 through Table 8.

3. 7:00 AM to 9:00 PM Monday-Friday, 7:00 AM to 10:00 PM Saturday, and 9:00 AM to 7:00 PM Sunday operations, with HVAC operating schedule of 5266 hours per year, typical of non-24/7 retail stores with DOAS. Use Table 9 through Table 11.

4. 7:00 AM to 9:00 PM Monday-Friday operation, with HVAC operating schedule of 3911 hours per year, typical of school buildings with DOAS. Use Table 12 through Table 14.

TE_{NC} = non-condensing thermal efficiency (TE), use federal minimum TE of 80% (0.80) or actual TE if known

TE_C = condensing thermal efficiency (TE), use actual TE or if unknown assume 90% (0.90)

100,000 = conversion factor (1 therm = 100,000 Btu)

EXAMPLE:

Continuing the previous example, for a climate zone 2 (Chicago O'Hare AP / Chicago) application using a 90% TE condensing DOAS with a supply air temperature from the DOAS of 95 ^{o}F:

$$\Delta Therms = [Q_{OA} * cfm * (1/TE_{NC} - 1/TE_C)]/ 100{,}000$$

$$= 303{,}268 * 5{,}000 * (1/0.80 – 1/0.90)/100{,}000$$

$$= 2{,}106 \text{ therms}$$

8760 Hour Annual Operation Scenario

Table 3. 8760 Hour Annual Operation Scenario for HDD45

Supply Air Fan Runtime = 8760 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone - Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	189,343	230,897	272,451	314,004
2 - Chicago O'Hare AP / Chicago	171,737	209,427	247,116	284,806
3 - Springfield #2 / Springfield	137,511	167,689	197,868	228,046
4 - Belleville SIU RSCH / Belleville	90,839	110,775	130,711	150,647
5 - Carbondale Southern IL AP / Marion	89,777	109,479	129,182	148,885

Table 4. 8760 Hour Annual Operation Scenario for HDD55

Supply Air Fan Runtime = 8760 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone - Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	216,145	268,852	321,559	374,266
2 - Chicago O'Hare AP / Chicago	203,850	253,559	303,268	352,977
3 - Springfield #2 / Springfield	172,329	214,351	256,374	298,397
4 - Belleville SIU RSCH / Belleville	127,248	158,278	189,307	220,337
5 - Carbondale Southern IL AP / Marion	128,817	160,229	191,641	223,053

Table 5. 8760 Hour Annual Operation Scenario for HDD65

Supply Air Fan Runtime = 8760 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone - Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	239,158	308,050	376,942	445,834
2 - Chicago O'Hare AP / Chicago	230,820	297,311	363,802	430,292
3 - Springfield #2 / Springfield	200,056	257,685	315,314	372,943
4 - Belleville SIU RSCH / Belleville	159,426	205,351	251,276	297,200
5 - Carbondale Southern IL AP / Marion	162,994	209,947	256,899	303,852

7300 Hour Annual Operation Scenario

Table 6. 7300 Hour Annual Operation Scenario for HDD45

Supply Air Fan Runtime = 7300 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone - Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	151,914	185,369	218,823	252,278
2 - Chicago O'Hare AP / Chicago	137,788	168,132	198,476	228,819
3 - Springfield #2 / Springfield	110,328	134,624	158,921	183,217
4 - Belleville SIU RSCH / Belleville	72,882	88,932	104,982	121,033
5 - Carbondale Southern IL AP / Marion	72,030	87,892	103,755	119,617

Table 7. 7300 Hour Annual Operation Scenario for HDD55

Supply Air Fan Runtime = 7300 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone - Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	173,511	215,950	258,389	300,828
2 - Chicago O'Hare AP / Chicago	163,641	203,666	243,691	283,716
3 - Springfield #2 / Springfield	138,338	172,174	206,010	239,846
4 - Belleville SIU RSCH / Belleville	102,149	127,133	152,118	177,103
5 - Carbondale Southern IL AP / Marion	103,408	128,701	153,993	179,286

Table 8. 7300 Hour Annual Operation Scenario for HDD65

Supply Air Fan Runtime = 7300 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone - Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	191,803	247,046	302,288	357,531
2 - Chicago O'Hare AP / Chicago	185,117	238,434	291,750	345,067
3 - Springfield #2 / Springfield	160,444	206,655	252,866	299,076
4 - Belleville SIU RSCH / Belleville	127,859	164,685	201,510	238,336
5 - Carbondale Southern IL AP / Marion	130,720	168,370	206,020	243,670

5266 Hour Annual Operation Scenario

Table 9. 5266 Hour Annual Operation Scenario for HDD45

Supply Air Fan Runtime = 5266 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone - Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	104,175	127,350	150,524	173,699
2 - Chicago O'Hare AP / Chicago	94,488	115,508	136,527	157,547
3 - Springfield #2 / Springfield	75,657	92,488	109,319	126,149
4 - Belleville SIU RSCH / Belleville	49,979	61,097	72,215	83,334
5 - Carbondale Southern IL AP / Marion	49,394	60,383	71,371	82,359

Table 10. 5266 Hour Annual Operation Scenario for HDD55

Supply Air Fan Runtime = 5266 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone - Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	118,320	147,406	176,492	205,578
2 - Chicago O'Hare AP / Chicago	111,590	139,021	166,452	193,884
3 - Springfield #2 / Springfield	94,335	117,524	140,714	163,904
4 - Belleville SIU RSCH / Belleville	69,657	86,780	103,904	121,027
5 - Carbondale Southern IL AP / Marion	70,516	87,850	105,184	122,519

Table 11. 5266 Hour Annual Operation Scenario for HDD65

Supply Air Fan Runtime = 5266 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone - Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	130,903	168,718	206,532	244,347
2 - Chicago O'Hare AP / Chicago	126,339	162,836	199,333	235,829
3 - Springfield #2 / Springfield	109,501	141,133	172,765	204,398
4 - Belleville SIU RSCH / Belleville	87,262	112,470	137,678	162,886
5 - Carbondale Southern IL AP / Marion	89,215	114,987	140,759	166,531

3911 Hour Annual Operation Scenario

Table 12. 3911 Hour Annual Operation Scenario for HDD45

Supply Air Fan Runtime = 3911 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone - Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	75,029	91,729	108,428	125,128
2 - Chicago O'Hare AP / Chicago	68,053	83,199	98,346	113,492
3 - Springfield #2 / Springfield	54,490	66,618	78,746	90,874
4 - Belleville SIU RSCH / Belleville	35,996	44,008	52,019	60,031
5 - Carbondale Southern IL AP / Marion	35,575	43,493	51,411	59,329

Table 13. 3911 Hour Annual Operation Scenario for HDD55

Supply Air Fan Runtime = 3911 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone - Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	85,672	106,825	127,979	149,132
2 - Chicago O'Hare AP / Chicago	80,799	100,749	120,699	140,649
3 - Springfield #2 / Springfield	68,305	85,170	102,035	118,901
4 - Belleville SIU RSCH / Belleville	50,436	62,890	75,343	87,797
5 - Carbondale Southern IL AP / Marion	51,058	63,665	76,272	88,879

Table 14. 3911 Hour Annual Operation Scenario for HDD65

Supply Air Fan Runtime = 3911 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone - Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	95,460	123,294	151,128	178,963
2 - Chicago O'Hare AP / Chicago	92,132	118,996	145,860	172,724
3 - Springfield #2 / Springfield	79,853	103,136	126,420	149,703
4 - Belleville SIU RSCH / Belleville	63,635	82,190	100,745	119,299
5 - Carbondale Southern IL AP / Marion	65,059	84,029	102,999	121,969

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The actual incremental annual maintenance costs should be used, if available. If not, the incremental cost of $0.05 per 1000 Btu/hr of output capacity should be used for maintaining the combustion condensate disposal system yearly. This incremental cost is from the DOE Technical Support Document for the Notice of Proposed Rulemaking (NOPR) for the Commercial Warm Air Furnace Standard6. Per the DOE documentation, it is based on their representative 250,000 Btu/hr input capacity furnace at a 92% TE.

MEASURE CODE: CI-HVC-DSFN-V01-160601

4.5 Lighting End Use

The commercial lighting measures use a standard set of variables for hours or use, waste heat factors, coincident factors and HVAC interaction effects. This table has been developed based on information provided by the various stakeholders. For ease of review, the table is included here and referenced in each measure.

Building/Space Type	Fixture Annual Operating Hours[524]	Screw based bulb Annual Operating hours[525]	Waste Heat Cooling Energy WHFe [526]	Waste Heat Cooling Demand WHFd	Coincid -ence Factor CF[527]	Waste Heat Gas Heating IFTherms [528]	Waste Heat Electric Resistance Heating IFkWh[529]	Waste Heat Electric Heat Pump Heating IFkWh
Assisted Living	7,862	5,950	1.14	1.30	0.66	0.035	0.823	0.358
Childcare/Pre-School	2,860	2,860	1.17	1.29	0.72	0.018	0.420	0.183
College	3,395	2,588	1.06	1.39	0.63	0.020	0.462	0.201
Convenience Store	4,672	3,650	1.09	1.26	0.76	0.035	0.828	0.360
Elementary School	3,038	2,118	1.17	1.29	0.72	0.018	0.420	0.183
Garage	3,401	3,540	1.00	1.00	0.92	0.000	0.000	0.000
Garage, 24/7 lighting	8,766	8,766	1.00	1.00	1.00	0.000	0.000	0.000
Grocery	4,650	3,650	1.05	1.22	0.73	0.022	0.511	0.222
Healthcare Clinic	3,890	4,207	1.40	1.85	0.65	0.006	0.144	0.063
High School	3,038	2,327	1.18	1.39	0.72	0.028	0.656	0.285
Hospital - CAV no econ	7,616	4,207	1.11	1.29	0.76	0.022	0.527	0.229
Hospital - CAV econ	7,616	4,207	1.06	1.27	0.75	0.023	0.533	0.232
Hospital - VAV econ	7,616	4,207	1.37	1.79	0.70	0.010	0.241	0.105

[524]Fixtures hours of use are based upon schedule assumptions used in the eQuest models, except for those building types where Illinois based metering results provide a statistically valid estimate (currently: College, Elementary School, High School, Manufacturing, Low and Mid rise Office, Retail Department Store and Warehouse). Miscellaneous is a weighted average of indoor spaces using the relative area of each building type in the region (CBECS).

[525] Hours of use for screw based bulbs are derived from DEER 2008 by building type for cfls. Garage, exterior and multi-family common area values are from the Hours of Use Table in this document. Miscellaneous is an average of interior space values. Some building types are averaged when DEER has two values: these include office, restaurant and retail. Healthcare clinic uses the hospital value.

[526] The Waste Heat Factor for Energy and is developed using EQuest models for various building types base on Chicago Illinois (closest to statewide average HDD and CDD). Exterior and garage values are 1, unknown is a weighted average of the other building types.

[527]Coincident diversity factors are based on either combined IL evaluation results (College, Elementary School, High School, Manufacturing, Low and Mid rise Office, Retail Department Store and Warehouse) or based upon schedules defined in the eQuest models described (all others).

[528] IF Therms value is developed using EQuest models consistent with methodology for Waste Heat Factor for Energy.

[529] Electric heat penalty assumptions are based on converting the IFTherm multiplier value in to kWh and then applying relative heating system efficiencies. The gas efficiency was assumed to be 78% AFUE based upon standard TRM assumption for existing unit average efficiency, and the electric resistance is assumed to be 100%, for Heat Pump is assumed to be 2.3COP: IFElectricHeat = IFTherms * 29.3 kWh/therm * 78% (Gas Heating Equipment Efficiency) / 100% (Electric Resistance Efficiency)

Building/Space Type	Fixture Annual Operating Hours[524]	Screw based bulb Annual Operating hours[525]	Waste Heat Cooling Energy WHFe [526]	Waste Heat Cooling Demand WHFd	Coincid -ence Factor CF[527]	Waste Heat Gas Heating IFTherms [528]	Waste Heat Electric Resistance Heating IFkWh[529]	Waste Heat Electric Heat Pump Heating IFkWh
Hospital - FCU	7,616	4,207	1.38	1.29	0.73	0.001	0.033	0.015
Manufacturing Facility	4,618	2,629	1.02	1.04	0.81	0.012	0.270	0.117
MF - High Rise - Common	6,138	5,950	1.14	1.32	0.64	0.025	0.596	0.259
MF - Mid Rise - Common	6,138	5,950	1.14	1.32	0.64	0.025	0.596	0.259
Hotel/Motel - Guest	2,390	777	1.18	1.36	0.28	0.020	0.463	0.201
Hotel/Motel - Common	6,138	4,542	1.20	1.24	0.73	0.032	0.748	0.325
Movie Theater	3,506	5,475	1.11	1.38	0.53	0.029	0.673	0.293
Office - High Rise - CAV no econ	2,886	3,088	1.00	1.07	0.57	0.037	0.874	0.380
Office - High Rise - CAV econ	2,886	3,088	1.00	1.07	0.57	0.039	0.905	0.394
Office - High Rise - VAV econ	2,886	3,088	1.27	1.65	0.53	0.022	0.510	0.222
Office - High Rise - FCU	2,886	3,088	1.35	1.56	0.59	0.015	0.346	0.150
Office - Low Rise	2,698	3,088	1.11	1.31	0.52	0.016	0.371	0.161
Office - Mid Rise	3,068	3,088	1.26	1.61	0.52	0.024	0.557	0.242
Religious Building	2,085	1,664	1.12	1.37	0.48	0.015	0.356	0.155
Restaurant	5,571	4,784	1.17	1.31	0.68	0.021	0.491	0.213
Retail - Department Store	5,478	2,935	1.12	1.31	0.95	0.022	0.514	0.223
Retail - Strip Mall	4,093	2,935	1.12	1.29	0.71	0.019	0.450	0.196
Warehouse	5,242	4,293	1.00	1.22	0.68	0.011	0.257	0.112
Unknown	3,379	3,612	1.09	1.36	0.58	0.022	0.522	0.227
Exterior	4,903	4,903	1.00	1.00	0.00	0.000	0.000	0.000
Low-Use Small Business	2,954	2,954	1.31	1.53	0.66	0.023	0.524	0.262
Uncooled Building	Varies	varies	1.00	1.00	0.66	0.014	0.320	0.160
Refrigerated Cases	5,802	n/a	1.29	1.29	0.69	0.000	0.000	0.000
Freezer Cases	5,802	n/a	1.50	1.5	0.69	0.000	0.000	0.000

4.5.1 Commercial ENERGY STAR Compact Fluorescent Lamp (CFL)

DESCRIPTION

A low wattage ENERGY STAR qualified compact fluorescent screw-in bulb (CFL) is installed in place of a baseline screw-in bulb. This characterization assumes that the CFL is installed in a commercial location. If the implementation strategy does not allow for the installation location to be known a deemed split should be used. For Residential targeted programs (e.g. an upstream retail program), a deemed split of 96% Residential and 4% Commercial assumptions should be used[530], and for Commercial targeted programs a deemed split of 4% Residential and 96% Commercial should be used[531].

Federal legislation stemming from the Energy Independence and Security Act of 2007 (EISA) required all general-purpose light bulbs between 40W and 100W to be approximately 30% more energy efficient than current incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012 followed by restrictions on 75W in 2013 and 60W and 40W in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard.

Finally, a provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL. Therefore the measure life (number of years that savings should be claimed) should be reduced once the assumed lifetime of the bulb exceeds 2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until mid-2020.

This measure was developed to be applicable to the following program types: TOS, NC, RF. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the high-efficiency equipment must be a standard ENERGY STAR qualified compact fluorescent lamp.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be an EISA qualified incandescent or halogen as provided in the table provided in the Electric Energy Savings section.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life (number of years that savings should be claimed) should be calculated by dividing the rated life of the bulb (10,000 hours[532]) by the run hours. For example using Miscellaneous at 4,589 hours would give 2.2 years. When the number of years exceeds June 2020, the number of years to that date should be used.

DEEMED MEASURE COST

The incremental capital cost assumption for all bulbs under 2600 lumens is $1.25, from June 2014 – May 2015, $1.6 from June 2015 to May 2016 and $1.70 from June 2017 to May 2018[533].

For bulbs over 2600 lumens the assumed incremental capital cost is $5.

[530] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY4-6 and Ameren PY5-6 in store intercept survey results.
[531] Based upon final weighted (by sales volume) average of the BILD program (ComEd's commercial lighting program) for PY 4 and PY5 and PY6.
[532] Energy Star bulbs have a rated life of at least 8000 hours. In commercial settings you expect significantly less on/off switching than residential and so a rated life assumption of 10,000 hours is used.
[533] Based upon pricing forecast developed by Applied Proactive Technologies Inc (APT) based on industry input and provided to Ameren.

LOADSHAPE

Loadshape C06 - Commercial Indoor Lighting

Loadshape C07 - Grocery/Conv. Store Indoor Lighting

Loadshape C08 - Hospital Indoor Lighting

Loadshape C09 - Office Indoor Lighting

Loadshape C10 - Restaurant Indoor Lighting

Loadshape C11 - Retail Indoor Lighting

Loadshape C12 - Warehouse Indoor Lighting

Loadshape C13 - K-12 School Indoor Lighting

Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)

Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)

Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)

Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)

Loadshape C18 - Industrial Indoor Lighting

Loadshape C19 - Industrial Outdoor Lighting

Loadshape C20 - Commercial Outdoor Lighting

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in section 4.5.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((WattsBase - WattsEE)/1000) * ISR * Hours * WHFe$$

Where:

WattsBase = Actual (if retrofit measure) or based on lumens of CFL bulb and program year installed:

Minimum Lumens	Maximum Lumens	Incandescent Equivalent Post-EISA 2007 (WattsBase)
5280	6209	300

Minimum Lumens	Maximum Lumens	Incandescent Equivalent Post-EISA 2007 (WattsBase)
3000	5279	200
2601	2999	150
1490	2600	72
1050	1489	53
750	1049	43
310	749	29
250	309	25

WattsEE = Actual wattage of CFL purchased or installed

ISR = In Service Rate or the percentage of units rebated that get installed.

=100%[534] if application form completed with sign off that equipment is not placed into storage

If sign off form not completed assume the following 3 year ISR assumptions:

Weighted Average 1st year In Service Rate (ISR)	2nd year Installations	3rd year Installations	Final Lifetime In Service Rate
71.2%[535]	14.5%	12.3%	98.0%[536]

Hours = Average hours of use per year are provided in Reference Table in Section 4.5, Screw based bulb annual operating hours, for each building type[537]. If unknown use the Miscellaneous value.

WHFe = Waste heat factor for energy to account for cooling energy savings from

[534] Illinois evaluation of PY1 through PY3 has not found that fixtures or lamps placed into storage to be a significant enough issue to warrant including an "In-Service Rate" when commercial customers complete an application form.

[535] 1st year in service rate is based upon review of PY4-6 evaluations from ComEd's commercial lighting program (BILD) (see 'IL Commercial Lighting ISR_2014.xls' for more information. The average first year ISR was calculated weighted by the number of bulbs sold.

[536]The 98% Lifetime ISR assumption is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings. Note that this Final Install Rate does NOT account for leakage of purchased bulbs being installed outside of the utility territory. EM&V should assess how and if data from evaluation should adjust this final installation rate to account for this impact

[537] Based on ComEd analysis taking DEER 2008 values and averaging with PY1 and PY2 evaluation results.

efficient lighting are provided below for each building type in Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, a 14W standard CFL is installed in an office in 2014 and sign off form provided:

ΔkWh = (((43 - 14)/1000)* 1.0 * 3088 * 1.25

= 111.9 kWh

HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}^{538} = (((WattsBase-WattsEE)/1000) * ISR * Hours * -IFkWh$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, a 14W standard CFL is installed in a heat pump heated office in 2014 and sign off form provided:

$\Delta kWh_{heatpenalty}$ = (((43 - 14)/1000)* 1.0*3088*-0.183

= - 16.4 kWh

DEFERRED INSTALLS

As presented above, if a sign off form is not completed the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

[538]Negative value because this is an increase in heating consumption due to the efficient lighting.

For example, for a 14W CFL (60W standard incandescent and 43W EISA qualified incandescent/halogen) purchased in 2014 and using miscellaneous hours assumption.

$\Delta kWH_{1st\ year\ installs}$ = ((43 - 14) / 1000) * 0.755 * 3198 * 1.06

= 74.2 kWh

$\Delta kWH_{2nd\ year\ installs}$ = ((43 - 14) / 1000) * 0.121 * 3198 * 1.06

= 11.9 kWh

Note: Here we assume no change in hours assumption. NTG value from Purchase year applied.

$\Delta kWH_{3rd\ year\ installs}$ = ((43 - 14) / 1000) * 0.103 * 3198 * 1.06

= 10.1 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ((WattsBase-WattsEE)/1000) * ISR * WHFd * CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

CF = Summer Peak Coincidence Factor for measure is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

Other factors as defined above

For example, a 14W standard CFLis installed in an office in 2014 and sign off form provided:

ΔkW = ((43 - 14)/1000)*1.0*1.3*0.66

= 0.025kW

NATURAL GAS ENERGY SAVINGS

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):

ΔTherms[539] = (((WattsBase-WattsEE)/1000) * ISR * Hours *- IFTherms

Where:

IFTherms = Lighting-HVAC Interation Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

Other factors as defined above

For example, a 14W standard CFL is installed in an office in 2014 and sign off form provided:

ΔTherms = (((43 - 14)/1000)* 1.0*3088*-0.016

= - 1.4 Therms

[539] Negative value because this is an increase in heating consumption due to the efficient lighting.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Bulb replacement costs assumed in the O&M calculations are provided below[540].

	Std Inc.	EISA Compliant Halogen
2014	$0.34	$1.25
2015	$0.34	$0.90
2016	$0.34	$0.80
2017	$0.34	$0.70
2018	$0.34	$0.60
2019	$0.34	$0.60
2020 & after	$0.34	N/A

In order to account for the falling EISA Qualified bulb replacement cost provided above, an equivalent annual levelized baseline replacement cost over the lifetime of the CFL bulb is calculated. Note that the measure life for these measures is capped to the number of years remaining until 2020.

The NPV for replacement lamps and annual levelized replacement costs using the statewide real discount rate of 5.34% are presented below. It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR:

Location	Lumen Level	NPV of replacement costs for period			Levelized annual replacement cost savings		
		June 2014 - May 2015	June 2015 - May 2016	June 2016 - May 2017	June 2014 - May 2015	June 2015 - May 2016	June 2016 - May 2017
Commercial	Lumens <310 or >2600 (EISA exempt)	$2.00	$2.00	$2.00	$0.75	$0.75	$0.75
	Lumens ≥ 310 and ≤ 2600 (EISA compliant)	$6.03	$4.87	$4.29	$2.26	$1.82	$1.60
Multi Family Common Areas	Lumens <310 or >2600 (EISA exempt)	$3.90	$3.90	$3.90	$2.56	$2.56	$2.56
	Lumens ≥ 310 and ≤ 2600 (EISA compliant)	$11.92	$9.55	$8.40	$7.83	$6.28	$5.52

For halogen bulbs, we assume the same replacement cycle as incandescent bulbs.[541] The replacement cycle is

[540] Based upon pricing forecast developed by Applied Proactive Technologies Inc (APT) based on industry input and provided to Ameren.

[541] The manufacturers of the new minimally compliant EISA Halogens are using regular incandescent lamps with halogen fill gas rather than halogen infrared to meet the standard and so the component rated life is equal to the standard incandescent.

based on the miscellaneous hours of use. Both incandescent and halogen lamps are assumed to last for 1,000 hours before needing replacement.

MEASURE CODE: CI-LTG-CCFL-V06-160601

4.5.2 Fluorescent Delamping

DESCRIPTION

This measure addresses the permanent removal of existing 8', 4', 3' and 2' fluorescent lamps. Unused lamps, lamp holders, and ballasts must be permanently removed from the fixture. This measure is applicable when retrofitting from T12 lamps to T8 lamps or simply removing lamps from a T8 fixture. Removing lamps from a T12 fixture that is not being retrofitted with T8 lamps are not eligible for this incentive.

Customers are responsible for determining whether or not to use reflectors in combination with lamp removal in order to maintain adequate lighting levels. Lighting levels are expected to meet the Illuminating Engineering Society of North America (IESNA) recommended light levels. Unused lamps, lamp holders, and ballasts must be permanently removed from the fixture and disposed of in accordance with local regulations. A pre-approval application is required for lamp removal projects.

This measure was developed to be applicable to the following program types: RF. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

Savings are defined on a per removed lamp basis. The retrofit wattage (efficient conditioned) is therefore assumed to be zero. The savings numbers provided below are for the straight lamp removal measures, as well as the lamp removal and install reflector measures. The lamp installed/retrofit is captured in another measure.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is either a T12 or a T8 lamp with default wattages provided below. Note, if the program does not allow for the lamp type to be known, then a T12:T8 weighting of 80%:20% can be applied[542].

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 11 years per DEER 2005.

DEEMED MEASURE COST

The incremental capital cost is provided in the table below:

Measure Category	Value	Source
8-Foot Lamp Removal	$16.00	ComEd/KEMA regression[543]
4-Foot Lamp Removal	$12.00	ICF Portfolio Plan
8-Foot Lamp Removal with reflector	$30.00	KEMA Assumption
4-Foot Lamp Removal with reflector	$25.00	KEMA Assumption
2-Foot or 3-Foot Removal	$12.35	KEMA Assumption
2-Foot or 3-Foot Removal with reflector	$25.70	KEMA Assumption

[542] Based on ComEd's estimate of lamp type saturation.
[543] Based on the assessment of active projects in the 2008-09 ComEd Smart Ideas Program. See files "ltg costs 12-10-10.xl." and "Lighting Unit Costs 102605.doc"

LOADSHAPE

Loadshape C06 - Commercial Indoor Lighting

Loadshape C07 - Grocery/Conv. Store Indoor Lighting

Loadshape C08 - Hospital Indoor Lighting

Loadshape C09 - Office Indoor Lighting

Loadshape C10 - Restaurant Indoor Lighting

Loadshape C11 - Retail Indoor Lighting

Loadshape C12 - Warehouse Indoor Lighting

Loadshape C13 - K-12 School Indoor Lighting

Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)

Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)

Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)

Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)

Loadshape C18 - Industrial Indoor Lighting

Loadshape C19 - Industrial Outdoor Lighting

Loadshape C20 - Commercial Outdoor Lighting

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in the reference section below.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh =((WattsBase-WattsEE)/1000) * ISR * Hours * WHFe

Where:

WattsBase = Assume wattage reduction of lamp removed

	Wattage of lamp removed[544]		Weighted average
	T8	T12	80% T12, 20% T8
8-ft T8	38.6	60.3	56.0
4-ft T8	19.4	33.7	30.8
3-ft T8	14.6	40.0	34.9
2-ft T8	9.8	28.0	24.4

WattsEE = 0

ISR = In Service Rate or the percentage of units rebated that get installed.

=100% if application form completed with sign off that equipment permanently removed and disposed of.

Hours = Average hours of use per year are provided in Reference Table in Section 4.5. If unknown use the Miscellaneous value.

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided below for each building type in Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, delamping a 4 ft T8 fixture in an office building:

ΔkWh =((19.4 - 0)/1000) * 1.0 * 4439 * 1.25

= 107.6 kWh

HEATING PENALTY

If electrically heated building:

$\Delta kWh_{heatpenalty}$[545] = (((WattsBase-WattsEE)/1000) * ISR * Hours * -IFkWh

[544] Default wattage reducetion is based on averaging the savings from moving from a 2 to 1, 3 to 2 and 4 to 3 lamp fixture, as provided in the Standard Performance Contract Procedures Manual: Appendix B: Table of Standard Fixture Wattages (http://www.sce.com/NR/rdonlyres/7A3455F0-A337-439B-9607-10A016D32D4B/0/spc_B_Std_Fixture_Watts.pdf). An adjustment is made to the T8 delamped fixture to account for the significant increase in ballast factor. See 'Delamping calculation.xls' for details.

[545]Negative value because this is an increase in heating consumption due to the efficient lighting.

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, delamping a 4 ft T8 fixture in a heat pump heated office building:

$\Delta kWh_{heatpenalty}$ =((19.4 - 0)/1000) * 1.0 * 4439 * -0.151

=-13.0 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ((WattsBase-WattsEE)/1000) * ISR * WHFd * CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

CF = Summer Peak Coincidence Factor for measure is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

Other factors as defined above

For example, delamping a 4 ft T8 fixture in an office building:

ΔkW =((19.4 - 0)/1000) * 1.0 * 1.3 * 0.66

= 0.017 kW

NATURAL GAS ENERGY SAVINGS

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):

ΔTherms[546] = (((WattsBase-WattsEE)/1000) * ISR * Hours *- IFTherms

Where:

IFTherms = Lighting-HVAC Interation Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

Other factors as defined above

For example, delamping a 4 ft T8 fixture in an office building:

ΔTherms =((19.4 - 0)/1000) * 1.0 * 4439 * -0.016

=-1.4 therms

[546] Negative value because this is an increase in heating consumption due to the efficient lighting.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-LTG-DLMP-V02-140601

4.5.3 High Performance and Reduced Wattage T8 Fixtures and Lamps

DESCRIPTION

This measure applies to "High Performance T8" (HPT8) lamp/ballast systems that have higher lumens per watt than standard T8 systems. This measure applies to the installation of new equipment with efficiencies that exceed that of the equipment that would have been installed following standard market practices and is applicable to time of sale as well as retrofit measures. Retrofit measures may include new fixtures or relamp/reballast measures. In addition, options have been provided to allow for the "Reduced Wattage T8 lamps" or RWT8 lamps that result in re-lamping opportunities that produce equal or greater light levels than standard T8 lamps while using fewer watts.

If the implementation strategy does not allow for the installation location to be known, a deemed split of 99% Commercial and 1% Residential should be used[547].

This measure was developed to be applicable to the following program types: TOS, RF, DI.

If applied to other program types, the measure savings should be verified.

The measure applies to all commercial HPT8 installations excluding new construction and major renovation or change of use measures (see lighting power density measure). Lookup tables have been provided to account for the different types of installations. Whenever possible, actual costs and hours of use should be utilized for savings calculations. Default new and baseline assumptions have been provided in the reference tables. Default component costs and lifetimes have been provided for Operating and Maintenance Calculations. Please see the Definition Table to determine applicability for each program. HPT8 configurations not included in the TRM may be included in custom program design using the provided algorithms as long as energy savings is achieved. The following table defines the applicability for different programs

Time of Sale (TOS)	Retrofit (RF) and Direct Install (DI)
This measure relates to the installation of new equipment with efficiency that exceeds that of equipment that would have been installed following standard market practices. In general, the measure will include qualifying high efficiency low ballast factor ballasts paired with high efficiency long life lamps as detailed in the attached tables. High-bay applications use this system paired with qualifying high ballast factor ballasts and high performance 32 w lamps. Custom lighting designs can use qualifying low, normal or high ballast factor ballasts and qualifying lamps in lumen equivalent applications where total system wattage is reduced when calculated using the Calculation of Savings Algorithms.	This measure relates to the replacement of existing equipment with new equipment with efficiency that exceeds that of the existing equipment. In general, the retrofit will include qualifying high efficiency low ballast factor ballasts paired with high efficiency long life lamps as detailed in the attached tables. Custom lighting designs can use qualifying low, normal or high ballast factor ballasts and qualifying lamps in lumen equivalent applications where total system wattage is reduced when calculated using the Calculation of Savings Algorithms. High efficiency troffers (new/or retrofit) utilizing HPT8 technology can provide even greater savings. When used in a high-bay application, high-performance T8 fixtures can provide equal light to HID high-bay fixtures, while using fewer watts; these systems typically utilize high ballast factor ballasts, but qualifying low and normal ballast factor ballasts may be used when appropriate light levels are provided and overall wattage is reduced.

[547] Based on weighted average of Final ComEd's BILD program data from PY5 and PY6. For Residential installations, hours of use assumptions from '5.5 Interior Hardwired Compact Fluorescent Lamp (CFL) Fixture' measure should be used.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient conditions for all applications are a qualifying HP or RWT8 fixture and lamp/ballast combinations listed on the CEE website under qualifying HP T8 products[548] and qualifying RWT8 products[549].

The definition of efficient equipment varies based on the program and is defined below:

Time of Sale (TOS)	Retrofit (RF) and Direct Install (DI)
High efficiency troffers combined with high efficiency lamps and ballasts allow for fewer lamps to be used to provide a given lumen output. High efficiency troffers must have a fixture efficiency of 80% or greater to qualify. Default values are given for a 2 lamp HPT8 fixture replacing a 3 lamp standard efficiency T8 fixture, but other configurations may qualify and the Calculation of savings algorithm used to account for base watts being replaced with EE watts.	High efficiency troffers (new or retrofit kits) combined with high efficiency lamps and ballasts allow for fewer lamps to be used to provide a given lumen output. High efficiency troffers must have a fixture efficiency of 80% or greater to qualify. Default values are given for a 2 lamp HPT8 fixture replacing a 3 lamp standard efficiency T8 fixture, but other configurations may qualify and the Calculation of savings algorithm used to account for base watts being replaced with EE watts.
High bay fixtures must have fixture efficiencies of 85% or greater.	High bay fixtures will have fixture efficiencies of 85% or greater.
RWT8 lamps: 2', 3' and 8' lamps must meet the wattage requirements specified in the RWT8 new and baseline assumptions table. This measure assumes a lamp only purchase.	RWT8: 2', 3' and 8' lamps must meet the wattage requirements specified in the RWT8 new and baseline assumptions table.

DEFINITION OF BASELINE EQUIPMENT

The definition of baseline equipment varies based on the program and is defined below:

[548] http://library.cee1.org/content/cee-high-performance-t8-specification
[549] http://library.cee1.org/content/reduced-wattage-t8-specification

Time of Sale (TOS)	Retrofit (RF) and Direct Install (DI)
The baseline is standard efficiency T8 systems that would have been installed. The baseline for high-bay fixtures is pulse start metal halide fixtures, the baseline for a 2 lamp high efficiency troffer is a 3 lamp standard efficency troffer.	The baseline is the existing system. In July 14, 2012, Federal Standards were enacted that were expected to eliminate T-12s as an option for linear fluorescent fixtures. Through v3.0 of the TRM, it was assumed that the T-12 would no longer be baseline for retrofits from 1/1/2016. However, due to significant loopholes in the legislation, T-12 compliant product is still freely available and in Illinois T-12s continue to hold a significant share of the existing and replacement lamp market. Therefore the timing of the sunsetting of T-12s as a viable baseline has been pushed back in v5.0 until 6/1/2018 and will be revisited in future update sessions. There will be a baseline shift applied to all measures installed before 6/1/2018. See table C-1.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed lifetime of efficient equipment varies based on the program and is defined below:

Time of Sale (TOS)	Retrofit (RF) and Direct Install (DI)
Fixture lifetime is 15 years[550]. Fixture retrofits which utilize RWT8 lamps have a lifetime equivalent to the life of the lamp, capped at 15 years. There is no guarantee that a reduced wattage lamp will be installed at time of burnout, but if one is, savings will be captured in the RWT8 measure below. RWT8 lifetime is the life of the product, at the reported operating hours (lamp life in hours divided by operating hours per year – see reference table "RWT8 Component Costs and Lifetime"), capped at 15 years.551	Fixture lifetime is 15 years. As per explanation above, for existing T12 fixtures, a mid life baseline shift should be applied in 6/1/2018 as described in table C-1. Note, since the fixture lifetime is deemed at 15 years, the replacement cost of both the lamp and ballast should be incorporated in to the O&M calculation.

DEEMED MEASURE COST

The deemed measure cost is found in the reference table at the end of this characterization.

[550] 15 years from GDS Measure Life Report, June 2007
[551] ibid

LOADSHAPE

Loadshape C06 - Commercial Indoor Lighting

Loadshape C07 - Grocery/Conv. Store Indoor Lighting

Loadshape C08 - Hospital Indoor Lighting

Loadshape C09 - Office Indoor Lighting

Loadshape C10 - Restaurant Indoor Lighting

Loadshape C11 - Retail Indoor Lighting

Loadshape C12 - Warehouse Indoor Lighting

Loadshape C13 - K-12 School Indoor Lighting

Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)

Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)

Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)

Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)

Loadshape C18 - Industrial Indoor Lighting

Loadshape C19 - Industrial Outdoor Lighting

Loadshape C20 - Commercial Outdoor Lighting

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((Watts_{base} - Watts_{EE})/1000) * Hours * WHF_e * ISR$$

Where:

$Watts_{base}$ = Input wattage of the existing system which depends on the baseline fixture configuration (number and type of lamp) and number of fixtures. Value can be selected from the appropriate reference table as shown below, or a custom value can be entered if the configurations in the tables is not representative of the exisitng system.

Program	Reference Table
Time of Sale	A-1: HPT8 New and Baseline Assumptions
Retrofit	A-2: HPT8 New and Baseline Assumptions
Reduced Wattage T8, time of sale or retrofit	A-3: RWT8 New and Baseline Assumptions

$Watts_{EE}$ = New Input wattage of EE fixture which depends on new fixture configuration (number of lamps) and ballast factor and number of fixtures. Value can be selected from the appropriate reference table as shown below, of a custom value can be entered if the configurations in the tables is not representative of the exisitng system.

Program	Reference Table
Time of Sale	A-1: HPT8 New and Baseline Assumptions
Retrofit	A-2: HPT8 New and Baseline Assumptions
Reduced Wattage T8, time of sale or retrofit	A-3: RWT8 New and Baseline Assumptions

Hours = Average hours of use per year as provided by the customer or selected from the Reference Table in Section 4.5, Fixture annual operating hours. If hours or building type are unknown, use the Miscellaneous value.

WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Reference Table in Section 4.5 for each building type. If building is un-cooled, the value is 1.0.

ISR = In Service Rate or the percentage of units rebated that get installed.

=100%[552] if application form completed with sign off that equipment is not placed into storage

If sign off form not completed assume the following 3 year ISR assumptions:

Weighted Average 1st year In Service Rate (ISR)	2nd year Installations	3rd year Installations	Final Lifetime In Service Rate
98%[553]	0%	0%	98.0%[554]

[552] Illinois evaluation of PY1 through PY3 has not found that fixtures or lamps placed into storage to be a significant enough issue to warrant including an "In-Service Rate" when commercial customers complete an application form.

[553] 1st year in service rate is based upon review of PY5-6 evaluations from ComEd's commercial lighting program (BILD) (see 'IL Commercial Lighting ISR_2014.xls' for more information

[554] The 98% Lifetime ISR assumption is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings. Note that this Final Install Rate does NOT account for leakage of purchased bulbs being installed outside of the utility territory. EM&V should assess how and if data from evaluation should adjust this final installation rate to account for this impact

HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}^{555} = (((WattsBase-WattsEE)/1000) * ISR * Hours * -IFkWh$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

SUMMER COINCIDENT DEMAND SAVINGS

$$\Delta kW = ((Watts_{base}-Watts_{EE})/1000) * WHF_d*CF*ISR$$

Where:

WHF_d = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is selected from the Reference Table in Section 4.5 for each building type. If the building is not cooled WHFd is 1.

CF = Summer Peak Coincidence Factor for measure is selected from the Reference Table in Section 4.5 for each building type. If the building type is unknown, use the Miscellaneous value of 0.66.

Other factors as defined above

NATURAL GAS SAVINGS

$$\Delta Therms^{556} = (((WattsBase-WattsEE)/1000) * ISR * Hours *- IFTherms$$

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Please select from the Reference Table in Section 4.5 for each building type.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Actual operation and maintenance costs will vary by specific equipment installed/replaced. See Reference tables for Operating and Maintenance Values;

[555]Negative value because this is an increase in heating consumption due to the efficient lighting.
[556] Negative value because this is an increase in heating consumption due to the efficient lighting.

Program	Reference Table
Time of Sale	B-1: HPT8 Component Costs and Lifetime
Retrofit	B-2: HPT8 Component Costs and Lifetime
Reduced Wattage T8, time of sale or retrofit	B-3: HPT8 Component Costs and Lifetime

REFERENCE TABLES

See following page

A-1: Time of Sale: HPT8 New and Baseline Assumptions[557]

EE Measure Description	Nominal Watts	$Watts_{EE}$	Baseline Description	Nominal Watt	$Watts_{BASE}$	Incremental Cost	$Watts_{SAVE}$
4-Lamp HPT8 w/ High-BF Ballast High-Bay	190	218.5	200 Watt Pulse Start Metal-Halide	200	232	$75	13.50
4-Lamp HPT8 w/ High-BF Ballast High-Bay	190	218.5	250 Watt Metal Halide	250	295	$75	76.50
6-Lamp HPT8 w/ High-BF Ballast High-Bay	287	330.05	320 Watt Pulse Start Metal-Halide	320	348.8	$75	18.75
6-Lamp HPT8 w/ High-BF Ballast High-Bay	287	330.05	400 Watt Pulse Start Metal Halide	400	455	$75	124.95
8-Lamp HPT8 w/ High-BF Ballast High-Bay	364	418.6	Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 320 PSMH	320	476	$75	57.40
8-Lamp HPT8 w/ High-BF Ballast High-Bay	364	418.6	Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 400 W Metal Halide	400	618	75	199.40
1-Lamp HPT8-high performance 32 w lamp	32	24.64	1-Lamp Standard F32T8 w/ Elec. Ballast	32	28.16	$15	3.52
1-Lamp HPT8-high performance 28 w lamp	29	22.33	1-Lamp Standard F32T8 w/ Elec. Ballast	32	28.16	$15	5.83
1-Lamp HPT8-high performance 25 w lamp	25	19.25	1-Lamp Standard F32T8 w/ Elec. Ballast	32	28.16	$15	8.91
2-Lamp HPT8 -high performance 32 w lamp	64	49.28	2-Lamp Standard F32T8 w/ Elec. Ballast	64	56.32	$18	7.04
2-Lamp HPT8-high performance 28 w lamp	56	43.12	2-Lamp Standard F32T8 w/ Elec. Ballast	64	56.32	$18	13.20
2-Lamp HPT8-high performance 25 w lamp	45	34.65	2-Lamp Standard F32T8 w/ Elec. Ballast	64	56.32	$18	21.67
3-Lamp HPT8-high performance 32 w lamp	94	72.38	3-Lamp Standard F32T8 w/ Elec. Ballast	96	84.48	$20	12.10
3-Lamp HPT8-high performance 28 w lamp	85	65.45	3-Lamp Standard F32T8 w/ Elec. Ballast	96	84.48	$20	19.03
3-Lamp HPT8-high performance 25 w lamp	75	57.75	3-Lamp Standard F32T8 w/ Elec. Ballast	96	84.48	$20	26.73
4-Lamp HPT8 -high performance 32 w lamp	122	93.94	4-Lamp Standard F32T8 w/ Elec. Ballast	128	112.64	$23	18.70
4-Lamp HPT8-high performance 28 w lamp	112	86.24	4-Lamp Standard F32T8 w/ Elec. Ballast	128	112.64	$23	26.40
4-Lamp HPT8-high performance 25 w lamp	100	77	4-Lamp Standard F32T8 w/ Elec. Ballast	128	112.64	$23	35.64
2-lamp High-Performance HPT8 Troffer	64	49.28	3-Lamp F32T8 w/ Elec. Ballast	96	84.48	$100	35.20

Table developed using a constant ballast factor of .77 for troffers/linear HPT8 and 1.15 for HPT8 highbay, 1.0 for all MH/MHPS, and 0.95 for T12 and 0.88 for standard T8. Input wattages are an average of manufacturer inputs that account for ballast efficacy

[557] Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment.

A-2: Retrofit HPT8 New and Baseline Assumptions[558]

EE Measure Description	Nominal Watts	Ballast Factor	$Watts_{EE}$	Baseline Description	Nominal Watts	$Watts_{BASE}$	$Watts_{SAVE}$	Full Measure Cost
4-Lamp HPT8 w/ High-BF Ballast High-Bay	190	1.15	218.5	200 Watt Pulse Start Metal-Halide	200	232	13.50	$200
4-Lamp HPT8 w/ High-BF Ballast High-Bay	190	1.15	218.5	250 Watt Metal Halide	250	295	76.50	$200
6-Lamp HPT8 w/ High-BF Ballast High-Bay	287	1.15	330.05	320 Watt Pulse Start Metal-Halide	320	348.8	18.75	$225
6-Lamp HPT8 w/ High-BF Ballast High-Bay	287	1.15	330.05	400 Watt Pulse Start Metal Halide	400	455	124.95	$225
8-Lamp HPT8 w/ High-BF Ballast High-Bay	364	1.15	418.6	Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 320 PSMH	320	476	57.40	$250
8-Lamp HPT8 w/ High-BF Ballast High-Bay	364	1.15	418.6	Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 400 W Metal Halide	400	618	199.40	$250
1-Lamp Relamp/Reballast T12 to HPT8	34	0.77	26.18	1-Lamp F34T12 w/ EEMag Ballast	34	42	15.82	$50
2-Lamp Relamp/Reballast T12 to HPT8	68	0.77	52.36	2-Lamp F34T12 w/ EEMag Ballast	68	67	14.64	$55
3-Lamp Relamp/Reballast T12 to HPT8	102	0.77	78.54	3-Lamp F34T12 w/ EEMag Ballast	102	104	25.46	$60
4-Lamp Relamp/Reballast T12 to HPT8	136	0.77	104.72	4-Lamp F34T12 w/ EEMag Ballast	136	144	39.28	$65
1-Lamp Relamp/Reballast T12 to HPT8	40	0.77	30.8	1-Lamp F40T12 w/ EEMag Ballast	40	41	10.20	$50
2-Lamp Relamp/Reballast T12 to HPT8	80	0.77	61.6	2-Lamp F40T12 w/ EEMag Ballast	80	87	25.40	$55
3-Lamp Relamp/Reballast T12 to HPT8	120	0.77	92.4	3-Lamp F40T12 w/ EEMag Ballast	120	141	48.60	$60
4-Lamp Relamp/Reballast T12 to HPT8	160	0.77	123.2	4-Lamp F40T12 w/ EEMag Ballast	160	172	48.80	$65
1-Lamp Relamp/Reballast T12 to HPT8	40	0.77	30.8	1-Lamp F40T12 w/ Mag Ballast	40	51	20.20	$50
2-Lamp Relamp/Reballast T12 to HPT8	80	0.77	61.6	2-Lamp F40T12 w/ Mag Ballast	80	97	35.40	$55
3-Lamp Relamp/Reballast T12 to HPT8	120	0.77	92.4	3-Lamp F40T12 w/ Mag Ballast	120	135	42.60	$60

[558] Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, Xcel Energy Lighting Efficiency Input Wattage Guide and professional judgment.

EE Measure Description	Nominal Watts	Ballast Factor	$Watts_{EE}$	Baseline Description	Nominal Watts	$Watts_{BASE}$	$Watts_{SAVE}$	Full Measure Cost
4-Lamp Relamp/Reballast T12 to HPT8	160	0.77	123.2	4-Lamp F40T12 w/ Mag Ballast	160	175	51.80	$65
1-Lamp Relamp/Reballast T8 to HPT8	32	0.77	24.64	1-Lamp F32T8 w/ Elec. Ballast	32	28.16	3.52	$50
2-Lamp Relamp/Reballast T8 to HPT8	64	0.77	49.28	2-Lamp F32T8 w/ Elec. Ballast	64	56.32	7.04	$55
3-Lamp Relamp/Reballast T8 to HPT8	96	0.77	73.92	3-Lamp F32T8 w/ Elec. Ballast	96	84.48	10.56	$60
4-Lamp Relamp/Reballast T8 to HPT8	128	0.77	98.56	4-Lamp F32T8 w/ Elec. Ballast	128	112.64	14.08	$65
2-lamp High-Performance HPT8 Troffer or high efficiency retrofit troffer	64	0.77	49.28	3-Lamp F32T8 w/ Elec. Ballast	96	84.48	35.20	$100

Table developed using a constant ballast factor of 0.77 for troffers/linear HPT8 and 1.15 for HPT8 highbay, 1.0 for all MH/MHPS, and 0.95 for T12 and 0.88 for standard T8. Input wattages are an average of manufacturer inputs that account for ballast efficacy.

A– 3: RWT8 New and Baseline Assumptions

EE Measure Description	Nominal Watts	$Watts_{EE}$	EE Lamp Cost	Baseline Description	Base Lamp Cost	Nominal Watts	$Watts_{BASE}$	$Watts_{SAVE}$	Measure Cost
RW T8 - F28T8 Lamp	28	24.64	$4.50	F32 T8 Standard Lamp	$2.50	32	28.16	3.52	$2.00
RWT8 F2T8 Extra Life Lamp	28	24.64	$4.50	F32 T8 Standard Lamp	$2.50	32	28.16	3.52	$2.00
RWT8 - F32/25W T8 Lamp	25	22.00	$4.50	F32 T8 Standard Lamp	$2.50	32	28.16	6.16	$2.00
RWT8 - F32/25W T8 Lamp Extra Life	25	22.00	$4.50	F32 T8 Standard Lamp	$2.50	32	28.16	6.16	$2.00
RWT8 F17T8 Lamp - 2 ft	16	14.08	$4.80	F17 T8 Standard Lamp - 2ft	$2.80	17	14.96	0.88	$2.00
RWT8 F25T8 Lamp - 3 ft	23	20.24	$5.10	F25 T8 Standard Lamp - 3ft	$3.10	25	22.00	1.76	$2.00
RWT8 F30T8 Lamp - 6' Utube	30	26.40	$11.31	F32 T8 Standard Utube	$9.31	32	28.16	1.76	$2.00
RWT8 F29T8 Lamp - Utube	29	25.52	$11.31	F32 T8 Standard Utube	$9.31	32	28.16	2.64	$2.00
RWT8 F96T8 Lamp - 8 ft	65	57.20	$9.00	F96 T8 Standard Lamp - 8 ft	$7.00	70	61.60	4.40	$2.00

Table developed using a constant ballast factor of 0.88 for RWT8 and Standard T8.

B-1: Time of Sale T8 Component Costs and Lifetime[559]

EE Measure Description	EE Lamp Cost	EE Lamp Life (hrs)	EE Lamp Rep. Labor Cost per lamp	EE Ballast Cost	EE Ballast Life (hrs)	EE Ballast Rep. Labor Cost	Baseline Description	Base Lamp Cost	Base Lamp Life (hrs)	Base Lamp Rep. Labor Cost	Base Ballast Cost	Base Ballast Life (hrs)	Base Ballast Rep. Labor Cost
4-Lamp HPT8 w/ High-BF Ballast High-Bay	$5.00	24000	$6.67	$32.50	70000	$15.00	200 Watt Pulse Start Metal-Halide	$21.00	10000	$6.67	$87.75	40000	$22.50
6-Lamp HPT8 w/ High-BF Ballast High-Bay	$5.00	24000	$6.67	$32.50	70000	$15.00	320 Watt Pulse Start Metal-Halide	$21.00	20000	$6.67	$109.35	40000	$22.50
8-Lamp HPT8 w/ High-BF Ballast High-Bay	$5.00	24000	$6.67	$32.50	70000	$15.00	Lamp HPT8 Equivalent to 320 PSMH	$21.00	20000	$6.67	$109.35	40000	$22.50
1-Lamp HPT8 – all qualifying lamps	$5.00	24000	$2.67	$32.50	70000	$15.00	1-Lamp Standard F32T12 w/ Elec Ballast	$2.50	20000	$2.67	$15.00	70000	$15.00
2-Lamp HPT8 – all qualifying lamps	$5.00	24000	$2.67	$32.50	70000	$15.00	2-Lamp Standard F32T12 w/ Elec Ballast	$2.50	20000	$2.67	$15.00	70000	$15.00
3-Lamp HPT8 – all qualifying lamps	$5.00	24000	$2.67	$32.50	70000	$15.00	3-Lamp Standard F32T8 w/ Elec. Ballast	$2.50	20000	$2.67	$15.00	70000	$15.00
4-Lamp HPT8 – all qualifying lamps	$5.00	24000	$2.67	$32.50	70000	$15.00	4-Lamp Standard F32T8 w/ Elec. Ballast	$2.50	20000	$2.67	$15.00	70000	$15.00
				$32.50									
2-lamp High-Performance HPT8 Troffer	$5.00	24000	$2.67	$32.50	70000	$15.00	3-Lamp F32T8 w/ Elec. Ballast	$2.50	20000	$2.67	$15.00	70000	$15.00

[559] Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment

B-2: T8 Retrofit Component Costs and Lifetime[560]

EE Measure Description	EE Lamp Cost	EE Lamp Life (hrs)	EE Lamp Rep. Labor Cost per lamp	EE Ballast Cost	EE Ballast Life (hrs)	EE Ballast Rep. Labor Cost	Baseline Description	Base Lamp Cost	Base Lamp Life (hrs)	Base Lamp Rep. Labor Cost	Base Ballast Cost	Base Ballast Life (hrs)	Base Ballast Rep. Labor Cost
4-Lamp HPT8 w/ High-BF Ballast High-Bay	$5.00	24000	$6.67	$32.50	70000	$15.00	200 Watt Pulse Start Metal-Halide	$29.00	12000	$6.67	$87.75	40000	$22.50
6-Lamp HPT8 w/ High-BF Ballast High-Bay	$5.00	24000	$6.67	$32.50	70000	$15.00	320 Watt Pulse Start Metal-Halide	$72.00	20000	$6.67	$109.35	40000	$22.50
8-Lamp HPT8 w/ High-BF Ballast High-Bay	$5.00	24000	$6.67	$32.50	70000	$15.00	Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 320 PSMH	$17.00	20000	$6.67	$109.35	40000	$22.50
1-Lamp Relamp/Reballast T12 to HPT8	$5.00	24000	$2.67	$32.50	70000	$15.00	1-Lamp F34T12 w/ EEMag Ballast	$2.70	20000	$2.67	$20.00	40000	$15.00
2-Lamp Relamp/Reballast T12 to HPT8	$5.00	24000	$2.67	$32.50	70000	$15.00	2-Lamp F34T12 w/ EEMag Ballast	$2.70	20000	$2.67	$20.00	40000	$15.00
3-Lamp Relamp/Reballast T12 to HPT8	$5.00	24000	$2.67	$32.50	70000	$15.00	3-Lamp F34T12 w/ EEMag Ballast	$2.70	20000	$2.67	$20.00	40000	$15.00
4-Lamp Relamp/Reballast T12 to HPT8	$5.00	24000	$2.67	$32.50	70000	$15.00	4-Lamp F34T12 w/ EEMag Ballast	$2.70	20000	$2.67	$20.00	40000	$15.00
1-Lamp Relamp/Reballast T8 to HPT8	$5.00	24000	$2.67	$32.50	70000	$15.00	1-Lamp F32T8 w/ Elec. Ballast	$2.70	20000	$2.67	$20.00	70000	$15.00
2-Lamp Relamp/Reballast T8 to HPT8	$5.00	24000	$2.67	$32.50	70000	$15.00	2-Lamp F32T8 w/ Elec. Ballast	$2.70	20000	$2.67	$20.00	70000	$15.00
3-Lamp Relamp/Reballast T8 to HPT8	$5.00	24000	$2.67	$32.50	70000	$15.00	3-Lamp F32T8 w/ Elec. Ballast	$2.70	20000	$2.67	$20.00	70000	$15.00
4-Lamp Relamp/Reballast T8 to HPT8	$5.00	24000	$2.67	$32.50	70000	$15.00	4-Lamp F32T8 w/ Elec. Ballast	$2.70	20000	$2.67	$20.00	70000	$15.00
2-lamp High-Performance HPT8 Troffer	$5.00	24000	$2.67	$32.50	70000	$15.00	3-Lamp F32T8 w/ Elec. Ballast	$2.50	20000	$2.67	$15.00	70000	$15.00

[560] Cost assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment

B-3: Reduced Wattage T8 Component Costs and Lifetime[561]

EE measure description	EE Lamp Cost	EE Lamp Life (hrs)	Baseline Description	Base Lamp Cost	Base Lamp Life (hrs)	Base Lamp Rep. Labor Cost
RW T8 - F28T8 Lamp	$4.50	30000	F32 T8 Standard Lamp	$2.50	15000	$2.67
RWT8 F2T8 Extra Life Lamp	$4.50	36000	F32 T8 Standard Lamp	$2.50	15000	$2.67
RWT8 - F32/25W T8 Lamp	$4.50	30000	F32 T8 Standard Lamp	$2.50	15000	$2.67
RWT8 - F32/25W T8 Lamp Extra Life	$4.50	36000	F32 T8 Standard Lamp	$2.50	15000	$2.67
RWT8 F17T8 Lamp - 2 ft	$4.80	18000	F17 T8 Standard Lamp - 2ft	$2.80	15000	$2.67
RWT8 F25T8 Lamp - 3 ft	$5.10	18000	F25 T8 Standard Lamp - 3ft	$3.10	15000	$2.67
RWT8 F30T8 Lamp - 6' Utube	$11.31	24000	F32 T8 Standard Utube	$9.31	15000	$2.67
RWT8 F29T8 Lamp - Utube	$11.31	24000	F32 T8 Standard Utube	$9.31	15000	$2.67
RWT8 F96T8 Lamp - 8 ft	$9.00	24000	F96 T8 Standard Lamp - 8 ft	$7.00	15000	$2.67

[561] Cost assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment.

C-1: T12 Baseline Adjustment:

For measures installed up to 6/1/2018, the full savings (as calculated above in the Algorithm section) will be claimed up to 6/1/2018. A savings adjustment will be applied to the annual savings for the remainder of the measure life. The adjustment to be applied for each measure is listed in the reference table below.

Savings Adjustment Factors

EE Measure Description	Savings Adjustment T12 EEmag ballast and 34 w lamps to HPT8	Savings Adjustment T12 EEmag ballast and 40 w lamps to HPT8	Savings Adjustment T12 mag ballast and 40 w lamps to HPT8
1-Lamp Relamp/Reballast T12 to HPT8	47%	30%	20%
2-Lamp Relamp/Reballast T12 to HPT8	53%	30%	22%
3-Lamp Relamp/Reballast T12 to HPT8	42%	38%	21%
4-Lamp Relamp/Reballast T12 to HPT8	44%	29%	23%

Measures installed in 2016 will claim full savings for two years and 2017 for one year,. Savings adjustment factors will be applied to the full savings for savings starting in 6/1/2018 and for the remainder of the measure life. The savings adjustment is equal to the ratio between wattage reduction from T8 baseline to HPT8 and wattage reduction from T12 EE ballast with 40 w lamp baseline from the table 'T8 New and Baseline Assumptions'.[562]

Example: 2 lamp T8 to 2 lamp HPT8 retrofit saves 10 watts, while the T12 EE with 40 w lamp to HPT8 saves 33 watts. Thus the ratio of wattage reduced is 30%.

MEASURE CODE: CI-LTG-T8FX-V05-160601

[562] See "HPRWT8_reference.xlsx" for more information.
EPE Program Downloads. Web accessed http://www.epelectricefficiency.com/downloads.asp?section=ci download Copy of LSF_2012_v4.04_250rows.xls.
Kuiken et al, Focus on Energy Evaluation. Business Programs: Deemed Savings Manual v1.0, Kema, march 22, 2010 available at http://www.focusonenergy.com/files/Document_Management_System/Evaluation/bpdeemedsavingsmanuav10_evaluationreport.pdf Based on ComEd's BILD program data from PY4 and PY5. For Residential installations, hours of use assumptions from '5.5.6 LED Downlights' should be used for LED fixtures and '5.5.8 LED Screw Based Omnidirectional Bulbs' should be used for LED bulbs.

4.5.4 LED Bulbs and Fixtures

DESCRIPTION

This characterization provides savings assumptions for a variety of LED lamps including Omnidirectional (e.g. A-Type lamps), Decorative (e.g. Globes and Torpedoes) and Directional (PAR Lamps, Reflectors, MR16), and fixtures including refrigerated case, recessed and outdoor/garage fixtures.

If the implementation strategy does not allow for the installation location to be known, a deemed split of 96% Commercial and 4% Residential should be used[563].

This measure was developed to be applicable to the following program types: TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, new lamps must be Energy Star labeled. Lamps and fixtures should be found in the reference tables below. Fixtures must be Energy Star labeled or on the Design Lights Consortium qualifying fixture list.

DEFINITION OF BASELINE EQUIPMENT

Refer to the baseline tables. In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 (EIAS) required all general-purpose light bulbs between 40 watts and 100 watts to have ~30% increased efficiency, essentially phasing out standard incandescent technology. In 2012, the 100 w lamp standards apply; in 2013 the 75 w lamp standards will apply, followed by restrictions on the 60 w and 40 w lamps in 2014.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

Lifetime is the life of the product, at the reported operating hours (lamp life in hours divided by operating hours per year – see reference table "LED component Costs and Lifetime." The analysis period is the same as the lifetime, capped at 15 years. (15 years from GDS Measure Life Report, June 2007).

DEEMED MEASURE COST

Wherever possible, actual incremental costs should be used. Refer to reference table “LED component Cost & Lifetime” for defaults.

LOADSHAPE

Loadshape C06 - Commercial Indoor Lighting

Loadshape C07 - Grocery/Conv. Store Indoor Lighting

Loadshape C08 - Hospital Indoor Lighting

Loadshape C09 - Office Indoor Lighting

Loadshape C10 - Restaurant Indoor Lighting

Loadshape C11 - Retail Indoor Lighting

Loadshape C12 - Warehouse Indoor Lighting

[563] Based on final ComEd’s BILD program data from PY4,PY5 and PY6. For Residential installations, hours of use assumptions from ‘5.5.6 LED Downlights’ should be used for LED fixtures and ‘5.5.8 LED Screw Based Omnidirectional Bulbs’ should be used for LED bulbs.

Loadshape C13 - K-12 School Indoor Lighting

Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)

Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)

Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)

Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)

Loadshape C18 - Industrial Indoor Lighting

Loadshape C19 - Industrial Outdoor Lighting

Loadshape C20 - Commercial Outdoor Lighting

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in the reference section below.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((Watts_{base} - Watts_{EE})/1000) * Hours * WHF_e * ISR$$

Where:

$Watts_{base}$ = Input wattage of the existing or baseline system. Reference the "LED New and Baseline Assumptions" table for default values.

$Watts_{EE}$ = Actual wattage of LED purchased / installed. If unknown, use default provided below:

For ENERGY STAR rated lamps the following lumen equivalence tables should be used:

Omnidirectional Lamps - ENERGY STAR Minimum Luminous Efficacy = 50Lm/W for <10W lamps and 55Lm/W for >=10W lamps.

Minimum Lumens	Maximum Lumens	Lumens used to calculate LED Wattage (midpoint)	LED Wattage[564] (WattsEE)	Baseline 2014-2019 (WattsBase)	Delta Watts 2014-2019 (WattsEE)	Baseline Post EISA 2020 requirement[565] (WattsBase)	Delta Watts Post 2020 (WattsEE)
5280	6209	5745	104.4	300.0	195.6	300.0	195.6
3000	5279	4140	75.3	200.0	124.7	200.0	124.7
2601	2999	2800	50.9	150.0	99.1	150.0	99.1
1490	2600	2045	37.2	72.0	34.8	45.4	8.3
1050	1489	1270	23.1	53.0	29.9	28.2	5.1
750	1049	900	16.4	43.0	26.6	20.0	3.6
310	749	530	9.6	29.0	19.4	11.8	2.1
250	309	280	5.6	25.0	19.4	25.0	19.4

Decorative Lamps - ENERGY STAR Minimum Luminous Efficacy = 40Lm/W for all lamps

Nominal wattage of lamp to be replaced ($Watts_{base}$)	Minimum initial light output of LED lamp (lumens)	LED Wattage ($Watts_{EE}$)	Delta Watts
10	70	1.75	8.25
15	90	2.25	12.75
25	150	3.75	21.25
40	300	7.5	32.5
60	500	12.5	47.5

Decorative lamps are exempt from EISA regulations.

[564] Based on ENERGY STAR specs – minimum luminous efficacy for Omnidirectional Lamps. For LED lamp power <10W = 50lm/W and for LED lamp power >=10W = 55lm/W.
[565] Calculated as 45lm/W for all EISA non-exempt bulbs.

Directional Lamps - ENERGY STAR Minimum Luminous Efficacy = 40Lm/W for lamps with rated wattages less than 20Wand 50 Lm/W for lamps with rated wattages >= 20 watts[566].

For Directional R, BR, and ER lamp types[567]:

Bulb Type	Lower Lumen Range	Upper Lumen Range	$Watts_{Base}$	Lumens used to calculate LED Wattage (midpoint)	LED Wattage ($Watts_{EE}$)	Delta Watts
R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below)	420	472	40	446	11	29
	473	524	45	499	12	33
	525	714	50	620	15	35
	715	937	65	826	21	44
	938	1259	75	1099	22	53
	1260	1399	90	1330	27	63
	1400	1739	100	1570	31	69
	1740	2174	120	1957	39	81
	2175	2624	150	2400	48	102
	2625	2999	175	2812	56	119
	3000	4500	200	3750	75	125
***R, BR, and ER with medium screw bases w/ diameter <=2.25"**	400	449	40	425	11	29
	450	499	45	475	12	33
	500	649	50	575	14	36
	650	1199	65	925	23	42
***ER30, BR30, BR40, or ER40**	400	449	40	425	11	29
	450	499	45	475	12	33
	500	649	50	575	14	36
***BR30, BR40, or ER40**	650	1419	65	1035	21	44
***R20**	400	449	40	425	11	29
	450	719	45	585	15	30
***All reflector lamps below lumen ranges specified above**	200	299	20	250	6	14
	300	399	30	350	9	21

Directional lamps are exempt from EISA regulations.

For PAR, MR, and MRX Lamps Types:

[566] From pg 10 of the Energy Star Specification for lamps v1.1
[567] From pg 11 of the Energy Star Specification for lamps v1.1

For these highly focused directional lamp types, it is necessary to have Center Beam Candle Power (CBCP) and beam angle measurements to accurately estimate the equivalent baseline wattage. The formula below is based on the Energy Star Center Beam Candle Power tool.[568] If CBCP and beam angle information are not available or if the equation below returns a negative value (or undefined), use the manufacturer's recommended baseline wattage equivalent.[569]

$$\text{Wattsbase} = 375.1 - 4.355(D) - \sqrt{227{,}800 - 937.9(D) - 0.9903(D^2) - 1479(BA) - 12.02(D * BA) + 14.69(BA^2) - 16{,}720 * \ln(CBCP)}$$

Where:

D = Bulb diameter (e.g. for PAR20 D = 20)

BA = Beam angle

CBCP = Center beam candle power

The result of the equation above should be rounded DOWN to the nearest wattage established by Energy Star:

Diameter	Permitted Wattages
16	20, 35, 40, 45, 50, 60, 75
20	50
30S	40, 45, 50, 60, 75
30L	50, 75
38	40, 45, 50, 55, 60, 65, 75, 85, 90, 100, 120, 150, 250

Hours = Average hours of use per year are provided in the Reference Table in Section 4.5, Screw based bulb annual operating hours, for each building type. If unknown, use the Miscellaneous value.

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided below for each building type in the Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

ISR = In Service Rate -the percentage of units rebated that actually get installed.

=100%[570] if application form completed with sign off that equipment is not placed into storage. If sign off form not completed assume the following 3 year ISR assumptions:

[568] http://energystar.supportportal.com/link/portal/23002/23018/Article/32655/

[569] The Energy Star Center Beam Candle Power tool does not accurately model baseline wattages for lamps with certain bulb characteristic combinations – specifically for lamps with very high CBCP.

[570] Illinois evaluation of PY1 through PY3 has not found that fixtures or lamps placed into storage to be a significant enough issue to warrant including an "In-Service Rate" when commercial customers complete an application form.

Weighted Average 1st year In Service Rate (ISR)	2nd year Installations	3rd year Installations	Final Lifetime In Service Rate
95.7%[571]	1.2%	1.1%	98.0%[572]

HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}^{573} = (((WattsBase-WattsEE)/1000) * ISR * Hours * -IFkWh$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, For example, a 9W LED lamp, 450 lumens, is installed in a heat pump heated office in 2014 and sign off form provided:

$$\Delta kWh_{heatpenalty} = ((29-9/1000)*1.0*3088* -0.151$$

$$= - 9.3 \text{ kWh}$$

DEFERRED INSTALLS

As presented above, if a sign off form is not completed the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

[571] Based on ComEd's BILD program data from PY5 and PY6, see "IL Commercial Lighting ISR_2014.xls".

[572] In the absence of any data for LEDs specifically it is assumed that the same proportion of bulbs eventually get installed as for CFLS. The 98% CFL assumption is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings. Note that this Final Install Rate does NOT account for leakage of purchased bulbs being installed outside of the utility territory. EM&V should assess how and if data from evaluation should adjust this final installation rate to account for this impact

[573]Negative value because this is an increase in heating consumption due to the efficient lighting.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = ((Watts_{base}-Watts_{EE})/1000) * ISR * WHF_d * CF$$

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

CF = Summer Peak Coincidence Factor for measure is provided in the Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, For example, a 9W LED lamp, 450 lumens, is installed in an office in 2014 and sign off form provided:

ΔkW = ((29-9/1000)* 1.0*1.3*0.66

= 0.002 kW

NATURAL GAS ENERGY SAVINGS

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):

$$\Delta Therms = (((WattsBase-WattsEE)/1000) * ISR * Hours * - IFTherms$$

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, For example, a 9W LED lamp, 450 lumens, is installed in an office in 2014 and sign off form provided:

ΔTherms = ((29-9/1000)*1.0*3088* -0.016

= - 0.99 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

For all measures except Standard Omnidirectional lamps (which have an EISA baseline shift) the individual component lifetimes and costs are provided in the reference table section below[574].

In order to account for the falling EISA Qualified bulb replacement cost provided above, an equivalent annual levelized baseline replacement cost over the lifetime of the LED bulb (assumed to be 25,000/4683 =5.3 years) is calculated[575]. The key assumptions used in this calculation are documented below[576]:

[574] See "LED Lighting Systems TRM Reference Tables" for breakdown of component cost assumptions.

[575] See C&I OmniDirectional LED O&M Calc.xls" for more information. The values assume the non-residential average hours assumption of 4683.

[576] Based upon pricing forecast developed by Applied Proactive Technologies Inc (APT) based on industry input and provided to Ameren.

	Std Inc.	EISA Compliant Halogen	CFL
2015	$0.34	$0.90	N/A
2016	$0.34	$0.80	N/A
2017	$0.34	$0.70	N/A
2018	$0.34	$0.60	N/A
2019	$0.34	$0.60	N/A
2020 & after	$0.34	N/A	$2.50

The NPV for replacement lamps and annual levelized replacement costs using the statewide real discount rate of 5.34% are presented below. It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR:

Location	Lumen Level	NPV of replacement costs for period			Levelized annual replacement cost savings		
		June 2016 - May 2017	June 2017 - May 2018	June 2018 - May 2019	June 2016 - May 2017	June 2017 - May 2018	June 2018 - May 2019
Commercial	Lumens <310 or >2600 (EISA exempt)	$6.88	$6.88	$6.88	$1.51	$1.51	$1.51
	Lumens ≥ 310 and ≤ 2600 (EISA compliant)	$11.63	$9.52	$7.76	$2.55	$2.09	$1.70
Multi Family Common Areas	Lumens <310 or >2600 (non-EISA compliant)	$7.03	$7.03	$7.03	$1.72	$1.72	$1.72
	Lumens ≥ 310 and ≤ 2600 (EISA compliant)	$12.69	$10.28	$8.28	$3.11	$2.52	$2.03

For halogen bulbs, we assume the same replacement cycle as incandescent bulbs.[577] The replacement cycle is based on the miscellaneous hours of use. Both incandescent and halogen lamps are assumed to last for 1,000 hours before needing replacement and CFLs after 10,000 hours.

[577] The manufacturers of the new minimally compliant EISA Halogens are using regular incandescent lamps with halogen fill gas rather than halogen infrared to meet the standard and so the component rated life is equal to the standard incandescent.

REFERENCE TABLES

LED Bulb Assumptions

Wherever possible, actual incremental costs should be used. If unavailable assume the following incremental costs[578]:

Bulb Type	LED Wattage	LED	Incandescent	Incremental Cost
Directional	< 20W	$22.42	$6.31	$16.11
	≥20W	$70.78		$64.47
Decorative and Globe	<15W	$12.76	$3.92	$8.84
	15 to <25W	$25.00		$21.08
	≥25W	$25.00		$21.08

Directional and Decorative O&M; apply incandescent cost assumption provided above with a frequency calculated by dividing the assumed rated life of the baseline bulb (1000 hours) by the building specific hours of use assumption.

[578] LED lamp costs are based on VEIC review of a year's worth of LED sales data through VEIC implemented programs and the retail cost averaged (see 2015 LED Sales Review.xls). Baseline cost based on "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014. Given LED prices are expected to continue declining assumed costs should be reassessed on an annual basis and replaced with IL specific LED program information when available.

LED Fixture Wattage and Incremental Cost Assumptions[579]

LED Category	EE Measure Description	$Watts_{EE}$	Baseline Description	$Watts_{BASE}$	Incremental Cost	Mid Life Savings Adjustment (2018)
LED Downlight Fixtures	LED Recessed, Surface, Pendant Downlights	17.6	Baseline LED Recessed, Surface, Pendant Downlights	54.3	$27	N/A
LED Interior Directional	LED Track Lighting	12.2	Baseline LED Track Lighting	60.4	$59	N/A
	LED Wall-Wash Fixtures	8.3	Baseline LED Wall-Wash Fixtures	17.7	$59	N/A
LED Display Case	LED Display Case Light Fixture	7.1 per ft	Baseline LED Display Case Light Fixture	36.2 per ft	$11/ft	N/A
	LED Undercabinet Shelf-Mounted Task Light Fixtures	7.1 per ft	Baseline LED Undercabinet Shelf-Mounted Task Light Fixtures	36.2 per ft	$11/ft	N/A
	LED Refrigerated Case Light, Horizontal or Vertical	7.6 per ft	Baseline LED Refrigerated Case Light, Horizontal or Vertical (per foot)	15.2 per ft	$11/ft	N/A
	LED Freezer Case Light, Horizontal or Vertical	7.7 per ft	Baseline LED Freezer Case Light, Horizontal or Vertical (per foot)	18.7 per ft	$11/ft	N/A
LED Linear Replacement Lamps	LED 4' Linear Replacement Lamp	18.7	80:20 T12:T8; Lamp Only 32w T8:34w T12	33.6	$24	89%
	LED 2' Linear Replacement Lamp	9.7	80:20 T12:T8; Lamp Only 17w T8:20w T12	19.4	$13	75%
LED Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	34.1	80:20 T12:Standard T8 2-Lamp 32w T8, 2-Lamp 34w T12	61.0	$48	85%
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	42.8	80:20 T12:Standard T8 3-Lamp 32w T8, 3-Lamp 34w T12	103.3	$91	69%
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	37.9	80:20 T12:Standard T8 2-Lamp 32w T8, 2-Lamp 34w T12	61.0	$62	83%
	LED 2x4 Recessed Light Fixture, 4501-6000 lumens	54.3	80:20 T12:Standard T8 3-Lamp 32w T8, 3-Lamp 34w T12	103.3	$99	62%
	LED 2x4 Recessed Light Fixture, 6001-7500 lumens	72.7	80:20 T12:Standard T8 4-Lamp 32w T8, 4-Lamp 34w T12	137.7	$150	61%
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	18.1	80:20 T12:Standard T8 1-Lamp 32w T8 , 1-Lamp 34w T12	30.6	$36	88%
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	39.6	80:20 T12:Standard T8 2-Lamp 32w T8, 2-Lamp 34w T12	61.0	$76	81%

[579] Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists alongside past Efficiency Vermont projects and PGE refrigerated case study. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment. Efficient cost data comes from 2012 DOE "Energy Savings Potential of Solid-State Lighting in General Illumination Applications", Table A.1. See "LED Lighting Systems TRM Reference Tables.xlsx" for more information and specific product links.

LED Category	EE Measure Description	$Watts_{EE}$	Baseline Description	$Watts_{BASE}$	Incremental Cost	Mid Life Savings Adjustment (2018)
	LED 1x4 Recessed Light Fixture, 4501-6000 lumens	53.1	80:20 T12:Standard T8 3-Lamp 32w T8, 3-Lamp 34w T12	103.3	$130	62%
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, <= 3000 lumens	19.7	80:20 T12:Standard T8 1-Lamp 32w T8, 1-Lamp 34w T12	30.6	$54	86%
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	37.8	80:20 T12:Standard T8 2-Lamp 32w T8, 2-Lamp 34w T12	61.0	$104	83%
	LED Surface & Suspended Linear Fixture, 4501-6000 lumens	55.9	80:20 T12:Standard T8 3-Lamp 32w T8, 3-Lamp 34w T12	103.3	$158	60%
	LED Surface & Suspended Linear Fixture, 6001-7500 lumens	62.6	T5HO 2L-F54T5HO - 4'	120.0	$215	N/A
	LED Surface & Suspended Linear Fixture, > 7500 lumens	95.4	T5HO 3L-F54T5HO - 4'	180.0	$374	N/A
LED High & Low Bay Fixtures	LED Low-Bay Fixtures, <= 10,000 lumens	90.3	3-Lamp T8HO Low-Bay	157.0	$191	N/A
	LED High-Bay Fixtures, 10,001-15,000 lumens	127.5	4-Lamp T8HO High-Bay	196.0	$331	N/A
	LED High-Bay Fixtures, 15,001-20,000 lumens	191.0	6-Lamp T8HO High-Bay	294.0	$482	N/A
	LED High-Bay Fixtures, > 20,000 lumens	249.7	8-Lamp T8HO High-Bay	392.0	$818	N/A
LED Agricultural Interior Fixtures	LED Ag Interior Fixtures, <= 2,000 lumens	17.0	25% 73 Watt EISA Inc, 75% 1L T8	42.0	$33	N/A
	LED Ag Interior Fixtures, 2,001-4,000 lumens	27.8	25% 146 Watt EISA Inc, 75% 2L T8	81.0	$54	N/A
	LED Ag Interior Fixtures, 4,001-6,000 lumens	51.2	25% 217 Watt EISA Inc, 75% 3L T8	121.0	$125	N/A
	LED Ag Interior Fixtures, 6,001-8,000 lumens	71.7	25% 292 Watt EISA Inc, 75% 4L T8	159.0	$190	N/A
	LED Ag Interior Fixtures, 8,001-12,000 lumens	103.5	200W Pulse Start Metal Halide	227.3	$298	N/A
	LED Ag Interior Fixtures, 12,001-16,000 lumens	143.8	320W Pulse Start Metal Halide	363.6	$450	N/A
	LED Ag Interior Fixtures, 16,001-20,000 lumens	183.3	350W Pulse Start Metal Halide	397.7	$595	N/A
	LED Ag Interior Fixtures, > 20,000 lumens	305.0	(2) 320W Pulse Start Metal Halide	727.3	$998	N/A
LED Exterior Fixtures	LED Exterior Fixtures, <= 5,000 lumens	42.6	100W Metal Halide	113.6	$190	N/A
	LED Exterior Fixtures, 5,001-10,000 lumens	68.2	175W Pulse Start Metal Halide	198.9	$287	N/A

LED Category	EE Measure Description	$Watts_{EE}$	Baseline Description	$Watts_{BASE}$	Incremental Cost	Mid Life Savings Adjustment (2018)
	LED Exterior Fixtures, 10,001-15,000 lumens	122.5	250W Pulse Start Metal Halide	284.1	$391	N/A
	LED Exterior Fixtures, > 15,000 lumens	215.0	400W Pulse Start Metal Halide	454.5	$793	N/A

LED Fixture Component Costs & Lifetime[580]

		EE Measure				Baseline			
LED Category	EE Measure Description	Lamp Life (hrs)	Total Lamp Replacement Cost	LED Driver Life (hrs)	Total LED Driver Replacement Cost	Lamp Life (hrs)	Total Lamp Replacement Cost	Ballast Life (hrs)	Total Ballast Replacement Cost
LED Downlight Fixtures	LED Recessed, Surface, Pendant Downlights	50,000	$30.75	70,000	$47.50	2,500	$8.86	40,000	$14.40
LED Interior Directional	LED Track Lighting	50,000	$39.00	70,000	$47.50	2,500	$12.71	40,000	$11.00
	LED Wall-Wash Fixtures	50,000	$39.00	70,000	$47.50	2,500	$9.17	40,000	$27.00
LED Display Case	LED Display Case Light Fixture	50,000	$9.75/ft	70,000	$11.88/ft	2,500	$6.70	40,000	$5.63
	LED Undercabinet Shelf-Mounted Task Light Fixtures	50,000	$9.75/ft	70,000	$11.88/ft	2,500	$6.70	40,000	$5.63
	LED Refrigerated Case Light, Horizontal or Vertical	50,000	$8.63/ft	70,000	$9.50/ft	15,000	$1.13	40,000	$8.00
	LED Freezer Case Light, Horizontal or Vertical	50,000	$7.88/ft	70,000	$7.92/ft	12,000	$0.94	40,000	$6.67
LED Linear Replacement Lamps	LED 4' Linear Replacement Lamp	50,000	$8.57	70,000	$13.67	24,000	$6.17	40,000	$11.96
	LED 2' Linear Replacement Lamp	50,000	$5.76	70,000	$13.67	24,000	$6.17	40,000	$11.96
LED Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	50,000	$46.68	70,000	$40.00	24,000	$26.33	40,000	$35.00

[580] Note some measures have blended baselines (T12:T8 80:20). All values are provided to enable calculation of appropriate O&M impacts. Total costs include lamp, labor and disposal cost assumptions where applicable, see "IL LED Lighting Systems TRM Tables" for more information.

		EE Measure				Baseline			
LED Category	EE Measure Description	Lamp Life (hrs)	Total Lamp Replacement Cost	LED Driver Life (hrs)	Total LED Driver Replacement Cost	Lamp Life (hrs)	Total Lamp Replacement Cost	Ballast Life (hrs)	Total Ballast Replacement Cost
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	50,000	$56.31	70,000	$40.00	24,000	$39.50	40,000	$35.00
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	50,000	$49.58	70,000	$40.00	24,000	$12.33	40,000	$35.00
	LED 2x4 Recessed Light Fixture, 4501-6000 lumens	50,000	$57.76	70,000	$40.00	24,000	$18.50	40,000	$35.00
	LED 2x4 Recessed Light Fixture, 6001-7500 lumens	50,000	$68.89	70,000	$40.00	24,000	$24.67	40,000	$35.00
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	50,000	$43.43	70,000	$40.00	24,000	$6.17	40,000	$35.00
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	50,000	$52.31	70,000	$40.00	24,000	$12.33	40,000	$35.00
	LED 1x4 Recessed Light Fixture, 4501-6000 lumens	50,000	$63.86	70,000	$40.00	24,000	$18.50	40,000	$35.00
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, <= 3000 lumens	50,000	$45.01	70,000	$40.00	24,000	$6.17	40,000	$35.00
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	50,000	$58.73	70,000	$40.00	24,000	$12.33	40,000	$35.00
	LED Surface & Suspended Linear Fixture, 4501-6000 lumens	50,000	$73.50	70,000	$40.00	24,000	$18.50	40,000	$35.00
	LED Surface & Suspended Linear Fixture, 6001-7500 lumens	50,000	$88.69	70,000	$40.00	30,000	$26.33	40,000	$60.00
	LED Surface & Suspended Linear Fixture, > 7500 lumens	50,000	$123.91	70,000	$40.00	30,000	$39.50	40,000	$60.00
LED High & Low Bay	LED Low-Bay Fixtures, <= 10,000	50,000	$90.03	70,000	$62.50	18,000	$64.50	40,000	$92.50

		EE Measure				Baseline			
LED Category	EE Measure Description	Lamp Life (hrs)	Total Lamp Replacement Cost	LED Driver Life (hrs)	Total LED Driver Replacement Cost	Lamp Life (hrs)	Total Lamp Replacement Cost	Ballast Life (hrs)	Total Ballast Replacement Cost
Fixtures	lumens								
	LED High-Bay Fixtures, 10,001-15,000 lumens	50,000	$122.59	70,000	$62.50	18,000	$86.00	40,000	$92.50
	LED High-Bay Fixtures, 15,001-20,000 lumens	50,000	$157.22	70,000	$62.50	18,000	$129.00	40,000	$117.50
	LED High-Bay Fixtures, > 20,000 lumens	50,000	$228.52	70,000	$62.50	18,000	$172.00	40,000	$142.50
LED Agricultural Interior Fixtures	LED Ag Interior Fixtures, <= 2,000 lumens	50,000	$37.00	70,000	$40.00	1,000	$1.23	40,000	$26.25
	LED Ag Interior Fixtures, 2,001-4,000 lumens	50,000	$44.96	70,000	$40.00	1,000	$1.43	40,000	$26.25
	LED Ag Interior Fixtures, 4,001-6,000 lumens	50,000	$63.02	70,000	$40.00	1,000	$1.62	40,000	$26.25
	LED Ag Interior Fixtures, 6,001-8,000 lumens	50,000	$79.78	70,000	$40.00	1,000	$1.81	40,000	$26.25
	LED Ag Interior Fixtures, 8,001-12,000 lumens	50,000	$119.91	70,000	$62.50	15,000	$63.00	40,000	$112.50
	LED Ag Interior Fixtures, 12,001-16,000 lumens	50,000	$151.89	70,000	$62.50	15,000	$68.00	40,000	$122.50
	LED Ag Interior Fixtures, 16,001-20,000 lumens	50,000	$184.62	70,000	$62.50	15,000	$73.00	40,000	$132.50
	LED Ag Interior Fixtures, > 20,000 lumens	50,000	$285.75	70,000	$62.50	15,000	$136.00	40,000	$202.50
LED Exterior Fixtures	LED Exterior Fixtures, <= 5,000 lumens	50,000	$86.92	70,000	$62.50	15,000	$58.00	40,000	$102.50
	LED Exterior Fixtures, 5,001-10,000 lumens	50,000	$111.81	70,000	$62.50	15,000	$63.00	40,000	$112.50
	LED Exterior Fixtures, 10,001-	50,000	$138.32	70,000	$62.50	15,000	$68.00	40,000	$122.50

		EE Measure				Baseline			
LED Category	EE Measure Description	Lamp Life (hrs)	Total Lamp Replacement Cost	LED Driver Life (hrs)	Total LED Driver Replacement Cost	Lamp Life (hrs)	Total Lamp Replacement Cost	Ballast Life (hrs)	Total Ballast Replacement Cost
	15,000 lumens								
	LED Exterior Fixtures, > 15,000 lumens	50,000	$223.67	70,000	$62.50	15,000	$73.00	40,000	$132.50

MEASURE CODE: CI-LTG-LEDB-V05-160601

4.5.5 Commercial LED Exit Signs

DESCRIPTION

This measure characterizes the savings associated with installing a Light Emitting Diode (LED) exit sign in place of a fluorescent or incandescent exit sign in a Commercial building. Light Emitting Diode exit signs have a string of very small, typically red or green, glowing LEDs arranged in a circle or oval. The LEDs may also be arranged in a line on the side, top or bottom of the exit sign. LED exit signs provide the best balance of safety, low maintenance, and very low energy usage compared to other exit sign technologies.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is assumed to be an exit sign illuminated by LEDs.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be a fluorescent or incandescent model.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 16 years[581].

DEEMED MEASURE COST

The incremental cost for this measure is assumed to be $30[582].

LOADSHAPE

Loadshape C53 - Flat

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 100%[583].

[581] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.
[582] NYSERDA Deemed Savings Database, Labor cost assumes 25 minutes @ $18/hr.
[583] Assuming continuous operation of an LED exit sign, the Summer Peak Coincidence Factor is assumed to equal 1.0.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((WattsBase - WattsEE) / 1000) * HOURS * WHF_e$$

Where:

WattsBase = Actual wattage if known, if unknown assume the following:

Baseline Type	WattsBase
Incandescent	35W[584]
Fluorescent	11W[585]
Unknown (e.g. time of sale)	23W[586]

WattsEE = Actual wattage if known, if unknown assume 2W[587]

HOURS = Annual operating hours

= 8766

WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided for each building type in the Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, replacing incandescent fixture in an office

ΔkWH = (35 – 2)/1000 * 8766 * 1.25

= 362 kWh

For example, replacing fluorescent fixture in a hospital

ΔkWH = (11 – 2)/1000 * 8766 * 1.35

= 106.5 kWh

HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}[588] = (((WattsBase-WattsEE)/1000) * Hours * -IFkWh$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the

[584] Based on review of available product.
[585] Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010
[586] ComEd has been using a weighted baseline of 70 percent incandescent and 30 percent compact fluorescent, reflecting program experience and a limited sample of evaluation verification findings that we consider to be reasonable (Navigant, through comment period February 2013)
[587] Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010
[588]Negative value because this is an increase in heating consumption due to the efficient lighting.

increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, replacing incandescent fixture in a heat pump heated office

$\Delta kWh_{heatpenalty}$ = (35 – 2)/1000 * 8766 * -0.151

= -43.7 kWh

For example, replacing fluorescent fixture in a heat pump heated hospital

$\Delta kWh_{heatpenalty}$ = (11 – 2)/1000 * 8766 * -0.104

= -8.2 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ((WattsBase - WattsEE) / 1000) * WHF_d * CF

Where:

WHF_d = Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

CF = Summer Peak Coincidence Factor for measure

= 1.0

For example, replacing incandescent fixture in an office

ΔkW = (35 – 2)/1000 * 1.3 * 1.0

= 0.043 kW

For example, replacing fluorescent fixture in a hospital

ΔkW = (11 – 2)/1000 * 1.69 * 1.0

= 0.015 kW

NATURAL GAS SAVINGS

Heating Penalty if natural gas heated building (or if heating fuel is unknown):

$\Delta therms$ = (((WattsBase-WattsEE)/1000) * Hours *- IFTherms

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, replacing incandescent fixture in an office

ΔTherms = (35 – 2)/1000 * 8766 * -0.016

= -4.63 Therms

For example, replacing fluorescent fixture in a hospital

ΔTherms = (11 – 2)/1000 * 8766 * -0.011

= - 0.87 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The annual O&M Cost Adjustment savings should be calculated using the following component costs and lifetimes.

	Baseline Measures	
Component	Cost	Life (yrs)
Lamp	$7.00[589]	1.37 years[590]

MEASURE CODE: CI-LTG-LEDE-V02-140601

[589] Consistent with assumption for a Standard CFL bulb with an estimated labor cost of $4.50 (assuming $18/hour and a task time of 15 minutes).

[590] Assumes a lamp life of 12,000 hours and 8766 run hours 12000/8766 = 1.37 years.

4.5.6 LED Traffic and Pedestrian Signals

DESCRIPTION

Traffic and pedestrian signals are retrofitted to be illuminated with light emitting diodes (LED) instead of incandescent lamps. Incentive applies for the replacement or retrofit of existing incandescent traffic signals with new LED traffic and pedestrian signal lamps. Each lamp can have no more than a maximum LED module wattage of 25. Incentives are not available for spare lights. Lights must be hardwired and single lamp replacements are not eligible, with the exception of pedestrian hand signals. Eligible lamps must meet the Energy Star Traffic Signal Specification and the Institute for Transportation Engineers specification for traffic signals.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

Refer to the Table titled 'Traffic Signals Technology Equivalencies' for efficient technology wattage and savings assumptions.

DEFINITION OF BASELINE EQUIPMENT

Refer to the Table titled 'Traffic Signals Technology Equivalencies' for baseline efficiencies and savings assumptions.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of an LED traffic signal is 100,000 hours (manufacturer's estimate), capped at 10 years.[591] The life in years is calculated by dividing 100,000 hrs by the annual operating hours for the particular signal type.

DEEMED MEASURE COST

The actual measure installation cost should be used (including material and labor).

LOADSHAPE

Loadshape C24 - Traffic Signal - Red Balls, always changing or flashing

Loadshape C25 - Traffic Signal - Red Balls, changing day, off night

Loadshape C26 - Traffic Signal - Green Balls, always changing

Loadshape C27 - Traffic Signal - Green Balls, changing day, off night

Loadshape C28 - Traffic Signal - Red Arrows

Loadshape C29 - Traffic Signal - Green Arrows

Loadshape C30 - Traffic Signal - Flashing Yellows

Loadshape C31 - Traffic Signal - "Hand" Don't Walk Signal

Loadshape C32 - Traffic Signal - "Man" Walk Signal

Loadshape C33 - Traffic Signal - Bi-Modal Walk/Don't Walk

[591] ACEEE, (1998) A Market Transformation Opportunity Assessment for LED Traffic Signals, http://www.cee1.org/gov/led/led-ace3/ace3led.pdf

COINCIDENCE FACTOR[592]

The summer peak coincidence factor (CF) for this measure is dependent on lamp type as below:

Lamp Type	CF
Red Round, always changing or flashing	0.55
Red Arrows	0.90
Green Arrows	0.10
Yellow Arrows	0.03
Green Round, always changing or flashing	0.43
Flashing Yellow	0.50
Yellow Round, always changing	0.02
"Hand" Don't Walk Signal	0.75
"Man" Walk Signal	0.21

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (W_{base} - W_{eff}) \times HOURS / 1000$$

Where:

Wbase =The connected load of the baseline equipment

= see Table 'Traffic Signals Technology Equivalencies'

Weff =The connected load of the baseline equipment

= see Table 'Traffic Signals Technology Equivalencies'

EFLH = annual operating hours of the lamp

= see Table 'Traffic Signals Technology Equivalencies'

1000 = conversion factor (W/kW)

EXAMPLE

For example, an 8 inch red, round signal:

$$\Delta kWh = ((69 - 7) \times 4818) / 1000$$

$$= 299 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (Wbase – Weff) \times CF / 1000$$

[592] Ibid

Where:

Wbase	=The connected load of the baseline equipment
	= see Table 'Traffic Signals Technology Equivalencies'
Weff	=The connected load of the efficient equipment
	= see Table 'Traffic Signals Technology Equivalencies'
CF	= Summer Peak Coincidence Factor for measure

EXAMPLE

For example, an 8 inch red, round signal:

$\Delta kW = ((69 – 7) \times 0.55) / 1000$

$= 0.0341$ kW

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

REFERENCE TABLES

Traffic Signals Technology Equivalencies[593]

Traffic Fixture Type	Fixture Size and Color	Efficient Lamps	Baseline Lamps	HOURS	Efficient Fixture Wattage	Baseline Fixture Wattage	Energy Savings (in kWh)
Round Signals	8" Red	LED	Incandescent	4818	7	69	299
Round Signals	12" Red	LED	Incandescent	4818	6	150	694
Flashing Signal[594]	8" Red	LED	Incandescent	4380	7	69	272
Flashing Signal	12" Red	LED	Incandescent	4380	6	150	631
Flashing Signal	8" Yellow	LED	Incandescent	4380	10	69	258
Flashing Signal	12" Yellow	LED	Incandescent	4380	13	150	600
Round Signals	8" Yellow	LED	Incandescent	175	10	69	10
Round Signals	12" Yellow	LED	Incandescent	175	13	150	24
Round Signals	8" Green	LED	Incandescent	3767	9	69	266
Round Signals	12" Green	LED	Incandescent	3767	12	150	520
Turn Arrows	8" Yellow	LED	Incandescent	701	7	116	76
Turn Arrows	12" Yellow	LED	Incandescent	701	9	116	75
Turn Arrows	8" Green	LED	Incandescent	701	7	116	76
Turn Arrows	12" Green	LED	Incandescent	701	7	116	76
Pedestrian Sign	12" Hand/Man	LED	Incandescent	8766	8	116	946

Reference specifications for above traffic signal wattages are from the following manufacturers:

1. 8" Incandescent traffic signal bulb: General Electric Traffic Signal Model 17325-69A21/TS
2. 12" Incandescent traffic signal bulb: General Electric Signal Model 35327-150PAR46/TS
3. Incandescent Arrows & Hand/Man Pedestrian Signs: General Electric Traffic Signal Model 19010-116A21/TS
4. 8" and 12" LED traffic signals: Leotek Models TSL-ES08 and TSL-ES12
5. 8" LED Yellow Arrow: General Electric Model DR4-YTA2-01A
6. 8" LED Green Arrow: General Electric Model DR4-GCA2-01A
7. 12" LED Yellow Arrow: Dialight Model 431-3334-001X
8. 12: LED Green Arrow: Dialight Model 432-2324-001X
9. LED Hand/Man Pedestrian Sign: Dialight 430-6450-001X

MEASURE CODE: CI-LTG-LEDT-V01-120601

[593] Technical Reference Manual for Pennsylvania Act 129 Energy Efficiency and Conservation Program and Act 213 Alternative Energy Portfolio Standards. Pennsylvania Public Utility Commission. May 2009
[594] Technical Reference Manual for Ohio, August 6, 2010