## REFERENCE SECTION

**Calculation of Savings**

Savings from programmable thermostats can be difficult to estimate from analytical methods due to the significant behavioral interactions in both the initial programming and the year-over year operation. Studies that evaluate the savings impacts of programmable thermostats vary, but there is considerable and credible regard for the findings of a 2007 study[321] that incorporated large sample sizes of survey response and billing analyses.

**Energy Savings**

n/a

**Summer Coincident Peak Demand Savings**

n/a

**Fossil Fuel Impact Descriptions and Calculation**

| | | |
|---|---|---|
| Average Savings | ΔMMBtu | = (Savings %) x (Annual Home Heating Load[322]) |
| | | = 6.8% x (71.2 MMBtu) |
| | | = 4.8 MMBtu |

**Water Impact Descriptions and Calculation**

n/a

**Deemed O&M Cost Adjustment Calculation**

n/a

**Version Date & Revision History**

| | |
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[321] 2007, RLW Analytics, "Validating the Impact of Programmable Thermostats"

[322] The value used here, 712 therms, is based on personal communication with Michael Blasnik, consultant to Columbia gas in May 2010, and derived from a billing analysis of approximately 600,000 Columbia Gas residential single family customers in Ohio.

## Condensing Furnaces-Residential (Time of Sale)

**Official Measure Code (Measure Number:** X-X-X-X (Program name, End Use)

**Description**
New ENERGY STAR-qualified high efficiency gas-fired condensing furnace for residential space heating. High efficiency features may include improved heat exchangers and modulating multi-stage burners.

**Definition of Efficient Equipment**
Furnace AFUE rating ≥ 90% and less than 225,000 BTUh input energy.

**Definition of Baseline Equipment**
Federal baseline for furnaces is 78%. Review of GAMA shipment data indicates a more suitable market baseline is 80% AFUE. The baseline unit is non-condensing. Early retirement programs the

**Deemed Savings for this Measure**

$$\Delta MMBtu = 712 * BtuH * (1 - AFUE_{BASE}/AFUE_{EFF}) * 10^{-6}$$

**Deemed Lifetime of Efficient Equipment**
The lifetime of this measure is estimated to be 15 years.[323]

**Deemed Measure Cost**
The incremental measure cost, based on material cost alone[324], as labor is comparable to baseline, shall be related to AFUE of the unit[325]:

| AFUE, % | Incremental Cost |
|---|---|
| 90 | $310 |
| 92 | $477 |
| 94 | $657 |
| 96 | $851 |

**Deemed O&M Cost Adjustments**
n/a

**Coincidence Factor**
n/a

**REFERENCE SECTION**

**Calculation of Savings**
Savings are calculated using the difference in required gas based upon the efficiency of the furnace and the average annual heating load for Ohio Residences. No change in the distribution system efficiency including fan motor is assumed.

**Electrical Energy Savings**
n/a

**Summer Coincident Peak Demand Savings**
n/a

[323] http://www.cee1.org/resrc/facts/gs-ht-fx.pdf
[324] CA DEER Database Res-HVAC
[325] http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf

**Fossil Fuel Impact Descriptions and Calculation**

$\Delta MMBtu = FLH_{HEAT} * BtuH * (1 - AFUE_{BASE}/AFUE_{EFF}) * 10^{-6}$

$FLH_{HEAT}$ = Equivalent Full Load Heating Hours
= 712[326]

BtuH = Size of equipment in Btuh
= Actual installed

$AFUE_{BASE}$ = Annual Fuel Utilization Efficiency % for the baseline equipment
= 0.80

$AFUE_{EFF}$ = Annual Fuel Utilization Efficiency % for the efficient equipment
= Actual installed

For example: savings for a furnace rated at 96 AFUE

$\Delta MMBtu = 712 * 100{,}000 * (1 - 0.80/0.96) * 10^{-6}$
= 11.9

**Water Impact Descriptions and Calculation**

n/a

**Deemed O&M Cost Adjustment Calculation**

n/a

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[326] Calculated based upon typical annual home heating load of 712 therms (based on personal communication with Michael Blasnik. Full load hours were determined assuming an average unit capacity of 100,000 BtuH. Actual program data should be compared against this assumed 100,000Btuh value and FLH may be adjusted as a result.

# Boilers (Time of Sale)

**Official Measure Code (Measure Number: X-X-X-X (Program name, End Use)**

**Description**
New energy star-qualified high efficiency gas-fired boiler for residential space heating

**Definition of Efficient Equipment**
Boiler AFUE rating ≥ 85% less than 300,000 BTUh energy input.

**Definition of Baseline Equipment**
Federal baseline AFUE for boilers is 80 %

**Deemed Savings for this Measure**

$$\Delta MMBtu = 712 * BtuH * (1 - AFUE_{BASE} / AFUE_{EFF}) * 10^{-6}$$

**Deemed Lifetime of Efficient Equipment**
The lifetime of this measure is 18 years[327].

**Deemed Measure Cost**
The incremental measure cost, based on material and installation costs are a function of the AFUE of the unit:[328]

| AFUE | Incremental Cost |
|---|---|
| 85-90 | $ 216 |
| ≥91 | $ 422 |

**Deemed O&M Cost Adjustments**
n/a

**Coincidence Factor**
n/a

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**REFERENCE SECTION**

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**Calculation of Savings**
Savings are calculated using the difference in required gas based upon the efficiency of the boiler and the average annual heating load for Ohio Residences. No changes in the distribution system efficiency including blower motor are assumed.

**Electrical Energy Savings**
n/a

**Summer Coincident Peak Demand Savings**
n/a

**Fossil Fuel Impact Descriptions and Calculation**

$$\Delta MMBtu = FLH_{HEAT} * BtuH * (1- AFUE_{BASE}/AFUE_{EFF}) * 10^{-6}$$

$FLH_{HEAT}$ = Equivalent Full Load Heating Hours
= 712[329]

[327] http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf
[328] http://www1.eere.energy.gov/buildings/appliance_standards/residential/fb_tsd_0907.html values for 85-90

| | |
|---|---|
| BtuH | = Size of equipment in Btuh<br>= Actual installed |
| $AFUE_{BASE}$ | = Annual Fuel Utilization Efficiency % for the baseline equipment<br>= 0.80 |
| $AFUE_{EFF}$ | = Annual Fuel Utilization Efficiency % for the efficient equipment<br>= Actual installed |

*For example:* savings for a boiler rated at AFUE 85%

$\Delta MMBtu = 712 * 100{,}000 * (1 - 0.80/0.85) * 10^{-6}$
$= 4.2$

**Water Impact Descriptions and Calculation**
n/a

**Deemed O&M Cost Adjustment Calculation**
n/a

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[329] Calculated based upon typical annual home heating load of 712 therms, unit capacity of 100,000 BtuH. Actual program data should be compared against this assumed 100,000Btuh value and FLH may be adjusted as a result.

## Water Heater Wrap (Direct Install)

**Official Measure Code (Measure Number: X-X-X-X (Program name, End Use)**

**Description**
This measure relates to a Tank Wrap or insulation "blanket" that is wrapped around the outside of a hot water tank to reduce stand-by losses. This measure applies only for homes that have an electric water heater that is not already well insulated. Generally this can be determined based upon the appearance of the tank[330]

**Definition of Efficient Equipment**
The measure is a properly installed insulating tank wrap to reduce standby energy losses from the tank to the surrounding ambient area.

**Definition of Baseline Equipment**
The baseline is a standard electric domestic hot water tank without an additional tank wrap. Gas storage water heaters are excluded due to the limitations of retrofit wrapping and the associated impacts on reduced savings and safety.

**Deemed Savings for this Measure**

| | Average Annual KWH Savings per unit | Average Summer Coincident Peak kW Savings per unit | Average Annual Fossil Fuel heating fuel savings (MMBTU) per unit | Average Annual Water savings per unit |
|---|---|---|---|---|
| Residential | 79 | 0.009 | 0 | 0 |

**Deemed Lifetime of Efficient Equipment**
The measure life is assumed to be 5 years [331].

**Deemed Measure Cost**
The incremental cost for this measure will be the actual material cost of procuring and labor cost of installing the tank wrap.

**Deemed O&M Cost Adjustments**
n/a

**Coincidence Factor**
This measure assumes a flat loadshape and as such the coincidence factor is 1.

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**REFERENCE SECTION**

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**Calculation of Savings**
This calculation relies upon the findings that a poorly insulated electric resistance water heater with a pre-wrap EF of 0.86 has a new and more effective EF of 0.88 after properly wrapped with supplemental insulation.[332]

**Energy Savings**

$$\Delta kWH = kWHbase * ((EFnew - EFbase)/EFnew)$$

*Where:*

[330] Generally this can be determined by the appearance of the tank and whether it is insulated by foam (newer, rigid, and more effective) or fiberglass (older, gives to gently pressure, and not as effective)
[331] This estimate assumes the tank wrap is installed on an existing unit with 5 years remaining life. On average when retrofitting an existing tank, the tanks would be roughly halfway through their 13-15 year life, but because the qualifying baseline tanks with fiberglass rather than foam insulation are older (we could not find any that are currently for sale) then we anticipate actual remaining life to be so if they have a measure life it would be lower by a few years.
[332] Impacts of waste heat on heating and cooling savings are not included in this characterization.

| | |
|---|---|
| $kWHB_{ase}$ | = Average kWH consumption of electric domestic hot water tank<br>= 3460 [333] |
| EFnew | = Assumed efficiency of electric tank with tank wrap installed<br>= 0.88 [334] |
| EFbase | = Assumed efficiency of electric tank without tank wrap installed<br>= 0.86 Error! Bookmark not defined. |

So:

$$\Delta kWH = 3460 * ((0.88-0.86)/0.88)$$

$$= 79 \text{ kWH}$$

**Summer Coincident Peak Demand Savings**

$$\Delta kW = \Delta kWh/8760$$

*Where:*

ΔkWH = kWH savings from tank wrap installation
8760 = Number of hours in a year (since savings are assumed to be constant over year).

$$\Delta kW = 79 / 8760$$

$$= 0.0090 \text{ kW}$$

**Fossil Fuel Impact Descriptions and Calculation**
n/a

**Water Impact Descriptions and Calculation**
n/a

**Deemed O&M Cost Adjustment Calculation**
n/a

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[333] Assumption taken from; Residential Water Heaters Technical Support Document for the January 17, 2001, Final Rule Table 9.3.9, p9-34, http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/09.pdf
Consistent with FEMP study; Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters http://www1.eere.energy.gov/femp/pdfs/tir_heatpump.pdf
[334] The Oak Ridge study predicted that wrapping a 40 gal water heater would increase Energy Factor of a 0.86 electric DHW tank by 0.02 (to 0.88);
"Meeting the Challenge: The Prospect of Achieving 30 percent Energy Savings Through the Weatherization Assistance Program" by the Oak Ridge National Laboratory - May 2002. http://www.cee1.org/eval/db_pdf/309.pdf

# Solar Water Heater with Electric Backup (Retrofit)

**Official Measure Code (Measure Number: X-X-X-X (Program name, End Use)**

**Description**
This measure relates to the installation of a new solar water heater system with electric backup meeting SRCC OG-300 performance standards presented below. This measure will relate to the installation of a new system in an existing home.

**Definition of Efficient Equipment**
In order for this characterization to apply, the efficient equipment is assumed to be a SRCC OG-300 certified Solar Water Heater with a solar energy factor (SEF) meeting the ENERGY STAR specification.

**Definition of Baseline Equipment**
In order for this characterization to apply, the baseline equipment is assumed to be a standard electric water heater meeting or exceeding the minimum energy factor set in the 2004 federal conservation standard for water heaters.

**Deemed Calculation for this Measure**

Annual kWh Savings = $(1/EF - 1/SEF) * Q_{DEL}$

Annual kW Savings = $(1/EF * Q_{DEL}) / Hours * CF$

**Deemed Lifetime of Efficient Equipment**
The expected measure life is assumed to be 20 years [335].

**Deemed Measure Cost**
The cost for this measure is $9,506[336].

**Deemed O&M Cost Adjustments**
$344[337]

**Coincidence Factor**
The summer peak coincidence factor for this measure is assumed to be 20%[338].

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**REFERENCE SECTION**

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**Calculation of Savings**

**Energy Savings**

$$\Delta kWH = (1/EF - 1/SEF) * Q_{DEL}$$

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[335] Based on ENERGY STAR Residential Water Heaters, Final Criteria Analysis: http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/WaterHeaterDraftCriteriaAnalysis.pdf

[336] The average cost of a fully installed solar thermal system was $9,506, and ranged between $6,825 and $11,850. Source: http://www.greenenergyohio.org/page.cfm?pageID=2712

[337] NPV of future costs including: glycol, pump, and tank replacement. Source: Appendix 2 APS-Incentives for Photovoltaic Distributed Generation (VEIC 2010). Because this retrofit measure replaces an existing water tank with some years remaining, this NPV conservatively overstates the O&M costs to the degree that existing tank would have required replacement a few years earlier.

[338] Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York.

Where:

| | |
|---|---|
| EF | = Minimum energy factor for residential electric water heater[339] |
| | = 0.97—(0.00132 × Rated Storage Volume in gallons) |
| | = 0.904 (50 gallon residential tank) |
| SEF | = Minimum system performance for solar water heaters[340] |
| | = Actual installed |
| $Q_{DEL}$ | = Energy delivered to the hot water load[341] |
| | = 64.3 gal/day * 77 degF * 8.3 BTU/lb-degF |
| | = 41,094 BTU/day |
| | = 4,395 kWh/year[342] |

For example, a solar water heater system with SEF rating of 1.8:

ΔkWH = (1/0.9 - 1/1.8) * 4,395 kWh/year
= 2461 kWh

**Summer Coincident Peak Demand Savings**

ΔkW = (1/EF * $Q_{DEL}$) / Hours * CF

Where:

| | |
|---|---|
| Hours | = Full load hours of water heater |
| | = 2533 [343] |
| CF | = Summer Peak Coincidence Factor for measure |
| | = 0.203 [344] |

ΔkW = (1/0.9 * 4,395) / 2533 * 0.203
= 0.39 kW[345]

**Fossil Fuel Impact Descriptions and Calculation**
n/a

**Water Impact Descriptions and Calculation**
n/a

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339 2004 Federal Energy Conservation Standard for water heaters

340 Based on Solar Rating and Certification Company (SRCC) annual system performance rating for solar water heaters (OG-300 7/28/2010). ENERGY STAR specifications require a solar fraction greater than 0.5, which equates to a minimum solar energy factor (SEF) of 1.8.

341 Based on DOE and Solar Rating and Certification Company (SRCC) test procedure assumptions of 64.3 gallons per day draw, 135 deg F hot water and 58 deg F cold water supply temperatures.

342 This baseline level of consumption is higher than the average baseline electrical usage for residential hot water heating (3,460kWh) but less than the consumption level indicated by following the DOE water heating standard test procedure formula: (12.03/EF) x 365 = 4,857kWh. These systems are generally installed in homes with higher usage and correlates with household size and income, and so the calculated value seems appropriate in this light.

343 Full load hours assumption based on Efficiency Vermont loadshape, calculated from Itron eShapes.

344 Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York.

345 The resultant demand reduction from the Itron eShapes is consistent with the results of the ADM whitepaper for FirstEnergy's solar water heater program in Pennsylvania, in which the demand reduction assumes that the system is designed to meet 100% of a home's hot water need during the summer months and is the product of two factors, the annual baseline energy usage of an electric water heater and the fraction of energy usage during the coincident peak times of 3-6PM during the months of June thru August. The fractional usage was calculated from PJM Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. http://www.pjm.com/~/media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx

**Deemed O&M Cost Adjustment Calculation**
n/a

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## Residential New Construction

**Official Measure Code (Measure Number: X-X-X-X (Program name, End Use)**

**Description**
This Residential New Construction (RNC) protocol describes the methodology by which program administrators shall calculate energy and demand savings for new homes built in Ohio. Accredited Home Energy Rating System (HERS) software that complies with the Mortgage Industry National Home Energy Rating Systems Accreditation Standards developed by the Residential Energy Services Network (RESNET) shall be used to calculate energy and demand savings. Likewise, Home Energy Raters (Raters) will follow the technical guidelines provided in the Mortgage Industry National Home Energy Rating Standards when conducting a Rating.

Energy and demand savings shall be estimated per home for heating, cooling, hot water, lighting, ceiling fans, and appliances, including refrigerators and dishwashers. To avoid double-counting of savings, products included in RNC savings should not also be included for savings under another program. However, savings for efficient products installed in the home other than those listed above and that are not claimed through the RNC program may be captured through another program.

**Definition of Efficient and Baseline Cases**
The following assumptions underlie this methodology:

1. Program implementers are using REM/Rate™ to conduct HERS ratings on each efficient new home built (the Rated Home).
2. Program administrators will employ the User Defined Reference Home (UDRH) feature provided in REM/Rate™ to estimate savings.

The UDRH feature allows energy consumption to be compared for a Rated Home and a User Defined Reference Home (UDRH). The UDRH is an exact replica of the Rated home in size, structure, and climate zone, but the energy characteristics are defined by local code or building practices. Until such a time as a formal study characterizing baseline building practices is completed for Ohio, the UDRH shall be defined by the Residential Energy Efficiency section of the prevailing Ohio Building Code. As of January, 2009 the Ohio Building Code is based on the 2006 International Energy Conservation Code (IECC). Section 0 provides the energy related requirements of the 2006 IECC that shall be used to create the UDRH.

While the assumption is that the HERS software employed by program implementers will be REM/Rate™, any RESNET approved software program may be used. For recommendations on estimating savings using a rating tool other than REM/Rate™, see section titled Other Software (below).

**Definitions and Acronyms**
***HERS*** - Home Energy Rating System

***HERS Provider*** - A firm or organization that develops, manages, and operates a home energy rating system and is currently accredited by RESNET

***Home Energy Rater or Rater*** – The person trained and certified by a HERS Provider to perform the functions of inspecting and analyzing a home to evaluate the minimum rated features and prepare an energy efficiency rating

***IECC*** - International Energy Conservation Code

***Rated Home*** - The specific home being evaluated using the rating procedures contained in the National Home Energy Rating Technical Guidelines

***Rating Tool*** - A procedure for calculating a home's energy efficiency rating, annual energy consumption, and annual energy costs and which is listed in the "National Registry of Accredited Rating Software Programs" as posted on the RESNET web site

***Reference Home*** - A hypothetical home configured in accordance with the specifications set forth in the National Home Energy Rating Technical Guidelines for the purpose of calculating rating scores

***REM/Rate™*** - RESNET approved residential energy analysis, code compliance and rating software supported by Architectural Energy Corporation, www.archenergy.com

***RNC*** - Residential New Construction

***RESNET*** - Residential Energy Services Network, the national standards making body for building energy efficiency rating system, www.resnet.us

***UDRH*** - *User Defined Reference Home* is a feature of REM/Rate™ that enables the HERS provider to create other reference buildings based on local construction practice, local code etc. that can be compared to the rated home

**Calculation of Savings**

**Energy Savings**
Energy savings, including fossil fuel savings, for heating, cooling, hot water, lighting, and appliances noted above will be a direct output of REM/Rate™ (or other RESNET approved) energy modeling software. Energy savings shall be calculated on a per home basis by the following calculation:

Energy savings = UDRH energy consumption – Rated Home energy consumption

The UDRH shall be defined by the 2006 IECC, with some supplemental clarifications, and is provided in Table 3 in the section titled User Defined Reference Home (UDRH) Specifications below.

For RNC projects that participate through a RESNET-approved sampling protocol, energy savings shall be determined based on the savings from the model home, linearly adjusted based on floor area to all other homes included in that sample set. Chapter 6 of the RESNET Mortgage Industry National Home Energy Rating Standards provides technical guidelines on the sampling protocol.

**Demand Savings**
Electric demand savings for heating, cooling, hot water, lighting, and appliances are a direct output of REM/Rate™ (or other RESNET approved) energy modeling software. System peak electric demand savings shall be calculated on a per home basis by the following calculation:

Coincident system peak electric demand savings =

(UDRH electric demand – Rated Home electric demand) * CF

Where RNC programs enforce right-sizing of mechanical equipment, the following calculations shall be used:

Coincident system peak electric demand savings =

((UDRH electric demand * OF*UDRH* ) – (Rated Home electric demand * OF*r* )) * CF

Where:

CF = Coincidence factor which equates the installed HVAC system's demand to its demand at time of system peak

OF*UDRH* = Over-sizing factor for the HVAC unit in the UDRH home

$OF_r$ = Over-sizing factor for the HVAC unit in the Rated Home

Rated Home = Rated Home electric demand output from REM/Rate™

UDRH = User Defined Reference Home electric demand output from REM/Rate™

Table 1 provides a summary of the input values and their data sources.

**Table 1. Peak Demand Variable Definitions**

| Variable | Type | Value | Sources |
|---|---|---|---|
| $OF_{UDRH}$ | Fixed | 1.60 | PSE&G 1997 Residential New Construction baseline study. 2004 Long Island Power Authority Residential New Construction Technical Baseline Study values of 155% to 172% over-sizing confirms this value. |
| $OF_r$ | Fixed | 1.15 | Program guideline for rated home |
| CF | Fixed | 0.50 | Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p32 |

**Lighting and Appliances**
REM/Rate™ offers two input modes for Lights and Appliances: simplified and detailed. The simplified input mode, or "Lights & Appliances – HERS", is the default mode in REM/Rate™ and is used to calculate a HERS Index. The detailed input mode, or "Lights & Appliances – AUDIT", is used to capture additional lighting and appliance data. Since only the simplified input mode is used when calculating a HERS Index, the simplified mode shall be used when calculating energy and demand savings for RNC.

Energy and demand savings shall be estimated per home for heating, cooling, hot water, lighting, ceiling fans, and appliances, including refrigerators and dishwashers. To avoid double-counting of savings, products included in RNC savings should not also be included for savings under another program. However, savings for efficient products installed in the home other than those listed above and that are not claimed through the RNC program may be captured through another program.

**User Defined Reference Home (UDRH) Feature**
The UDRH feature in REM/Rate™ provides a home-by-home comparison of energy consumption against a user-defined reference home. REM/Rate™ modifies the thermal and energy performance features of the Rated Home to the specifications provided by the UDRH, leaving the building size, structure and climate zone the same as the Rated Home. The energy consumption of the Rated Home can then be compared to the energy consumption of the same home had it been built to different specifications.

The UDRH shall be defined by the Residential Energy Efficiency section of the prevailing Ohio Building Code. As of January, 2009 the Ohio Building Code is based on the 2006 International Energy Conservation Code (IECC). Therefore, energy and demand savings in Ohio will be based on the difference in estimated energy consumption of the program home, and that same home had it been built to 2006 (or any subsequently-updated) IECC specifications.

For REM/Rate™, the UDRH specifications are contained in an ASCII script file that follows a specific syntax. Details on creating a UDRH file can be found in the REM/Rate™ Help module. Inputs for a UDRH file based on 2006 IECC (with supplemental clarifications) can be found in Table 3 in the section titled User Defined Reference Home (UDRH) Specifications below.

A UDRH report may be run singly for each home, or in batch mode for multiple homes. Data from the UDRH report may also be exported from REM/Rate™ to an Access database for additional data manipulation and to calculate savings. Additional information on using the UDRH batch export feature can be found in the REM/Rate™ Help module.

**Ohio Climate Zones**
Climate zones from Figure 1 or Table 2 shall be used in determining the applicable energy requirements for the UDRH. Details of the UDRH are listed in Table 3.

**Figure 1. Ohio Climate Zones Map**


**Table 2. Ohio Climate Zones by County**

| OHIO |
|---|
| Zone 5 except Zone 4 |
| Adams |
| Brown |
| Clermont |
| Gallia |
| Hamilton |
| Lawrence |
| Pike |
| Scioto |
| Washington |

**User Defined Reference Home (UDRH) Specifications**
Table 3 below provides inputs for a UDRH based on the 2006 IECC, with some supplemental clarifications.

**Table 3. 2006 IECC UDRH Specifications**

| Data Point | Value | | Unit | Source | Comment |
|---|---|---|---|---|---|
| **Building Thermal Envelope** | | | | | |
| | *Zone 4* | *Zone 5* | | | |
| Fenestration | 0.40 | 0.35 | U-factor | 2006 IECC Table 402.1.3 | |
| Skylight | 0.60 | 0.60 | U-factor | 2006 IECC Table 402.1.3 | |
| Glazed Fenestration SHGC | 0.40 | 0.40 | SHGC | 2006 IECC Table 404.5.2(1) | No prescriptive requirement. |
| Ceiling | .030 | .030 | U-factor | 2006 IECC Table 402.1.3 | |
| Wood Frame Wall | .082 | .060 | U-factor | 2006 IECC Table 402.1.3 | |
| Rim and Band Joists | .082 | .060 | U-factor | | Code requirement for wood frame wall. |
| Mass Wall | .141 | .082 | U-factor | 2006 IECC Table 402.1.3 | |
| Frame Floor | .047 | .033 | U-factor | 2006 IECC Table 402.1.3 | |
| Basement Wall | .059 | .059 | U-factor | 2006 IECC Table 402.1.3 | |
| Slab, unheated | 10, 2 | 10, 2 | R-value, ft | 2006 IECC Table 402.1.1 | "ft" = feet from top of slab edge below grade. |
| Slab, heated | 15, 2 | 15, 2 | R-value, ft | 2006 IECC Table 402.1.1 | "ft" = feet from top of slab edge below grade. |
| Crawl Space Wall | .065 | .065 | U-factor | 2006 IECC Table 402.1.3 | |
| Air Infiltration Rate | .00036 | .00036 | SLA | 2006 IECC Table 404.5.2(1) | Approximately 7 to 8 ACH50. |
| **Mechanical Systems** | | | | | |
| Furnace | 80 | | AFUE | Federal Standard | Standard is 78 AFUE, 80 AFUE is adopted based on typical minimum availability and practice. |
| Boiler | 80 | | AFUE | Federal Standard | |
| Heat Pump, Heating | 7.7 | | HSPF | Federal Standard | All heat pumps shall be characterized as an ASHP. |
| Central Air Conditioning | 13 | | SEER | Federal Standard | |
| Heat Pump, Cooling | 13 | | SEER | Federal Standard | |
| Water Heating, gas | 0.58 | | EF | Federal Standard | Federal requirements vary based on tank size. The UDRH feature does not allow adjustments to efficiency values based on tank size, therefore the UDRH reference efficiency shall be based on minimum federal efficiency requirements for a 50 gal tank. |
| Water Heating, oil | 0.50 | | EF | Federal Standard | See Water Heating, gas. |
| Water heating, electric | 0.90 | | EF | Federal Standard | See Water Heating, gas. |

| Data Point | Value | Unit | Source | Comment |
|---|---|---|---|---|
| Integrated Space/Water Heating, heating | 80 | AFUE | Federal Standard, Boiler | Combination space and water heating units shall reference the minimum Federal standard boiler efficiency for the heating portion of the unit |
| Integrated Space/Water Heating, water | .58 (gas)<br>.50 (oil)<br>.90 (electric) | EF | Federal Standard, Water heating | Combination space and water heating units shall reference the minimum Federal standard water heating efficiency for the water heating portion of the unit. |
| Thermostat, type | Manual | | 2006 IECC Table 404.5.2(1) | |
| Thermostat, cooling set point | 78 | Degree F | 2006 IECC Table 404.5.2(1) | |
| Thermostat, heating set point | 68 | Degree F | 2006 IECC Table 404.5.2(1) | |
| Duct Insulation | 8 | R-value | 2006 IECC 403.2.1 | |
| Duct Insulation, in floor truss | 6 | R-Value | 2006 IECC 403.2.1 | |
| Duct Leakage | 0.80 | DSE | 2006 IECC Table 404.5.2(1) | |
| Mechanical Ventilation | n/a | | | Ventilation is not required by code. The UDRH shall not reference ventilation. This way the program home will see no energy savings or energy penalty from ventilation. |
| **Lights & Appliances** | | | | |
| Efficient Lighting | 10 | Percent | RESNET Standard | |
| Refrigerator | 585 | kWh/yr | VEIC | Based on the weighted average of NAECA baseline kWh/yr installed in Vermont, 5000 hr/yr. |
| Dishwasher | 0.46 | EF | RESNET Standard | |
| Ceiling Fan | None | | RESNET Standard | |

**Active Solar & Photovoltaics (PV)**

Solar systems installed for water and/or space heating and photovoltaic systems installed to meet electricity demand are not addressed in the 2006 IECC. However, they need to be addressed in the UDRH. If the RNC program allows for savings to be claimed from the use of active solar or PV systems, these systems should eliminated from the UDRH so that their savings shows up when compared to the rated home with the solar system installed.

If the RNC program does not allow savings to be claimed from the use of active solar or PV systems, these systems should not be included in the UDRH. When a system is not referenced in the UDRH, that system will be the same in both the Rated and the Reference home. This way, energy consumption for the Rated Home and the UDRH will be estimated assuming both configurations have the solar or PV system installed, so no savings will be reported. The specific syntax for this is provided in the REM/Rate™ UDRH Syntax Report.

**Other Software**

If the program implementer is using a RESNET approved software program other than REM/Rate™, where possible a module similar to the UDRH feature in REM/Rate™ shall be used to estimate energy and demand savings. If no such feature exists, the following steps shall be taken to estimate energy and demand savings:

1. Model the home in a RESNET approved software program and capture energy consumption and electric demand.
2. Model the same home a second time using the 2006 UDRH specifications provided in Table 3 and capture energy consumption and electric demand.
3. The difference between energy consumption in the Rated Home and the Rated Home modeled to 2006 IECC specifications shall be the energy savings for that home.
4. The difference between electric demand in the Rated Home and the Rated Home modeled to 2006 IECC specifications shall be the electric demand savings for that home.

Savings from lighting and appliances shall be estimated using the alternate RESNET approved software. Any appliances not captured by the alternate software program shall be captured by a program other than RNC.

**Deemed Lifetime of Efficient Building**

25 yr (for heating, cooling, and shell savings measures)[346]

**Deemed Measure Cost**

Incremental costs can be calculated for different tiers of efficient homes from the following table.

**Table 4. Incremental Costs from Baseline to Specific HERS Levels[347]**

| | ENERGY STAR Minimum (HERS 85)* | HERS 70 | HERS 65 |
|---|---|---|---|
| Single Family Home with Gas Furnace total and per square foot cost | $2,869<br>$1.18 | $7,136<br>$2.94 | $9,286<br>$3.83 |
| Single Family Home with Gas Boiler total and per square foot cost | $2,646<br>$1.09 | $6,570<br>$2.71 | $8,160<br>$3.36 |
| Single Family Home with Oil Boiler total and per square foot cost | $2,371<br>$0.98 | $6,325<br>$2.61 | $7,914<br>$3.26 |
| Average for all single family total and per square foot cost | $2,599<br>$1.07 | $6,677<br>$2.75 | $8,453<br>$3.49 |

*Calculated as an average of the packages provided for each housing type/HVAC system combination

**Deemed O&M Cost Adjustments**

There are no operation and maintenance cost adjustments for this measure

**Fossil Fuel Impact Descriptions and Calculation**

Energy savings, including fossil fuel savings, for heating, cooling, hot water, lighting, and appliances noted above will be a direct output of REM/Rate™ (or other RESNET approved) energy modeling software as described above

**Water Impact Descriptions and Calculation**

n/a

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[346] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007; http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

[347] Evaluation of the Massachusetts New Homes with Energy Star® Program, Incremental Cost Analysis Nexus Market Research, Inc. and Dorothy Conant, Nov. 2007

**Version Date & Revision History**

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# Whole-House Residential Retrofit

**Official Measure Code** (Measure Number: X-X-X-X (Program name, End Use)

**Description**
Whole house retrofit programs, like Home Performance with ENERGY STAR and Low Income Weatherization initiatives, may include a variety of treatments, including building shell and HVAC upgrades and the direct installation of energy efficient products. This protocol describes how building energy modeling of each individual home treated through a program may be used to estimate savings for the building shell (e.g., air-sealing and insulation) and HVAC (e.g., duct sealing and central heating and/or cooling system replacements) measures installed in those homes. Savings from other measures such as efficient lighting, appliances, or water heating should be estimated using deemed values or deemed calculations provided for such measures elsewhere in this TRM.

The alternative to using building energy modeling to develop energy savings for the shell and HVAC measures would be to use the deemed measure savings calculations found elsewhere in this TRM for the installed measures (air-sealing, insulation, duct sealing, etc.). Deemed savings calculations are simpler to administer and implement but may be less precise because they are based on some assumed average characteristics of homes (e.g., average heating system efficiencies) and do not capture interactive effects between some measures.

**Definition of Efficient Case**
House as treated by installed building shell and HVAC measures. Installed measures outside of these categories should follow the appropriate measure-specific characterizations.

**Definition of Baseline Case**
The baseline is the house as it is before it is retrofitted with installed measures. The only exception to this rule is that the assumed baseline efficiency of a heating system or central air conditioner that is being replaced should be consistent with the current minimum federal efficiency standards for such equipment, unless it is clear that the equipment would not have been replaced at that particular point in time were it not for the influence of the program (i.e., the program must document that old equipment would otherwise not have been replaced in order to claim a baseline efficiency that is lower than current minimum federal efficiency standards).

**Calculation of Savings**
The requirements for a model-based approach to savings claims are in part are delineated through adherence with at least one of the following national standards for whole-house savings calculations:

- RESNET[348] approved rating software
- Software energy simulation performance exceeding the requirements of National Renewable Energy Laboratory's Home Energy Rating System BESTEST[349]
- US DOE Weatherization Assistance Program approval[350]

Proper savings estimates from modeling software also require that the R-value of uninsulated walls or ceilings (i.e., baseline conditions) should be modeled as being no less than R-5. In addition, software tools must be calibrated against actual consumption data for each treated home or from a sample sized for 90% confidence interval and 10% margin of error statistical precision. These requirements address concerns that modeling software can over-estimates savings, particularly cooling savings.

The software tools must provide outputs that separately account for heating and cooling energy savings so

[348] http://resnet.us
[349] http://www.nrel.gov/docs/legosti/fy96/7332b.pdf
[350] http://www.waptec.org

that demand and fuel-related economic savings may be properly addressed.

**Summer Coincident Peak Demand Savings**

Cooling only:

$\Delta kW = \Delta kWh_{COOL} / FLH_{COOL} * CF$

where:

$FLH_{COOL}$ = Full load cooling hours, dependent on location as below:

| Location | Run Hours[351] |
|---|---|
| Akron | 476 |
| Cincinnati | 664 |
| Cleveland | 426 |
| Columbus | 552 |
| Dayton | 631 |
| Mansfield | 474 |
| Toledo | 433 |
| Youngstown | 369 |

CF = Summer Peak Coincidence Factor for measure
= 0.5[352]

For example if the cooling savings output from the software tool for a home in Toledo is 350kWh then:

$\Delta kW = \Delta kWh / FLHcool * CF$
$= 350 / 433 * 0.5$
$= 0.404$ kW

**Deemed Lifetime of Efficient Case**
The average savings-weighted lifetime for this measure is assumed to be 20 years, based upon an anticipated mixture of shell and HVAC measures that range from 15 to 25 years.[353]

**Deemed Measure Cost**
The total of the actual costs in procuring and installing the equipment, materials, and/or services

**Deemed O&M Cost Adjustments**
n/a

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[351] Based on Full Load Hour assumptions taken from the ENERGY STAR calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) and reduced by 33% due to assumption that the average air conditioning is oversized by 50% (Neme, Proctor, Nadal, 1999; "National Energy Savings Potential From Addressing Residential HVAC Installation Problems"). Note this approach results in full load hour estimates within 10% of measured estimates from the Energy Center of Wisconsin, May 2008 study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."

[352] Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p32

[353] A review of actual measures installed through the program should be conducted to assess whether on a savings basis the weighted average should be adjusted in accordance with a measure distribution that favors longer (insulation) or shorter (air sealing) lifetimes.

# III. Commercial & Industrial Market Sector

## Electric Chiller (Time of Sale)

**Official Measure Code** (Measure Number: X-X-X-X (Program name, End Use)

**Description**
This measure relates to the installation of a new electric chiller meeting the efficiency standards presented below. This measure could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in an existing building (i.e. time of sale). Only single-chiller applications should be assessed with this methodology. The characterization is not suited for multiple chillers projects or chillers equipped with variable speed drives (VSDs). Multiple chiller projects and chillers equipped with VSDs should be evaluated on a custom basis.

**Definition of Efficient Equipment**
In order for this characterization to apply, the efficient equipment is assumed to exceed the efficiency requirements of the 2006 International Energy Conservation Code, Table 503.2.3(7).

**Definition of Baseline Equipment**
In order for this characterization to apply, the baseline equipment is assumed to meet the efficiency requirements of the 2006 International Energy Conservation Code, Table 503.2.3(7).

**Deemed Calculation for this Measure**

Annual kWh Savings = TONS * ((3.516/IPLVbase) – (3.516/IPLVee)) * EFLH

Summer Coincident Peak kW Savings = TONS * ((3.516/COPbase) – (3.516/COPee)) * CF

**Deemed Lifetime of Efficient Equipment**
The expected measure life is assumed to be 20 years [354].

**Deemed Measure Cost**
The incremental capital cost for this measure is provided below.

| Equipment Type | Size Category | Incremental Cost ($/ton)[355] |
|---|---|---|
| Air cooled, electrically operated | All capacities | $127/ton[356] |
| Water cooled, electrically operated, positive displacement (reciprocating) | All capacities | $22/ton |
| Water cooled, electrically operated, positive displacement (rotary screw and scroll) | < 150 tons | $128/ton |
| | >= 150 tons and < 300 tons | $70/ton |
| | >= 300 tons | $48/ton |

[354] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008 (http://deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)
[355] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Cost Values and Summary Documentation", California Public Utilities Commission, December 16, 2008 (http://deeresources.com/deer0911planning/downloads/DEER2008_Costs_ValuesAndDocumentation_080530Rev1.zip )
[356] Calculated as the simple average of screw and reciprocating air-cooled chiller incremental costs from the reference noted in Footnote 355.

| Equipment Type | Size Category | Incremental Cost ($/ton)[355] |
|---|---|---|
| Water cooled, electrically operated, centrifugal | All capacities | $177/ton[357] |

**Deemed O&M Cost Adjustments**
n/a

**Coincidence Factor**
The summer peak coincidence factor for this measure is assumed to be 74%[358].

**REFERENCE SECTION**

**Calculation of Savings**

**Energy Savings**

$$\Delta kWH = TONS * ((3.516/IPLVbase) - (3.516/IPLVee)) * EFLH$$

Where:

TONS = chiller nominal cooling capacity in tons (note: 1 ton = 12,000 Btu/h)
= Actual installed

3.516 = conversion factor to express Integrated Part Load Value (IPLV) in terms of kW per ton

IPLVbase = efficiency of baseline equipment expressed as Integrated Part Load Value. Dependent on chiller type. See Table A in the Reference Tables section.

IPLVee[359] = efficiency of high efficiency equipment expressed as Integrated Part Load Value
= Actual installed

EFLH = equivalent full load hours
Dependent on location as below:

| System Type | EFLH by Location[360] | | | | | | |
|---|---|---|---|---|---|---|---|
| | Akron | Columbus | Cincinnati | Cleveland | Dayton | Mansfield | Toledo |
| CV reheat, no economizer | 2,866 | 2,633 | 2,940 | 2,762 | 3,063 | 2,960 | 2,743 |
| CV reheat, economizer | 793 | 941 | 955 | 932 | 976 | 921 | 859 |
| VAV reheat, economizer | 788 | 946 | 974 | 768 | 896 | 669 | 848 |

**Summer Coincident Peak Demand Savings**

$$\Delta kW = TONS * ((3.516/COPbase) - (3.516/COPee)) * CF$$

Where:

COPbase = efficiency of baseline equipment expressed as COP

[357] Calculated as the simple average of non-VSD water-cooled centrifugal chiller incremental costs from the reference noted in Footnote 355.
[358] Summer Peak Coincidence Factor has been preserved from the "Technical Reference Manual (TRM) for Ohio Senate Bill 221 Energy Efficiency and Conservation Program and 09-512-GE-UNC", October 15, 2009. This is likely a conservative estimate, but is recommended for further study.
[359] Integrated Part Load Value is simply a seasonal average efficiency rating calculated in accordance with ARI Standard 550/590. It may be calculated using any measure of efficiency (EER, kW/ton, COP), but for consistency with IECC 2006, it is expressed in terms of COP here.
[360] Cooling EFLHs have been preserved from the "Technical Reference Manual (TRM) for Ohio Senate Bill 221 Energy Efficiency and Conservation Program and 09-512-GE-UNC", October 15, 2009. These appear reasonable, but are recommended for further study.

Dependent on chiller type. See Table A in the Reference Tables section.

| | |
|---|---|
| COPee | = efficiency of high efficiency equipment expressed as COP<br>= Actual installed |
| CF | = Summer Peak Coincidence Factor for measure<br>= 74% |

**Fossil Fuel Impact Descriptions and Calculation**
n/a

**Water Impact Descriptions and Calculation**
n/a

**Deemed O&M Cost Adjustment Calculation**
n/a

**Reference Tables**

**Table A: Baseline Efficiency Values by Chiller Type and Capacity**[361]

| Equipment Type | Size Category | Baseline Efficiency (IPLVbase, COPbase) |
|---|---|---|
| Air cooled, with condenser, electrically operated | < 150 tons | 2.80 IPLV, 2.80 COP |
| | >= 150 tons | 2.50 IPLV, 2.50 COP |
| Air cooled, without condenser, electrically operated | All capacities | 3.10 IPLV, 3.10 COP |
| Water cooled, electrically operated, positive displacement (reciprocating) | All capacities | 4.65 IPLV, 4.20 COP |
| Water cooled, electrically operated, positive displacement (rotary screw and scroll) | < 150 tons | 4.50 IPLV, 4.45 COP |
| | >= 150 tons and < 300 tons | 4.95 IPLV, 4.90 COP |
| | >= 300 tons | 5.60 IPLV, 5.50 COP |
| Water cooled, electrically operated, centrifugal | < 150 tons | 5.00 IPLV, 5.00 COP |
| | >= 150 tons and < 300 tons | 5.55 IPLV, 5.55 COP |
| | >= 300 tons | 6.10 IPLV, 6.10 COP |

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[361] 2006 International Energy Conservation Code, International Code Council, Inc., January 2006.

# C&I Lighting Controls (Time of Sale, Retrofit)

**Official Measure Code (Measure Number: X-X-X-X (Program name, End Use)**

**Description**
This measure relates to the installation of a new lighting control on a new or existing lighting system. Lighting control types covered by this measure include wall- or ceiling-mounted occupancy sensors, fixture mounted occupancy sensors, remote-mounted daylight dimming sensors, fixture mounted daylight dimming sensors, central lighting controls (timeclocks), and switching controls for multi-level lighting. This measure could relate to the installation of a new system in an existing building or a new construction application (i.e., time of sale). Lighting controls required by state energy codes are not eligible.

**Definition of Efficient Equipment**
In order for this characterization to apply, the efficient equipment is assumed to be a lighting system controlled by one of the lighting controls systems listed above.

**Definition of Baseline Equipment**
The baseline equipment is assumed to be an uncontrolled lighting systems operated by a manual switch.

**Deemed Calculation for this Measure**

Annual kWh Savings = kWcontrolled * HOURS * (1 + IFkWh) * ESF

Summer Coincident Peak kW Savings = kWcontrolled * (1 + IFkW) * ESF * CF

**Deemed Lifetime of Efficient Equipment**
The expected measure life for all lighting controls is assumed to be 8 years [362].

**Deemed Measure Cost**
The incremental capital cost for this measure is provided below.

| Lighting Control Type | Incremental Cost |
|---|---|
| Wall-Mounted Occupancy Sensors | $42[363] |
| Ceiling-Mounted Occupancy Sensors | $66[364] |
| Fixture Mounted Occupancy Sensors | $125[365] |
| Remote-Mounted Daylight Dimming Sensors | $65[366] |
| Fixture Mounted Daylight Dimming Sensors | $50[367] |
| Switching Controls for Multi-Level Lighting | $274[368] |
| Central Lighting Controls (Timeclocks) | $103[369] |

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362 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008 (http://deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)
363 Goldberg et al, State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs: Incremental Cost Study, KEMA, October 28, 2009.
364 Ibid.
365 Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010.
366 Ibid.
367 Ibid.
368 Goldberg et al, State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs: Incremental Cost Study, KEMA, October 28, 2009.
369 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Cost Values and Summary Documentation", California Public Utilities Commission, December 16, 2008

**Deemed O&M Cost Adjustments**
n/a

**Coincidence Factor**
The summer peak coincidence factor for this measure is dependent on technology type as below:

| Lighting Control Type | CF |
|---|---|
| Wall- or Ceiling-Mounted Occupancy Sensors | 0.15[370] |
| Fixture-Mounted Occupancy Sensors | 0.15[371] |
| Remote-Mounted Daylight Dimming Sensors | 0.90[372] |
| Fixture-Mounted Daylight Dimming Sensors | 0.90[373] |
| Switching Controls for Multi-Level Lighting | 0.77[374] |
| Central Lighting Controls (Timeclocks) | 0.00[375] |

## REFERENCE SECTION

**Calculation of Savings**

**Energy Savings**

$$\Delta kWh = kWcontrolled * HOURS * (1 + IFkWh) * ESF$$

Where:

kWcontrolled = total lighting load connected to the control in kilowatts
= Actual installed

HOURS = total operating hours of the controlled lighting before the lighting controls are installed. If actual site-specific value is unknown, assume default values dependent on building type as below:

| Building Type | HOURS[376] |
|---|---|
| Food Sales | 5,544 |
| Food Service | 4,482 |
| Health Care | 3,677 |
| Hotel/Motel | 3,356 |
| Office | 3,526 |
| Public Assembly | 2,729 |
| Public Services (non-food) | 3,425 |
| Retail | 4,226 |
| Warehouse | 3,464 |
| School | 2,302 |

(http://deeresources.com/deer0911planning/downloads/DEER2008_Costs_ValuesAndDocumentation_080530Rev1.zip)

370 Coincidence Factor Study Residential and Commercial Industrial Lighting Measures, RLW Analytics, Spring 2007.
371 Ibid.
372 Kuiken et al, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, KEMA, March 22, 2010.
373 Ibid.
374 Ibid.
375 Conservative assumption based on professional judgment considering that timeclocks are unlikely to produce significant savings during the summer on-peak period.
376 Kuiken et al, "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Parameter Development", KEMA, November 13, 2009, unless otherwise noted.

| Building Type | HOURS[376] |
|---|---|
| College | 3,900 |
| Industrial – 1 Shift | 2,857[377] |
| Industrial – 2 Shift | 4,730[378] |
| Industrial – 3 Shift | 6,631[379] |
| Exterior | 3,833[380] |
| Other | 3,672 |

IFkWh = lighting-HVAC Interation Factor for energy; this factor represents the reduced electric space cooling requirements due to the reduction on waste heat rejected by the efficent lighting.
= 0.095 (interior fixtures), 0.000 (exterior fixtures)[381]

ESF = Energy Savings Factor; percent operating hours reduced due to the installation of the occupancy lighting controls or timeclocks, or percent wattage reduction multiplied by the hours of dimming for dimming lighting controls and multilevel switching.
Dependent on control type as below:

| Lighting Control Type | ESF[382] |
|---|---|
| Wall- or Ceiling-Mounted Occupancy Sensors | 30% |
| Fixture-Mounted Occupancy Sensors | 30% |
| Remote-Mounted Daylight Dimming Sensors | 30% |
| Fixture-Mounted Daylight Dimming Sensors | 30% |
| Switching Controls for Multi-Level Lighting | 30% |
| Central Lighting Controls (Timeclocks) | 10% |

**Summer Coincident Peak Demand Savings**

$\Delta kW$ = kWconnected * (1 + IFkW) * ESF * CF

Where:

IFkW = lighting-HVAC Interation Factor for demand; this factor represents the reduced electric space cooling requirements due to the reduction on waste heat rejected by the efficent lighting.
= 0.200 (interior fixtures), 0.000 (exterior fixtures)[383]

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[377] UI and CL&P Program Savings Documentation for 2010 Program Year, United Illuminating Company, September 2009.
[378] Ibid.
[379] Ibid.
[380] Exterior lighting 3,833 hours per year assumes 10.5 hours per day; typical average for photocell control.
[381] Interactive factor data based on a series of prototypical small commercial building simulation runs. Values shown are weighted averages across fast food restaurant, full service restaurant, assembly, big box retail, small retail, small office, light industrial and school building models. The prototypes are based on the California DEER study prototypes, modified for local construction practices. Simulations were run using TMY3 weather data for the following Ohio cities: Cincinnati, Cleveland, Columbus and Dayton. Building prototypes used in the energy modeling are described in Appendix A - Prototypical Building Energy Simulation Model Development.
[382] Energy Savings Factors determined from a review of Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010, New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs, TecMarket Works, September 1, 2009, Goldberg et al, State of Wisconsin Public Service Commission of Wisconsin, Kuiken et al, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, KEMA, March 22, 2010.
[383] Interactive factor data based on a series of prototypical small commercial building simulation runs. Values shown are weighted averages across fast food restaurant, full service restaurant, assembly, big box retail, small retail, small office, light industrial and school building models. The prototypes are based on the California DEER study prototypes, modified for local construction practices. Simulations were run using TMY3 weather data for the following Ohio

CF = Summer Peak Coincidence Factor for measure
Dependent on control type as presented in the introductory "Coincidence Factor" section.

**Fossil Fuel Impact Descriptions and Calculation**

$$\Delta MMBtu = \Delta kWh * IF_{MMBtu}$$

Where:

$IF_{MMBtu}$ = 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.
= -0.0028 (interior fixtures), 0.0000 (exterior fixtures) [384]

**Water Impact Descriptions and Calculation**
n/a

**Deemed O&M Cost Adjustment Calculation**
n/a

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cities: Cincinnati, Cleveland, Columbus and Dayton. Building prototypes used in the energy modeling are described in Appendix A - Prototypical Building Energy Simulation Model Development.
[384] Ibid.

## Lighting Systems (Non-Controls) (Time of Sale, New Construction)

**Official Measure Code (Measure Number: X-X-X-X (Program name, End Use)**

**Description**
This measure relates to the installation of new lighting equipment with efficiency that exceeds that of equipment that would have been installed following standard market practices. This characterization includes compact fluorescent lamps (CFLs) and fixtures, linear fluorescent lamps and fixtures, linear fluorescent fixtures replacing high-intensity discharge (HID) fixtures in high-bay applications, and high-intensity discharge (HID) fixtures. This measure could relate to the replacement of an existing unit at the end of its useful life or the installation of a new unit in a new or existing facility.

**Definition of Efficient Equipment**
In order for this characterization to apply, the efficient equipment must have higher efficiency than the existing equipment and meet program specific equipment criteria.

**Definition of Baseline Equipment**
The assumed baseline equipment varies by technology type.

**Compact Fluorescent Lamps**

**Deemed Calculation for Compact Fluorescent Lamps**

This measure relates to the installation of a new ENERGY STAR certified compact fluorescent screw-in lamp (CFL) (for those equipment types for which an ENERGY STAR category exists). This measure could relate to the replacing of an existing unit at the end of its useful life, or the installation of a new unit in a new or existing building (i.e. time of sale). This measure applies to the installation of a screw-in CFL replacing a standard general service incandescent lamp.

Annual kWh Savings[385] = (WATTSee * 2.79) * HOURS * (1 + WHFe) / 1000

Summer Coincident Peak kW Savings = (WATTSee * 2.79) * CF * (1 + WHFd) / 1000

Note: The multiplier should be adjusted according to the table below to account for the change in baseline stemming from the Energy Independence and Security Act of 2007 discussed below:

| CFL Wattage | Delta Watts Multiplier[386] | | | |
|---|---|---|---|---|
| | 2009 - 2011 | 2012 | 2013 | 2014 and Beyond |
| 15 or less | 2.79 | 2.79 | 2.79 | 1.72 |
| 16-20 | 2.79 | 2.79 | 1.68 | 1.68 |
| 21W+ | 2.79 | 1.73 | 1.73 | 1.73 |

**Baseline Adjustment for Compact Fluorescent Lamps**

[385] Kuiken et al, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, KEMA, March 22, 2010. Source document cites several evaluations indicating that the overall average existing incandescent lamp wattage is 75.7W and the overall average replacement wattage is 20.0W for CFLs <= 32W. For the purposes of this characterization, it is assumed that the baseline and efficient wattages are directly proportional. These assumptions have been simplified as follows: (WATTSbase – WATTSee) = [(75.7/20.0)* WATTSee] – WATTSee = WATTSee * 2.79.
[386] Calculated by finding the new delta watts after incandescent bulb wattage reduced (from 100W to 72W in 2012, 75W to 53W in 2013 and 60W to 43W in 2014).

Federal legislation stemming from the Energy Independence and Security Act of 2007 will require all general-purpose light bulbs between 40 and 100W to be approximately 30% more energy efficient than current incandescent bulbs, in essence beginning the phase out of standard incandescent bulbs[387]. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will therefore become bulbs (improved incandescent or halogen) that meet the new standard.

To account for these new standards, the first year annual savings for this measure must be reduced for 100W equivalent bulbs (21W+ CFLs) in 2012, for 75W equivalent bulbs (16-20W CFLs) in 2013 and for 60 and 40W equivalent bulbs (15W or less CFLs) in 2014. To account for this adjustment the delta watt multiplier is adjusted as shown above. In addition, since during the lifetime of a CFL, the baseline incandescent bulb will be replaced multiple times, the annual savings claim must be reduced within the life of the measure. For example, for 100W equivalent bulbs (21W+ CFLs) installed in 2010, the full savings (as calculated above in the Algorithm) should be claimed for the first two years, but a reduced annual savings claimed for the remainder of the measure life.

The appropriate adjustments as a percentage of the base year savings for each CFL range are provided below[388]:

| CFL Wattage | Savings as Percentage of Base Year Savings | | | |
|---|---|---|---|---|
| | 2009 - 2011 | 2012 | 2013 | 2014 and Beyond |
| 15 or less | 100% | 100% | 100% | 62% |
| 16-20 | 100% | 100% | 60% | 60% |
| 21W+ | 100% | 62% | 62% | 62% |

**Deemed O&M Cost Adjustment Calculation for Compact Fluorescent Lamps**
In order to account for the shift in baseline due to the Federal Legislation discussed above, the levelized baseline replacement cost over the lifetime of the CFL is calculated (see CFL baseline savings shift.xls). The key assumptions used in this calculation are documented below:

| | Standard Incandescent | Efficient Incandescent |
|---|---|---|
| Replacement Cost | $0.50 | $2.00 |
| Component Life (years) (based on lamp life / assumed annual run hours) | 0.27[389] | 0.81[390] |

The calculated net present value of the baseline replacement costs for CFL type and installation year are presented below:

| CFL wattage | NPV of baseline Replacement Costs | | | | |
|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2013 | 2014 on |
| 21W+ | $6.34 | $6.91 | $7.50 | $7.50 | $7.50 |
| 16-20W | $5.80 | $6.34 | $6.91 | $7.50 | $7.50 |

387 http://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf
388 Calculated by finding the ratio of delta watt savings before and after the legislation change (from 100W to 72W in 2012, 75W to 53W in 2013 and 60W to 43W in 2014).
389 Assumes rated life of incandescent bulb of approximately 1000 hours.
390 VEIC best estimate of future technology.

| CFL wattage | NPV of baseline Replacement Costs | | | | |
|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2013 | 2014 on |
| 15W and less | $5.69 | $5.80 | $6.34 | $6.91 | $7.50 |

<u>**Compact Fluorescent Fixtures**</u>

**Deemed Calculation for Compact Fluorescent Fixtures**

This measure relates to the installation of a new ENERGY STAR certified compact fluorescent lamp (CFL) fixture (for those equipment types for which an ENERGY STAR category exists). This measure could relate to the replacing of an existing unit at the end of its useful life, typically during a major renovation, or the installation of a new system in a new or existing building (i.e. time of sale). This measure applies to the installation of a pin-based CFL fixture (including modular lamp and ballast) replacing a standard general service incandescent lamp.

Annual kWh Savings[391] = (WATTSee * 2.79) * HOURS * (1 + WHFe) / 1000

Summer Coincident Peak kW Savings = (WATTSee * 2.79) * CF * (1 + WHFd) / 1000

Note: The multiplier should be adjusted according to the table below to account for the change in baseline stemming from the Energy Independence and Security Act of 2007 discussed below:

| CFL Wattage | Delta Watts Multiplier[392] | | | |
|---|---|---|---|---|
| | 2009 - 2011 | 2012 | 2013 | 2014 and Beyond |
| 15 or less | 2.79 | 2.79 | 2.79 | 1.72 |
| 16-20 | 2.79 | 2.79 | 1.68 | 1.68 |
| 21W+ | 2.79 | 1.73 | 1.73 | 1.73 |

**Baseline Adjustment for Compact Fluorescent Fixtures**

Federal legislation stemming from the Energy Independence and Security Act of 2007 will require all general-purpose light bulbs between 40 and 100W to be approximately 30% more energy efficient than current incandescent bulbs, in essence beginning the phase out of standard incandescent bulbs[393]. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will therefore become bulbs (improved incandescent or halogen) that meet the new standard.

To account for these new standards, the first year annual savings for 100W equivalent bulbs (21W+ CFLs) in 2012, for 75W equivalent bulbs (16-20W CFLs) in 2013 and for 60 and 40W equivalent bulbs (15W or less CFLs) in 2014. To account for this adjustment the delta watt multiplier is adjusted as shown above. In addition, since during the lifetime of a CFL, the baseline incandescent bulb will be replaced multiple times, the annual savings claim must be reduced within the life of the measure. For example, for 100W equivalent bulbs (21W+ CFLs) installed in 2010, the full savings (as calculated above in the Algorithm)

[391] Kuiken et al, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, KEMA, March 22, 2010. Source document cites several evaluations indicating that the overall average existing incandescent lamp wattage is 75.7W and the overall average replacement wattage is 20.0W for CFLs <= 32W. For the purposes of this characterization, it is assumed that the baseline and efficient wattages are directly proportional. These assumptions have been simplified as follows: (WATTSbase – WATTSee) = [(75.7/20.0)* WATTSee] – WATTSee = WATTSee * 2.79.

[392] Calculated by finding the new delta watts after incandescent bulb wattage reduced (from 100W to 72W in 2012, 75W to 53W in 2013 and 60W to 43W in 2014).

[393] http://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf

should be claimed for the first two years, but a reduced annual savings claimed for the remainder of the measure life. .

The appropriate adjustments as a percentage of the base year savings for each CFL range are provided below[394]:

| CFL Wattage | Savings as Percentage of Base Year Savings | | | |
|---|---|---|---|---|
| | 2009 - 2011 | 2012 | 2013 | 2014 and Beyond |
| 15 or less | 100% | 100% | 100% | 62% |
| 16-20 | 100% | 100% | 60% | 60% |
| 21W+ | 100% | 62% | 62% | 62% |

**Deemed O&M Cost Adjustment Calculation for Compact Fluorescent Fixtures**
Conservatively not included

## High Bay Fluorescent Fixtures

**Deemed Calculation for High Bay Fluorescent Fixtures**

The assumed baseline for installation of a high bay fluorescent fixture is a metal halide system. The Energy Independence and Security Act of 2007 (EISA) requires that as of January 1, 2009, metal halide fixtures designed for use with lamps ≥150 W and ≤500 W must use "probe start" ballasts with ballast efficiency ≥94% or "pulse start" ballasts with ballast efficiency ≥88. It is therefore likely that new metal halide fixtures will utilize "pulse start" technology. Therefore, the assumed baseline system is a magnetic ballast "pulse start" metal halide system.

Annual kWh Savings = (WATTSbase – WATTSee) * HOURS * (1 + WHFe) / 1000

[394] Calculated by finding the ratio of delta watt savings before and after the legislation change (from 100W to 72W in 2012, 75W to 53W in 2013 and 60W to 43W in 2014).

Summer Coincident Peak kW Savings = (WATTSbase – WATTSee) * CF * (1 + WHFd) / 1000

See

Table 4 for WATTSbase and WATTSee values.

**Deemed O&M Cost Adjustment Calculation for High Bay Fluorescent Fixtures**

O&M cost adjustments were developed assuming a typical baseline system and two typical efficient equipment scenarios. For T5HO High Bay fixtures replacing pulse start metal halide fixtures, the levelized annual baseline replacement cost assumption is calculated as $5.87. For T8VHO high bay fixtures replacing pulse start metal halide fixtures, the levelized annual baseline replacement cost assumption is calculated as -$1.69. The assumptions used to calculate these adjustments are detailed below.

| | |
|---|---|
| Baseline 320W Metal-Halide Lamp Cost: | $25.00 |
| Baseline 320W Lamp Life: | 15,000 hrs |
| Baseline Lamp Labor Cost: | $5.00 (15 min @ $20 per hour labor) |
| Baseline 320W Ballast Cost: | $60.00 |
| Baseline Ballast Life: | 40,000 |
| Baseline Ballast Labor Cost: | $22.50 (30 min @ $45 per hour labor) |

| | |
|---|---|
| T5 High-Bay Lamp Cost: | $5 per lamp (assumes 4 lamps fixture) |
| T5 High-Bay Lamp Life: | 20,000 hrs |
| T5 High-Bay Lamp Labor Cost: | $6.67 (20 min @ $20 per hour labor) |
| T5 High-Bay Ballast Cost: | $51.00 |
| T5 High-Bay Ballast Life: | 70,000 hrs |
| T5 High-Bay Ballast Labor Cost: | $22.50 (30 min @ $45 per hour labor) |

| | |
|---|---|
| T8 High-Bay Lamp Cost: | $10 per lamp (assumes 6 lamp fixture) |
| T8 High-Bay Lamp Life: | 18,000 hrs |
| T8 High-Bay Lamp Labor Cost: | $13.33 (40 min @ $20 per hour labor) |
| T8 High-Bay Ballast Cost: | $100.00 (2 ballasts) |
| T8 High-Bay Ballast Life: | 70,000 hrs |
| T8 High-Bay Ballast Labor Cost: | $45 (60 min @ $45 per hour labor) |

## High Efficiency Linear Fluorescent Fixtures

### Deemed Calculation for High Efficiency Fluorescent Fixtures

The assumed baseline for installation of a fluorescent fixture varies by the efficient system installed. High Performance and Reduced Wattage T8s must comply with the requirements as published by the Consortium for Energy Efficiency[395].

Annual kWh Savings = (WATTSbase – WATTSee) * HOURS * (1 + WHFe) / 1000

Summer Coincident Peak kW Savings = (WATTSbase – WATTSee) * CF * (1 + WHFd) / 1000

See Table 5 for WATTSbase and WATTSee values.

**Baseline Adjustment**
The U.S. Department of Energy issued on June 26, 2009 a final rule, amending the energy conservation standards for

[397] equipment types, baseline lamps will become unavailable and participants will be required to upgrade both lamps and ballasts to High Performance T8s, thus negating any savings. Assuming a typical lamp has a lifetime of 18,000 hours and is operated 3,730 hours per year, new lamps installed shortly before the impending federal standards take effect will need to be replaced in mid-2017, indicating that savings should be claimed for only 7 years for measures installed in 2010. This baseline adjustment has been incorporated into the measure life for the applicable equipment types.

**Deemed O&M Cost Adjustment Calculation**
Conservatively not included

## Metal Halide Track Lighting

### Deemed Calculation for Metal Halide Track Lighting

A metal-halide track head produces equal or more light as compared to halogen track head(s), while using fewer watts. This measure applies to the installation of a metal halide track head replacing (a) halogen track head(s).

Annual kWh Savings = (WATTSbase – WATTSee) * HOURS * (1 + WHFe) / 1000

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395 The Consortium for Energy Efficiency publishes the High Performance T8 Specifications and the Reduced Wattage T8 Specifications periodically including a list of qualifying equipment at the following address: http://www.cee1.org/com/com-lt/com-lt-main.php3

396 For more information, see "http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/74fr34080.pdf."

397 Neubauer, M., Ka-BOOM! The Power of Appliance Standards Opportunities for New Federal Appliance and Equipment Standards, ACEEE, July 2009.

Summer Coincident Peak kW Savings = (WATTSbase – WATTSee) * CF * (1 + WHFd) / 1000

See Table 6 for WATTSbase and WATTSee values.

## Ceramic Metal Halide Fixtures

### Deemed Calculation for Ceramic Metal Halide Fixtures

Ceramic Metal-Halide is a new type of metal-halide that provides excellent light quality with a high color-rendering index. It is typically used in place of halogen bulb(s) in applications that require excellent light quality and/or tight beam control. Ceramic Metal-Halide bulbs have high lumen output, and thus can replace multiple halogen fixtures.

Annual kWh Savings = (WATTSbase – WATTSee) * HOURS * (1 + WHFe) / 1000

Summer Coincident Peak kW Savings = (WATTSbase – WATTSee) * CF * (1 + WHFd) / 1000

See Table 7 for WATTSbase and WATTSee values.

### Deemed O&M Cost Adjustment Calculation for Ceramic Metal Halide Fixtures

O&M cost adjustments were developed assuming a typical baseline and efficient equipment scenario. For ceramic metal halide fixtures replacing halogen fixtures, the levelized annual baseline replacement cost assumption is calculated as $24.29. The assumptions used to calculate these adjustments are detailed below.

| | |
|---|---|
| Baseline 75W Halogen Lamp Cost: | $30.00 (3 lamps) |
| Baseline 75W Halogen Lamp Life: | 2,500 hrs |
| Baseline 75W Halogen Lamp Labor Cost: | $2.67 |

| | |
|---|---|
| 70W CMH Lamp Cost: | $60 |
| 70W CMH Lamp Life: | 12,000 hrs |
| 70W CMH Lamp Labor Cost: | $2.67 |
| 70W CMH Ballast Cost: | $90 |
| 70W CMH Ballast Life: | 40,000 hrs |
| 70W CMH Ballast Labor Cost: | $22.50 (30 min @ $45 per hour labor) |

### Deemed Lifetime of Efficient Equipment

The expected measure life is dependent on technology type as below:

| Technology Type | Lifetime |
|---|---|
| Screw-in CFL | 3.2 years[398] |
| CFL Fixture | 12 years[399] |
| High Bay Fluorescent Fixture | 15 years[400] |
| High Efficiency Linear Fluorescent Fixtures – 4ft lamps | 7 years[401] |
| High Efficiency Linear Fluorescent Fixtures – all others | 15 years[402] |

[398] Kuiken et al, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, KEMA, March 22, 2010. Assumes 12,000 hours lamp lifetime with extended burn times per start typical in commercial applications. Assuming 3,730 annual lighting operating hours for the commercial sector from the source document, the lamp lifetime is calculated as: 12,000 / 3,730 = 3.2 years

[399] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008

[400] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

[401] See discussion in measure's "Baseline Adjustment" section.

| | |
|---|---|
| Metal Halide Track Lighting | 15 years[403] |
| Ceramic Metal Halide | 15 years[404] |

**Deemed Measure Cost**

The incremental capital costs for this measure vary by the assumed baseline and efficient equipment scenarios. Incremental costs by measure type are presented below:

| Measure Type | Incremental Cost |
|---|---|
| Screw-in CFL | $3[405] |
| CFL Fixture (1-lamp) | $35[406] |
| CFL Fixture (2-lamp) | $40[407] |
| High Bay Fluorescent Fixture | $150[408] |
| High Efficiency Linear Fluorescent Fixture | 25[409] |
| 20 Watt Ceramic Metal Halide | $130[410] |
| 39 Watt Ceramic Metal Halide | $130 |
| 50 Watt Ceramic Metal Halide | $95 |
| 70 Watt Ceramic Metal Halide | $95 |
| 100 Watt Ceramic Metal Halide | $90 |
| 150 Watt Ceramic Metal Halide | $90 |
| 20 Watt Metal Halide Track | $155 |
| 39 Watt Metal Halide Track | $155 |
| 70 Watt Metal Halide Track | $145 |

**Coincidence Factor**

The summer peak coincidence factor for this measure is dependent on building type as below:

| Building Type | CF[411] |
|---|---|
| Food Sales | 0.92 |
| Food Service | 0.83 |
| Health Care | 0.78 |
| Hotel/Motel | 0.37 |
| Office | 0.76 |
| Public Assembly | 0.65 |
| Public Services (non-food) | 0.64 |
| Retail | 0.84 |

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[402] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

[403] Ibid.

[404] Ibid.

[405] Based on review of TRM assumptions from Vermont, New York, New Jersey and Connecticut.

[406] Based on review of TRM assumptions from Vermont, New York, California, and Northwestern states.

[407] Ibid.

[408] Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010

[409] Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010, p. 110 (incremental costs vary from $20 to $27.50 for 1 to 4 lamps).

[410] Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010. This document is the source for all subsequent incremental cost estimates presented in the table.

[411] Methodology adapted from Kuiken et al, "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Parameter Development", KEMA, November 13, 2009, assuming summer coincident peak period is defined as June through August on weekdays between 3:00 p.m. and 6:00 p.m., unless otherwise noted.

| Building Type | CF[411] |
|---|---|
| Warehouse | 0.79 |
| School | 0.50 |
| College | 0.68 |
| Industrial | 0.76 |
| Garage | 1.00[412] |
| Exterior | 0.00[413] |
| Other | 0.65 |

## REFERENCE SECTION

**Calculation of Savings**

**Energy Savings**

ΔkWH = (WATTSbase – WATTSee) * HOURS * (1 + WHFe) / 1000

Where:

WATTSbase = connected wattage of the baseline fixtures
= Assumed baseline wattage for time of sale application. See corresponding measure table for default values.

WATSSee = connected wattage of the high efficiency fixtures
= Actual installed

HOURS = total operating hours of the lighting. If actual site-specific value is unknown, assume default values dependent on building type as below:

| Building Type | HOURS[414] |
|---|---|
| Food Sales | 5,544 |
| Food Service | 4,482 |
| Health Care | 3,677 |
| Hotel/Motel | 3,356 |
| Office | 3,526 |
| Public Assembly | 2,729 |
| Public Services (non-food) | 3,425 |
| Retail | 4,226 |
| Warehouse | 3,464 |
| School | 2,302 |
| College | 3,900 |
| Industrial – 1 Shift | 2,857[415] |
| Industrial – 2 Shift | 4,730[416] |
| Industrial – 3 Shift | 6,631[417] |
| Exterior | 3,833[418] |

412 Assumption consistent with 8,760 operating hours assumption.
413 Assumes that no exterior lighting is operating during the summer on-peak demand period.
414 Kuiken et al, "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Parameter Development", KEMA, November 13, 2009, unless otherwise noted.
415 UI and CL&P Program Savings Documentation for 2010 Program Year, United Illuminating Company, September 2009.
416 Ibid.
417 Ibid.
418 Exterior lighting 3,833 hours per year assumes 10.5 hours per day; typical average for photocell control.

| Building Type | HOURS[414] |
|---|---|
| Other | 3,672 |

WHFe = lighting-HVAC Interation Factor for energy; this factor represents the reduced electric space cooling requirements due to the reduction of waste heat rejected by the efficent lighting.
= 0.095 (interior fixtures), 0.000 (exterior fixtures)[419]

1 / 1000 = conversion factor from watts to kilowatts

**Summer Coincident Peak Demand Savings**

$$\Delta kW = (WATTSbase - WATTSee) * CF * (1 + WHFd) / 1000$$

Where:

WHFd = lighting-HVAC waste heat factor for demand; this factor represents the reduced electric space cooling requirements due to the reduction of waste heat rejected by the efficent lighting.
= 0.200 (interior fixtures), 0.000 (exterior fixtures)[420]

CF = Summer Peak Coincidence Factor for measure
Dependent on building type as below:

| Building Type | CF[421] |
|---|---|
| Food Sales | 0.92 |
| Food Service | 0.83 |
| Health Care | 0.78 |
| Hotel/Motel | 0.37 |
| Office | 0.76 |
| Public Assembly | 0.65 |
| Public Services (non-food) | 0.64 |
| Retail | 0.84 |
| Warehouse | 0.79 |
| School | 0.50 |
| College | 0.68 |
| Industrial | 0.76 |
| Garage | 1.00[422] |

[419] Interactive factor data based on a series of prototypical small commercial building simulation runs. Values shown are weighted averages across fast food restaurant, full service restaurant, assembly, big box retail, small retail, small office, light industrial and school building models. The prototypes are based on the California DEER study prototypes, modified for local construction practices. Simulations were run using TMY3 weather data for the following Ohio cities: Cincinnati, Cleveland, Columbus and Dayton. Values were weighted based on program participation data for a small commercial program conducted in Indiana for Duke Energy. See An Evaluation of the Indiana Small Commercial and Industrial Incentive Program. Prepared by TecMarket Works for Duke Energy. June 2007. Building prototypes used in the energy modeling are described in the referenced document, "Prototypical Building Energy Simulation Model Development.doc".

[420] Ibid.

[421] Methodology adapted from Kuiken et al, "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Parameter Development", KEMA, November 13, 2009, assuming summer coincident peak period is defined as June through August on weekdays between 3:00 p.m. and 6:00 p.m., unless otherwise noted.

[422] Assumption consistent with 8,760 operating hours assumption.

| Building Type | CF[421] |
|---|---|
| Exterior | 0.00[423] |
| Other | 0.65 |

**Fossil Fuel Impact Descriptions and Calculation**

$$\Delta MMBtu = \Delta kWh * IF_{MMBtu}$$

Where:

$IF_{MMBtu}$ = 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.
= -0.0028 (interior fixtures), 0.0000 (exterior fixtures)[424]

**Water Impact Descriptions and Calculation**
n/a

**Deemed O&M Cost Adjustment Calculation**
See the individual technology sections above.

[423] Assumes that no exterior lighting is operating during the summer on-peak demand period.
[424] Interactive factor data based on a series of prototypical small commercial building simulation runs. Values shown are weighted averages across fast food restaurant, full service restaurant, assembly, big box retail, small retail, small office, light industrial and school building models. The prototypes are based on the California DEER study prototypes, modified for local construction practices. Simulations were run using TMY3 weather data for the following Ohio cities: Cincinnati, Cleveland, Columbus and Dayton. Values were weighted based on program participation data for a small commercial program conducted in Indiana for Duke Energy. See An Evaluation of the Indiana Small Commercial and Industrial Incentive Program. Prepared by TecMarket Works for Duke Energy. June 2007. Building prototypes used in the energy modeling are described in the referenced document, "Prototypical Building Energy Simulation Model Development.doc".

**Reference Tables**

## Calculation of O&M Impact for Baseline

| | |
|---|---|
| Measure Life | 3.22 |
| Real Discount Rate (RD | 5.00% |

| | Bulb Assumptions | |
|---|---|---|
| | Inc | Halogen |
| Component 1 Life (years) | 0.27 | 0.81 |
| Component 1 Replacement Cost | $1.87 | $2.46 |

| 2010 | | Year<br>NPV | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|
| 21W+ | Baseline Replacement Costs | $8.34 | $1.87 | $1.87 | $2.46 | $0.54 |
| 16-20W | Baseline Replacement Costs | $5.80 | $1.87 | $1.87 | $1.87 | $0.54 |
| 15W and less | Baseline Replacement Costs | $5.69 | $1.87 | $1.87 | $1.87 | $0.41 |

| 2011 | | Year<br>NPV | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|
| 21W+ | Baseline Replacement Costs | $8.91 | $1.87 | $2.46 | $2.46 | $0.54 |
| 16-20W | Baseline Replacement Costs | $8.34 | $1.87 | $1.87 | $2.46 | $0.54 |
| 15W and less | Baseline Replacement Costs | $5.80 | $1.87 | $1.87 | $1.87 | $0.54 |

| 2012 | | Year<br>NPV | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|
| 21W+ | Baseline Replacement Costs | $7.50 | $2.46 | $2.46 | $2.46 | $0.54 |
| 16-20W | Baseline Replacement Costs | $8.91 | $1.87 | $2.46 | $2.46 | $0.54 |
| 15W and less | Baseline Replacement Costs | $8.34 | $1.87 | $1.87 | $2.46 | $0.54 |

| 2013 | | Year<br>NPV | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|
| 21W+ | Baseline Replacement Costs | $7.50 | $2.46 | $2.46 | $2.46 | $0.54 |
| 16-20W | Baseline Replacement Costs | $7.50 | $2.46 | $2.46 | $2.46 | $0.54 |
| 15W and less | Baseline Replacement Costs | $8.91 | $1.87 | $2.46 | $2.46 | $0.54 |

| | NPV of baseline Replacement Costs | | | | |
|---|---|---|---|---|---|
| CFL wattage | 2010 | 2011 | 2012 | 2013 | 2014 on |
| 21W+ | $8.34 | $8.91 | $7.50 | $7.50 | $7.50 |
| 16-20W | $5.80 | $8.34 | $8.91 | $7.50 | $7.50 |
| 15W and less | $5.69 | $5.80 | $8.34 | $8.91 | $7.50 |

**Table 4: High Bay Fixture Baseline and Efficient Wattages**

| Type of Measure | Efficient Lamp | Efficient Fixture Ballast Type | Baseline Lamp | Baseline Fixture Ballast Type | Efficient Fixture Wattage (WATTSee) | Efficient Fixture Wattage Source | Baseline Fixture Wattage (WATTSbase) | Baseline Fixture Wattage Source | Fixture Savings (Watts) |
|---|---|---|---|---|---|---|---|---|---|
| High Bay | T-5 46" Two Lamp High Output | Electronic - PRS | 150W Pulse Start Metal Halide | Magnetic-CWA | 117 | 4 | 183 | 4 | 66 |
| High Bay | T-5 46" Three Lamp High Output | Electronic - PRS | 200W Pulse Start Metal Halide | Magnetic-CWA | 181 | 4 | 232 | 3 | 51 |
| High Bay | T-5 46" Four Lamp High Output | Electronic – IS | 320W Pulse Start Metal Halide | Magnetic-CWA | 234 | 3 | 365 | 3 | 131 |
| High Bay | T-5 46" Six Lamp High Output | Electronic – IS | 350W Pulse Start Metal Halide | Magnetic-CWA | 351 | 3 | 400 | 3 | 49 |
| High Bay | T-5 46" Eight Lamp High Output | Electronic – IS | 1000W Pulse Start Metal Halide | Magnetic-CWA | 468 | 3 | 1080 | 3 | 612 |
| High Bay | T-5 46" Six Lamp High Output (2 Fixtures) | Electronic – IS | 1000W Pulse Start Metal Halide | Magnetic-CWA | 702 | 3 | 1080 | 3 | 378 |
| High Bay | T-8 48" Two Lamp Very High Output | Electronic – IS | 150W Pulse Start Metal Halide | Magnetic-CWA | 77 | 4 | 183 | 4 | 106 |
| High Bay | T-8 48" Three Lamp Very High Output | Electronic – IS | 150W Pulse Start Metal Halide | Magnetic-CWA | 112 | 3 | 183 | 4 | 71 |
| High Bay | T-8 48" Four Lamp Very High Output | Electronic – IS | 200W Pulse Start Metal Halide | Magnetic-CWA | 151 | 3 | 232 | 3 | 81 |
| High Bay | T-8 48" Six Lamp Very High Output | Electronic – IS | 320W Pulse Start Metal Halide | Magnetic-CWA | 226 | 3 | 365 | 3 | 139 |
| High Bay | T-8 48" Eight Lamp Very High Output | Electronic - PRS | 350W Pulse Start Metal Halide | Magnetic-CWA | 288 | 4 | 400 | 3 | 112 |
| High Bay | T-8 48" Eight Lamp Very High Output (2 Fixtures) | Electronic – PRS | 1000W Pulse Start Metal Halide | Magnetic-CWA | 576 | 4 | 1080 | 3 | 504 |

**Table 5: High Efficiency Fluorescent (HEF) Fixture Baseline and Efficient Wattages**

| Type of Measure | Efficient Lamp | Efficient Fixture Ballast Type | Baseline Lamp | Baseline Fixture Ballast Type | Efficient Fixture Wattage (WATTSee) | Efficient Fixture Wattage Source | Baseline Fixture Wattage (WATTSbase) | Baseline Fixture Wattage Source | Fixture Savings (Watts) |
|---|---|---|---|---|---|---|---|---|---|
| HEF | T-8 24" One Lamp | Electronic | T-12 24" One Lamp | Magnetic-STD | 18 | 3 | 28 | 3 | 10 |
| HEF | T-8 24" Two Lamp | Electronic | T-12 24" Two Lamp | Magnetic-STD | 32 | 3 | 56 | 3 | 24 |

| Type of Measure | Efficient Lamp | Efficient Fixture Ballast Type | Baseline Lamp | Baseline Fixture Ballast Type | Efficient Fixture Wattage (WATTSee) | Efficient Fixture Wattage Source | Baseline Fixture Wattage (WATTSbase) | Baseline Fixture Wattage Source | Fixture Savings (Watts) |
|---|---|---|---|---|---|---|---|---|---|
| HEF | T-8 24" Three Lamp | Electronic | T-12 24" Three Lamp | Magnetic-STD | 50 | 3 | 62 | 3 | 12 |
| HEF | T-8 24" Four Lamp | Electronic | T-12 24" Four Lamp | Magnetic-STD | 65 | 3 | 112 | 3 | 47 |
| HEF | T-8 36" One Lamp | Electronic | T-12 36" One Lamp | Magnetic-STD | 25 | 3 | 46 | 3 | 21 |
| HEF | T-8 36" Two Lamp | Electronic | T-12 36" Two Lamp | Magnetic-STD | 46 | 3 | 81 | 3 | 35 |
| HEF | T-8 36" Three Lamp | Electronic | T-12 36" Three Lamp | Magnetic-STD | 70 | 3 | 127 | 3 | 57 |
| HEF | T-8 36" Four Lamp | Electronic | T-12 36" Four Lamp | Magnetic-STD | 88 | 3 | 162 | 3 | 74 |
| HEF | Reduced Wattage T-8 48" One Lamp-28W | Electronic – IS | T-8 48" One Lamp | Electronic - IS | 23.3 | 2 | 31 | 3 | 7.7 |
| HEF | Reduced Wattage T-8 48" Two Lamp-28W | Electronic – IS | T-8 48" Two Lamp | Electronic - IS | 47 | 2 | 59 | 3 | 12 |
| HEF | Reduced Wattage T-8 48" Three Lamp-28W | Electronic – IS | T-8 48" Three Lamp | Electronic - IS | 69.9 | 2 | 89 | 3 | 19.1 |
| HEF | Reduced Wattage T-8 48" Four Lamp-28W | Electronic – IS | T-8 48" Four Lamp | Electronic - IS | 92.6 | 2 | 112 | 3 | 19.4 |
| HEF | Reduced Wattage T-8 48" One Lamp-25W | Electronic – IS | T-8 48" One Lamp | Electronic - IS | 22 | 2 | 31 | 3 | 9 |
| HEF | Reduced Wattage T-8 48" Two Lamp-25W | Electronic – IS | T-8 48" Two Lamp | Electronic - IS | 41 | 2 | 59 | 3 | 18 |
| HEF | Reduced Wattage T-8 48" Three Lamp-25W | Electronic – IS | T-8 48" Three Lamp | Electronic - IS | 61.3 | 2 | 89 | 3 | 27.7 |
| HEF | Reduced Wattage T-8 48" Four Lamp-25W | Electronic – IS | T-8 48" Four Lamp | Electronic - IS | 80.5 | 2 | 112 | 3 | 31.5 |
| HEF | T-8 96" One Lamp | Electronic – IS | T-12 96" One Lamp-ES | Magnetic-STD | 58 | 3 | 75 | 3 | 17 |
| HEF | T-8 96" Two Lamp | Electronic – IS | T-12 96" Two Lamp-ES | Magnetic-ES | 109 | 3 | 123 | 3 | 14 |
| HEF | T-8 96" Four Lamp | Electronic – IS | T-12 96" Four Lamp-ES | Magnetic-ES | 219 | 3 | 246 | 3 | 27 |
| HEF | High Performance T-8 48" One Lamp | Electronic | T-8 48" One Lamp | Electronic - IS | 25 | 6 | 31 | 3 | 6 |
| HEF | High Performance T-8 48" Two Lamp | Electronic | T-8 48" Two Lamp | Electronic - IS | 48 | 6 | 59 | 3 | 10 |
| HEF | High Performance T-8 48" Three Lamp | Electronic | T-8 48" Three Lamp | Electronic - IS | 73 | 6 | 89 | 3 | 17 |
| HEF | High Performance T-8 48" Four Lamp | Electronic | T-8 48" Four Lamp | Electronic - IS | 96 | 6 | 112 | 3 | 18 |