# State of Ohio Energy Efficiency Technical Reference Manual

# Volume II: Residential Market Sector

Including
Predetermined Savings Values
and Protocols for Determining Energy and Demand Savings

Prepared for the Public Utilities Commission of Ohio
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August 6, 2010
Updated by Michaels Energy
September 23, 2019

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# I. Appliances

## ENERGY STAR Air Purifier Cleaner (Time of Sale)

**Description**
An air cleaner meeting the ENERGY STAR specifications and installed in a residential setting.

**Definition of Efficient Equipment**
To qualify for this measure, the installed air cleaner must meet the ENERGY STAR standards as of July 20, 2011[1]:

- Qualifying air cleaner models **shall** produce a minimum 50 clean-air delivery rate (CADR) for dust.
- Calculated CADR/Watt shall be equal to or greater than 2.0- CADR/Watt (Dust)
- Measured standby power shall not exceed 2 Watts.

**Definition of Baseline Equipment**
The baseline for this measure is defined as a new air cleaner that does not meet the ENERGY STAR requirements.

**Default Deemed Savings for this Measure**
The savings for this measure can be claimed using a deemed savings approach. These deemed savings are based on a typical dehumidifier installations and the nominal baseline and efficient dehumidifier specifications presented above.

| Clean Air Delivery Rate (CADR) | kWh | Peak kW |
|---|---|---|
| 51-100 | 124 | 0.014 |
| 101-150 | 275 | 0.031 |
| 151-200 | 443 | 0.051 |
| 201-250 | 573 | 0.065 |
| >250 | 814 | 0.093 |

**Deemed Lifetime of Efficient Equipment**
The assumed lifetime of the measure is 9 years[2]

**Deemed Measure Cost**
The incremental cost for an ENERGY STAR unit is assumed to be $70.[3]

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

**Coincidence Factor**
The coincidence factor is assumed to be 0.67[4]

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[1] ENERGY STAR Program Requirements Product Specifications for Room Air Cleaners Version 1.2. https://www.energystar.gov/ia/partners/prod_development/revisions/downloads/room_aircleaners/Room_Air_Cleaners_Final_V1.2_Specification.pdf?891a-649f
[2] ENERGY STAR Appliance Calculator https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx
[3] Ibid
[4] Assume 16 hours per day per ENERGY STAR calculator. Operation is assumed to be evenly distributed.

## REFERENCE SECTION

### Calculation of Savings

**Energy Savings**
The energy savings are based on the consumption values calculated by the ENERGY STAR Appliance calculator. Where:

| Clean Air Delivery Rate (CADR) | Average CADR[5] | Average CADR/W[6] | Baseline kWh/year | ENERGY STAR kWh/year | kWh Savings |
|---|---|---|---|---|---|
| 51-100 | 80 | 2.73 | 297 | 173 | 124 |
| 101-150 | 122 | 3.26 | 495 | 220 | 275 |
| 151-200 | 172 | 3.58 | 725 | 282 | 443 |
| 201-250 | 226 | 3.54 | 948 | 375 | 573 |
| >250 | 273 | 4.09 | 1206 | 392 | 814 |

**Summer Coincident Peak Demand Savings**

$\Delta kW = \Delta kWh / Hours * CF$

Where:

CF = Summer Peak Coincidence Factor for measure
= 0.67

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

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

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

[5] Based on the average of the qualifying air cleaners included in the ENERGY STAR certified products list as of July 23, 2019. (https://www.energystar.gov/productfinder/product/certified-room-air-cleaners/results)
[6] Ibid.

## ENERGY STAR and CEE TIER 2 Clothes Washer (Time of Sale)

**Description**

This measure relates to the purchase (time of sale) and installation of a clothes washer exceeding either the ENERGY STAR[7] or CEE TIER 2[8] minimum qualifying efficiency standards presented below:

| Efficiency Level for Top Loading > 2.5 cu. ft. | Integrated Modified Energy Factor (IMEF) | Integrated Water Factor (IWF) |
|---|---|---|
| Federal Standard | >= 1.57 | <= 6.5 |
| ENERGY STAR | >= 2.06 | <= 4.3 |
| CEE TIER 2 | >= 2.92 | <= 3.2 |

| Efficiency Level for Front Loading > 2.5 cu. ft. | Integrated Modified Energy Factor (IMEF) | Integrated Water Factor (IWF) |
|---|---|---|
| Federal Standard | >= 1.84 | <= 4.7 |
| ENERGY STAR | >= 2.76 | <= 3.2 |
| CEE TIER 2 | >= 2.92 | <= 3.2 |

The integrated modified energy factor (IMEF) measures energy consumption of the total laundry cycle (washing and drying). It indicates how many cubic feet of laundry can be washed and dried with one kWh of electricity; the higher the number, the greater the efficiency.

The integrated water factor is the number of gallons needed for each cubic foot of laundry. A lower number indicates lower consumption and more efficient use of water.

**Definition of Efficient Equipment**

The efficient condition is a clothes washer meeting either the ENERGY STAR or CEE TIER 2 efficiency criteria presented above.

**Definition of Baseline Equipment**

The baseline condition is a clothes washer at the minimum federal baseline efficiency presented above.

**Default Deemed Savings for this Measure**

The savings for this measure can be claimed using a deemed savings approach.  These deemed savings are based on a typical clothes washer installation and the nominal baseline and efficient dryer specification presented in the table above. Default savings values are given for each combination of electric or natural gas dryers as well as electric, natural gas, fuel oil, or propane water heating systems. If the water heating fuel type is unknown or not tracked by the program, the "unknown" DHW column should be used. Similarly, if the dryer type is unknown or not tracked by the program, the "Unknown Dryer" row in the table should be used.

Key assumptions:

Washer Volume = 3.23 cubic feet [9]

[7] ENERGY STAR Product Specification for Clothes Washers Version 8.0. https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Final%20Version%208.0%20Clothes%20Washer%20Partner%20Commitments%20and%20Eligibility%20Criteria.pdf

[8] CEE Super Efficient Home Appliances Initiative https://library.cee1.org/system/files/library/13445/CEE_ResidentialClothesWasherSpecification_05Feb2018.pdf

[9] Average unit size from Efficiency Vermont program.

Baseline IMEF/IWF =Federal standard

Efficient IMEF/IWF =ENERGY STAR or CEE Tier 2 values presented above

Number of cycles per year = 320 [10]

Additional assumpions are included in detail in the reference section

| kWh Savings | | ENERGY STAR | | | CEE Tier 2 | | |
|---|---|---|---|---|---|---|---|
| | | Electric DHW | Other DHW | Unknown DHW | Electric DHW | Other DHW | Unknown DHW |
| Top Loading | Electric Dryer | 165.5 | 147.5 | 152.4 | 317.7 | 177.2 | 215.1 |
| | Gas Dryer | 51.0 | 33.1 | 37.9 | 157.9 | 17.4 | 55.4 |
| | Unknown Dryer | 126.5 | 108.6 | 113.5 | 263.4 | 122.9 | 160.8 |
| Front Loading | Electric Dryer | 193.3 | 161.3 | 169.9 | 213.8 | 98.9 | 130.0 |
| | Gas Dryer | 61.8 | 29.8 | 38.5 | 117.2 | 2.3 | 33.4 |
| | Unknown Dryer | 148.6 | 116.6 | 125.2 | 181.0 | 66.1 | 97.1 |

| kW Savings | | ENERGY STAR | | | CEE Tier 2 | | |
|---|---|---|---|---|---|---|---|
| | | Electric DHW | Other DHW | Unknown DHW | Electric DHW | Other DHW | Unknown DHW |
| Top Loading | Electric Dryer | 0.023 | 0.021 | 0.021 | 0.045 | 0.025 | 0.030 |
| | Gas Dryer | 0.007 | 0.005 | 0.005 | 0.022 | 0.002 | 0.008 |
| | Unknown Dryer | 0.018 | 0.015 | 0.016 | 0.037 | 0.017 | 0.023 |
| Front Loading | Electric Dryer | 0.027 | 0.023 | 0.024 | 0.030 | 0.014 | 0.018 |
| | Gas Dryer | 0.009 | 0.004 | 0.005 | 0.016 | 0.000 | 0.005 |
| | Unknown Dryer | 0.021 | 0.016 | 0.018 | 0.025 | 0.009 | 0.014 |

[10] Weighted average of 2005 Residential Energy Consumption Survey (RECS) for East North Central Census Division: (http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc10homeappliaceindicators/pdf/tablehc12.10.pdf)

| Natural Gas MMBTU Savings | | ENERGY STAR | | | CEE Tier 2 | | |
|---|---|---|---|---|---|---|---|
| | | Electric DHW | Other DHW | Unknown DHW | Electric DHW | Other DHW | Unknown DHW |
| Top Loading | Electric Dryer | 0.08 | - | 0.05 | 0.60 | - | 0.38 |
| | Gas Dryer | 0.47 | 0.39 | 0.44 | 1.14 | 0.55 | 0.92 |
| | Unknown Dryer | 0.21 | 0.13 | 0.18 | 0.78 | 0.19 | 0.56 |
| Front Loading | Electric Dryer | 0.14 | N/A | 0.09 | 0.49 | N/A | 0.31 |
| | Gas Dryer | 0.59 | 0.45 | 0.53 | 0.82 | 0.33 | 0.64 |
| | Unknown Dryer | 0.29 | 0.15 | 0.24 | 0.60 | 0.11 | 0.42 |

| Fuel Oil MMBTU Savings | ENERGY STAR | | | CEE Tier 2 | | |
|---|---|---|---|---|---|---|
| | Electric DHW | Other DHW | Unknown DHW | Electric DHW | Other DHW | Unknown DHW |
| Top Loading—All Dryer Types | 0.076 | - | 0.005 | 0.599 | - | 0.036 |
| Front Loading—All Dryer Types | 0.137 | - | 0.008 | 0.490 | - | 0.029 |

| Propane MMBTU Savings | ENERGY STAR | | | CEE Tier 2 | | |
|---|---|---|---|---|---|---|
| | Electric DHW | Other DHW | Unknown DHW | Electric DHW | Other DHW | Unknown DHW |
| Top Loading—All Dryer Types | 0.076 | - | 0.003 | 0.599 | - | 0.024 |
| Front Loading—All Dryer Types | 0.137 | - | 0.005 | 0.490 | - | 0.020 |

**Calculated Savings Approach for this Measure**

Alternatively, the savings for this measure can be calculated using the approach shown in the reference section. If the calculated approach is used, actual equipment specifications, such as washer volume, installed equipment IMEF, and installed equipment IWF can be used rather than the default assumptions.

**Deemed Lifetime of Efficient Equipment**

The measure life is assumed to be 11 years[11].

**Deemed Measure Cost**

The incremental cost for this measure is assumed to be $84 for an ENERGY STAR unit and $141 for a CEE TIER 2 unit[12].

**Deemed O&M Cost Adjustments**

n/a

[11] ENERGY STAR calculator (https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx)
[12] Illinois Technical Reference Manual v7.0...(. (http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_3_Res_092818_Final.pdf).

**Coincidence Factor**
The coincidence factor for this measure is assumed to be 0.045[13].

## REFERENCE SECTION

**Calculation of Energy Savings**

Savings are determined using the Integrated Modified Energy Factor approach and applying the proportion of consumption used for water heating, clothes washer and clothes dryer operation and then to the mix of domestic hot water heating fuels and dryer fuels. Savings from reduced water usage are also included. For the full calculation see the Clothes Washer Analsys workbook. However, key assumptions and their sources are provided below.

The IMEF energy usage for the baseline and high efficiency washer are calculated (example values shown are for top load washer):

IMEF-kWh = Capacity * (1/IMEF) * Ncycles

Where:

| | |
|---|---|
| Capacity | = Actual if known (3.23 cubic feet default)[14] |
| Baseline MEF | = 1.57 |
| ENERGY STAR MEF | = IMEF<br>= Actual if known (2.06 default) |
| CEE TIER 3 MEF | = IMEF<br>= Actual if known (2.92 default) |
| Number of cycles per year | = 320[15] |

Based on this approach, the baseline and efficient IMEF energy usage values are:

$\text{IMF-kWh}_{base}$ = 658.3 kWh
$\text{IMF-kWh}_{ES}$ = 501.4 kWh
$\text{IMF-kWh}_{CEE}$ = 354.0 kWh

This energy usage value includes the direct energy usage of the clothes washer as well as associated usage of the clothes dryer and water heating system. The energy usage of the clothes dryer and water heating system may be either electric or fossil fuel, therefore, the energy usage of each piece of equipment is analyzed seperately. The percent of the overall usage assocaited with the clothes washer, the dryer, and the water heater is shown in the table below, for each efficiency condition.

[13] Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York and adjusted for OH peak definitions.
[14] Average unit size from Efficiency Vermont program.
[15] Weighted average of 2005 Residential Energy Consumption Survey (RECS) for East North Central Census Division: (http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc10homeappliaceindicators/pdf/tablehc12.10.pdf)

| Percent of Total Energy Consumption[16] | | | |
|---|---|---|---|
| Condition | %CW | %DHW | %Dryer |
| Federal Standard | 8.1% | 26.5% | 65.4% |
| ENERGY STAR | 5.8% | 31.2% | 63.0% |
| CEE TIER 2 | 13.9% | 9.6% | 76.5% |

The total energy savings for the installation of the efficient ENERGY STAR clothes washer is then:

$$\Delta kWh = \Delta kWh_{CW} + \Delta kWh_{DHW} + \Delta kWh_{Dryer} + \Delta kWh_{Water}$$
$$\Delta Gas = \Delta Gas_{DHW} + \Delta Gas_{Dryer}$$
$$\Delta Oil = \Delta Oil_{DHW}$$
$$\Delta Propane = \Delta Propane_{DHW}$$

$\Delta kWh_{CW}$ is the direct electrical savings for the clothes washer and is calculated:

$$\Delta kWh_{CW} = (IMF\text{-}kWh_{Base} * \%CW_{Base}) - (IMF\text{-}kWh_{ES} * \%CW_{ES})$$

$\Delta kWh_{DHW}$, $\Delta Gas_{DHW}$, $\Delta Oil_{DHW}$, $\Delta Propane_{DHW}$ are the hot water savings due to the clothes washer. The electric hot water savings are calculated:

$$\Delta kWh_{DHW} = (IMF\text{-}kWh_{Base} * \%DHW_{Base} - IMF\text{-}kWh_{ES} * \%DHW_{ES}) * EF_{DHW} / Eff_{DHW}$$

The EffDHW is the water heating efficinecy $EF_{DHW}$ is a factor to account for the hot water heating fuel source. When calculating electric savings, this factor has a value of 1.0 for sites with electric hot water heating or zero for sites with fossil fuel hot water heating. If the water heating type is unknown, the factor should be selected based on the percent of homes with electric heating, shown in the table below:

| Fuel | $EF_{DHW}$ [17] | $Eff_{DHW}$ |
|---|---|---|
| Electric | 27% | 1.0 |
| Natural Gas | 63% | 0.8 |
| Oil | 6% | 0.8 |
| Propane | 4% | 0.8 |

The natural gas, oil, and propane can be calcualted using a similar approach, adjuting the $EF_{DHW}$ and $EFF_{DHW}$ based on the size water heating fuel source or the default values from the table above as well as a the conversion factor of 0.003412 MMBTU per kWh.

Similarly, $\Delta kWh_{Dryer}$ is the hot water savings due to the clothes dryer and is calculated:

$$\Delta kWh_{Dryer} = (IMF\text{-}kWh_{Base} * \%Dryer_{Base} - IMF\text{-}kWh_{ES} * \%Dryer_{ES}) * EF_{Dryer}$$

[16] Illinois Technical Reference Manual v7.0. (http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_3_Res_092818_Final.pdf).
[17] 2005 Residential Energy Consumption Survey (RECS) for East North Central Census Division: (http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc8waterheating/pdf/tablehc12.8.pdf)

The $EF_{Dryer}$ is a factor to account for the dryer heating fuel source. When calculating electric savings, this factor has a value of 1.0 for sites with an electric dryer or zero for sites with a natural gas dryer. If the dryer type is unknown, the factor should be selected from the table below:

| Fuel | % of Homes[18] |
|---|---|
| Electric | 66% |
| Natural Gas | 34% |

Natural gas savings can be calculated similarly.

Finally, secondary savings due to reduced water supply and wastewater treatment are calculated:

$$\Delta kWh_{Water} = Capacity * (IWF_{Base} - IWF_{Eff}) * Ncycles * Ewater$$

The IWFBase should be taken from the federal standard and the EWFEff should be taken from the actual usit specifications or the default ENERGY STAR or CEE criteria. Ewater is the community/municipal water and wastewater pump kWh savings per gallon water saved, or 0.0039kWh per gallon of water saved[19]

**Summer Coincident Peak Demand Savings**

$$\Delta kW = \Delta kWh/Hours * CF$$

The peak coincidence factor (CF) is 0.045.

**Water Impact Descriptions and Calculation**

$$\Delta Gallons = Capacity * (IWF_{Base} - IWF_{Eff}) * Ncycles$$

**Deemed O&M Cost Adjustment Calculation**

n/a

[18] 2005 Residential Energy Consumption Survey (RECS) for East North Central Census Division: (http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc9homeappliance/pdf/tablehc12.9.pdf)

[19] Efficiency Vermont analysis of Community/Municipal Water and Wastewater pump energy consumption showed 0.0024 kWh pump energy consumption per gallon of water supplied, and 0.0015 kWh consumption per gallon for waste water treatment.

## ENERGY STAR Dehumidifier (Time of Sale)

**Description**
A dehumidifier installed in a residential setting that exceeds the minimum qualifying efficiency standard established by ENERGY STAR Version 5.0 (effective 10/31/2019) or the ENERGY STAR Most Efficient Equipment criteria.

**Definition of Efficient Equipment**
To qualify for this measure, the new dehumidifier must meet the ENERGY STAR standards as of 10/31/2019[20] or the ENERGY STAR Most Efficient criteria of 1/1120121/2019[21], shown below:

| Portable Unit Capacity (pints/day) | Federal Standard Criteria (L/kWh) | ENERGY STAR Criteria (L/kWh) | ENERGY STAR Most Efficient (L/kWh) |
|---|---|---|---|
| ≤25 | ≥1.30 | ≥1.57 | ≥2.20 |
| > 25 to ≤50 | ≥1.61 | ≥1.80 | ≥2.20 |
| > 50 | ≥2.80 | ≥3.30 | N/A |

| Whole House Unit Product Case Volume (cu ft) | Federal Standard Criteria (L/kWh) | ENERGY STAR Criteria (L/kWh) | ENERGY STAR Most Efficient (L/kWh) |
|---|---|---|---|
| ≤8 | ≥1.77 | ≥2.09 | ≥2.30 |
| >8 | ≥2.41 | ≥3.30 | N/A |

**Definition of Baseline Equipment**
The baseline for this measure is defined as a new dehumidifier that meets the Federal Standard efficiency standards as of June 13, 2019, shown above

**Default Deemed Savings for this Measure**
The savings for this measure can be claimed using a deemed savings approach. These deemed savings are based on a typical dehumidifier installations and the nominal baseline and efficient dehumidifier specifications presented above.

[20] ENERGY STAR Version 5.0 Specifications. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Dehumidifiers%20Version%205.0%20Program%20Requirements.pdf
[21] ENERGY STAR Most Efficient Products Criteria for Dehumidifiers. https://www.energystar.gov/sites/default/files/Dehumidifiers%20ENERGY%20STAR%20Most%20Efficient%202019%20Proposed%20Criteria.pdf

| Portable Dehumidifiers | ENERGY STAR | | ENERGY STAR Most Efficient | |
|---|---|---|---|---|
| | kWh | Peak kW | kWh | Peak kW |
| ≤25 | 94 | 0.021 | 223 | 0.050 |
| > 25 to ≤50 | 89 | 0.020 | 219 | 0.050 |
| > 50 | 131 | 0.030 | N/A | N/A |

| Whole House Dehumidifiers | ENERGY STAR | | ENERGY STAR Most Efficient | |
|---|---|---|---|---|
| | kWh | Peak kW | kWh | Peak kW |
| ≤8 | 165 | 0.037 | 248 | 0.056 |
| > 8 | 213 | 0.048 | N/A | N/A |

### Calculated Savings Approach for this Measure

In addition to the default savings values presented above, the savings for this measure can be calculated using the approach set forth in the reference section. If the calculated approach is used, actual installed equipment specifications, such as dehumidifier capacity and kWh/L values should be used.

### Deemed Lifetime of Efficient Equipment

The assumed lifetime of the measure is 12 years[22]

### Deemed Measure Cost

The incremental cost for an ENERGY STAR unit is assumed to be $10.29 and for an ENERGY STAR Most Efficient unit is $75.[23]

### Deemed O&M Cost Adjustments

n/a

### Coincidence Factor

The coincidence factor is assumed to be 0.37 [24]

[22] ENERGY STAR Dehumidifier Calculator http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerDehumidifier.xls

[23] Based on available data from the Department of Energy's Life Cycle Cost analysis spreadsheet: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/lcc_dehumidifier.xls Illinois Technical Reference Manual v7.0. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_3_Res_092818_Final.pdf.

[24] Assume usage is evenly distributed day vs night, weekend vs weekday and is used between April through the end of September (4392 possible hours). 1620 operating hours from ENERGY STAR Dehumidifier Calculator. Coincidence peak during summer peak is therefore 1620/4392 = 36.9%

## REFERENCE SECTION

### Calculation of Savings

**Energy Savings**

kWH = (Capacity * 0.473) / 24 * Hours / Efficiency

ΔkWH = $kWH_{Base}$ - $kWH_{Efficient}$

Where:

0.473 = Constant to convert Pints to Liters

Hours = Run hours per year
= 1632 [25]

Efficiency = Liters of water per kWh consumed
= As provided in tables above

Capacity = Dehumidification capacity in Pints/day if the capacity is unknown use the capacity values shown in the table below

| Dehumidifier Type | Capacity Range | Pints/day used |
|---|---|---|
| Portable | ≤25 Pints/day | 22.4 |
| | > 25 to ≤50 Pints/day | 40 |
| | > 50 Pints/day | 75 |
| Whole House | ≤8 cu. ft. | 59.2 |
| | > 8 cu. ft. | 59.2 |

**Summer Coincident Peak Demand Savings**

ΔkW = ΔkWh/Hours * CF

Where:

CF = Summer Peak Coincidence Factor for measure
= 0.37 [26]

**Fossil Fuel Impact Descriptions and Calculation**

n/a

**Water Impact Descriptions and Calculation**

n/a

**Deemed O&M Cost Adjustment Calculation**

n/a

[25] ENERGY STAR Dehumidifier Calculator http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerDehumidifier.xls

[26] Assume usage is evenly distributed day vs night, weekend vs weekday and is used between April through the end of September (4392 possible hours). 1632 operating hours from ENERGY STAR Dehumidifier Calculator. Coincidence peak during summer peak is therefore 1632/4392 = 37.2%

## ENERGY STAR Dishwasher

**Description**
This measure relates to the purchase (time of sale) and installation of a clothes washer exceeding the ENERGY STAR[27] minimum qualifying efficiency standards presented below:

| Dishwasher Type | Federal Standard | | ENERGY STAR | |
|---|---|---|---|---|
| | Maximum kWh/Year | Maximum gallons/cycle | Maximum kWh/Year | Maximum gallons/cycle |
| Standard | 307 | 5.0 | 270 | 3.8 |
| Standard with Connected Functionality | 307 | 5.0 | 283 | 3.5 |
| Compact | 222 | 3.5 | 203 | 3.1 |

**Definition of Efficient Equipment**
The efficient condition is a dishwasher meeting either the ENERGY STAR criteria presented above.

**Definition of Baseline Equipment**
The baseline condition is a dishwasher at the minimum federal baseline efficiency presented above.

**Deemed Savings for this Measure**
The savings for this measure can be claimed using a deemed savings approach. These deemed savings are based on a typical dishwasher installation and the nominal baseline and efficient dishwasher specification presented in the table above. Default savings values are given for each combination of electric or natural gas hot water heating systems. If the water heating fuel type is unknown or not tracked by the program, the "unknown" DHW column should be used.

| Dishwasher Type | kWh Savings | | | kW Savings | | |
|---|---|---|---|---|---|---|
| | Electric DHW | Other DHW | Unknown DHW | Electric DHW | Other DHW | Unknown DHW |
| Standard | 38.0 | 17.3 | 22.9 | 0.003 | 0.001 | 0.002 |
| Standard, Connected | 25.0 | 11.5 | 15.2 | 0.002 | 0.001 | 0.001 |
| Compact | 19.3 | 9.3 | 12.2 | 0.001 | 0.001 | 0.001 |

[27] ENERGY STAR Program Requirements for Residential Dishwashers. Version 6.0.
https://www.energystar.gov/sites/default/files/specs/ENERGY%20STAR%20Draft%201%20Version%206%200%20Residential%20Dishwasher%20Specification.pdf

| Dishwasher Type | Natural Gas MMBTU Savings | | |
|---|---|---|---|
| | NG DHW | Other DHW | Unknown DHW |
| Standard | 0 | 0.089 | 0.056 |
| Standard, Connected | 0 | 0.058 | 0.036 |
| Compact | 0 | 0.046 | 0.029 |

**Deemed Lifetime of Efficient Equipment**
The measure life is assumed to be 10 years[28].

**Deemed Measure Cost**
The incremental cost for this measure is assumed to be $76 for an ENERGY STAR dishwasher.[29]

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

**Coincidence Factor**
The coincidence factor for this measure is assumed to be 0.026[30].

## REFERENCE SECTION

**Calculation of Energy Savings**

Savings are determined using the kWh/year values from the ENERGY STAR and federal baseline unit and applying the proportion of consumption used for the dishwasher and water heating. Savings from reduced water usage are also included.

| Dishwasher Type | All-Electric Energy Savings |
|---|---|
| Standard | 38.0 |
| Standard, Connected | 25.0 |
| Compact | 19.3 |

This energy usage value includes the direct energy usage of the dishasher as well as associated usage of the hot water system, which may be either electric or fossil fuel. Therefore, the energy usage of each piece of equipment is analyzed seperately. The percent of the overall usage assocaited with the dishwasher and the water heater is shown in the table below.

[28] ENERGY STAR calculator (https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx)
[29] Illinois Technical Reference Manual v7.0. (http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_3_Res_092818_Final.pdf).
[30] Ibid.

| Equipment | Percent of Total Energy Consumption[31] |
|---|---|
| Dishwasher | 44% |
| Hot Water | 56% |

The total energy savings for the installation of the efficient ENERGY STAR dishwasher is then:

$$\Delta kWh = \Delta kWh_{DW} + \Delta kWh_{DHW} + \Delta kWh_{Water}$$
$$\Delta Gas = \Delta Gas_{DHW}$$

$\Delta kWh_{CW}$ is the direct electrical savings for the clothes washer and is calculated:

$$\Delta kWh_{DW} = (kWh_{Base} - kWh_{ES}) * \%DW$$

$\Delta kWh_{DHW}$ and $\Delta Gas_{DHW}$ are the hot water savings due to the clothes washer. The hot water savings are calculated:

$$\Delta kWh_{DW} = (kWh_{Base} - kWh_{ES}) * \%DHW * EF_{DHW\text{-}E}$$
$$\Delta Gas = (Gas_{Base} - Gas_{ES}) * \%DHW * Eff_{DHW} * 0.003412 * EF_{DHW\text{-}NG}$$

The $Eff_{DHW}$ is the water heating recovery factor of 1.26 and $EF_{DHW}$ is the energy factor to account for the water heating fuel type. If the water heating type is electric $EF_{DHW\text{-}E}$ is 1.0 and $EFD_{HW\text{-}NG}$ is 0. For installations with natural gas hot water heating then $EF_{DHW\text{-}E}$ is 0 and $EFD_{HW\text{-}NG}$ is 1.0. If the water heating type is unknown, the factor should be selected based on the percent of homes with electric heating, shown in the table below:

| Fuel | $EF_{DHW}$ [32] |
|---|---|
| $EF_{DHW\text{-}E}$ | 27% |
| $EF_{DHW\text{-}NG}$ | 63% |

Finally, secondary savings due to reduced water supply and wastewater treatment are calculated:

$$\Delta kWh_{Water} = Capacity * (Gal/cycle_{Base} – Gal/cycle_{Eff}) * Ncycles * Ewater$$

The Gal/cycle should be taken from the federal standard and ENERGY STAR criteria. The Ewater is the community/municipal water and wastewater pump kWh savings per gallon water saved, or 0.0039 kWh per gallon of water saved[33]

**Summer Coincident Peak Demand Savings**

$$\Delta kW = \Delta kWh/Hours * CF$$

The peak coincidence factor (CF) is 0.026.

[31] Illinois Technical Reference Manual v7.0. (http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_3_Res_092818_Final.pdf).
[32] 2005 Residential Energy Consumption Survey (RECS) for East North Central Census Division: (http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc8waterheating/pdf/tablehc12.8.pdf)
[33] Efficiency Vermont analysis of Community/Municipal Water and Wastewater pump energy consumption showed 0.0024 kWh pump energy consumption per gallon of water supplied, and 0.0015 kWh consumption per gallon for waste water treatment.

**Water Impact Descriptions and Calculation**

$\Delta$Gallons = $(Gal/cycle_{Base} - Gal/cycle_{Eff})$ * Ncycles

Ncycles =168 cycles per year.[34]

**Deemed O&M Cost Adjustment Calculation**

n/a

[34] Illinois Technical Reference Manual v7.0. (http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_3_Res_092818_Final.pdf).

## ENERGY STAR Freezer (Time of Sale)

**Description**
This measure relates to the purchase and installation of a new freezer meeting ENERGY STAR specifications.

**Definition of Efficient Equipment**
The efficient condition is a new freezer meeting the ENERGY STAR version 5.0[35] efficiency standards.

**Definition of Baseline Equipment**
The baseline condition is a new freezer meeting the minimum federal efficiency standard for refrigerator and freezer efficiency as set forth in DOE 10 CFR §430.32[36].

**Default Deemed Savings for this Measure**
The savings for this measure can be claimed using a deemed savings approach. These deemed savings are based on a typical freezer installation and the expected energy use for an ENERGY STAR freezer compared to a baseline freezer that meets the federal efficiency standards.

Key assumptions:

Refrigerator Adjusted Volume = 27.9 cubic feet for full-size freezers and 104 cubic feet for compact freezers [37]

Additional assumpions are included in detail in the reference section

| Freezer Product Class | Adjusted Volume (cu. ft.) | ENERGY STAR | |
|---|---|---|---|
| | | Annual kWh | Summer Peak kW |
| 8. Upright freezers with manual defrost | 27.9 | 35 | 0.006 |
| 9. Upright freezers with automatic defrost without an automatic icemaker | 27.9 | 42 | 0.007 |
| 9I. Upright freezers with automatic defrost with an automatic icemaker. | 27.9 | 50 | 0.009 |
| 10. Chest freezers and all other freezers except compact freezers. | 27.9 | 31 | 0.005 |
| 10A. Chest freezers with automatic defrost. | 27.9 | 43 | 0.008 |
| 16. Compact upright freezers with manual defrost | 10.4 | 32 | 0.006 |
| 17. Compact upright freezers with automatic defrost | 10.4 | 46 | 0.008 |
| 18. Compact chest freezers | 10.4 | 23 | 0.004 |

**Calculated Savings Approach for this Measure**
In addition to the default savings values presented above, the savings for this measure can be calculated using the approach set forth in the reference section. If the calculated approach is used, actual installed

[35] ENERGY STAR program requirements product specification for residential refrigerators and freezers. (https://www.energystar.gov/ia/partners/product_specs/program_reqs/Refrigerators_and_Freezers_Program_Requirements_V5.0.pdf)
[36] Energy conservation program for consumer products. (https://www.ecfr.gov/cgi-bin/text-idx?SID=48f64e166fe3561666f871e521996e13&mc=true&node=se10.3.430_132&rgn=div8)
[37] Volume is based on ENERGY STAR Calculator

equipment specifications, such as federal standard kWh/year, efficient equipment certified kWh/year and/or the refrigerated adjusted volume should be used rather than the default assumptions.

**Deemed Lifetime of Efficient Equipment**
The measure life is assumed to be 14 Years [38].

**Deemed Measure Cost**
The incremental cost for this measure is assumed to be $40[39] for an ENERGY STAR unit and $140[40] for a CEE Tier 2 unit.

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

**Coincidence Factor**
A coincidence factor is not used to calculate peak demand savings for this measure. See discussion below.

## REFERENCE SECTION

**Calculation of Savings**

**Energy Savings**

$$\Delta kWh = UEC_{BASE} - UEC_{EE}$$

Where:

$UEC_{BASE}$ = Annual Unit Energy Consumption of baseline freezer meeting the minimum federal efficiency standard as determined from the ENERGY STAR certified product list or calculated using the table below [41]

[38] California DEER database 2011
[39] From ENERGY STAR calculator: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Consumer_Residential_Refrig_Sav_Calc.xls
[40] Based on weighted average of units participating in Efficiency Vermont program and retail cost data provided in Department of Energy, "TECHNICAL REPORT: Analysis of Amended Energy Conservation Standards for Residential Refrigerator-Freezers", October 2005; http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrigerator_report_1.pdf
[41] Energy conservation program for consumer products. (https://www.ecfr.gov/cgi-bin/text-idx?SID=48f64e166fe3561666f871e521996e13&mc=true&node=se10.3.430_132&rgn=div8)

| Product Type | Annual Energy Consumption |
|---|---|
| 8. Upright freezers with manual defrost | 5.57AV + 193.7 |
| 9. Upright freezers with automatic defrost without an automatic icemaker | 6.82AV + 228.3 |
| 9I. Upright freezers with automatic defrost with an automatic icemaker. | 6.82AV + 312.3 |
| 10. Chest freezers and all other freezers except compact freezers. | 7.29AV + 107.8 |
| 10A. Chest freezers with automatic defrost. | 10.24AV + 148.1 |
| 16. Compact upright freezers with manual defrost | 8.65AV + 225.7 |
| 17. Compact upright freezers with automatic defrost | 10.17AV + 351.9 |
| 18. Compact chest freezers | 9.25AV + 136.8 |

$UEC_{EE}$ = Annual Unit Energy Consumption of installed freezer as determined from the ENERGY STAR certified product list or calculated based on a 90% of $UEC_{Base}$.

**Summer Coincident Peak Demand Savings**

$\Delta kW = (\Delta kWh/8760) * TAF * LSAF$

Where:

TAF = Temperature Adjustment Factor
= 1.30 [42]

LSAF = Load Shape Adjustment Factor
= 1.18 [43]

**Fossil Fuel Impact Descriptions and Calculation**

n/a

**Water Impact Descriptions and Calculation**

n/a

**Deemed O&M Cost Adjustment Calculation**

n/a

[42] Temperature adjustment factor based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 47). It assumes 64% of Ohio homes have central air conditioning.

[43] Daily load shape adjustment factor also based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 48, extrapolated by taking the ratio of existing summer to existing annual profile for hours ending 16 through 18, and multiplying by new annual profile).

## ENERGY STAR and CEE Tier 2 Refrigerators (Time of Sale)

**Description**
This measure relates to the purchase and installation of a new refrigerator meeting either ENERGY STAR or CEE TIER 2 specifications. This is a time of sale measure characterization.

**Definition of Efficient Equipment**
The efficient condition is a new refrigerator meeting either the ENERGY STAR version 5.0[44] or CEE TIER 2[45] efficiency standards.

**Definition of Baseline Equipment**
The baseline condition is a new refrigerator meeting the minimum federal efficiency standard for refrigerator and freezer efficiency as set forth in DOE 10 CFR §430.32[46].

**Default Deemed Savings for this Measure**
The savings for this measure can be claimed using a deemed savings approach. These deemed savings are based on a typical refrigerator installation and the expected energy use for an ENERGY STAR or CEE Tier 2 refrigerator compared to a baseline refrigerator that meets the federal efficiency standards. Built-in refrigerators are excluded from the default deemed savings values.

| Refrigerator Product Class | Adjusted Volume (cu. ft.) | ENERGY STAR | | CEE Tier 2 | |
|---|---|---|---|---|---|
| | | Annual kWh | Summer Peak kW | Annual kWh | Summer Peak kW |
| 1. Refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost | 10.4 | 30.81 | 0.005 | 46.21 | 0.008 |
| 1A. All-refrigerators—manual defrost | 10.4 | 26.42 | 0.005 | 39.63 | 0.007 |
| 2. Refrigerator-freezers—partial automatic defrost | 9.6 | 30.17 | 0.005 | 45.26 | 0.008 |
| 3. Refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic icemaker | 16.9 | 37.00 | 0.006 | 55.50 | 0.008 |
| 3I. Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service | 21.2 | 48.85 | 0.009 | 73.27 | 0.010 |
| 3A. All-refrigerators—automatic defrost | 13.3 | 29.55 | 0.005 | 44.33 | 0.008 |
| 4. Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker | 30.4* | 55.62 | 0.010 | 83.43 | 0.015 |
| 4I. Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service | 30.4* | 64.02 | 0.011 | 96.03 | 0.017 |
| 5. Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker | 18.6 | 48.17 | 0.008 | 72.26 | 0.013 |

44 ENERGY STAR program requirements product specification for residential refrigerators and freezers. (https://www.energystar.gov/ia/partners/product_specs/program_reqs/Refrigerators_and_Freezers_Program_Requirements_V5.0.pdf)
45 CEE Super Efficient Home Appliances Initiative. (https://library.cee1.org/system/files/library/9563/CEE_ResidentialRefrigeratorSpecification_15Sep2014.pdf)
46 Energy conservation program for consumer products. (https://www.ecfr.gov/cgi-bin/text-idx?SID=48f64e166fe3561666f871e521996e13&mc=true&node=se10.3.430_132&rgn=div8)

| | | | | | |
|---|---|---|---|---|---|
| 5I. Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service | 26.3 | 63.40 | 0.011 | 95.11 | 0.017 |
| 5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service | 32.0 | 77.18 | 0.014 | 115.76 | 0.020 |
| 6. Refrigerator-freezers—automatic defrost with top-mounted freezer with through-the-door ice service | 21.2* | 56.32 | 0.010 | 84.48 | 0.015 |
| 7. Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service | 30.4 | 69.21 | 0.012 | 103.81 | 0.018 |

*No products were included in the certified products list for ENERGY STAR categories 4, 4I, or 6. Therefore, the typical size for these units are based on the average size from similar categories.

**Calculated Savings Approach for this Measure**

In addition to the default savings values presented above, the savings for this measure can be calculated using the approach set forth in the reference section. If the calculated approach is used, actual installed equipment specifications, such as federal standard kWh/year, efficient equipment certified kWh/year and/or the refrigerated adjusted volume should be used rather than the default assumptions.

**Deemed Lifetime of Efficient Equipment**

The measure life is assumed to be 14 Years [47].

**Deemed Measure Cost**

The incremental cost for this measure is assumed to be $40[48] for an ENERGY STAR unit and $140[49] for a CEE Tier 2 unit.

**Deemed O&M Cost Adjustments**

n/a

**Coincidence Factor**

A coincidence factor is not used to calculate peak demand savings for this measure. See discussion below.

## REFERENCE SECTION

**Calculation of Savings**

**Energy Savings**

$$\Delta kWh = UEC_{BASE} - UEC_{EE}$$

Where:

[47] California DEER database 2011

[48] From ENERGY STAR calculator: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Consumer_Residential_Refrig_Sav_Calc.xls

[49] Based on weighted average of units participating in Efficiency Vermont program and retail cost data provided in Department of Energy, “TECHNICAL REPORT: Analysis of Amended Energy Conservation Standards for Residential Refrigerator-Freezers”, October 2005; http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrigerator_report_1.pdf

$UEC_{BASE}$ = Annual Unit Energy Consumption of baseline unit meeting the minimum federal efficiency standard as determined from the ENERGY STAR certified product list or calculated using the table below [50]

| Product Type | 7.99AV + 225.0 |
|---|---|
| 1. Refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost | 7.99AV + 225.0 |
| 1A. All-refrigerators—manual defrost | 6.79AV + 193.6 |
| 2. Refrigerator-freezers—partial automatic defrost | 7.99AV + 225.0 |
| 3. Refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic icemaker | 8.07AV + 233.7 |
| 3-BI. Built-in refrigerator-freezer—automatic defrost with top-mounted freezer without an automatic icemaker | 9.15AV + 264.9 |
| 3I. Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service | 8.07AV + 317.7 |
| 3I-BI. Built-in refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service | 9.15AV + 348.9 |
| 3A. All-refrigerators—automatic defrost | 7.07AV + 201.6 |
| 3A-BI. Built-in All-refrigerators—automatic defrost | 8.02AV + 228.5 |
| 4. Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker | 8.51AV + 297.8 |
| 4-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker | 10.22AV + 357.4 |
| 4I. Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service | 8.51AV + 381.8 |
| 4I-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service | 10.22AV + 441.4 |
| 5. Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker | 8.85AV + 317.0 |
| 5-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker | 9.40AV + 336.9 |
| 5I. Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service | 8.85AV + 401.0 |
| 5I-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service | 9.40AV + 420.9 |
| 5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service | 9.25AV + 475.4 |
| 5A-BI. Built-in refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service | 9.83AV + 499.9 |
| 6. Refrigerator-freezers—automatic defrost with top-mounted freezer with through-the-door ice service | 8.40AV + 385.4 |
| 7. Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service | 8.54AV + 432.8 |
| 7-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service | 10.25AV + 502.6 |

[50] Energy conservation program for consumer products. (https://www.ecfr.gov/cgi-bin/text-idx?SID=48f64e166fe3561666f871e521996e13&mc=true&node=se10.3.430_132&rgn=div8)KWh assumptions for base condition are based on the average federal standard baseline usage for the range of efficient units purchased through the Efficiency Vermont's Residential Refrigerator program during 2009.

$UEC_{EE}$ = Annual Unit Energy Consumption of installed refrigerator as determined from the ENERGY STAR certified product list or calculated based on a 90% of $UEC_{Base}$ for ENERGY STAR of 85% of $UEC_{Base}$ for CEE Tier 2 refrigerators.

**Summer Coincident Peak Demand Savings**

$\Delta kW = (\Delta kWh/8760) * TAF * LSAF$

Where:

TAF = Temperature Adjustment Factor
= 1.30 [51]

LSAF = Load Shape Adjustment Factor
= 1.18 [52]

**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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[51] Temperature adjustment factor based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 47). It assumes 64% of Ohio homes have central air conditioning.

[52] Daily load shape adjustment factor also based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 48, extrapolated by taking the ratio of existing summer to existing annual profile for hours ending 16 through 18, and multiplying by new annual profile).

## Refrigerator Replacement (Low Income)

**Description**
This measure describes the early removal of an existing inefficient refrigerator from service, prior to its natural end of life, and replacement with a new ENERGY STAR qualifying unit. This measure is suitable for a Low Income or Home Performance program. Savings are calculated for the estimated energy consumption during the remaining life of the existing unit.

**Definition of Efficient Equipment**
The efficient condition is a new replacement refrigerator meeting the ENERGY STAR efficiency standard (defined as requiring >= 20% less energy consumption than an equivalent unit meeting federal standard requirements).

**Definition of Baseline Equipment**
The baseline condition is the existing inefficient refrigerator for the remaining assumed useful life of the unit, and then for the remainder of the measure life the baseline becomes a new refrigerator meeting the minimum federal efficiency standard.

**Deemed Savings for this Measure**

| | Average Annual KWH Savings per unit | Average Summer Coincident Peak kW Savings per unit |
|---|---|---|
| Remaining life of existing unit (1st 8 years) | 655 | 0.098 |
| Remaining measure life (next 6 years) | 47 | 0.008 |

**Deemed Lifetime of Efficient Equipment**
The measure life is assumed to be 14 Years [53].

**Deemed Lifetime of Replaced (Existing) Equipment**
The assumed remaining useful life of the existing refrigerator being replaced is 8 Years [54].

**Deemed Measure Cost**
The actual measure cost for removing the existing unit and installing the new should be used.

**Deemed O&M Cost Adjustments**
The net present value of the deferred replacement cost (the cost associated with the replacement of the existing unit with a standard unit that would have had to have occurred in 8 years, had the existing unit not been replaced) is calculated as $328.73[55].

**Coincidence Factor**
A coincidence factor is not used to calculate peak demand savings for this measure. See discussion below.

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[53] California DEER database 2011
[54] KEMA "Residential refrigerator recycling ninth year retention study", 2004
[55] Determined by calculating the Net Present Value (with a 5% discount rate) of the annuity payments from years 9 to 14 of a deferred replacement of a standard efficiency unit costing $1150 (from ENERGY STAR calculator: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Consumer_Residential_Refrig_Sav_Calc.xls).

## REFERENCE SECTION

### Calculation of Savings

**Energy Savings**

$\Delta$kWh for remaining life of existing unit (1st 8 years) $= UEC_{existing} - UEC_{ES}$

$\Delta$kWh for remaining measure life (next 6 years) $= UEC_{base} - UEC_{ES}$

Where:

$UEC_{existing}$ = Unit Energy Consumption of existing refrigerator
= 1,081 kWh[56]

$UEC_{ES}$ = Unit Energy Consumption of new Energy Star refrigerator
= 427 kWh [57]

$UEC_{base}$ = Unit Energy Consumption of new baseline refrigerator
= 474 kWh [58]

$\Delta$kWh for remaining life of existing unit (1st 8 years) = 1,081 – 427
= 655 kWh

$\Delta$kWh for remaining measure life (next 6 years) = 474 – 427
= 47 kWh

**Summer Coincident Peak Demand Savings**

$\Delta kW = (\Delta kWh/8760) * TAF * LSAF$

Where:

TAF = Temperature Adjustment Factor
= 1.30 [59]

LSAFexist = Load Shape Adjustment Factor for existing unit

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56 Based on evaluated estimates, from Cadmus for the Public Service Commission of Wisconsin, "Focus on Energy Evaluated Deemed Savings Changes", September 14, 2015. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2015_final.pdf). Savings are based on the removal of a primary refrigerator. Therefore, the part-use factor was removed.

57 Approximate energy consumption of an ENERGY STAR refrigerator based on the average size from the ENERGY STAR certified product list for product class 3, 3I, and 6.

58 Approximate energy consumption of a baseline refrigerator at the federal standard efficiency level, using the average size from the ENERGY STAR certified product list for product class 3, 3I, and 6. http://www.energystar.gov/index.cfm?fuseaction=refrig.display_products_excel

59 Temperature adjustment factor based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 47). It assumes 64% of Ohio homes have central air conditioning.

= 1.074 [60]

LSAFnew = Load Shape Adjustment Factor for new unit
= 1.18 [61]

ΔkW for remaining life of existing unit (1st 8 years)
= (1081/8760 * 1.3 * 1.074) – (398/8760 * 1.3 * 1.18)
= 0.103 kW

ΔkW for remaining measure life (next 6 years)
= 44/8760 * 1.3 * 1.18
= 0.008 kW

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

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

**Deemed O&M Cost Adjustment Calculation**
The net present value of the deferred replacement cost (the cost associated with the replacement of the existing unit with a standard unit that would have had to have occurred in 8 years, had the existing unit not been replaced) is calculated as $328.73[62].

[60] Daily load shape adjustment factor also based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 48, using the average Existing Units Summer Profile for hours ending 16 through 18)
[61] Daily load shape adjustment factor also based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 48, extrapolated by taking the ratio of existing summer to existing annual profile for hours ending 16 through 18, and multiplying by new annual profile.
[62] Determined by calculating the Net Present Value (with a 5% discount rate) of the annuity payments from years 9 to 17 of a deferred replacement of a standard efficiency unit costing $1150 (from ENERGY STAR calculator: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Consumer_Residential_Refrig_Sav_Calc.xls).

## Refrigerator and/or Freezer Retirement (Early Retirement)

**Description**
This measure involves the removal of an existing inefficient refrigerator or stand-alone freezer from service, prior to its natural end of life (early retirement) [63]. The program should target units with an age greater than 10 years, though it is expected that the average age will be greater than 20 years based on other similar program performance. Savings are calculated for the estimated energy consumption during the remaining life of the existing unit.

**Definition of Efficient Equipment**
n/a

**Definition of Baseline Equipment**
In order for this characterization to apply, the existing inefficient unit must be in working order and be removed from service.

**Deemed Savings for this Measure**

| | Average Annual KWH Savings per unit | Average Summer Coincident Peak kW Savings per unit |
|---|---|---|
| Refrigerator | 886 | 0.141 |
| Freezer | 962 | 0.153 |

**Deemed Measure Life**
The remaining useful life of the retired unit is assumed to be 8 Years [64].

**Deemed Measure Cost**
The incremental cost for this measure will be the actual cost associated with the removal and recyling of the retired unit.

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

**Coincidence Factor**
A coincidence factor is not used to calculate peak demand savings for this measure. See discussion below.

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[63] This measure assumes a mix of primary and secondary units will be replaced (and the savings are reduced accordingly). By definition, the refrigerator in a household's kitchen that satisfies the majority of the household's demand for refrigeration is the primary refrigerator. One or more additional refrigerators in the household that satisfy supplemental needs for refrigeration are referred to as secondary refrigerators.
[64] KEMA "Residential refrigerator recycling ninth year retention study", 2004

## REFERENCE SECTION

### Calculation of Savings

**Energy Savings**

$\Delta kWh$ = Average in situ Unit Energy Consumption of retired unit, adjusted for part use

Refrigerator = 886 kWh [65]
Freezer = 962 kWh [66]

**Summer Coincident Peak Demand Savings**

$\Delta kW = (\Delta kWh/8760) * TAF * LSAF$

Where:

TAF = Temperature Adjustment Factor
= 1.30 [67]

LSAF = Load Shape Adjustment Factor
= 1.074 [68]

Refrigerator $\Delta kW$ = 886/8760 * 1.30 * 1.074
= 0.141 kW

Freezer $\Delta kW$ = 962/8760 * 1.30 * 1.074
= 0.153 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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[65] Based on evaluated estimates, from Cadmus for the Public Service Commission of Wisconsin, "Focus on Energy Evaluated Deemed Savings Changes", September.September 14, 2015. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2015_final.pdf)

[66] Ibid.

[67] Temperature adjustment factor based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 47). It assumes 64% of Ohio homes have central air conditioning.

[68] Daily load shape adjustment factor also based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 48, using the average Existing Units Summer Profile for hours ending 16 through 18)

## Ozone Laundry (Time of Sale)

**Description**
This measure involves the installation of an ENERGY STAR clothes dryer in a residential setting.

**Definition of Efficient Equipment**
The efficient condition is a new clothes dryer meeting the ENERGY STAR efficiency standard (defined as requiring >= 20% less energy consumption than an equivalent unit meeting federal standard requirements).

**Definition of Baseline Equipment**
The baseline condition is a standard efficiency clothes dryer that meets the minimum federal efficiency requirements for units manufactured on or after January 1, 2015.

**Deemed Savings for this Measure**

| Dryer Type | Average Annual KWH Savings per unit | Average Summer Coincident Peak kW Savings per unit | Natural Gas Savings per unit MMBTU |
|---|---|---|---|
| Vented Electric, Standard (>=4.4 $ft^3$) | 160 | 0.0215 | 0 |
| Vented Electric, Compact (120V, <4.4 $ft^3$) | 59 | 0.0079 | 0 |
| Vented Electric, Compact (2400V, <4.4 $ft^3$) | 65 | 0.0087 | 0 |
| Vented Electric, Compact (120V, <4.4 $ft^3$) | 82 | 0.0110 | 0 |
| Vented Gas | 25 | 0.0033 | 0.44 |

**Deemed Measure Life**
The remaining useful life of the retired unit is assumed to be 12 Years [69].

**Deemed Measure Cost**
The incremental cost for an ENERGY STAR clothes dryer is assumed to be $152.[70]

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

**Coincidence Factor**
A coincidence factor for this measure is assumed to be 3.8%.[71]

[69] ENERGY STAR Calculator. (https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx)
[70] Per the costs presented in "Bringing North American Clothes Dryers into the 21st Century: A Case Study in Moving Markets" https://aceee.org/files/proceedings/2012/data/papers/0193-000286.pdf)
[71] Illinois Technical Reference Manual v7.0. (http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_3_Res_092818_Final.pdf).

## REFERENCE SECTION

**Calculation of Savings**

**Energy Savings**

$\Delta$kWh = Load*($1/CEF_{Base}$ – $1/CEF_{ES}$) * Cycles * %Electric

$\Delta$Gas = Loads*($1/CEF_{Base}$ – $1/CEF_{ES}$) * Cycles * %Gas *0.003412

Where:

Loads = Weight of clothes per drying cycle
= 8.45 lbs for standard dryers and 3 lbs for compact dryers[72]

Cycles = Dryer cycles per year
= 283[73]

The CEF is the combined energy factor (lbs/kWh) for the baseline and ENERGY STAR dryer and the %Electric and %Gas are the percent of savings associated with electric and gas fuels, respectively.

| Product Class | $CEF_{Base}$ | $CEF_{ES}$ | %Electric | %Gas |
|---|---|---|---|---|
| Vented Electric, Standard (>=4.4 ft$^3$) | 3.11 | 3.93 | 1 | 0 |
| Vented Electric, Compact (120V, <4.4 ft$^3$) | 3.01 | 3.80 | 1 | 0 |
| Vented Electric, Compact (2400V, <4.4 ft$^3$) | 2.73 | 3.45 | 1 | 0 |
| Vented Electric, Compact (120V, <4.4 ft$^3$) | 2.13 | 2.68 | 1 | 0 |
| Vented Gas | 2.84 | 3.48 | 0.16 | 0.84 |

**Summer Coincident Peak Demand Savings**

$\Delta$kW = ($\Delta$kWh/283[74]) * CF

**Fossil Fuel Impact Descriptions and Calculation**

n/a

**Water Impact Descriptions and Calculation**

n/a

**Deemed O&M Cost Adjustment Calculation**

n/a

[72] Based on ENERGY STAR test procedures.
[73] Appendix D to Subpart B of Part 430 – Uniform Test Method for Measuring the Energy Consumption of Dyers.
[74] Assuming one hour per dryer cycle.

# II. HVAC

## Residential HVAC Maintenance/Tune Up (Retrofit)

**Description**
This measure involves the measurement of refrigerant charge levels and airflow over the central air conditioning or heat pump unit coil, correction of any problems found and post-treatment re-measurement. Measurements must be performed with standard industry tools and the results tracked by the efficiency program.
Savings from this measure are developed using a reputable Wisconsin study. It is recommended that future evaluation be conducted in Ohio to generate a more locally appropriate characterization.

**Definition of Efficient Equipment**
n/a

**Definition of Baseline Equipment**
This measure assumes that the existing unit being maintained is either a residential central air conditioning unit or an air source heat pump.

**Deemed Calculation for this Measure**

Annual kWh Savings (central air conditioning) $= FLHcool * BtuH * (1/SEER_{CAC}) * 5 * 10^{-5}$

Annual kWh Savings (air source heat pump) $= (FLHcool * BtuH * (1/SEER_{ASHP}) * 5 * 10^{-5}) + (FLHheat * BtuH * (1/HSPF_{ASHP})) * 5 * 10^{-5})$

Summer Coincident Peak kW Savings $= BtuH * (1/EER)) * 1.0 * 10^{-5} * CF$

**Deemed Lifetime of Efficient Equipment**
The measure life is assumed to be 5 years[75].

**Deemed Measure Cost**
If the implementation mechanism involves delivering and paying for the tune up service, the actual cost should be used. If however the customer is provided a rebate and the program relies on private contractors performing the work with no other work performed on the unit during that visit, the measure cost should be assumed to be $175[76]. If the contractor visit involves additional work on the unit beyond this measure, the measure cost should be assumed to be $80[77]

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

**Coincidence Factor**
The summer peak coincidence factor for this measure is assumed to be 0.68[78].

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[75] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
[76] Based on personal communication with HVAC efficiency program consultant Buck Taylor or Roltay Inc., 6/21/10, who estimated the cost of tune up at $125 to $225, depending on the market and the implementation details.
[77] Based on estimates derived from a CSG survey in Dayton of 12 HVAC contractors and their costs for performing an inspection as part of a larger visit. The $80 value comes from $175 - $96, which is from the CSG survey.
[78] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. TRM v7.0 Vol. 3_September 28, 2018_Final

## REFERENCE SECTION

**Calculation of Savings**

**Energy Savings**

$\Delta kWh_{Central\ AC}$ = (FLHcool * BtuH * (1/$SEER_{CAC}$))/1000 * MFe

$\Delta kWh_{Air\ Source\ Heat\ Pump}$ = ((FLHcool * BtuH * (1/$SEER_{ASHP}$))/1000 * MFe)
+ (FLHheat * BtuH * (1/$HSPF_{ASHP}$))/1000 * MFe)

Where:

FLHcool = Full load cooling hours
Dependent on location as below:

| Location | Run Hours[79] |
|---|---|
| Akron | 476 |
| Cincinnati | 664 |
| Cleveland | 426 |
| Columbus | 552 |
| Dayton | 631 |
| Mansfield | 474 |
| Toledo | 433 |
| Youngstown | 369 |

BtuH = Size of equipment in Btuh (note 1 ton = 12,000Btuh)
= Actual

$SEER_{CAC}$ = SEER Efficiency of existing central air conditioning unit receiving maintenence
= Actual[80]

MFe = Maintenance energy savings factor
= 0.05[81]

$SEER_{ASHP}$ = SEER Efficiency of existing air source heat pump unit receiving maintenence
= Actual [82]

FLHheat = Full load heating hours

[79] 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."

[80] Use actual SEER rating where it is possible to measure or reasonably estimate. When unknown use SEER 10 (VEIC estimate of existing unit efficiency, based on minimum federal standard between the years of 1992 and 2006)

[81] Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."p.39.

[82] Use actual SEER rating where it is possible to measure or reasonably estimate. When unknown use SEER 10 (VEIC estimate of existing unit efficiency, based on minimum federal standard between the years of 1992 and 2006)

Dependent on location as below:

| Location | Run Hours[83] |
|---|---|
| Akron | 1576 |
| Cincinnati | 1394 |
| Cleveland | 1567 |
| Columbus | 1272 |
| Dayton | 1438 |
| Mansfield | 1391 |
| Toledo | 1628 |

HSPFbase = Heating Season Performance Factor of existing air source heat pump unit receiving maintenence
= Actual[84]

For example, maintenance of a 3-ton, SEER 10 air conditioning unit in Cincinnati:

$\Delta kWh_{CAC}$ = (657 * 36000 * (1/10))/1000 * 0.05
= 118.3 kWh

For example, maintenance of a 3-ton, SEER 10, HSPF 6.8 air source heat pump unit in Cincinnati:

$\Delta kWh_{ASHP}$ = ((657 * 36000 * (1/10))/1000 * 0.05) + (1394 * 36000 * (1/6.8))/1000 * 0.05)
= 487.3 kWh

**Summer Coincident Peak Demand Savings**

$\Delta kW$ = BtuH * (1/EER)/1000 * MFd * CF

Where:

EER = EER Efficiency of existing unit receiving maintenence
= Calculate using Actual SEER
= (SEER * 0.9)[85]

MFd = Maintenance demand savings factor
= 0.02[86]

CF = Summer Peak Coincidence Factor for measure
= 0.72[87]

For example, maintenance of 3-ton, SEER 10 (equals EER 9.0) unit:

$\Delta kW$ = 36000 * (1/(9.0)/1000 * 0.02 * 0.72

= 0.058 kW

83 Heating EFLH extracted from simulations conducted for Duke Energy, OH Joint Utility TRM, October 2009; "Technical Reference Manual (TRM) for Ohio Senate Bill 221Energy Efficiency and Conservation Program and 09-512-GE-UNC"
84 Use actual HSPF rating where it is possible to measure or reasonably estimate. When unknown use HSPF 6.8 (Minimum Federal Standard between 1992 and 2006).
85 If SEER is unknown, default EER would be (10 * 0.9) = 9.0. Calculation based on prior VEIC assessment of industry equipment efficiency ratings.
86 Based on June 2010 personal conversation with Scott Pigg, author of Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research" suggesting the average WI unit system draw of 2.8kW under peak conditions, and average peak savings of 50W.
87 Based on metering of 24 homes with heat pumps PY5 in Ameren Illinois service territory. 2019 IL TRM v7.0 Vol. 3_September 28, 2018_Final

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

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

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

## Central Air Conditioning (Time of Sale)

**Description**
This measure relates to the installation of a new Central Air Conditioning ducted split system meeting ENERGY STAR efficiency standards presented below. This measure could relate to the replacing of an existing unit at the end of its useful life, or the installation of a new system in an existing home (i.e. time of sale).

**Definition of Efficient Equipment**
In order for this characterization to apply, the efficient equipment is assumed to be a ducted split central air conditioning unit meeting the minimum ENERGY STAR efficiency level standards; 15 SEER and 12.5 EER.

**Definition of Baseline Equipment**
In order for this characterization to apply, the baseline equipment is assumed to be a ducted split central air conditioning unit meeting the Federal Standard efficiency level; 13 SEER and 11 EER.

**Deemed Calculation for this Measure**

Annual kWh Savings = (Hours * BtuH * (1/13 - 1/SEERee))/1000

Summer Coincident Peak kW Savings = (BtuH * (1/11 - 1/EERee))/1000 * 0.68

**Deemed Lifetime of Efficient Equipment**
The expected measure life is assumed to be 18 years [88].

**Deemed Measure Cost**
The incremental capital cost for this measure is provided below[89].

| Efficiency Level | Cost per Ton |
|---|---|
| SEER 15 | $108 |
| SEER 16 | $221 |
| SEER 17 | $620 |
| SEER 18+ | $620 |

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

**Coincidence Factor**
The summer peak coincidence factor for this measure is assumed to be 0.68[90].

88 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
89 Based on incremental cost results from Cadmus “HVAC Program: Incremental Cost Analysis Update”, December 19, 2016.
90 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. TRM v7.0 Vol. 3_September 28, 2018_Final

## Calculation of Savings

### Energy Savings

ΔkWH = (FLHcool * BtuH * (1/SEERbase - 1/SEERee))/1000

Where:

FLHcool = Full load cooling hours
Dependent on location as below:

| Location | Run Hours[91] |
|---|---|
| Akron | 476 |
| Cincinnati | 664 |
| Cleveland | 426 |
| Columbus | 552 |
| Dayton | 631 |
| Mansfield | 474 |
| Toledo | 433 |
| Youngstown | 369 |

BtuH = Size of equipment in Btuh (note 1 ton = 12,000Btuh)
= Actual installed

SEERbase = SEER Efficiency of baseline unit
= 13 [92]

SEERee = SEER Efficiency of ENERGY STAR unit
= Actual installed

For example, a 3 ton unit with SEER rating of 14.5, in Dayton:

ΔkWH = (631 * 36000 * (1/13 – 1/15)) / 1000

= 233.0 kWh

### Summer Coincident Peak Demand Savings

ΔkW = (BtuH * (1/EERbase - 1/EERee))/1000 * CF

Where:

EERbase = EER Efficiency of baseline unit
= 11 [93]

[91] 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."..
[92] Minimum Federal Standard
[93] Minimum Federal Standard

EERee = EER Efficiency of ENERGY STAR unit
= Actual installed

CF = Summer Peak Coincidence Factor for measure
= 0.68 [94]

For example, a 3 ton unit with EER rating of 12.5:

$\Delta kW = (36000 * (1/11 – 1/12.5)) / 1000 * 0.68$
$= 0.27\ kW$

**Fossil Fuel Impact Descriptions and Calculation**

n/a

**Water Impact Descriptions and Calculation**

n/a

**Deemed O&M Cost Adjustment Calculation**

n/a

[94] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. TRM v7.0 Vol. 3_September 28, 2018_Final

## Air Source Heat Pump (Time of Sale)

**Description**
This measure relates to the installation of a new Air Source Heat Pump system meeting ENERGY STAR efficiency standards presented below. This measure could relate to the replacing of an existing unit at the end of its useful life, or the installation of a new system in an existing home (i.e. time of sale).

**Definition of Efficient Equipment**
In order for this characterization to apply, the efficient equipment is assumed to be an Air Source Heat Pump unit meeting the minimum ENERGY STAR efficiency level standards; 15 SEER, 12.5 EER and 8.5 HSPF.

**Definition of Baseline Equipment**
In order for this characterization to apply, the baseline equipment is assumed to be an Air Source Heat Pump unit meeting the Federal Standard efficiency level; 14 SEER, 11.8 EER, and 8.2 HSPF.

**Deemed Calculation for this Measure**

Annual kWh Savings = (FLHcool * BtuH * (1/14 - 1/SEERee))/1000 + (FLHheat * BtuH * (1/8.2 – 1/HSPFee))/1000

Summer Coincident Peak kW Savings = (BtuH * (1/11.8 - 1/EERee))/1000 * 0.72

**Deemed Lifetime of Efficient Equipment**
The expected measure life is assumed to be 18 years [95].

**Deemed Measure Cost**
The incremental capital cost for this measure is provided below[96].

| Efficiency Level | Cost per Ton |
|---|---|
| HSPF 8.5-9.9 | $62 |
| HSPF 10-10.9 | $224 |
| HSPF 11-12.9 | $334 |
| HSPF 13+ | $660 |

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

**Coincidence Factor**
The summer peak coincidence factor for this measure is assumed to be 0.72[97].

[95] 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
[96] Full costs based upon full install cost of an ASHP plus incremental costs provided in Memo from Opinion Dynamics Evaluation Team, Ductless Mini-Split Heat Pumps: Incremental Cost Analysis, April 27, 2017. 2019 IL TRM v7.0 Vol. 3_September 28, 2018_Final
[97] Based on metering of 24 homes with ASHP during PY5 in Ameren Illinois service territory. TRM v7.0 Vol. 3_September 28, 2018_Final

**Calculation of Savings**

**Energy Savings**

ΔkWH = (FLHcool * BtuH * (1/SEERbase - 1/SEERee))/1000 + (FLHheat * BtuH * (1/HSPFbase – 1/HSPFee))/1000

Where:

FLHcool = Full load cooling hours
Dependent on location as below:

| Location | Run Hours[98] |
|---|---|
| Akron | 476 |
| Cincinnati | 664 |
| Cleveland | 426 |
| Columbus | 552 |
| Dayton | 631 |
| Mansfield | 474 |
| Toledo | 433 |
| Youngstown | 369 |

BtuH = Size of equipment in Btuh (note 1 ton = 12,000Btuh)
= Actual installed

SEERbase = SEER Efficiency of baseline unit
= 14 [99]

SEERee = SEER Efficiency of ENERGY STAR unit
= Actual installed

FLHheat = Full load heating hours
Dependent on location as below:

| Location | Run Hours[100] |
|---|---|
| Akron | 1576 |
| Cincinnati | 1394 |
| Cleveland | 1567 |
| Columbus | 1272 |
| Dayton | 1438 |
| Mansfield | 1391 |
| Toledo | 1628 |

[98] 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.".
[99] Based on relevant Federal Standards.
[100] Heating EFLH extracted from simulations conducted for Duke Energy, OH Joint Utility TRM, October 2009; "Technical Reference Manual (TRM) for Ohio Senate Bill 221Energy Efficiency and Conservation Program and 09-512-GE-UNC"

HSPFbase = Heating Season Performance Factor for baseline unit
= 8.2[101]

HSPFee = Heating Season Performance Factor for efficient unit
= Actual Installed

For example, a 3 ton unit with SEER rating of 15 and HSPF of 8.5 in Dayton:

ΔkWH = (631 * 36000 * (1/14 – 1/15)) / 1000 + (1438 * 36000 * (1/8.2 – 1/8.5)) / 1000

= 331.0 kWh

**Summer Coincident Peak Demand Savings**

ΔkW = BtuH * (1/EERbase - 1/EERee))/1000 * CF

Where:

EERbase = EER Efficiency of baseline unit
= 11 [102]

EERee = EER Efficiency of ENERGY STAR unit
= Actual installed

CF = Summer Peak Coincidence Factor for measure
= 0.72 [103]

For example, a 3 ton unit with EER rating of 12.5:

ΔkW = (36000 * (1/11 – 1/12.5)) / 1000 * 0.72

= 0.28 kW

**Fossil Fuel Impact Descriptions and Calculation**

n/a

**Water Impact Descriptions and Calculation**

n/a

**Deemed O&M Cost Adjustment Calculation**

n/a

[101] Based on relevant Federal Standards.
[102] Minimum Federal Standard
[103] Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p32

## ENERGY STAR Room Air Conditioner (Time of Sale)

**Description**
This measure relates to the purchase and installation of a room air conditioning unit that meets either the ENERGY STAR or CEE TIER 1 minimum qualifying efficiency specifications, in place of a baseline unit meeting minimum Federal Standard efficiency ratings presented below:

| Product Class (BtuH) | Federal Standard (EER) | ENERGY STAR (EER)/CEE TIER 1 | CEE TIER 2 (EER) |
|---|---|---|---|
| 8,000 to 13,999 | >= 10.9[104] | >= 12.0[105] | >= 12.5[106] |

**Definition of Efficient Equipment**
To qualify for this measure the new room air conditioning unit must meet either the ENERGY STAR or CEE TIER 1 efficiency standards presented above.

**Definition of Baseline Equipment**
The baseline assumption is a new room air conditioning unit that meets the current minimum federal efficiency standards presented above.

**Deemed Calculation for this Measure**

Annual kWh Savings:

$$\Delta kWH = (Hours * BtuH * (1/EER_{base} - 1/EERee))/1000$$

Summer Peak Coincident Demand Savings:

$$\Delta kW = BtuH * (1/EER_{base} - 1/EERee))/1000 * CF$$

**Deemed Lifetime of Efficient Equipment**
The measure life is assumed to be 12 years [107].

**Deemed Measure Cost**
The incremental cost for this measure is assumed to be $40 for an ENERGY STAR unit and $80 for a CEE TIER 1 unit [108].

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

**Coincidence Factor**
The coincidence factor for this measure is assumed to be 0.3[109].

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104 Federal standard is increased to 10.9 EER on 6/1/2014.
105 With federal standard increasing in 2014, ENERGY STAR efficiency changed to 12 EER.
106 With federal standard increasing in 2014, CEE increased CEE TIER 1 to 12.0 and TIER 2 to 12.5
107 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
108 Based on field study conducted by Efficiency Vermont
109 Consistent with coincidence factors found in:
RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008 (http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf)

**Calculation of Savings**

**Energy Savings**

$\Delta kWH$ = (Hours * BtuH * (1/EERbase - 1/EERee))/1000

Where:

Hours = Full Load Hours of room air conditioning unit[110]
Dependent on location as below:

| Location | Run Hours |
|---|---|
| Akron | 148 |
| Cincinnati | 206 |
| Cleveland | 132 |
| Columbus | 171 |
| Dayton | 196 |
| Mansfield | 147 |
| Toledo | 134 |
| Youngstown | 114 |

BtuH = Average size of rebated unit
= 10,000[111]

EERbase = Efficiency of baseline unit
= 10.9[112]

EERee = Efficiency of ENERGY STAR unit
= 12[113]

Or = Efficiency of CEE Tier 2 unit
= 12.5[114]

For example, replacing a unit in Dayton yields these values:

$\Delta kWH_{ENERGY\ STAR}$
= (196 * 10000 * (1/10.9 – 1/12)) / 1000
= 16.48 kWh

$\Delta kWH_{CEE\ TIER\ 2}$
= (196 * 10000 * (1/10.9 – 1/12.5)) / 1000
= 23.0 kWh

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110 The average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008: http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf) to FLH for Central Cooling for the same location (provided by AHRI: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) is 31%. This factor was applied to the FLH for Central Cooling provided for OH cities to come up with the assumption for FLH for Room AC.
111 Based on average unit size used in ENERGY STAR analyses.
112 Minimum Federal Standard for capacity range
113 Minimum qualifying standard for ENERGY STAR.
114 Minimum qualifying standard for CEE Tier 1.

**Summer Coincident Peak Demand Savings**

$\Delta kW = BtuH * (1/EERbase - 1/EERee))/1000 * CF$

Where:

CF = Summer Peak Coincidence Factor for measure
= 0.3[115]

$\Delta kW_{ENERGY\ STAR}$
= (10000 * (1/10.9 – 1/12.0)) / 1000 * 0.3
= 0.025 kW

$\Delta kW_{CEE\ TIER\ 2}$
= (10000 * (1/10.9 – 1/12.5)) / 1000 * 0.3
= 0.035 kW

**Fossil Fuel Impact Descriptions and Calculation**

n/a

**Water Impact Descriptions and Calculation**

n/a

**Deemed O&M Cost Adjustment Calculation**

n/a

[115] Consistent with coincidence factors found in:
RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008 (http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf)

## ENERGY STAR Room Air Conditioner Replacement (Low Income, Early Replacement)

**Description**
This measure describes the early removal of an existing inefficient Room Air Conditioner unit from service, prior to its natural end of life, and replacement with a new ENERGY STAR qualifying unit. This measure is suitable for a Low Income or a Home Performance program. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life.

**Definition of Efficient Equipment**
The efficient condition is a new replacement room air conditioning unit meeting the ENERGY STAR efficiency standard (i.e. with an efficiency rating greater than or equal to 12 EER).

**Definition of Baseline Equipment**
The baseline condition is the existing inefficient room air conditioning unit for the remaining assumed useful life of the unit, and then for the remainder of the measure life the baseline becomes a new replacement unit meeting the minimum federal efficiency standard (i.e. with an efficiency rating greater than or equal to 10.9 EER).

**Deemed Calculation for this Measure**

Annual kWh Savings:

$$\Delta kWH = (Hours * BtuH * (1/EER_{base} - 1/EERee))/1000$$

Summer Peak Coincident Demand Savings:

$$\Delta kW = BtuH * (1/EER_{base} - 1/EERee))/1000 * CF$$

**Deemed Lifetime of Efficient Equipment**
The measure life is assumed to be 12 Years[116].

**Deemed Lifetime of Replaced (Existing) Equipment (for early replacement measures only)**
The assumed remaining useful life of the existing room air conditioning unit being replaced is 3 years[117].

**Deemed Measure Cost**
The actual measure cost for removing the existing unit and installing the new should be used.

**Deemed O&M Cost Adjustments**
The net present value of the deferred replacement cost (the cost associated with the replacement of the existing unit with a standard unit that would have had to have occurred in 3 years, had the existing unit

[116] 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
[117] Based on Connecticut TRM; Connecticut Energy Efficiency Fund; CL&P and UI Program Savings Documentation for 2008 Program Year

not been replaced) should be calculated as (Actual Cost of ENERGY STAR unit - $50 (incremental cost of ENERGY STAR unit over baseline unit[118]) * 69%[119].

**Coincidence Factor**
The coincidence factor for this measure is assumed to be 0.3[120].

## REFERENCE SECTION

**Calculation of Savings**

**Energy Savings**

ΔkWh for remaining life of existing unit (1st 3 years)
= (Hours * BtuH * (1/EERexist - 1/EERee))/1000

ΔkWh for remaining measure life (next 9 years)
= (Hours * BtuH * (1/EERbase - 1/EERee))/1000

Where:

Hours = Full Load Hours of room air conditioning unit[121]
Dependent on location as below:

| Location | Run Hours |
|---|---|
| Akron | 148 |
| Cincinnati | 206 |
| Cleveland | 132 |
| Columbus | 171 |
| Dayton | 196 |
| Mansfield | 147 |
| Toledo | 134 |
| Youngstown | 114 |

BtuH = Average size of rebated unit
= 10000[122], unless the unit's capacity is known, in which case it should be used in place of the 10,000 BtuH value.

EERexist = Efficiency of existing unit

[118] From ENERGY STAR calculator (ENERGY STAR - $220, Baseline - $170); http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerRoomAC.xls)
[119] 69% is the ratio of the Net Present Value (with a 5% discount rate) of the annuity payments from years 4 to 12 of a deferred replacement of a standard efficiency unit costing $170, divided by the standard efficiency unit cost ($170). The calculation is done in this way to allow the use of the known ENERGY STAR replacement cost to calculate an appropriate baseline replacement cost.
[120] Consistent with coincidence factors found in:
RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008 (http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf)
[121] The average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008: http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf) to FLH for Central Cooling for the same location (provided by AHRI: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) is 31%. This factor was applied to the FLH for Central Cooling provided for OH cities to come up with the assumption for FLH for Room AC.
[122] Based on average unit capacity used by ENERGY STAR.

= 7.7[123]

EERbase = Efficiency of baseline unit
= 10.9[124]

EERee = Efficiency of ENERGY STAR unit
= 12.0[125], unless the efficient unit's EER is known, in which case it should be used in place of the 12.0 value.

For example, replacing a unit of unknown capacity in Dayton yields these results:
ΔkWh for remaining life of existing unit (1st 3 years)
= (196 * 10000 * (1/7.7 – 1/12.0)) / 1000
= 91.21 kWh

ΔkWh for remaining measure life (next 9 years)
= (196 * 10000 * (1/10.9 – 1/12)) / 1000
= 21.57 kWh

**Summer Coincident Peak Demand Savings**

ΔkW for remaining life of existing unit (1st 3 years)
= (BtuH * (1/EERexist - 1/EERee))/1000 * CF

ΔkW for remaining measure life (next 9 years)
= (BtuH * (1/EERbase - 1/EERee))/1000 * CF

Where:

CF = Summer Peak Coincidence Factor for measure
= 0.3[126]

ΔkW for remaining life of existing unit (1st 3 years)
= (10000 * (1/7.7 – 1/12)) / 1000 * 0.3
= 0.139 kW

ΔkW for remaining measure life (next 9 years)
= (10000 * (1/10.9 – 1/12)) / 1000 * 0.3
= 0.025 kW

**Fossil Fuel Impact Descriptions and Calculation**

n/a

**Water Impact Descriptions and Calculation**

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123 Based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report."

124 Minimum Federal Standard for capacity range. This was increased to 10.9 on 6/1/2014

125 Minimum qualifying standard for ENERGY STAR. This increased to 12 on 6/1/2014.

126 Consistent with coincidence factors found in:
RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008 (http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf)

n/a

**Deemed O&M Cost Adjustment Calculation**

The net present value of the deferred replacement cost (the cost associated with the replacement of the existing unit with a standard unit that would have had to have occurred in 3 years, had the existing unit not been replaced) should be calculated as (Actual Cost of ENERGY STAR unit - $50 (incremental cost of ENERGY STAR unit over baseline unit[127]) * 69%[128].

[127] From ENERGY STAR calculator (ENERGY STAR - $220, Baseline - $170); http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerRoomAC.xls)

[128] 69% is the ratio of the Net Present Value (with a 5% discount rate) of the annuity payments from years 4 to 12 of a deferred replacement of a standard efficiency unit costing $170, divided by the standard efficiency unit cost ($170). The calculation is done in this way to allow the use of the known ENERGY STAR replacement cost to calculate an appropriate baseline replacement cost.

## ENERGY STAR Room Air Conditioner Recycling (Early Retirement)

**Description**
This measure describes the savings resulting from running a drop off service taking existing inefficient Room Air Conditioner units from service, prior to their natural end of life. This measure assumes that a percentage of these units will be replaced with a baseline standard efficiency unit (note that if it is actually replaced by a new ENERGY STAR qualifying unit, the savings increment between baseline and ENERGY STAR will be recorded in the Efficient Products program).

**Definition of Efficient Equipment**
n/a. This measure relates to the retiring of an existing inefficient unit.

**Definition of Baseline Equipment**
The baseline condition is the existing inefficient room air conditioning unit.

**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 |
|---|---|---|---|
| 140.14 | 0.153 | n/a | n/a |

**Deemed Lifetime of Replaced (Existing) Equipment (for early replacement measures only)**
The assumed remaining useful life of the existing room air conditioning unit being retired is 3 Years.

**Deemed Measure Cost**
The actual implementation cost for recycling the existing unit plus the cost for the replacement of some of the units of $129[129].

**Deemed O&M Cost Adjustments**
The net present value of the deferred replacement cost (the cost associated with the replacement of those units that would be replaced, with a standard unit that would have had to have occurred in 3 years, had the existing unit not been replaced) is calculated as $89.36[130].

**Coincidence Factor**
The coincidence factor for this measure is assumed to be 0.3[131].

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[129] This is calculated by multiplying the percentage assumed to be replaced – 76% (from Based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report") by the assumed cost of a standard efficiency unit of $170 (ENERGY STAR calculator; http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerRoomAC.xls). 0.76 * 170 = $129.2.
[130] Determined by calculating the Net Present Value (with a 5% discount rate) of the annuity payments from years 4 to 12 of a deferred replacement of a standard efficiency unit costing $170 multiplied by the 76%, the percentage of units being replaced (i.e. 0.76 * $170 = $129.2. Baseline cost from ENERGY STAR calculator; http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerRoomAC.xls)
[131] Consistent with coincidence factors found in:
RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008 (http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf)

## REFERENCE SECTION

### Calculation of Savings

### Energy Savings

$\Delta kWh = kWh_{exist} – (\%replaced * kWh_{newbase})$

$= ((Hours * BtuH * (1/EERexist))/1000) - (\%replaced * ((Hours * BtuH * (1/EERnewbase))/1000)$

Where:

Hours = Full Load Hours of room air conditioning unit
= 233[132]

BtuH = Average size of rebated unit
= 10000[133]

EERexist = Efficiency of baseline unit
= 7.7[134]

%replaced = Percentage of units dropped off that are replaced
= 76%[135]

EERnewbase = Efficiency of baseline unit
= 10.9[136]

$\Delta kWh = ((233 * 10000 * (1/7.7)) / 1000) – (0.76 * ((233 * 10000 * (1/10.9)) / 1000)$
$= 140.14$ kWh

### Summer Coincident Peak Demand Savings

$\Delta kW = (kW_{exist} – (\%replaced * kW_{newbase})) * CF$

$= ((BtuH * (1/EERexist))/1000) - (\%replaced * ((BtuH * (1/EERnewbase))/1000) * CF$

Where:

CF = Summer Peak Coincidence Factor for measure
= 0.3[137]

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[132] The average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008: http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf) to FLH for Central Cooling for the same location (provided by AHRI: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) is 31%. This factor was applied to the FLH for Central Cooling provided for OH cities and averaged to come up with the assumption for FLH for Room AC.
[133] Based on average unit capacity used by ENERGY STAR.
[134] Based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report."
[135] Based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report." Report states that 63% were replaced with ENERGY STAR units and 13% with non-ENERGY STAR. However this formula assumes all are non-ENERGY STAR since the increment of savings between baseline units and ENERGY STAR would be recorded by the Efficient Products program when the new unit is purchased.
[136] Minimum Federal Standard for capacity range. This was increased increasing to 10.9 on 6/1/2014.
[137] Consistent with coincidence factors found in:

$$\Delta kW = ((10000 * (1/7.7)) / 1000) – (0.76 * ((10000 * (1/10.6)) / 1000) * 0.3$$
$$= 1.066 \text{ kW}$$

**Fossil Fuel Impact Descriptions and Calculation**

n/a

**Water Impact Descriptions and Calculation**

n/a

**Deemed O&M Cost Adjustment Calculation**

The net present value of the deferred replacement cost (the cost associated with the replacement of those units that would be replaced, with a standard unit that would have had to have occurred in 3 years, had the existing unit not been replaced) is calculated as $89.36[138].

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RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008 (http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf)

[138] Determined by calculating the Net Present Value (with a 5% discount rate) of the annuity payments from years 4 to 12 of a deferred replacement of a standard efficiency unit costing multiplied by the 76%, the percentage of units being replaced (i.e. 0.76 * $170 = $129.2. Baseline cost from ENERGY STAR calculator; http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerRoomAC.xls)

## Central Air Conditioning (Early Replacement)

**Description**
This measure describes the early removal of an existing inefficient Central Air Conditioning unit from service, prior to its natural end of life, and replacement with a new ENERGY STAR qualifying unit. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life.

**Definition of Efficient Equipment**
In order for this characterization to apply, the efficient equipment is assumed to be a ducted split central air conditioning unit or air-source heat pump meeting the minimum ENERGY STAR efficiency level standards; 15 SEER and 12.5 EER.

**Definition of Baseline Equipment**
The baseline condition is the existing inefficient central air conditioning unit or air-source heat pump for the remaining assumed useful life of the unit, and then for the remainder of the measure life the baseline becomes a new replacement unit meeting the minimum federal efficiency standard (i.e. 13 SEER and 11 EER).

**Deemed Calculation for this Measure**

Annual kWh Savings for remaining life of existing unit ($1^{st}$ 5 years)
= (FLHcool * BtuH * (1/SEERexist - 1/SEERee))/1000

Annual kWh Savings for remaining measure life (next 13 years)
= (FLHcool * BtuH * (1/13 - 1/SEERee))/1000

Summer Coincident Peak kW Savings for remaining life of existing unit ($1^{st}$ 5 years)
= (BtuH * (1/EERexist - 1/EERee))/1000 * 0..68

Summer Coincident Peak kW Savings for remaining measure life (next 13 years)
= (BtuH * (1/11 - 1/EERee))/1000 * 0.68

**Deemed Lifetime of Efficient Equipment**
The expected measure life is assumed to be 18 years [139].

**Deemed Lifetime of Replaced (Existing) Equipment (for early replacement measures only)**

The assumed remaining useful life of the existing central air conditioning unit being replaced is 6 years[140].

**Deemed Measure Cost**
The actual measure cost for removing the existing unit and installing the new should be used.

[139] 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
[140] 1/3 of the EUL

**Deemed O&M Cost Adjustments**

The net present value of the deferred replacement cost (the cost associated with the replacement of the existing unit with a standard unit that would have had to have occurred after 6 years, had the existing unit not been replaced) should be calculated as (Actual Cost of ENERGY STAR unit - incremental cost of ENERGY STAR unit over baseline unit from table below[141]) * 63%[142].

| Efficiency Level | Cost per Ton |
|---|---|
| SEER 15 | $108 |
| SEER 16 | $221 |
| SEER 17 | $620 |
| SEER 18+ | $620 |

**Coincidence Factor**

The summer peak coincidence factor for this measure is assumed to be 0.68[143].

## REFERENCE SECTION

**Calculation of Savings**

**Energy Savings**

ΔkWh for remaining life of existing unit (1st 6 years)

= (FLHcool * BtuH * (1/SEERexist - 1/SEERee))/1000

ΔkWh for remaining measure life (next 12 years)

= (FLHcool * BtuH * (1/SEERbase - 1/SEERee))/1000

Where:

FLHcool = Full load cooling hours

Dependent on location as below:

| Location | Run Hours[144] |
|---|---|
| Akron | 476 |
| Cincinnati | 664 |
| Cleveland | 426 |
| Columbus | 552 |

[141] DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).

[142] 63% is the ratio of the Net Present Value (with a 5% discount rate) of the annuity payments from years 6 to 18 of a deferred replacement of a standard efficiency unit costing $2857, divided by the standard efficiency unit cost ($2857). The calculation is done in this way to allow the use of the known ENERGY STAR replacement cost to calculate an appropriate baseline replacement cost. Standard unit cost from ENERGY STAR calculator; http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls

[143] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. TRM v7.0 Vol. 3_September 28, 2018_Final

[144] 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."..

| | |
|---|---|
| Dayton | 631 |
| Mansfield | 474 |
| Toledo | 433 |
| Youngstown | 369 |

BtuH = Size of equipment in Btuh (note 1 ton = 12,000Btuh)
= Actual

SEERexist = SEER Efficiency of existing unit
= Actual[145]

SEERee = SEER Efficiency of ENERGY STAR unit
= Actual installed

SEERbase = SEER Efficiency of baseline unit
= 13[146]

For example, replacing a 3 ton SEER 10 unit with a new SEER 15 unit, in Dayton:

ΔkWh for remaining life of existing unit (1st 6 years)
= (631 * 36000 * (1/10 – 1/15)) / 1000
= 757.2 kWh

ΔkWh for remaining measure life (next 12 years)
= (631 * 36000 * (1/13 – 1/15)) / 1000
= 233.0 kWh

**Summer Coincident Peak Demand Savings**

ΔkW for remaining life of existing unit (1st 5 years)
= (BtuH * (1/EERexist - 1/EERee))/1000 * CF

ΔkW for remaining measure life (next 13 years)
= (BtuH * (1/EERbase - 1/EERee))/1000 * CF

Where:

EERexist = EER Efficiency of existing unit
= Calculate using Actual SEER
= (SEER * 0.9)[147]

EERbase = EER Efficiency of baseline unit
= 11 [148]

[145] Use actual SEER rating where it is possible to measure or reasonably estimate. When unknown use SEER 10 (VEIC estimate of existing unit efficiency, based on minimum federal standard between the years of 1992 and 2006)
[146] Minimum Federal Standard
[147] If SEER is unknown, default EER would be (10 * 0.9) = 9.0. Calculation based on prior VEIC assessment of industry equipment efficiency ratings.
[148] Minimum Federal Standard

EERee = EER Efficiency of ENERGY STAR unit
= Actual installed

CF = Summer Peak Coincidence Factor for measure
= 0.68 [149]

For example, replacing a 3 ton SEER 10 unit (EER 9)with a new SEER 15, EER 12.5 unit, in Dayton:

ΔkW for remaining life of existing unit (1st 5 years)
= (36000 * (1/9 – 1/12.5)) / 1000 * 0.68
= 0.76 kW

ΔkW for remaining measure life (next 13 years)
= (36000 * (1/11 – 1/12.5)) / 1000 * 0.68
= 0.27 kW

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

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

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

[149] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. TRM v7.0 Vol. 3_September 28, 2018_Final

## Ground Source Heat Pumps (Time of Sale)

**Description**
This measure relates to the installation of a new Ground Source Heat Pump system meeting ENERGY STAR efficiency standards presented below. This measure relates to the installation of a new system in an existing home (i.e. time of sale).

| **Tier 1 Requirements (Effective January 1, 2012)** | | |
|---|---|---|
| Product Type | EER | COP |
| Water-to-air | | |
| Closed Loop | 17.1 | 3.6 |
| Open Loop | 21.1 | 4.1 |
| Water-to-Water | | |
| Closed Loop | 16.1 | 3.1 |
| Open Loop | 20.1 | 3.5 |
| DGX | 16 | 3.6 |

**Definition of Efficient Equipment**
In order for this characterization to apply, the efficient equipment must be a Ground Source Heat Pump unit meeting the minimum ENERGY STAR efficiency level standards effective at the time of installation as detailed above.

**Definition of Baseline Equipment**
The baseline equipment is assumed to be an Air Source Heat Pump meeting the Federal Standard efficiency level; 14 SEER and 11.8 EER and 8.2 HSPF.

**Deemed Calculation for this Measure**

Annual kWh Savings = (FLHcool * BtuH * (1/14 – (1/(EERee * 1.02)))/1000) + (FLHheat * BtuH * (1/8.2– (1/COPee * 3.412)))/1000)

Summer Coincident Peak kW Savings = BtuH * (1/11.8 - 1/(((EERee * 1.02) * 0.37) + 6.43))/ 1000 * 0.72

**Deemed Lifetime of Efficient Equipment**
The expected measure life is assumed to be 18 years [150].

**Deemed Measure Cost**
The actual installed cost of the Ground Source Heat Pump should be used, minus the assumed installation cost of a 3 ton standard baseline Air Source Heat Pump of $3,609[151].

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

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[150] 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
[151] Based on DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com). Material cost of 13 SEER AC is $796 per ton, and labor cost of $407 per ton. For a 3 ton unit this would be (796+407) *3 = $3609.

**Coincidence Factor**

The summer peak coincidence factor for this measure is assumed to be 0.72[152].

## REFERENCE SECTION

**Calculation of Savings**

**Energy Savings**

ΔkWH = (FLHcool * BtuH * (1/SEERbase – (1/(EERee * 1.02))/1000 + (FLHheat * BtuH * (1/HSPFbase – (1/COPee * 3.412))/1000

Where:

FLHcool = Full load cooling hours
Dependent on location as below:

| Location | Run Hours[153] |
|---|---|
| Akron | 476 |
| Cincinnati | 664 |
| Cleveland | 426 |
| Columbus | 552 |
| Dayton | 631 |
| Mansfield | 474 |
| Toledo | 433 |
| Youngstown | 369 |

BtuH = Size of equipment in Btuh (note 1 ton = 12,000Btuh)
= Actual installed

SEERbase = SEER Efficiency of baseline unit
= 14 [154]

EERee = EER Efficiency of efficient unit
= Actual installed

1.02 = Constant used to estimate the SEER based on the efficient unit's EER[155].

FLHheat = Full load heating hours
Dependent on location as below:

152 Based on metering of 24 homes with ASHP during PY5 in Ameren Illinois service territory. TRM v7.0 Vol. 3_September 28, 2018_Final

153 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 Wisconsin study.

154 Minimum Federal Standard; Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.

155 Note that EERs of GSHPs are measured differently than EERs of air source heat pumps (focusing on entering water temperatures rather than ambient air temperatures). The equivalent SEER of a GSHP can be estimated by multiplying EER by 1.02, based on VEIC extrapolation of manufacturer data.

| Location | Run Hours[156] |
|---|---|
| Akron | 1576 |
| Cincinnati | 1394 |
| Cleveland | 1567 |
| Columbus | 1272 |
| Dayton | 1438 |
| Mansfield | 1391 |
| Toledo | 1628 |

HSPFbase =Heating Season Performance Factor for baseline unit
=8.2[157]

COPee = Coefficient of Performance of efficient unit
= Actual Installed

3.413 = Constant to convert the COP of the unit to the Heating Season Performance Factor HSPF).

For example, a 3 ton unit with EER rating of 17.1 and COP of 3.6 in Dayton:

ΔkWH = (FLHcool * BtuH * (1/SEERbase – (1/(EERee * 1.02))/1000
+ (FLHheat * BtuH * (1/HSPFbase – (1/COPee * 3.412))/1000

ΔkWH = (631 * 36000 * (1/14 – 1/ (17.1*1.02))) / 1000 + (1438 * 36000 * (1/8.2 – 1/ (3.6*3.412)) / 1000
= 2419 kWh

**Summer Coincident Peak Demand Savings**

ΔkW = BtuH * (1/EERbase - 1/(((EERee * 1.02) * 0.37) + 6.43))/1000 * CF

Where:

EERbase = EER Efficiency of baseline unit
= 11.8 [158]

EERee = EER Efficiency of ENERGY STAR unit
= Actual installed

1.02 = Constant used to estimate the unit’s equivalent air conditioning SEER based on the GSHP unit’s EER[159].
This is then converted to the unit’s equivalent air conditioning EER to enable comparisons to the baseline unit using the following algorithm:

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[156] Heating EFLH extracted from simulations conducted for Duke Energy, OH Joint Utility TRM, October 2009; “Technical Reference Manual (TRM) for Ohio Senate Bill 221Energy Efficiency and Conservation Program and 09-512-GE-UNC”

[157] Minimum Federal Standard; Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.

[158] Minimum Federal Standard for baseline ASHP; as above.

[159] Note that EERs of GSHPs are measured differently than EERs of air source heat pumps (focusing on entering water temperatures rather than ambient air temperatures). The equivalent SEER of a GSHP can be estimated by multiplying EER by 1.02, based on VEIC extrapolation of manufacturer data.

$EER_{ac} = (SEER * 0.37) + 6.43$[160]

CF = Summer Peak Coincidence Factor for measure
= 0.72[161]

For example, a 3 ton unit with EER rating of 17.1:

ΔkW = (36000 * (1/11.8 – 1/ (((17.1 * 1.02) * 0.37) + 6.43)) / 1000 * 0.72
= 0.18 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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[160] Roberts and Salcido, Architectural Energy Corporation, Feb 2008; "Peak Electric Demand Calculations in the REM/Rate Home Energy Rating Software and REM/Design Home Energy Analysis Software". This formulaic relationship was derived from 1861 unique combinations of data, from nearly 200,000 ARI-rated residential central air conditioners.

[161] Based on metering of 24 homes with ASHP during PY5 in Ameren Illinois service territory. TRM v7.0 Vol. 3_September 28, 2018_Final

## Air Sealing - Reduce Infiltration (Retrofit)

**Description**
This measure characterization is for the improvement of a building's air-barrier, which together with its insulation defines the thermal boundary of the conditioned space. Air-leakage in buildings represents from 5% to 40% of the space conditioning costs[162] but is also very difficult to control. The measure assumes that a trained auditor, contractor or utility staff member is on location, and will measure and record the existing air-leakage rate[163] and post air-sealing leakage using a blower door, and the efficiency of the heating and cooling system used in the home.

**Definition of Efficient Equipment**
Air sealing materials and diagnostic testing should meet all eligibility program qualification criteria. The initial and final tested leakage rates should be performed in such a manner that the identified reductions can be properly discerned, particularly in situations wherein multiple building envelope measures may be implemented simultaneously.

**Definition of Baseline Equipment**
The existing air leakage should be determined through approved and appropriate test methods. The baseline condition of a building upon first inspection significantly impacts the opportunity for cost-effective energy savings through air-sealing.

**Deemed Calculation for this Measure**

Annual Cooling kWh Savings $= 1.3*(((CFM50Exist – CFM50New) * 0.64 / 29.4) *60 * CDH * 0.0135) / 1000 / \eta Cool$

Summer Coincident Peak kW Savings $= \Delta kWh / FLHcool * 0.5$

Space Heating Savings:

MMBTU Savings (fossil fuel heating)

$= (((CFM50Exist – CFM50New) * 0.64/ N\text{-}factor) *60 * 24 * HDD * 0.018) / 1{,}000{,}000 / \eta Heat$

kWh Savings (electric heating) $= ((((CFM50Exist – CFM50New) / N\text{-}factor) *60 * 24 * HDD * 0.018) / 1{,}000{,}000 / \eta Heat) * 293.1$

**Deemed Lifetime of Efficient Equipment**
The measure life is assumed to be 15 years[164].

**Deemed Measure Cost**
The actual air sealing measure cost should be used.

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162 Krigger, J. Dorsi, C. "Residential Energy" 2004, p.73
163 In accordance with industry best practices see: BPI Building Analyst and Envelope Professional standards, http://www.bpi.org/standards_approved.aspx
164 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

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

**Coincidence Factor**
The summer peak coincidence factor for this measure is assumed to be 0.68[165].

## REFERENCE SECTION

**Calculation of Savings**

**Energy Savings (Space Cooling – if home has Central AC)**

$\Delta kWh = 1.3*((((CFM50Exist - CFM50New) * 0.64) / N\text{-}factor) *60 * CDH * DUA * 0.018) / 1000 / \eta Cool$

Where:

| | |
|---|---|
| CFM50Exist | = Existing Cubic Feet per Minute at 50 Pascal pressure differential as measured by the blower door before airsealing.<br>= actual recorded |
| CFM50New | = New Cubic Feet per Minute at 50 Pascal pressure differential as measured by the blower door after airsealing.<br>= actual recorded |
| 0.64 | = Converts CFM50 to CFFM25[166] |
| N-Factor | = Conversion factor to convert 50-pascal air flows to natural airflow.<br>= 29.4 (for cooling, 17.8 for heating)[167] |
| 60 | = Constant to convert cubic feet per minute to cubic feet per hour |
| CDH | = Cooling Degree Hours[168]. |
| 1000 | = Constant to convert Watts to Kilowatts |
| 1.3 | = Multiplier to account for latent load savings (latent factor from ASHRAE[169]) |

Dependent on location:

[165] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. TRM v7.0 Vol. 3_September 28, 2018_Final Based

[166] Pascals is the standard assumption for typical pressures experienced in the duct system under normal operating conditions. To convert CFM50 to CFM25 you multiply by 0.64 (inverse of the "Can't Reach Fifty" factor for CFM25; see Energy Conservatory Blower Door Manual).

[167] Maximum n-factor from methodology developed by the Lawrence Berkeley Laboratory (LBL), since minimal stack effect for cooling savings. Further information collected from this textbook: Krigger, J. Dorsi, C. "Residential Energy" 2004, p.284.

[168] Derived by summing the delta between the average outdoor temperature and the base set point of 75 degrees (above which cooling is assumed to be used) each hour of the year. Hourly temperature data obtained from TMY3 data (http://rredc.nrel.gov/solar/)

[169] ASHRAE Handbook – Fundamentals, 2001, p28.5. Sensible heat ratio for typical home is 0.77, reciprocal of that value is 1.3, which indicates that latent loads are 30% of the sensible loads. It is assumed here that the latent load savings will also be 30% of the sensible load savings.

| Location | Cooling Degree Hours (75°F set point) |
|---|---|
| Akron | 3,986 |
| Cincinnati | 7,711 |
| Cleveland | 5,817 |
| Columbus | 4,367 |
| Dayton | 5,934 |
| Toledo | 4,401 |
| Youngtown | 3,689 |

DUA = Discretionary Use Adjustment to account for the fact that people do not always operate their air conditioning system when the outside temperature is greater than 75°F
= 0.75 [170]

0.018 = The volumetric heat capacity of air (Btu/ft3°F)

ηCool = Efficiency of Air Conditioning equipment
= actual recorded

For example, reducing air leakage in a Toledo home from 5000CFM50 to 3500CFM50, with SEER 10 AC:

ΔkWh = 1.3*(((5000 – 3500) / 29.4) *0.64* 60 * 4401 * 0.75 * 0.018) / 1,000 / 10
= 15 kWh

**Summer Coincident Peak Demand Savings**

ΔkW = ΔkWh / FLHcool * CF

Where:

FLHcool = Full load cooling hours
Dependent on location as below:

[170] Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31

| Location | Run Hours[171] |
|---|---|
| Akron | 476 |
| Cincinnati | 664 |
| Cleveland | 426 |
| Columbus | 552 |
| Dayton | 631 |
| Mansfield | 474 |
| Toledo | 433 |
| Youngstown | 369 |

CF = Summer Peak Coincidence Factor for measure
= 0.68[172]

For example, reducing air leakage in a Toledo home from 5000CFM50 to 3500CFM50, with SEER 10 AC:

$\Delta$kW = 15 / 428 * 0.68

= 0.024 kW

**Space Heating Savings Calculation**

$\Delta$MMBTU = (((CFM50Exist – CFM50New) / N-factor) *60 * 24 * HDD * 0.018) / 1,000,000 / $\eta$Heat

Where:

HDD = Heating Degree Days (60° base temperature) for location[173]

| Location | Heating Degree Days (60°F base temperature) |
|---|---|
| Akron | 4,754 |
| Cincinnati | 3,769 |
| Cleveland | 4,544 |
| Columbus | 4,033 |
| Dayton | 4,360 |
| Toledo | 4,806 |
| Youngstown | 4,841 |

[171] 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."

[172] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. TRM v7.0 Vol. 3_September 28, 2018_Final

[173] The 10 year average (2003-2012) annual heating degree day value, using a balance point for heating equipment use of 60 degrees was calculated for each location based on data obtained from http://academic.udayton.edu/kissock/http/Weather/citylistUS.htm. The 60 degree balance point is used based on a PRISM evaluation of approximately 600,000 Ohio residential single family customers. Days with no data were approximated by averaging the daily average temperatures from the two nearest days with data.

$\eta Heat$ = Average Net Heating System Efficiency (Equipment Efficiency * Distribution Efficiency) [174]
= actual recorded

For example, reducing air leakage in a 2 story, well-shielded Toledo home from 5000CFM50 to 3500CFM50, with a gas heating system with efficiency of 70%:

$\Delta$MMBTU = (((5000 – 3500) / 17.8) * 0.64*60 * 24 * 4806 * 0.018) / 1,000,000 / 0.7

= 4.36 MMBtu

**Note for homes with electric heat (resistance or heat pump), follow the MMBTU formula above and convert to kWh by multiplying by 293.1. For heat pumps the equipment efficiency used in the above algorithm should be the Coefficient Of Performance or COP (i.e., divide HSPF by 3.412; e.g., HSPF 7.7 is COP of 2.26).**

For example, reducing air leakage in a 2-story, well-shielded Toledo home from 5000CFM50 to 3500CFM50, with electric resistance heating:

$\Delta$MMBTU (electric) = ((((5000 – 3500) / 17.8) * 0.64 * 60 * 24 * 4806 * 0.018) / 1,000,000 / 1.0) * 293.1
= 1477 kWh

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

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

[174] The System Efficiency can be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf) or by performing duct blaster testing.
If there is more than one heating system, the weighted (by consumption) average efficiency should be used.
If the heating system or distribution is being upgraded within a package of measures together with the insulation upgrade, the new average heating system efficiency should be used.
In the case of electric heat use 1.0 as the heating system efficiency, and for heat pumps use COP (HSPF/3.412).

## Duct Sealing (Retrofit)

**Description**
This measure describes evaluating the savings associated with performing duct sealing using mastic sealant or metal tape to the distribution system of homes with either central air conditioning or a ducted heating system.

Two methodologies for estimating the savings associate from sealing the ducts are provided. The first preferred method requires the use of a blower door and the second requires careful inspection of the duct work.

1. **Modified Blower Door Subtraction** – this technique is described in detail on p44 of the Energy Conservatory Blower Door Manual;
http://www.energyconservatory.com/download/bdmanual.pdf

2. **Evaluation of Distribution Efficiency** – this methodology requires the evaluation of three duct characteristics below, and use of the Building Performance Institutes 'Distribution Efficiency Look-Up Table';
http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf

    a. Percentage of duct work found within the conditioned space
    b. Duct leakage evaluation
    c. Duct insulation evaluation

**Definition of Efficient Equipment**
The efficient condition is sealed duct work throughout the unconditioned space in the home.

**Definition of Baseline Equipment**
The existing baseline condition is leaky duct work within the unconditioned space in the home.

**Deemed Calculation for this Measure**

Annual kWh savings $= (((CFM50_{\text{Whole House}} - CFM50_{\text{Envelope Only}}) * SCF)_{before} - (CFM50_{\text{Whole House}} - CFM50_{\text{Envelope Only}}) * SCF)_{after}) * 60 * 0.64 * CDH * 0.0135) / 1000 / \eta Cool$

Or $= ((DE_{after} - DE_{before}) / DE_{after})) * FLHcool * BtuH * (1/SEER)/1000$

Summer Coincident Peak kW savings $= \Delta kWh / FLHcool * 0.68$

Annual MMBtu savings (fossil fuel) $= (((CFM50_{\text{Whole House}} - CFM50_{\text{Envelope Only}}) * SCF)_{before} - (CFM50_{\text{Whole House}} - CFM50_{\text{Envelope Only}}) * SCF)_{after}) * 60 * 0.64 * 24 * HDD * 0.018) / 1{,}000{,}000 / \eta Heat$

Annual MMBtu savings (electric) $= ((((CFM50_{\text{Whole House}} - CFM50_{\text{Envelope Only}}) * SCF)_{before} -$

$(CFM50_{Whole\ House} – CFM50_{Envelope\ Only}) * SCF)_{after}) * 60 * 0.64 * 24 * HDD * 0.018) / 1,000,000 / \eta Heat) * 293.1$

Or

Annual MMBtu savings (fossil fuel) $= ((DE_{after} – DE_{before}) / DE_{after})) * 71.2$

Annual MMBtu savings (electric) $= ((DE_{after} – DE_{before}) / DE_{after})) * FLHheat * BtuH * (1/COP * 3.413)/1000$

**Deemed Lifetime of Efficient Equipment**
The assumed lifetime of this measure is 20 years[175].

**Deemed Measure Cost**
The actual duct sealing measure cost should be used.

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

**Coincidence Factor**
The summer peak coincidence factor for this measure is assumed to be 0.68[176].

## REFERENCE SECTION

**Calculation of Savings**

**Energy Savings**

***Methodology 1: Modified Blower Door Subtraction***

Determine Duct Leakage rate before and after performing duct sealing:

Duct Leakage $(CFM50_{DL}) = (CFM50_{Whole\ House} – CFM50_{Envelope\ Only}) * SCF$

Where:

$CFM50_{Whole\ House}$ = Standard Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential

$CFM50_{Envelope\ Only}$ = Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential with all supply and return registers sealed.

SCF = Subtraction Correction Factor to account for underestimation of duct leakage due to connections between the duct system and the home.

175 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

176 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. TRM v7.0 Vol. 3_September 28, 2018_Final Based

Determined by measuring pressure in duct system with registers sealed and using look up table provided by Energy Conservatory.

Calculate Energy Savings:

$\Delta kWh_{cooling}$ = ((CFM50$_{DL\ before}$ - CFM50$_{DL\ after}$) * 60 * 0.64 * CDH * DUA * 0.018) / 1000 / ηCool

Where:

CFM50$_{DL\ before}$ = Duct Leakage rate before duct sealing
= calculated as above

CFM50$_{DL\ after}$ = Duct Leakage rate after duct sealing
= calculated as above

0.64 = Converts CFM50 to CFFM25[177]

60 = Constant to convert cubic feet per minute to cubic feet per hour

CDH = Cooling Degree Hours[178].
Dependent on location:

| Location | Cooling Degree Hours (75°F set point) |
|---|---|
| Akron | 3,986 |
| Cincinnati | 7,711 |
| Cleveland | 5,817 |
| Columbus | 4,367 |
| Dayton | 5,934 |
| Toledo | 4,401 |
| Youngtown | 3,689 |

DUA = Discretionary Use Adjustment to account for the fact that people do not always operate their air conditioning system when the outside temperature is greater than 75°F
= 0.75 [179]

0.018 = The volumetric heat capacity of air (Btu/ft3°F)

ηCool = Efficiency of Air Conditioning equipment
= Actual

For example, duct sealing in a house in Akron with SEER 11 central air conditioning and the following blower door test results:

[177] Pascals is the standard assumption for typical pressures experienced in the duct system under normal operating conditions. To convert CFM50 to CFM25 you multiply by 0.64 (inverse of the “Can’t Reach Fifty” factor for CFM25; see Energy Conservatory Blower Door Manual).
[178] Derived by summing the delta between the average outdoor temperature and the base set point of 75 degrees (above which cooling is assumed to be used) each hour of the year. Hourly temperature data obtained from TMY3 data (http://rredc.nrel.gov/solar/)
[179] Based on Energy Center of Wisconsin, May 2008 metering study; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research”, p31

Before: $CFM50_{Whole\ House}$ = 4800 CFM50
$CFM50_{Envelope\ Only}$ = 4500CFM50
House to duct pressure of 45 Pascals. = 1.29 SCF (Energy Conservatory look up table)

After: $CFM50_{Whole\ House}$ = 4700 CFM50
$CFM50_{Envelope\ Only}$ = 4500CFM50
House to duct pressure of 43 Pascals = 1.39 SCF (Energy Conservatory look up table)

Duct Leakage:

$CFM50_{DL\ before}$ = (4800 – 4500) * 1.29
= 387 CFM

$CFM50_{DL\ after}$ = (4700 – 4500) * 1.39
= 278 CFM

Energy Savings:

ΔkWh = ((387 – 278) * 60 * 0.64 * 3986 * 0.75* 0.018) / 1000 / 11
= 20 kWh

***Methodology 2: Evaluation of Distribution Efficiency***

Determine Distribution Efficiency by evaluating duct system before and after duct sealing using Building Performance Institute "Distribution Efficiency Look-Up Table"

$\Delta kWh_{cooling} = ((DE_{after} - DE_{before}) / DE_{after})) * FLHcool * BtuH * (1/SEER)/1000$

Where:

$DE_{after}$ = Distribution Efficiency after duct sealing

$DE_{before}$ = Distribution Efficiency before duct sealing

FLHcool = Full load cooling hours
Dependent on location as below:

| Location | Run Hours[180] |
|---|---|
| Akron | 476 |
| Cincinnati | 664 |
| Cleveland | 426 |
| Columbus | 552 |
| Dayton | 631 |
| Mansfield | 474 |
| Toledo | 433 |
| Youngstown | 369 |

[180] 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."

BtuH = Size of equipment in Btuh (note 1 ton = 12,000Btuh)
= Actual

SEER = SEER Efficiency of AC unit
= Actual

For example, duct sealing in a house in Akron, with 3-ton SEER 11 central air conditioning and the following duct evaluation results:

$DE_{after}$ = 0.92

$DE_{before}$ = 0.85

Energy Savings:

$\Delta kWh = ((0.92 – 0.85)/0.92) * 476 * 36000 * (1/11)) / 1000$
$= 118.5$ kWh

**Summer Coincident Peak Demand Savings**

$\Delta kW = \Delta kWh / FLHcool * CF$

Where:

FLHcool = Full load cooling hours
Dependent on location as below:

| Location | Run Hours[181] |
|---|---|
| Akron | 476 |
| Cincinnati | 664 |
| Cleveland | 426 |
| Columbus | 552 |
| Dayton | 631 |
| Mansfield | 474 |
| Toledo | 433 |
| Youngstown | 369 |

CF = Summer Peak Coincidence Factor for measure
= 0.68[182]

**Space Heating Savings Calculation**

***Methodology 1: Modified Blower Door Subtraction***

$$\Delta MMBTU = ((CFM50_{DL\ before} - CFM50_{DL\ after}) * 60 * 24 * HDD * 0.018) / 1{,}000{,}000 / \eta Heat$$

[181] 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."

[182] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. TRM v7.0 Vol. 3_September 28, 2018_Final

Where:

$CFM50_{DL\ before}$ = Duct Leakage rate before duct sealing
= calculated as above

$CFM50_{DL\ after}$ = Duct Leakage rate after duct sealing
= calculated as above

HDD = Heating Degree Days (60° base temperature) for location[183]

| Location | Heating Degree Days (60°F base temperature) |
|---|---|
| Akron | 4,754 |
| Cincinnati | 3,769 |
| Cleveland | 4,544 |
| Columbus | 4,033 |
| Dayton | 4,360 |
| Toledo | 4,806 |
| Youngtown | 4,841 |

ηHeat = Average Net Heating System Efficiency (Equipment Efficiency * Distribution Efficiency) [184]
= actual recorded

**Note for homes with electric heat (resistance or heat pump), follow the MMBTU formula above and convert to kWh by multiplying by 293.1. For heat pumps the equipment efficiency used in the above algorithm should be the Coefficient Of Performance or COP (i.e. divide HSPF by 3.412, e.g. HSPF 7.7 is COP of 2.26).**

For example, duct sealing in a house in Akron with a 80% AFUE natural gas furnace and the following blower door test results:

Before: $CFM50_{Whole\ House}$ = 4800 CFM50
$CFM50_{Envelope\ Only}$ = 4500CFM50
House to duct pressure of 45 Pascals = 1.29 SCF (Energy Conservatory look up table)

After: $CFM50_{Whole\ House}$ = 4700 CFM50
$CFM50_{Envelope\ Only}$ = 4500CFM50
House to duct pressure of 43 Pascals = 1.39 SCF (Energy Conservatory look up table)

[183] The 10 year average (2003-2012) annual heating degree day value, using a balance point for heating equipment use of 60 degrees was calculated for each location based on data obtained from http://academic.udayton.edu/kissock/http/Weather/citylistUS.htm. The 60 degree balance point is used based on a PRISM evaluation of approximately 600,000 Ohio residential single family customers. Days with no data were approximated by averaging the daily average temperatures from the two nearest days with data.

[184] The System Efficiency can be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf) or by performing duct blaster testing.
If there are more than one heating systems, the weighted (by consumption) average efficiency should be used.
If the heating system or distribution is being upgraded within a package of measures together with the insulation upgrade, the new average heating system efficiency should be used.

Duct Leakage:

$CFM50_{DL\ before}$ = (4800 – 4500) * 1.29
= 387 CFM

$CFM50_{DL\ after}$ = (4700 – 4500) * 1.39
= 278 CFM

Energy Savings:

ΔMMBTU = ((387 - 278) * 60 * 24 * 4754 * 0.018) / 1,000,000 / 0.80
= 16.8 MMBtu

***Methodology 2: Evaluation of Distribution Efficiency***

$$\Delta MMBTUfossil\ fuel = ((DE_{after} - DE_{before}) / DE_{after}) * MMBTU_{heat}$$

Where:

$DE_{after}$ = Distribution Efficiency after duct sealing

$DE_{before}$ = Distribution Efficiency before duct sealing

$MMBTU_{heat}$ = Heating energy consumption
= 71.2 MMBtu[185]

For example, duct sealing in a fossil fuel heated house in Akron with the following duct evaluation results:

$DE_{after}$ = 0.92

$DE_{before}$ = 0.85

Energy Savings:

ΔMMBTU = ((0.92 – 0.85)/0.92) * 71.2
= 5.42 MMBtu

$$\Delta MMBTUelectric = ((DE_{after} - DE_{before}) / DE_{after}) * FLHheat * BtuH * (1/COP * 3.413)/1000$$

Where:

FLHheat = Full load heating hours
Dependent on location as below:

| Location | Run Hours[186] |
|---|---|
| Akron | 1576 |
| Cincinnati | 1394 |
| Cleveland | 1567 |
| Columbus | 1272 |
| Dayton | 1438 |
| Mansfield | 1391 |

185 Assumption based on review of Ohio State average home heating output (based on gas utility data)
186 Heating EFLH extracted from simulations conducted for Duke Energy, OH Joint Utility TRM, October 2009; "Technical Reference Manual (TRM) for Ohio Senate Bill 221Energy Efficiency and Conservation Program and 09-512-GE-UNC"

| | |
|---|---|
| Toledo | 1628 |

BtuH = Size of equipment in Btuh (note 1 ton = 12,000Btuh)
= Actual

COP = Coefficient of Performance of electric heating system[187]

For example, duct sealing a heat pump (HSPF 6.8) heated house in Akron with the following duct evaluation results:

$DE_{after}$ = 0.92

$DE_{before}$ = 0.85

Energy Savings:

$\Delta kWh = ((0.92 – 0.85)/0.92) * 1576 * 36000 * (1/6.8)/1000$
$= 635 \text{ kWh}$

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

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

[187] Note that the HSPF of a heat pump is equal to the COP * 3.413.

## Smart Thermostats (Time of Sale)

**Description**
Smart thermostats can save energy by reducing heating and cooling through setpoint adjustments. Similar to programmable thermostats, users can configure schedules and setpoints. Over time, smart thermostats can automatically make adjustments to schedules and setpoints in order to continuously optimize energy efficiency and occupant comfort. The algorithms and inputs used to make these changes vary by the specific type of smart thermostat. Most use manually input setpoint adjustments and occupancy sensors. Some also use weather data, data collected from other thermostat users, and various other specific features. There is not sufficient data to attribute energy savings to specific features. However, there have been several studies of overall energy savings from this product category and specific models, which are used as the basis for savings calculated in this measure.

**Definition of Efficient Equipment**
This measure applies to any thermostat that uses an algorithm to automatically adjust schedules and setpoints with no input from the user.

**Definition of Baseline Equipment**
The baseline is either a programmable thermostat or a standard non-programmable thermostat. Savings may be calculated relative to the actual baseline type if known, or an assumed mix of the two based on available market data. This mix may vary by customer segment for specific programs, but a default of 51% programmable, 49% manual may be used.[188]

**Deemed Savings for this Measure**

$$\Delta kWh = (kWh_{heating} * \%Reduction_{heating} + kWh_{cooling} * \%Reduction_{cooling}) * ISR$$

$$\Delta kW = \Delta kWh / FLH * CF$$

$$\Delta MMBtu = \%GasHeat * MMBtu_{heating} * \%Reduction_{heating} * ISR$$

**Deemed Lifetime of Efficient Equipment**
The assumed equipment lifetime is assumed to be 11 years.[189]

**Deemed Measure Cost**
The incremental cost for this measure is $165.[190]

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

**Coincidence Factor**
n/a

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188 Opinion Dynamics Corporation, "ComEd Residential Saturation/End Use, Market Penetration & Behavioral Study", Appendix 3: Detailed Mail Survey Results, p34, April 2013

189 Based on 2017 Residential Smart Thermostat Workpaper, prepared by SCE and Nest for SCE (Work Paper SCE17HC054, Revision #0). Estimate ability of smart systems to continue providing savings after disconnection and conduct statistical survival analysis which yields 9.2-13.8 year range.

190 Smart thermostats vary in price from $150 to $250. Savings are based on an average price of $200 minus a $35 baseline cost.

## REFERENCE SECTION

**Calculation of Savings**

There is not sufficient data to calculate energy savings directly from the feature set of smart thermostats. Savings are based on an evaluation report that assessed savings for smart thermostats based on a regression analysis of customer bill data.**Error! Bookmark not defined.**, [193]

**Energy Savings**

$\Delta kWh = (kWh_{heating} * \%Reduction_{heating} + kWh_{cooling} * \%Reduction_{cooling}) * ISR$

$kWh_{heating} = \%ElectricHeat * kWh_{ElectricHeat}$

$kWh_{cooling} = \%AC * FLH * Capacity / SEER / 1000$

Where:

$\%Reduction_{heating}$ = 7.2%[191]

or dependent on existing as below:

| Existing | Savings[192] |
|---|---|
| Programmable | 5.6% |
| Non-Programmable | 8.8% |

$\%Reduction_{cooling}$ = 2%[193]

ISR = In Service Rate
= 100%

%ElectricHeat = Fraction of customers with electric heating
=11%[194]

$kWh_{ElectricHeat}$ = 3,653[195]

%AC = Fraction of customers with central air conditioning

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191 Based on average of values in table below, assuming 51% of existing thermostats are programmable, from Opinion Dynamics Corporation, "ComEd Residential Saturation/End Use, Market Penetration & Behavioral Study", Appendix 3: Detailed Mail Survey Results, p34, April 2013

192 Based on ComEd Advanced Thermostat Evaluation Research Report, which evaluated the Illinois TRM heating savings values and found that they are consistent with customer billing data analysis. The study uses Linear Fixed Effects Regression (LFER) billing analysis. (http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY9_Evaluation_Reports_Final/ComEd_Advanced_Thermostat_Evaluation_Research_Report_2018-11-02_Final.pdf)

193 Based on ComEd Advanced Thermostat Evaluation Research Report, which evaluated the Illinois TRM cooling savings value of 8% and found that it was not supported by a study of customer billing. The study uses Linear Fixed Effects Regression (LFER) billing analysis and finds a cooling savings of 2%. (http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY9_Evaluation_Reports_Final/ComEd_Advanced_Thermostat_Evaluation_Research_Report_2018-11-02_Final.pdf)

194 Based on all forms of electric heat from 2005 Residential Energy Consumption Survey (RECS) for East North Central Census Division: (https://www.eia.gov/consumption/residential/data/2005/hc/pdf/tablehc12.4.pdf)

195 Average for electric resistance and heat pumps, from 2005 Residential Energy Consumption Survey (RECS) for East North Central Census Division: (https://www.eia.gov/consumption/residential/data/2015/c&e/pdf/ce4.8.pdf)

= 70%[196]

FLH = Full load cooling hours

= 503[197]

or dependent on location as below:

| Location | Run Hours[198] |
|---|---|
| Akron | 476 |
| Cincinnati | 664 |
| Cleveland | 426 |
| Columbus | 552 |
| Dayton | 631 |
| Mansfield | 474 |
| Toledo | 433 |
| Youngstown | 369 |

Capacity = Size of AC unit in Btu/hr (Note one ton equals 12,000 Btu/hr)

= 47,000[199]

SEER = AC Efficiency rating

= 9.3[200]

**Summer Coincident Peak Demand Savings**

$\Delta kW = \Delta kWh / FLH * CF$

Where:

CF = Summer Peak Coincidence Factor for measure

= 0.68 [201]

**Fossil Fuel Impact Descriptions and Calculation**

$\Delta MMBtu = \%GasHeat * MMBtu_{heating} * \%Reduction_{heating} * ISR$

Where:

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[196] From 2005 Residential Energy Consumption Survey (RECS) for East North Central Census Division: (https://www.eia.gov/consumption/residential/data/2015/hc/hc7.7.xlsx)

[197] Based on average of values in table below.

[198] 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."

[199] Based on 400 sf/ton and an average cooled area of 1,564 sf for all residential units in the East North Central Region from 2005 Residential Energy Consumption Survey (RECS) (www.eia.gov/consumption/residential/data/2015/hc/php/hc10.3.php)

[200] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'

[201] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. TRM v7.0 Vol. 3_September 28, 2018_Final

%GasHeat = 74%[202]

MMBtu =Annual Home Heating Load
=65[203]

$\%Reduction_{heating}$ = 7.2%[204]
or dependent on existing as below:

| Existing | Savings[205] |
|---|---|
| Programmable | 5.6% |
| Non-Programmable | 8.8% |

ISR = In Service Rate
= 100%

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

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

202 From 2005 Residential Energy Consumption Survey (RECS) for East North Central Census Division: (https://www.eia.gov/consumption/residential/data/2005/hc/pdf/tablehc12.4.pdf)
203 Average for all households with gas heating from 2005 Residential Energy Consumption Survey (RECS) for East North Central Census Division: (https://www.eia.gov/consumption/residential/data/2015/c&e/pdf/ce4.8.pdf)
204 Based on average of values in table below, assuming 51% of existing thermostats are programmable, from Opinion Dynamics Corporation, "ComEd Residential Saturation/End Use, Market Penetration & Behavioral Study", Appendix 3: Detailed Mail Survey Results, p34, April 2013
205 Based on ComEd Advanced Thermostat Evaluation Research Report, which evaluated the Illinois TRM cooling savings value of 8% and found that it was not supported by a study of customer billing. The study uses Linear Fixed Effects Regression (LFER) billing analysis and finds a cooling savings of 2%. (http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY9_Evaluation_Reports_Final/ComEd_Advanced_Thermostat_Evaluation_Research_Report_2018-11-02_Final.pdf)

## Programmable Thermostats (Time of Sale, Direct Install)

**Description**
Programmable Thermostats can save energy through the advanced scheduling of time-of-day and/or day-of-week setbacks to control heating and cooling setpoints. Typical usage reduces the heating setpoint during times of the day when occupants are usually not at home (work hours), keeping the home at a cooler temperature in the winter reduces heat losses relative to a higher temperature.

**Definition of Efficient Equipment**
Programmable Thermostat

**Definition of Baseline Equipment**
Standard, non-programmable thermostat for central heating system (baseboard electric is excluded from this characterization.

**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 | n/a[206] | n/a | 4.8 | n/a |

**Deemed Lifetime of Efficient Equipment**
The lifetime of this measure is assumed to be 15 years in accordance with the EPA's determination of the lifetime of the thermostats.

**Deemed Measure Cost**
The incremental cost for the purchase of a programmable thermostat shows significant variation, but is typically on the order of $35 based upon current retail market prices. Measures directly installed through retrofit programs should use the actual material, and labor costs.

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

**Coincidence Factor**
n/a

### 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

[206] The referenced study only evaluated heating savings and did not address savings during the cooling season. We do not believe it is appropriate to assume a similar pattern of savings from setting your thermostat down during the heating season and up during the cooling season. A literature review could not find any appropriate defensible source of cooling savings from programmable thermostats

credible regard for the findings of a 2007 study[207] 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

$\Delta$MMBtu = (Savings %) x (Annual Home Heating Load [208])

= 6.2% x (71.2 MMBtu)

= 4.4 MMBtu

**Water Impact Descriptions and Calculation**

n/a

**Deemed O&M Cost Adjustment Calculation**

n/a

[207] Values in table are based on converting an average household heating load (834 therms) for Chicago based on 'Table E-1, Energy Efficiency/Demand Response Nicor Gas Plan Year 1: Research Report: Furnace Metering Study, Draft, Navigant, August 1 2013

[208] 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)

**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 80%. The baseline unit is non-condensing.

**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 18 years.[209]

**Deemed Measure Cost**
The incremental measure cost, based on material cost alone[210], as labor is comparable to baseline, shall be related to AFUE of the unit[211]:

| AFUE, % | Incremental Cost |
|---|---|
| 90 | $392 |
| 92 | $429 |
| 94 | $537 |
| 96 | $659 |

**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.

[209] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
[210] C Itron, Mid-Atlantic TRM Version 7.0 Incremental Costs Update, 2017. Adapted from Department of Energy, Residential Furnaces and Boilers Final Rule Technical Support Document, 2016, Table 8-2-16. https://www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0217. CA DEER Database Res-HVAC
[211] http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf

**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[212]

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

[212] 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)

**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 82 %

**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[213].

**Deemed Measure Cost**
The incremental measure cost, based on material and installation costs are a function of the AFUE of the unit:[214]

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

**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 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

[213]http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf
[214] Based on data provided in Energy Efficiency and Renewable Energy Office 2016 draft rule for boiler efficiency. https://www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0230

**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[215]

BtuH = Size of equipment in Btuh
= Actual installed

$AFUE_{BASE}$ = Annual Fuel Utilization Efficiency % for the baseline equipment
= 0.82

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

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

$\Delta MMBtu = 712 * 100{,}000 * (1- 0.82/0.85) * 10^{-6}$
$= 2.5$

**Water Impact Descriptions and Calculation**

n/a

**Deemed O&M Cost Adjustment Calculation**

n/a

[215] 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.

# III. Hot Water

## Heat Pump Water Heaters (Time of Sale)

**Description**
This measure relates to the installation of a heat pump domestic hot water heater in place of a standard electric hot water heater in conditioned space. This is a time of sale measure. Savings are presented dependent on the heating system installed in the home.

**Definition of Efficient Equipment**
To qualify for this measure the installed equipment must meet or exceed Energy Star requirements[219] for the domestic electric storage water heater category. For water heaters under 55 gallons and under, a uniform energy factor (UEF) of 2.0 is required. For units over 55 gallons a UEF of 2.2 is required.

**Definition of Baseline Equipment**
The baseline is a water heater complying with minimum federal efficiency standards[216]. Uniform Energy Factor (UEF) is calculated based on formulas with coefficients that vary based on the tank size and draw pattern. A full set of these formulas is included in the Reference Section for this measure.

**Deemed Savings for this Measure**
Heat pump water heaters work by drawing heat from air in the occupied space and using it to heat water. Therefore the impact on space heating and cooling must be included using the following formula[217]:

$$\Delta kWH = 3{,}222 * ((1/\ UEF_{Base}\ - 1/UEF_{Eff}) + KWHcooling - KWHheating$$

Units over 55 gallons are required by federal standards to be heat pumps. Efficient equipment will therefore have no impact on heating and cooling loads and the following simplified formula can be used:

$$\Delta kWH = 3{,}222 * ((1/\ UEF_{Base}\ - 1/UEF_{Eff})$$

For units under 55 gallons, deemed savings may be assumed based on common equipment types. The table below is based on a 40 gallon heat pump water heater with a ‘medium’ draw pattern, resulting in a baseline Uniform Energy Factor (UEF) of 0.92 according to the federal standard formula. Energy savings will depend on the type of heating system installed. See the Reference Section for calculation details.

| Heating System: | Average Annual KWH Savings per unit | Average Summer Coincident Peak kW Savings per unit[218]. | Average Annual Fossil Fuel heating fuel savings (MMBTU) per unit | Percent of Households |
|---|---|---|---|---|
| Electric Resistance | 704 | 0.010 | n/a | 15.5% |
| Heat Pump | 1,429 | 0.20 | n/a | 3.3% |
| Fossil Fuel | 2,154 | 0.29 | -6.19 | 81.2% |
| Weighted Average | 1,905 | 0.26 | -5.02 | |

[216] Federal Standard: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=32
[217] The coefficient in this formula is based on average usage by electric water heating in this region. Compiled in the Energy Information Administration’s Residential Energy Consumption Survey (RECS) 2015, East North Central
[218] Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York, adjusted for OH peak definitions. Resultant coincident peak kW is consistent with result shown in FEMP study; Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters
http://www1.eere.energy.gov/femp/pdfs/tir_heatpump.pdf

**Deemed Lifetime of Efficient Equipment**
The measure life is assumed to be 10 years[219].

**Deemed Measure Cost**
The incremental cost for this measure is $741 for units 55 gallons and under, and $560 for units over 55 gallons. [220].

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

**Coincidence Factor**
The summer coincidence factor is assumed to be 0.346 [221].

## REFERENCE SECTION

**Calculation of Savings**

**Energy Savings**

$\Delta$kWH = KWHbase * (1/ $UEF_{Base}$ - 1/$UEF_{Eff}$) + KWHcooling - KWHheating

Where:

KWHbase = Average electric water heater usage
= 3,222 [222]

$UEF_{Eff}$ = Uniform Energy Factor for the efficient equipment
= actual installed

$UEF_{Base}$ = Uniform Energy Factor for the baseline equipment
Use the following table to calculate minimum federal standard UEF

| Rated storage volume | Draw pattern | Uniform energy factor |
|---|---|---|
| ≥20 gal and ≤55 gal | Very Small | 0.8808 − (0.0008 × Vr) |
| | Low | 0.9254 − (0.0003 × Vr) |
| | Medium | 0.9307 − (0.0002 × Vr) |
| | High | 0.9349 − (0.0001 × Vr) |
| >55 gal and ≤120 gal | Very Small | 1.9236 − (0.0011 × Vr) |
| | Low | 2.0440 − (0.0011 × Vr) |
| | Medium | 2.1171 − (0.0011 × Vr) |
| | High | 2.2418 − (0.0011 × Vr) |

[219]DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).
[220] Navigant Consulting, Inc., September 2018; "Water Heating, Boiler, and Furnace Cost Study (RES 19)" prepared for Massachusetts residential program evaluation. This study includes marketplace data for a range of efficiencies. Baseline and efficient equipment costs that best matched the UEF criteria were used to calculate incremental costs. Vermont Energy Investment Corporation "Residential Heat Pump Water Heaters: Energy Efficiency Potential and Industry Status" November 2005
[221] Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York, adjusted for OH peak definitions. Resultant coincident peak kW is consistent with result shown in FEMP study; Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters
http://www1.eere.energy.gov/femp/pdfs/tir_heatpump.pdf
[222] Energy Information Administration's Residential Energy Consumption Survey (RECS) 2015, East North Central

KWHcooling = Cooling savings from conversion of heat in home to water heat
= 296 [223]

KWHheating = Heating cost from conversion of heat in home to water heat.

Dependent on heating fuel as follows[224]:

KWHheating (electric resistance) = 1,450
KWHheating (heat pump COP 2.0) = 725
KWHheating (fossil fuel) = 0

ΔkWH electric resistance heat $= 3{,}222 * (1/\ UEF_{Base} - 1/UEF_{Eff}) + 296 – 1{,}450$
= 499 kWh

ΔkWH heat pump heat $= 3{,}222 * (1/\ UEF_{Base} - 1/UEF_{Eff}) + 296 - 725$
= 1,297 kWh

ΔkWH fossil fuel heat $= 3{,}222 * (1/\ UEF_{Base} - 1/UEF_{Eff}) + 296 - 0$
= 2,076 kWh

**Summer Coincident Peak Demand Savings**

ΔkW = ΔkWh / Hours * CF

Where:

Hours = Full load hours of hot water heater
= 2533 [225]

CF = Summer Peak Coincidence Factor for measure
= 0.346

**Fossil Fuel Impact Descriptions and Calculation**
(For homes with fossil fuel heating system)

ΔMMBtu = -6.19 MMBtu[226]

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[223] Determined by calculating the MMBtu removed from the air, applying the REMRate determined percentage (35%) of lighting savings that result in reduced cooling loads (lighting is used as a proxy for hot water heating since load shapes suggest their seasonal usage patterns are similar), assuming a SEER 13 central AC unit, multiplying by 92% to adjust for the percentage of OH homes having cooling (East North Central census division from Energy Information Administration, 200520152005 Residential Energy Consumption Survey

[224] Determined by calculating the MMBtu removed from the air, as above, applying the REMRate determined percentage (45%) of lighting savings that result in increased heating loads, converting to kWh and dividing by efficiency of heating system (1.0 for electric resistance, 2.0 for heat pump).

[225] Full load hours assumption based on Efficiency Vermont loadshape, calculated from Itron eShapes.

[226] This is the additional energy consumption (therefore a negative value) required to replace the heat removed from the home during the heating season by the heat pump water heater. Determined by calculating the MMBtu removed from the air, applying the REMRate determined percentage (45%) of lighting savings that result in increased heating loads (lighting is used as a proxy for hot water heating since load shapes suggest their seasonal usage patterns are similar), dividing by the efficiency of the heating system (estimated assuming that natural gas central furnace heating is typical for Ohio residences (65% of East North Central census division has a Natural Gas Furnace (based on Energy Information Administration, 2005 Residential Energy Consumption Survey: http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc4spaceheating/pdf/tablehc12.4.pdf))

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

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

In 2000, 40% of furnaces purchased in Ohio were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process). Assuming typical efficiencies for condensing and non condensing furnace and duct losses, the average heating system efficiency is estimated as follows:
((0.4*0.92) + (0.6*0.8)) * (1-0.15) = 0.72.

## Low Flow Faucet Aerator (Time of Sale or Early Replacement)

**Description**
This measure relates to the installation of a low flow faucet aerator, using 1.5 gallons per minute (GPM) or less. This could be a retrofit direct install measure or a new installation. Both electric and fossil fuel savings are provided, although only savings corresponding to the hot water heating fuel should be claimed.

**Definition of Efficient Equipment**
The efficient equipment is a low flow aerator, typically 1.5 GPM or less. The EPA's WaterSense program labels new products below 1.5 GPM as efficient.

**Definition of Baseline Equipment**
The baseline equipment is a standard faucet aerator using 2.2 GPM. This represents the maximum allowable flow for faucets under federal standards since 1998[231].

**Deemed Calculation for this Measure**

Annual kWh savings = ISR * ((2.2 – GPMlow) / 2.2) * 99

Summer Coincident Peak savings = ΔkWH * 0.000121

Annual MMBTU savings = ISR * ((2.2 – GPMlow) / 2.2) * 0.422

Annual Water savings (gallons) = ISR * ((2.2 – GPMlow) / 2.2) * 1797

Savings for a standard 1.5 GPM aerator are shown in the following tables:

1.5 GPM Aerator, Direct Install

| Heater Type | Energy (kWh) | Demand (kW) | Gas (MMBtu) | Water (gallons) |
|---|---|---|---|---|
| Electric | 31.5 | 0.00382 | | 572 |
| Gas | | | 0.134 | 572 |

1.5 GPM Aerator, Self Install

| Heater Type | Energy (kWh) | Demand (kW) | Gas (MMBtu) | Water (gallons) |
|---|---|---|---|---|
| Electric | 15.13 | 0.00183 | | 275 |
| Gas | | | 0.0644 | 275 |

**Deemed Lifetime of Efficient Equipment**
The measure life is assumed to be 10 years[227].

**Deemed Measure Cost**
As a retrofit measure, the cost will be the actual cost of the aerator and its installation.
As a measure distributed to, but installed by, participants, the cost will be the cost of the aerator and the distribution costs.

[227] California DEER database 2011

As a time of sale measure, the cost is assumed to be $3[228].

**Deemed O&M Cost Adjustments**
When a retrofit measure, there would be a very small O&M benefit associated with the deferral of the next replacement, but this has conservatively not been characterized.

**Coincidence Factor**
The coincidence factor for this measure is calculated at 0.0026[229].

## REFERENCE SECTION

**Calculation of Savings**

**Energy Savings**
If electric domestic hot water heater:

ΔkWH =ISR * ((((GPMbase - GPMlow) / GPMbase) * # people * gals/day * days/year * DR) / F/home) * 8.3 * (Tft - Tmains) / 1,000,000) / DHW Recovery Efficiency / 0.003412

Where:

ISR = In Service Rate or fraction of units that get installed
Retrofit/Direct Install = 1.0
Customer self install = 0.48[230]

GPMbase = Gallons Per Minute of baseline faucet
= 2.2 [231]

GPMlow = Gallons Per Minute of low flow faucet
= Actual

# people = Average number of people per household
= 2.51 [232]

gals/day = Average gallons per day used by all faucets in home
= 10.9 [233]

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228 Illinois Technical Reference Manual v7.0. (http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_3_Res_092818_Final.pdf).
229 Calculated as follows: Assume 13% faucet use takes place during peak hours (based on: http://www.aquacraft.com/Download_Reports/DISAGGREGATED-HOT_WATER_USE.pdf)
13% * 3.6 minutes per day (10.9 * 2.56 / 3.5 / 2.2 = 3.6) = 0.47 minutes
= 0.47 / 180 (minutes in peak period) = 0.00262
230 EGD_2009_DSM_Annual Report from table 27 survey of Install rates: Overall averages of 62% and 34% for kitchen and bath aerators respectively are averaged to get 48%. There is significant variation in rates by building type, aerator type, and distribution so surveying participants is encouraged
231 In 1998, the Department of Energy adopted a maximum flow rate standard of 2.2 gpm at 60 psi for all faucets: 63 Federal Register 13307; March 18, 1998.
232 US Energy Information Administration, Residential Energy Consumption Survey 2015, East North Central Census Division; Table HC9.7 (assume only six members in "six or more" category)
233 Most commonly quoted value of gallons of water used per person per day (including in U.S. Environmental Protection Agency's "water sense" documents; http://www.epa.gov/watersense/docs/home_suppstat508.pdf)

days/y = Days faucet used per year
= 365

DR = Percentage of water flowing down drain (if water is collected in a sink, a faucet aerator will not result in any saved water)
= 63% [234]

F/home = Average number of faucets in the home
= 3.5 [235]

8.3 = Constant to convert gallons to lbs

Tft = Assumed temperature of water used by faucet
= 80 [236]

Tmains = Assumed temperature of water entering house
= 57.8 [237]

DHW Recovery Efficiency = Recovery efficiency of electric hot water heater
= 0.98 [238]

0.003412 = Constant to converts MMBtu to kWh

For example, a 1.5GPM direct installation:

ΔkWH =1.0 * ((((2.2 – 1.5) / 2.2) * 2.51 * 10.9 * 365 * 0.63)) / 3.5 * 8.3 * (80-57.8) / 1,000,000) / 0.98 / 0.003412
= 31.5 kWh

**Summer Coincident Peak Demand Savings**

ΔkW = ΔkWh/hours * CF

Where:

Hours = Average number of hours per year spent using faucet
= (Gal/person * # people * 365) / F/home / GPM / 60
= (10.9 * 2.51 * 365) / 3.5 / 2.2 / 60
= 21.6 hours

CF = Summer Peak Coincidence Factor for measure
= 0.00262

For example, a 1.5GPM direct installation:

ΔkW = 31.5 / 21.6 * 0.00262

234 Estimate consistent with Ontario Energy Board, "Measures and Assumptions for Demand Side Management Planning", using the 50% kitchen faucet and 70% bathroom faucet values to calculate a weighted average assuming two bathroom faucets and one kitchen faucet.
235 Estimate based on East Bay Municipal Utility District; "Water Conservation Market Penetration Study" http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf
236 Connecticut Energy Efficiency Fund; CL&P and UI Program Savings Documentation for 2008 Program Year
237 Annual average of all cities obtained from OH Joint Utility TRM; Table 39: Monthly Mains Water Temperature for Selected Cities (°F).
238 Electric water heater have recovery efficiency of 98%: http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576

$= 0.00382$ kW

**Fossil Fuel Impact Descriptions and Calculation**

If fossil fuel domestic hot water heater, MMBtu savings provided below:

ΔMMBtu = ISR * ((((GPMbase - GPMlow) / GPMbase) * # people * gals/day * days/year * DR) / F/home) * 8.3 * (Tft - Tmains) / 1,000,000) / Gas DHW Recovery Efficiency

Where:

Gas DHW Recovery Efficiency = Recovery efficiency of gas hot water heater
= 0.785 [239]

For example, a 1.5GPM direct installation:

ΔMMBtu = 1.0 * ((((2.2 – 1.5) / 2.2) * 2.51 * 10.9 * 365 * 0.63)) / 3.5 * 8.3 * (80-57.8) / 1,000,000) / 0.785
= 0.134 MMBtu

**Water Impact Descriptions and Calculation**

Water Savings = ISR * (((GPMbase - GPMlow) / GPMbase) * # people * gals/day * days/year * DR) / F/home

For example, a 1.5GPM direct installation:

Water Savings = 1.0 * ((((2.2 – 1.5) / 2.2) * 2.51 * 10.9 * 365 * 0.63)) / 3.5
= 572 gallons

**Deemed O&M Cost Adjustment Calculation**

When a retrofit measure, there would be a very small O&M benefit associated with the deferral of the next replacement, but this has conservatively not been characterized.

[239] Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 7578.575%

## Low Flow Showerhead (Time of Sale or Early Replacement)

**Description**
This measure relates to the installation of a low flow showerhead in a home. This is a retrofit direct install measure or a new installation. Both electric and fossil fuel savings are provided, although only savings corresponding to the hot water heating fuel should be claimed.

**Definition of Efficient Equipment**
The efficient condition is a low flow showerhead typically 2.0 GPM or less. The EPA's WaterSense program labels new products below 2.0 GPM as efficient

**Definition of Baseline Equipment**
The baseline is a standard showerhead using 2.5 GPM[240].

**Deemed Calculation for this Measure**

Annual kWh savings = ISR * (2.5 – GPMlow) * 173

Summer Coincident Peak savings = ΔkWH * 0.000112

Annual MMBTU savings = ISR * (2.5 – GPMlow) * 0.77

Annual Water savings (gal) = ISR * ((2.5 – GPMlow) / 2.5) * 4960

Savings for a standard 2.0 GPM shower head are shown in the following tables:

2.0 GPM Shower Head, Direct Install

| Heater Type | Energy (kWh) | Demand (kW) | Gas (MMBtu) | Water (gallons) |
|---|---|---|---|---|
| Electric | 87 | 0.010 | | 1,012 |
| Gas | | | 0.39 | 1,012 |

2.0 GPM Shower Head, Self Install

| Heater Type | Energy (kWh) | Demand (kW) | Gas (MMBtu) | Water (gallons) |
|---|---|---|---|---|
| Electric | 70 | 0.010 | | 820 |
| Gas | | | 0.31 | 820 |

**Deemed Lifetime of Efficient Equipment**
The measure life is assumed to be 10 years [241].

**Deemed Measure Cost**
As a retrofit measure, the incremental cost will be the cost of the showerhead including its installation.

[240] Federal standard is 2.5 GPM, established by the Energy Policy Act in 1992. Shower heads are limited to 2.5 GPM at 80 PSI of water pressure.
[241] California DEER database 2011

As a measure distributed to, but installed by, participants, the cost will be the cost of the showerhead and the distribution costs.
As a time of sale measure, the incremental cost is assumed to be $7[242].

**Deemed O&M Cost Adjustments**
When a retrofit measure, there would be a very small O&M benefit associated with the deferral of the next replacement, but this has conservatively not been characterized.

**Coincidence Factor**
The coincidence factor for this measure is calculated at 0.00371 [243].

## REFERENCE SECTION

### Calculation of Savings

**Energy Savings**
If electric domestic hot water heater:

$$\Delta kWH = ISR * (GPMbase - GPMlow) * kWh/GPMreduced$$

Where:

ISR = In Service Rate or fraction of units that get installed
Retrofit/Direct Install = 1.0
Customer self install = 0.81[244]

GPMbase = Gallons Per Minute of baseline showerhead
= 2.5 [245]

GPMlow = Gallons Per Minute of low flow showerhead
= Actual

kWh/GPMreduced = Assumed kWh savings per GPM reduction
= 173 kWh per gallon per minute reduced[246]

For example, a 2.0 GPM direct installation:

[242] Illinois Technical Reference Manual v7.0. (http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_3_Res_092818_Final.pdf).
[243] Calculated as follows: Assume 9% showers take place during peak hours (based on: http://www.aquacraft.com/Download_Reports/DISAGGREGATED-HOT_WATER_USE.pdf)
9% * 7.42 minutes per day (11.6 * 2.56 / 1.6 / 2.5 = 7.42) = 0.668 minutes
= 0.668 / 180 (minutes in peak period) = 0.00371
[244] EGD_2009_DSM_Annual Report from table 27 survey of Install rates: Overall averages 81%. There may be significant variations due to specifics of the program distribution, so surveying participants is encouraged.
[245] The Energy Policy Act of 1992 (EPAct) established the maximum flow rate for showerheads at 2.5 gallons per minute (gpm).
[246] This is based on an Enbridge metering study (Enbridge Gas Distribution Inc., April 2010; "Demand Side Management 2009 DSM Draft Annual Report", p75) that found 46m$^3$ of natural gas savings when replacing all existing showerheads (with average flow rate of 2.45 GPM) with 1.25GPM showerheads (the replacement GPM and the number of showers per home (2.1) were determined during personal conversations with study authors). This equates to 0.66MMBtu of savings per showerhead per 1GPM reduction. This is converted to kWh by multiplying by the recovery efficiency of a gas heater (0.75 based on review of AHRI Directory) over the recovery efficiency of an electric heater (0.98 from: http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576)

$\Delta$kWH = 1.0 * (2.5 – 2.0) * 173
= 87 kWh

**Summer Coincident Peak Demand Savings**
If electric domestic hot water heater:

$\Delta$kW = $\Delta$kWh/Hours * CF

Where:

Hours = Average number of hours per year spent using shower head
= (Gal/person * # people * days/y) / SH/home / GPM / 60

gals/day = Average gallons per day used for showering
= 11.6 [247]

# people = Average number of people per household
= 2.51 [248]

days/y = Days shower used per year
= 365

SH/home = Average number of showers in the home
= 2.1 [249]

Hours = (11.6 * 2.51 * 365) / 2.1 / 2.5 / 60
= 33.7 hours

CF = Summer Peak Coincidence Factor for measure
= 0.00371 [250]

For example, a 2.0 GPM direct installation:

$\Delta$kW =87 / 33.7 * 0.00371
= 0.010 kW

**Fossil Fuel Impact Descriptions and Calculation**
If fossil fuel domestic hot water heater:

$\Delta$MMBtu = ISR * (GPMbase – GPMlow) * MMBtu/GPMreduced

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and multiplying by 293 (kWh/MMBtu). This analysis was performed for both of the baseline showerhead flow rates included in the study and a weighted average was used for the final kWh/GPM value.

[247] Most commonly quoted value of gallons of water used per person per day (including in U.S. Environmental Protection Agency's "water sense" documents; http://www.epa.gov/watersense/docs/home_suppstat508.pdf)

[248] US Energy Information Administration, Residential Energy Consumption Survey 2015, East North Central Census Division; Table HC9.7 (assume only six members in "six or more" category)

[249] Personal communication with authors of Enbridge Gas Distribution Inc., April 2010; "Demand Side Management 2009 DSM Draft Annual Report"

[250] Calculated as follows: Assume 9% showers take place during peak hours (based on: http://www.aquacraft.com/Download_Reports/DISAGGREGATED-HOT_WATER_USE.pdf)
9% * 7.42 minutes per day (11.6 * 2.56 / 1.6 / 2.5 = 7.42) = 0.668 minutes
= 0.668 / 180 (minutes in peak period) = 0.00371

Where:

MMBtu/GPMreduced = Assumed MMBtu savings per GPM reduction
= 0.77 MMBtu per gallon reduced [251]

For example, a 2.0 GPM direct installation:

$\Delta$MMBtu = 1.0 * (2.5 – 2.0) * 0..77
= 0.39 MMBtu

**Water Impact Descriptions and Calculation**

Water Savings = ISR * (((GPMbase - GPMlow) / GPMbase) * # people * gals/day * days/year)) / SH/home

For example, a 2.0 GPM direct installation:

Water Savings = 1.0* ((((2.5 – 2.0) / 2.5) * 2.51 * 11.6 * 365)) / 2.1
= 1,012 gallons

**Deemed O&M Cost Adjustment Calculation**
When a retrofit measure, there would be a very small O&M benefit associated with the deferral of the next replacement, but this has conservatively not been characterized.

[251] This is based on an Enbridge metering study (Enbridge Gas Distribution Inc., April 2010; "Demand Side Management 2009 DSM Draft Annual Report", p75) that found 46$m^3$ of natural gas savings when replacing all existing showerheads (with average flow rate of 2.45 GPM) with 1.25GPM showerheads (the replacement GPM and the number of showers per home (2.1) were determined during personal conversations with study authors). This was only the more conservative of two different baselines used in the study. By averaging the results for each of the two baselines in the study, the savings amounts to 0.77 MMBtu of savings per showerhead per 1GPM reduction.

## Domestic Hot Water Pipe Insulation (Retrofit)

**Description**
This measure describes adding insulation to un-insulated domestic hot water pipes. The measure assumes the pipe wrap is installed to the first length of both the hot and cold pipe up to the first elbow.

**Definition of Efficient Equipment**
To efficiency case is installing pipe wrap insulation to a length of hot water carrying copper pipe.

**Definition of Baseline Equipment**
The baseline is an un-insulated hot water carrying copper pipe.

**Deemed Calculation for this Measure**

Annual kWh savings (electric DHW systems) = ((D – (D+1)/Rnew) * L * 44.6

Summer Coincident Peak Savings (electric DHW systems) = ΔkWh/8760

Annual MMBtu savings (fossil fuel DHW systems) = ((D – (D+1)/Rnew) * L * 0.189

**Deemed Lifetime of Efficient Equipment**
The measure life is assumed to be 15 years [252].

**Deemed Measure Cost**
The measure cost including material and installation is assumed to be $3 per linear foot[253].

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

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

**REFERENCE SECTION**

**Calculation of Savings**

**Energy Savings**
For electric DHW systems:

$$\Delta kWh = ((D/Rexist – (D+t)/Rnew) * L * \Delta T * \pi / 12 * 8{,}760) / \eta DHW / 3412$$

Where:

Rexist = Pipe heat loss coefficient of uninsulated pipe (existing) (Btu/hr-°F-ft)

[252] 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
[253] Consistent with DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).

= 1.0[254]

Rnew = Pipe heat loss coefficient of insulated pipe (new) (Btu/hr-°F-ft)
= Actual

L = Length of pipe from water heating source covered by pipe wrap (ft)
= actual

D = Pipe Diameter (in)
= actual

t =Insulation Thickness (in)
=1[255]

ΔT = Average temperature difference between supplied water and the temperature of the water heater surroundings (°F)
= 65°F [256]

Π =3.14

8,760 = Hours per year

ηDHW = Recovery efficiency of electric hot water heater
= 0.98 [257]

3412 = Conversion from Btu to kWh

For example, insulating 5 feet of 0.75" pipe with R-5 wrap:

ΔkWh = ((D/Rexist – (D+1)/Rnew) * L * * ΔT * π / 12 * 8,760) / ηDHW / 3412

= ((0.75/1– (0.75+1)/4) * 5 * * 65 * 3.14 / 12 * 8760) / 0.98 /3412

= 89.1kWh

**Summer Coincident Peak Demand Savings**

ΔkW = ΔkWh/8760

Where:

ΔkWh = kWh savings from pipe wrap installation
8760 = Number of hours in a year (since savings are assumed to be constant over year).

For example, insulating 5 feet of 0.75" pipe with R-4 wrap:

ΔkW = 89.1/8760

[254] Navigant Consulting Inc., April 2009; "Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets", p77.
[255] ASHRAE Standard 90.1 2010 Table 6.8.3A requires 1-inch insulation for pipes up to 1.5 inches in diameter, for fluids up to 140° F
[256] Assumes 130°F water leaving the hot water tank and average temperature of basement of 65°F.
[257] Electric water heater have recovery efficiency of 98%: http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576

$= 0.010\text{kW}$

**Fossil Fuel Impact Descriptions and Calculation**
For fossil fuel DHW systems:

$$\Delta MMBtu = ((D/Rexist - (D+t)/Rnew) * L * * \Delta T * \pi / 12 * 8{,}760) / \eta DHW / 1{,}000{,}000$$

Where:

$\eta DHW$ = Recovery efficiency of gas hot water heater
= 0.785 [258]

For example, insulating 5 feet of 0.75" pipe with R-5 wrap:

$$\Delta MMBtu = ((0.75/1 - (0.75+1)/5) * 5 * * 65 * 3.14 / 12 * 8760) / 0.785 / 1{,}000{,}000$$
$$= 0.380 \text{ MMBtu}$$

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

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

[258] Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 76-90%. Average of existing units is estimated at 78.5%

## Water Heater Wrap (Direct Install)

**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[259]

**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 | 85 | 0.0097 | 0 | 0 |

**Deemed Lifetime of Efficient Equipment**
The measure life is assumed to be 5 years [260].

**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.

[259] 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)
[260] 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.

**Calculation of Savings**

This calculation relies upon the findings that a poorly insulated electric resistance water heater with a pre-wrap UEF of 0.86 has a new and more effective UEF of 0.88 after properly wrapped with supplemental insulation.[261]

**Energy Savings**

$\Delta kWH = kWHbase * (1/UEFbase-1/UEFnew)$

Where:

$kWHB_{ase}$ = Average kWH consumption of electric domestic hot water tank = 3,222 [262]

UEFnew = Assumed efficiency of electric tank with tank wrap installed = 0.88 [263]

UEFbase = Assumed efficiency of electric tank without tank wrap installed = 0.86

$\Delta kWH = 3{,}222 * (1/0.86-1/0.88)$

$= 85$ kWH

**Summer Coincident Peak Demand Savings**

$\Delta kW = \Delta kWh/8760$

Where:

$\Delta kWH$ = kWH savings from tank wrap installation

8760 = Number of hours in a year (since savings are assumed to be constant over year).

$\Delta kW = 85/ 8760$

$= 0.0097$ kW

**Fossil Fuel Impact Descriptions and Calculation**

n/a

**Water Impact Descriptions and Calculation**

n/a

[261] Impacts of waste heat on heating and cooling savings are not included in this characterization.

[262] US Energy Information Administration, Residential Energy Consumption Survey 2015, East North Central Census Division (https://www.eia.gov/consumption/residential/data/2015/c&e/pdf/ce5.3a.pdf)

[263] 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

**Deemed O&M Cost Adjustment Calculation**

n/a

## Gas Water Heaters (Time of Sale)

**Description**
This measure describes the purchase and installation of an efficient gas water heater meeting or exceeding Energy Star criteria[264] for the water heater category.

**Definition of Efficient Equipment**
The minimum efficiency Energy Star qualification criteria[264] by category are:

| Water Heater Type | Uniform Energy Factor (UEF) |
|---|---|
| Gas Storage ≤ 55 gallons | 0.64 |
| Gas Storage > 55 gallons | 0.78 |
| Gas Instantaneous > 50,000 Btu/hr | 0.87 |

**Definition of Baseline Equipment**
The baseline is a water heater complying with minimum federal efficiency standards**Error! Bookmark not defined.**. Uniform Energy Factor (UEF) is calculated based on formulas with coefficients that vary based on the tank size and draw pattern. A full set of these formulas is included in the Reference Section for this measure.

**Deemed Savings for this Measure**
Energy savings are calculated according to the following formula[265]:

$$\text{Savings } \Delta\text{MMBtu} \quad = 18.95 * (1/\ UEF_{Base}\ - 1/UEF_{Eff})$$

Deemed savings for this measure may be assumed based on common equipment types. The table below shows baseline UEF values and corresponding savings for units with a 'medium' draw pattern, and tank sizes of 40 gallons for the small category, and 70 gallons for the large category. The UEF for the efficient equipment is based on Energy Star requirements defined above.

| Water Heater Type | Baseline Uniform Energy Factor (UEF) | Deemed Savings (MMBtu) |
|---|---|---|
| Gas Storage ≤ 55 gallons | 0.58 | 3.0 |
| Gas Storage > 55 gallons | 0.76 | 0.6 |
| Gas Instantaneous | 0.81 | 1.6 |

**Deemed Lifetime of Efficient Equipment**
The measure life is assumed to be 13 years[266]

[264] ENERGY STAR Residential Water Heaters Key Product Criteria: https://www.energystar.gov/products/water_heaters/residential_water_heaters_key_product_criteria
[265] The coefficient in this formula is based on average gas usage for hot water heating in this region. Compiled in the Energy Information Administration's Residential Energy Consumption Survey (RECS) 2015, East North Central
[266] DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).For all water heaters, life expectancy will depend on local variables such as water chemistry and homeowner maintenance. There is currently insufficient data to determine tankless water heaters lifetimes. Preliminary data show lifetimes up to 20 years are possible.

**Deemed Measure Cost**

| Water Heater Type | Incremental Cost[267] |
|---|---|
| Gas Storage (0.67 UEF) | $342 |
| Gas Storage (0.80 UEF) | $896 |
| Gas Tankless (Whole house 0.9 UEF) | $615 |

**Deemed O&M Cost Adjustments**
There is no justification at this time for O&M cost adjustments.

**Coincidence Factor**
n/a

## REFERENCE SECTION

**Calculation of Savings**
Savings are determined using Energy Factor assumptions, applying the proportion of consumption used for water heating.

**Energy Savings**

$\Delta MMBtu = MMBtuHW_{USAGE} * (1/\ UEF_{Base}\ - 1/UEF_{Eff})$

Where:

$MMBtuHW_{USAGE}$ = typical household hot water consumption in MMBtu per year
= 18.95[268]

$UEF_{Eff}$ = Uniform Energy Factor for the efficient equipment
= actual installed

$UEF_{Base}$ = Uniform Energy Factor for the baseline equipment
Use the following table to calculate minimum federal standard UEF

| Product class | Rated storage volume and input rating (if applicable) | Draw pattern | Uniform energy factor |
|---|---|---|---|
| Gas-fired Storage Water Heater | ≥20 gal and ≤55 gal | Very Small | 0.3456 − (0.0020 × Vr) |
| | | Low | 0.5982 − (0.0019 × Vr) |
| | | Medium | 0.6483 − (0.0017 × Vr) |
| | | High | 0.6920 − (0.0013 × Vr) |
| | >55 gal and ≤100 gal | Very Small | 0.6470 − (0.0006 × Vr) |
| | | Low | 0.7689 − (0.0005 × Vr) |
| | | Medium | 0.7897 − (0.0004 × Vr) |
| | | High | 0.8072 − (0.0003 × Vr) |
| | <2 gal and >50,000 Btu/h | Very Small | 0.8 |

267 Navigant Consulting, Inc., September 2018; "Water Heating, Boiler, and Furnace Cost Study (RES 19)" prepared for Massachusetts residential program evaluation. This study includes marketplace data for a range of efficiencies. Baseline and efficient equipment costs that best matched the UEF criteria were used to calculate incremental costs.
268 Energy Information Administration's Residential Energy Consumption Survey (RECS) 2015, East North Central

| | | | |
|---|---|---|---|
| Instantaneous Gas-fired Water Heater | | Low | 0.81 |
| | | Medium | 0.81 |
| | | High | 0.81 |

*Vr is the rated storage volume in gallons.

For example for a new 30 gallon water heater with a “low” draw pattern and a UEF of 0.7:

$UEF_{Base}$ = 0.5982-(0.0019 × 30)
=0.541

ΔMMBtu = 18.95 * (1/0.541 – 1/0.7)
=7.96

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

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

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

## Solar Water Heater with Electric Backup (Retrofit)

**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**

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

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

**Deemed Lifetime of Efficient Equipment**
The expected measure life is assumed to be 20 years [269].

**Deemed Measure Cost**
The cost for this measure is $2,950[270].

**Deemed O&M Cost Adjustments**
$275[271]

**Coincidence Factor**
The summer peak coincidence factor for this measure is assumed to be 20%[272].

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**REFERENCE SECTION**

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**Calculation of Savings**

[269] 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
[270] This is based on flat plate collectors which are most common. It is estimated that 50 square feet of panel is needed for a typical household, with a mean installed cost from NREL of $59/sf. (http://www.alternative-energy-tutorials.com/solar-hot-water/flat-plate-collector.html), (https://www.nrel.gov/analysis/tech-lcoe-re-cost-est.html)
[271] NPV of future costs, based on annual cost of 0.75% of installed cost, and a discount rate of 5%. NREL data shows O&M between 0.5% and 1% of installed cost: (https://www.nrel.gov/analysis/tech-lcoe-re-cost-est.html)
[272] Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York.

**Energy Savings**

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

Where:

UEF = Minimum uniform energy factor for residential electric water heater[273]

Use the following table to calculate minimum federal standard UEF[274]

| Rated storage volume | Draw pattern | Uniform energy factor |
|---|---|---|
| ≥20 gal and ≤55 gal | Very Small | 0.8808 − (0.0008 × Vr) |
| | Low | 0.9254 − (0.0003 × Vr) |
| | Medium | 0.9307 − (0.0002 × Vr) |
| | High | 0.9349 − (0.0001 × Vr) |
| >55 gal and ≤120 gal | Very Small | 1.9236 − (0.0011 × Vr) |
| | Low | 2.0440 − (0.0011 × Vr) |
| | Medium | 2.1171 − (0.0011 × Vr) |
| | High | 2.2418 − (0.0011 × Vr) |

*Vr is the rated storage volume in gallons

SEF = Minimum system performance for solar water heaters[275]
= Actual installed

$Q_{DEL}$ = Baseline water heater usage[276]
= 3,222 kWh/year

For example, a solar water heater system with SEF rating of 1.8, and an electric water heater with a 40 gallon capacity and "medium" draw pattern:

UEF =(0.9307-0.0002*40)
=0.92

$\Delta kWH$ = (1/0.92 - 1/1.8) * 3,222 kWh/year
= 1,712 kWh

**Summer Coincident Peak Demand Savings**

$\Delta kW = (1/UEF * Q_{DEL}) / Hours * CF$

Where:

[273] 2004 Federal Energy Conservation Standard for water heaters
[274] Federal Standard: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=32
[275] 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. SEF is a ratio of "useful energy out" compared to the "fuel energy in."
[276] Energy Information Administration's Residential Energy Consumption Survey (RECS) 2015, East North Central, Table CE5.3a

| | |
|---|---|
| Hours | = Full load hours of water heater<br>= 2533 [277] |
| CF | = Summer Peak Coincidence Factor for measure<br>= 0.203 [278]<br>For example, a solar water heater system with SEF rating of 1.8, and an electric water heater with a 40 gallon capacity and "medium" draw pattern. (UEF calculated in previous example.) |
| ΔkW | = (1/0.92 * 3,222) / 2533 * 0.203<br>= 0.28 kW[279] |

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

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

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

[277] Full load hours assumption based on Efficiency Vermont loadshape, calculated from Itron eShapes.
[278] Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York.
[279] 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

# IV. Lighting

## Residential LED Screw-In Lamp (Time of Sale)

**Description**
A low wattage ENERGY STAR qualified LED screw-in bulb is purchased through a retail outlet in place of a baseline screw-in bulb as defined by the Energy Independence and Security Act of 2007 (EISA). EISA will require after 1/1/2020 that all general purpose lighting meet 45 lumens per watt standard (a "backstop" provision). The DOE released a final rule on 1/19/2017 that removed the exemption for specialty lamps resulting in the backstop provision defining the baseline of specialty lamps as the same 45 lumens per watt used for general purpose lamps taking affect 1/1/2020.

The incremental cost of the LED compared to the baseline light bulb is offset via either rebate coupons or via upstream markdowns. Assumptions are based on a time of sale purchase, not as a retrofit or direct install installation.

This characterization assumes that the LED is installed in a residential location. Where the implementation strategy does not allow for the installation location to be known and absent verifiable evaluation data to support an appropriate residential v commercial split, it is recommended to use this residential characterization for all purchases to be appropriately conservative in savings assumptions.

**Definition of Efficient Equipment**
In order for this characterization to apply, the high-efficiency equipment must be a standard ENERGY STAR qualified LED lamp; General Purpose and Specialty Lamp.

**Definition of Baseline Equipment**
In order for this characterization to apply, the baseline equipment is assumed to meet the EISA backstop provision of 45 lumens per watt after January 1st, 2020.

**Deemed Calculation for this Measure[280]**

$$\text{Annual kWh Savings}_{\text{Interrior}} = (LED_{Watts} * 1.75) * 0.957$$

$$\text{Summer Coincident Peak kW Savings} = (LED_{Watts} * 1.75) * 0.000114$$

$$\text{Annual MMBtu Increase} = (LED_{Watts} * 1.75) * 0.001908$$

**Deemed Lifetime of Efficient Equipment**
The expected lifetime of the measure is capped at 10 years[281].

**Deemed Measure Cost**

[280] Calculated by comparing the difference of ENERGY STAR V2.1 specs for omnidirectional <90CRI: 80 lm/W and for omnidirectional >=90CRI: 70 lm/W. These two values were weighted based on the ENERGY STAR qualified list which contained 87.8% lamps <90CRI and 12.2% >=90CRI for an average lm/W of 78.78. Resulting in 78.78 lm/W / EISA 45 lm/W = 1.75
[281] Calculated based on 15,000 hours divided by 1,040 hours a year for LED bulbs.

The price of LED lamps are rapidly falling and actual LED lamp price should be used when feasibly. The incremental cost for this measure is assumed to be $1.45 for going from a halogen to an LED lamp[282]. Currently there are no halogen lamps that can meet the EISA backstop provision. In the event halogen lamps are not a viable baseline in the future a CFL baseline will be used with an assumed incremental cost of $1.25.[283]

**Deemed O&M Cost Adjustments**
The NPV of the replacement lamps was calculated for the halogen baseline and CFL baseline case.

| | |
|---|---|
| Halogen baseline NPV replacement cost | = $9.25 |
| CFL baseline NPV replacement cost | = $0.98 |
| LED NPV replacement cost | = $0 |

**Coincidence Factor**
The summer peak coincidence factor for this measure is 0.11[284].

## REFERENCE SECTION

**Calculation of Savings**

**Energy Savings**

$\Delta$kWh = (($\Delta$Watts) /1000) * ISR * HOURS * WHFe

Where:

$\Delta$Watts = Compact Fluorescent Watts * 1.75[285]

ISR = In Service Rate or percentage of units rebated that get installed.
= 0.86[286]

HOURS = Average hours of use per year
= 1040 for Interior (2.85 hrs per day)[287]

WHFe = Waste Heat Factor for Energy to account for cooling savings from efficient lighting.

282 Illinois Statewide TRM v7.0 p.269 based on 2020 EISA Halogen at $1.25 – LED A-Lamp at $2.70
283 Illinois Statewide TRM v7.0 p. 269 based on CFL at $1.45 and LED at $2.70.
284 Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009"
285 Calculated by comparing the difference of ENERGY STAR V2.1 specs for omnidirectional <90CRI: 80 lm/W and for omnidirectional >=90CRI: 70 lm/W. These two values were weighted based on the ENERGY STAR qualified list which contained 87.8% lamps <90CRI and 12.2% >=90CRI for an average lm/W of 78.78. Resulting in 78.78 lm/W / EISA 45 lm/W = 1.75
286 Starting with a first year ISR of 0.77 and a lifetime ISR of 0.97 from Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009", and assuming 43% of the remaining 20% not installed in the first year replace incandescents (24 out of 56 respondents not purchased as spares; Nexus Market Research, RLW Analytics, October 2004; "Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs", table 6-4). ISR is therefore calculated as 0.77 + (0.43*0.2) = 0.86.
287 Based on weighted average daylength adjusted hours from Duke Energy, June 2010; "Ohio Residential Smart Saver CFL Program"

= 1.07 [288]

For example, a 4watt LED bulb installed in 2020:

$\Delta$kWh = ((4 * 1.75)/1000) * 0.86 * 1040 * 1.07

= 6.7 kWh

**Summer Coincident Peak Demand Savings**

$\Delta$kW = (($\Delta$Watts) /1000) * ISR * WHFd * CF

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting
= 1.21 [289]

CF = Summer Peak Coincidence Factor for measure
= 0.11

For example, a 4watt LED bulb installed in 2020:

$\Delta$kW = ((4*1.75) / 1000) * 0.86 * 1.21 * 0.11

= 0.0008 kW

**Fossil Fuel Impact Descriptions and Calculation**

$\Delta MMBTU_{WH}$ = ((($\Delta$Watts) /1000) * ISR * HOURS * 0.003413 * HF) / $\eta$Heat

Where:

$\Delta MMBTU_{WH}$ = gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.

0.003413 = conversion from kWh to MMBTU

[288] Waste heat factor for energy to account for cooling savings from efficient lighting. The value is estimated at 1.07 (calculated as 1 + (0.64*(0.35 / 3.1)). Based on cooling loads decreasing by 35% of the lighting savings (average result from REMRate modeling of several different configurations and OH locations of homes), assuming typical cooling system operating efficiency of 3.1 COP (starting from standard assumption of SEER 11 central AC unit, converted to 10.5 EER using algorithm EER = (SEER * 0.37) + 6.43 (based on Roberts and Salcido, Architectural Energy Corporation, Feb 2008; "Peak Electric Demand Calculations in the REM/Rate Home Energy Rating Software and REM/Design Home Energy Analysis Software"), converted to COP = EER/3.412 = 3.1COP) and assuming 64% of homes have central cooling (East North Central census division from Energy Information Administration, 2005 Residential Energy Consumption Survey; http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc6airconditioningchar/pdf/tablehc12.6.pdf).

[289] Waste heat factor for demand to account for cooling savings from efficient lighting. The value is estimated at 1.21 (calculated as 1 + (0.64 / 3.1)). Based on typical cooling system operating efficiency of 3.1 COP (starting from standard assumption of SEER 11 central AC unit, converted to 10.5 EER using algorithm EER = (SEER * 0.37) + 6.43 (based on Roberts and Salcido, Architectural Energy Corporation, Feb 2008; "Peak Electric Demand Calculations in the REM/Rate Home Energy Rating Software and REM/Design Home Energy Analysis Software"), converted to COP = EER/3.412 = 3.1COP), and 64% of homes having central cooling (East North Central census division from Energy Information Administration, 2005 Residential Energy Consumption Survey).

HF = Heating Factor or percentage of light savings that must be heated
= 0.45[290]

ηHeat = average heating system efficiency
= 0.72 [291]

For example, a 4watt LED bulb installed in 2020:

$\Delta MMBTU_{WH}$ = (((4 * 1.75)/1000) * 0.86 * 1040 * 0.003413 * 0.45) / 0.72

= 0.013 MMBtu

**Deemed O&M Cost Adjustment Calculation**

The calculated net present value of the baseline replacement cost using a halogen bulb is $9.25 over the 10 year life of an LED bulb using a discount rate of 5%.

The net present value of the baseline replacement cost using CFL bulbs is $0.98 over the 10 year life of the LED bulb using the discount rate of 5%[292].

| | Halogen | CFL | LED |
|---|---|---|---|
| Replacement Cost | $1.25 | $1.45 | $270 |
| Component Life (years) (based on lamp life / assumed annual run hours) | 0.96 | 9.61 | 10* |

*The LED life is capped at 10 years based on a 15,000 hour life.

[290] I.e. heating loads increase by 45% of the lighting savings (average result from REMRate modeling of several different configurations and OH locations of homes),

[291] This has been estimated assuming that natural gas central furnace heating is typical for Ohio residences (65% of East North Central census division has a Natural Gas Furnace (based on Energy Information Administration, 2005 Residential Energy Consumption Survey: http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc4spaceheating/pdf/tablehc12.4.pdf))
In 2000, 40% of furnaces purchased in Ohio were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:
((0.4*0.92) + (0.6*0.8)) * (1-0.15) = 0.72

[292] Illinois Statewide TRM v7.0 p. 268 halogen EUL is 1,000 hours and CFL EUL is 10,000 hours

## ENERGY STAR Ceiling Fan (Time of Sale)

**Description**
This measure describes the installation of an ENERGY STAR ceiling fan that uses a high efficiency motor and efficient fan blades..

**Definition of Efficient Equipment**
The efficient equipment must be an ENERGY STAR certified ceiling fan.

**Definition of Baseline Equipment**
The baseline equipment is assumed to be a standard fan, with energy usage given in the ENERGY STAR ceiling fan calculator[293].

**Deemed Savings for this Measure**
This measure is based on energy savings from the fan motor only. If the unit includes lighting, use the formulas in the lighting section of this manual to calculate savings. Note that ENERGY STAR rated fans are required to have a minimum lighting efficacy of 70 lumens per watt for integrated lighting, and 65 lumens per watt for removable lights or screw-in bulbs.

Fan energy savings are calculated based on energy usage at low, medium, and high speeds for standard units and efficient ENERGY STAR rated units. See the reference section of this measure for a complete description of this calculation and all inputs.

Typical energy savings can be calculated using standard assumptions included in the ENERGY STAR ceiling fan calculator[293]. See the reference section of this measure for a complete description of the assumed inputs.

$\Delta kWh = 11.2\ kWh$

$\Delta kW = 0.003\ kW$

**Deemed Lifetime of Efficient Equipment**
The measure life is assumed to be 10 years[293].

**Deemed Measure Cost**
The incremental cost for the ENERGY STAR ceiling fan is $46[293].

**Coincidence Factor**
The summer peak coincidence factor for this measure is 0.3 for the fan energy savings[294].

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### REFERENCE SECTION

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**Calculation of Savings**

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293 ENERGY STAR Ceiling Fan Savings Calculator (https://www.energystar.gov/sites/default/files/asset/document/light_fixture_ceiling_fan_calculator.xlsx()
294 Assuming that the CF same as a Room AC. Consistent with coincidence factors found in: RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

**Fan Energy Savings**

$\Delta kWh$ = $((\%_{low} * (LowKW_{base} - LowKW_{ee}) + \%_{med} * (MedKW_{base} - MedKW_{ee}) + \%_{high} * (HighKW_{base} - HighKW_{ee})) * HOURS_{fan}) + ((IncKW – CFLKW) * HOURS_{light} * WHFe)$

Where [295]:

| | | |
|---|---|---|
| $\%_{low}$ | = Percent of time on Low Speed | = 40% |
| $\%_{med}$ | = Percent of time on Medium Speed | = 40% |
| $\%_{high}$ | = Percent of time on High Speed | = 20% |
| $LowWatt_{base}$ | = Low speed baseline ceiling fan wattage | = 0.015kW |
| $LowWatt_{ee}$ | = Low speed ENERGY STAR ceiling fan wattage | = 0.006kW |
| $MedWatt_{base}$ | = Medium speed baseline ceiling fan wattage | = 0.034kW |
| $MedWatt_{ee}$ | = Medium speed ENERGY STAR ceiling fan wattage | = 0.023kW |
| $HighWatt_{base}$ | = High speed baseline ceiling fan wattage | = 0.067kW |
| $HighWatt_{ee}$ | = High speed ENERGY STAR ceiling fan wattage | = 0.056kW |
| $HOURS_{fan}$ | = Typical fan operating hours (3/day, 365 days per year) | = 1095 hours |

$\Delta kWh$ = ((0.4 * (0.015 – 0.006) + 0.4 * (0.034 – 0.023) + 0.2 * (0.067 – 0.056)) * 1095)

= 11.2 kWh

**Summer Coincident Peak Demand Savings**

Fan Demand Savings

$\Delta kW$ = $(\%_{low} * (LowKW_{base} - LowKW_{ee}) + \%_{med} * (MedKW_{base} - MedKW_{ee}) + \%_{high} * (HighKW_{base} - HighKW_{ee})) * CF_{fan}$

Where:

$CF_{fan}$ = Summer Peak Coincidence Factor for ceiling fan
= 0.3

$\Delta kW$ = ((0.4 * (0.015 – 0.006) + 0.4 * (0.034 – 0.023) + 0.2 * (0.067 – 0.056)) * 0.446

$\Delta kW$ = 0.003kW

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

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

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

[295] All data points come from the ENERGY STAR Ceiling Fan Savings Calculator (https://www.energystar.gov/sites/default/files/asset/document/light_fixture_ceiling_fan_calculator.xlsx ()

# V. Shell/Envelope

## Wall Insulation (Retrofit)

**Description**
This measure characterization is for the installation of new additional insulation in the walls of a residential building. The measure assumes that an auditor, contractor or utility staff member is on location, and will measure and record the existing and new insulation depth and type (to calculate R-values), the surface area of insulation added, and the efficiency of the heating and cooling system used in the home.

**Definition of Efficient Equipment**
The new insulation should meet any qualification criteria required for participation in the program. The new insulation R-value should include the total wall assembly and include any existing insulation that is left in situ. The total effective R-value is typically close to the R-value of the cavity insulation (existing and new R-values added) and the R-values of the remaining parts of the wall assembly do not add to the effective R-value of the entire assembly, except for the addition of insulating sheathing to the interior or exterior of the wall surface.

**Definition of Baseline Equipment**
The existing insulation R-value should include the total wall assembly. An effective R-value of 5 should be assumed for the wall assembly with the addition of the R-value of any existing insulation included in an estimate of the effective R-value of the entire wall[296]. In general, the total effective R-value of the wall is close or equal to the R-value of the cavity insulation, unless there is insulating sheathing on the wall surfaces, in which case, the sheathing R-values can be added to the cavity insulation R-values.

**Deemed Calculation for this Measure**

Air conditioning Savings

Annual kWh Savings

$$= ((1/Rexist - 1/Rnew) * CDH * 0.75 * Area) / 1000 / \eta Cool$$

Summer Coincident Peak kW Savings

$$= \Delta kWh / FLHcool * 0.68$$

Space Heating Savings:

Annual MMBTU Savings (fossil fuel heating)

$$= ((1/Rexist - 1/Rnew) * HDD * 24 * Area) / 1{,}000{,}000 / \eta Heat$$

Annual kWh Savings (electric heating)

$$= (((1/Rexist - 1/Rnew) * HDD * 24 * Area) / 1{,}000{,}000 / \eta Heat) * 293.1$$

**Deemed Lifetime of Efficient Equipment**
The measure life is assumed to be 25 years [297].

**Deemed Measure Cost**
The actual insulation installation measure cost should be used.

[296] The R-5 assumption for wall assembly is based on J.Neymark & Associates and National Renewable Energy Laboratory, June 2009; "BESTEST-EX Interim Test Procedure" p25.
[297] 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

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

**Coincidence Factor**
The summer peak coincidence factor for this measure is assumed to be 0.5[298].

## REFERENCE SECTION

**Calculation of Savings**

**Energy Savings**

ΔkWh = ((1/Rexist – 1/Rnew) * CDH * DUA * Area) / 1000 / ηCool

Where:

Rexist = existing effective whole-assembly thermal resistance value or R-value[299]
= actual recorded

Rnew = new total effective whole-assembly thermal resistance value or R-value[300]
= actual recorded

CDH = Cooling Degree Hours[301].
Dependent on location:

| Location | Cooling Degree Hours (75°F set point) |
|---|---|
| Akron | 3,986 |
| Cincinnati | 7,711 |
| Cleveland | 5,817 |
| Columbus | 4,367 |
| Dayton | 5,934 |
| Toledo | 4,401 |
| Youngtown | 3,689 |

DUA = Discretionary Use Adjustment to account for the fact that people do not always operate their air conditioning system when the outside temperature is greater than 75°F
= 0.75 [302]

Area = Square footage of insulated area
= actual recorded

298 Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p32
299 If uninsulated assembly assume R-5.
300 Include the R-value for any existing insulation remaining.
301 Derived by summing the delta between the average outdoor temperature and the base set point of 75 degrees (above which cooling is assumed to be used) each hour of the year. Hourly temperature data obtained from TMY3 data (http://rredc.nrel.gov/solar/)
302 Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31

ηCool = Efficiency of Air Conditioning equipment
= actual recorded

For example, insulating 300 square feet of wall area from R-5 to R-13, in a Cincinnati home with AC SEER 10:

ΔkWh = ((1/Rexist – 1/Rnew) * CDH * DUA * Area) / 1000 / ηCool

= ((1/5 – 1/13) * 7711 * 0.75 * 300) / 1000 / 10

= 21 kWh

**Summer Coincident Peak Demand Savings**

ΔkW = ΔkWh / FLHcool *CF

Where:

FLHcool = Full load cooling hours
Dependent on location as below:

| Location | Run Hours[303] |
|---|---|
| Akron | 476 |
| Cincinnati | 664 |
| Cleveland | 426 |
| Columbus | 552 |
| Dayton | 631 |
| Mansfield | 474 |
| Toledo | 433 |
| Youngstown | 369 |

CF = Summer Peak Coincidence Factor for measure
= 0.68[304]

For example, insulating 300 square feet of wall area from R-5 to R-13, in a Cincinnati home with AC SEER 10:

ΔkW = ΔkWh / FLHcool *CF

= 21 / 664 * 0.68

= 0.022 kW

[303] 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."

[304] based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. TRM v7.0 Vol. 3_September 28, 2018_Final

**Space Heating Savings Calculation**

$$\Delta MMBTU = ((1/Rexist - 1/Rnew) * HDD * 24 * Area) / 1{,}000{,}000 / \eta Heat$$

Where:

HDD = Heating Degree Days (60° base temperature) for location[305]

| Location | Heating Degree Days (60°F base temperature) |
|---|---|
| Akron | 4,754 |
| Cincinnati | 3,769 |
| Cleveland | 4,544 |
| Columbus | 4,033 |
| Dayton | 4,360 |
| Toledo | 4,806 |
| Youngtown | 4,841 |

ηHeat = Average Net Heating System Efficiency (Equipment Efficiency * Distribution Efficiency) [306]
= actual recorded

**Note for homes with electric heat (resistance or heat pump), follow the MMBTU formula above and convert to kWh by multiplying by 293.1. For heat pumps the equipment efficiency used in the above algorithm should be the Coefficient Of Performance or COP (i.e., divide HSPF by 3.412; e.g., HSPF 7.7 is COP of 2.26).**

For example, insulating 300 square feet of wall area from R-5 to R-13, in a Cincinnati home with heating system efficiency of 70%:

$$\Delta MMBTU = ((1/Rexist - 1/Rnew) * HDD * 24 * Area) / 1{,}000{,}000 / \eta Heat$$

$$= ((1/5 - 1/13) * 3{,}769 * 24 * 300) / 1{,}000{,}000 / 0.7$$

$$= 4.8 \text{ MMBtu}$$

**Water Impact Descriptions and Calculation**

n/a

**Deemed O&M Cost Adjustment Calculation**

n/a

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305 The 10 year average (2003-2012) annual heating degree day value, using a balance point for heating equipment use of 60 degrees was calculated for each location based on data obtained from http://academic.udayton.edu/kissock/http/Weather/citylistUS.htm. The 60 degree balance point is used based on a PRISM evaluation of approximately 600,000 Ohio residential single family customers. Days with no data were approximated by averaging the daily average temperatures from the two nearest days with data.

306 The System Efficiency can be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf) or by performing duct blaster testing.
If there are more than one heating systems, the weighted (by consumption) average efficiency should be used.
If the heating system or distribution is being upgraded within a package of measures together with the insulation upgrade, the new average heating system efficiency should be used.

# ENERGY STAR Windows (Time of Sale)

**Description**
This measure describes the purchase of ENERGY STAR Windows meeting the minimum requirement for the North region[307] (u factor ≤ 0.30), at natural time of replacement or new construction. This does not relate to a window retrofit program.

**Definition of Efficient Equipment**
To qualify for this measure, the new window must meet ENERGY STAR criteria for the North region (u factor ≤ 0.27). There is no minimum criterion for Solar Heat Gain Coefficient (SHGC) for windows in the North region, so an assumed typical SHGC of 0.30 for a u-0.27 window is used (this is also the minimum criteria for the federal tax credit).

**Definition of Baseline Equipment**
The baseline window is assumed to be a standard double pane window with vinyl sash, (u-0.49, SHGC-0.58).

**Deemed Savings for this Measure**

**NOTE: These savings are all per 100 square feet of windows**

| | 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 |
|---|---|---|---|---|
| Heating Savings (Electric Resistance) | 345 | n/a | n/a | n/a |
| Heating Savings (Heat Pump) | 270 | n/a | n/a | n/a |
| Heating Savings (Fossil Fuel) | n/a | n/a | 2.51 | n/a |
| Cooling Savings (Central AC) | 144 | 0.10 | n/a | n/a |

**Deemed Lifetime of Efficient Equipment**
The measure life is assumed to be 25 years[308].

**Deemed Measure Cost**
The incremental cost for this measure is assumed to be $150 per 100 square feet of windows [309].

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

[307] Energy Star Qualification Criteria January 1, 2016; https://www.energystar.gov/sites/default/files/asset/document/Windows_Doors_and_Skylights_Program_Requirements%20v6.pdf;
[308] 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
[309] Alliance to Save Energy Efficient Windows Collaborative Report, December 2007

**Coincidence Factor**

The summer peak coincidence factor for this measure is assumed to be 0.68[310].

## REFERENCE SECTION

**Calculation of Savings**

**Energy Savings** [311]

Heating kWh Savings (Electric Resistance) = 302 kWh per 100 square feet window area

Heating kWh Savings (Heat Pump COP 2.0) = 237 kWh per 100 square feet window area

Cooling kWh Savings = %CoolKWHSav * (FLHcool * BtuH * (1/SEER))/1000

Where:

%CoolKWHSav = Percentage of cooling energy savings per 100 sf of window
= 8%[312]

FLHcool = Full load cooling hours
= 552[313]

BtuH = Size of equipment in Btuh
= 36,000[314]

SEER = Assumed SEER efficiency of central AC unit
= 11[315]

Cooling kWh Savings = 0.08 * (552 * 36000 * (1/11))/1000

= 144 kWh per 100 square feet window area

**Summer Coincident Peak Demand Savings**

ΔkWcooling = %CoolKWSav * BtuH * (1/EER)/1000 * CF

Where:

%CoolKWSav = Percentage of cooling energy savings per 100 square feet of window

[310] based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. TRM v7.0 Vol. 3_September 28, 2018_Final

[311] Savings for this measure are based on REMRate modeling of a typical home in Columbus, Ohio climate with electric resistance or air source heat pump (COP 2.0), and assuming SEER 11 air conditioning.

[312] REMRate analysis indicated that installing Energy Star windows in a home in Columbus OH would reduce cooling consumption by 7% per 100 square feet of window. Increased by 16%, the ratio of u-values improvement over baseline to reflect increasing ENERGY STAR requirements.

[313] Based on Full Load Hour assumptions for Columbus OH (used as proxy for the State) 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").

[314] Assumption of typical central AC unit capacity.

[315] VEIC estimate of existing unit efficiency, based on minimum federal standard prior to 2006 of SEER 10, and SEER 13 after 2006.

= 4.3%[316]

EER = Assumed EER Efficiency of central AC unit
= 10.5 [317]

CF = Summer Peak Coincidence Factor for measure
= 0.68[318]

ΔkWcooling = 0.043 * 36000 * (1/10.5)/1000 * 0.68

= 0.10 kW per 100 square feet of windows

**Fossil Fuel Impact Descriptions and Calculation**

Heating MMBtu Savings (Fossil Fuel) = 2.51 MMBtu per 100 square feet window area [319]

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

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

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316 REMRate analysis indicated that installing Energy Star windows in a home in Columbus OH would reduce cooling design loads by 3.7% per 100 square feet of window. Increased by 16%, the ratio of u-values improvement over baseline to reflect increasing ENERGY STAR requirements.
317 Converting 11 SEER to 10.5 EER using algorithm EER = (SEER * 0.37) + 6.43 (based on Roberts and Salcido, Architectural Energy Corporation, Feb 2008; “Peak Electric Demand Calculations in the REM/Rate Home Energy Rating Software and REM/Design Home Energy Analysis Software”).
318 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. TRM v7.0 Vol. 3_September 28, 2018_Final Based
319 Savings for this measure are based on REMRate modeling of a typical home in Columbus, Ohio climate with a 72% AFUE natural gas furnace, and assuming SEER 11 air conditioning. 72% AFUE is estimated based on in 2000, 40% of furnaces purchased in Ohio were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process). Increased by 16%, the ratio of u-values improvement over baseline to reflect increasing ENERGY STAR requirements. Assuming typical efficiencies for condensing and non condensing furnace and duct losses, the average heating system efficiency is estimated as follows:
((0.4*0.92) + (0.6*0.8)) * (1-0.15) = 0.72

## Attic/Roof/Ceiling Insulation (Retrofit)

**Description**
This measure characterization is for the installation of new additional insulation in the attic/roof/ceiling of a residential building. The measure assumes that an auditor, contractor or utility staff member is on location, and will measure and record the existing and new insulation depth and type (to calculate R-values), the surface area of insulation added, and the efficiency of the heating system used in the home.

**Definition of Efficient Equipment**
The new insulation should meet any qualification criteria required for participation in the program. The new insulation R-value should include the total attic floor /roof assembly and include any existing insulation that is left in situ.

**Definition of Baseline Equipment**
The existing insulation R-value should include the total attic floor / roof assembly. An R-value of 5 should be assumed for the roof assembly plus the R-value of any existing insulation[320].

**Deemed Calculation for this Measure**

Air conditioning Savings

Annual kWh Savings = ((1/Rexist – 1/Rnew) * CDH * 0.75 * Area) / 1000 / ηCool

Summer Coincident Peak kW Savings = ΔkWh / FLHcool * 0.68

Space Heating Savings:

MMBTU Savings (fossil fuel heating)

= ((1/Rexist – 1/Rnew) * HDD * 24 * Area) / 1,000,000 / ηHeat

Annual kWh Savings (electric heating)

= (((1/Rexist – 1/Rnew) * HDD * 24 * Area) / 1,000,000 / ηHeat) * 293.1

**Deemed Lifetime of Efficient Equipment**
The measure life is assumed to be 25 years[321].

**Deemed Measure Cost**
The actual insulation installation measure cost should be used.

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

**Coincidence Factor**
The summer peak coincidence factor for this measure is assumed to be 0.68[322].

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[320] The R-5 assumption for roof assembly is based on J.Neymark & Associates and National Renewable Energy Laboratory, June 2009; "BESTEST-EX Interim Test Procedure" p27. The attic floor and roof should be modeled as a system including solar gains and attic ventilation, and R-5 is the standard assumption for the thermal resistance of the whole attic/roof system.
[321] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007: https://library.cee1.org/system/files/library/8842/CEE_Eval_MeasureLifeStudyLights%2526HVACGDS_1Jun2007.pdf

[322] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. TRM v7.0 Vol. 3_September 28, 2018_Final

## REFERENCE SECTION

**Calculation of Savings**

**Energy Savings**

$\Delta$kWh = ((1/Rexist – 1/Rnew) * CDH * DUA * Area) / 1000 / $\eta$Cool

Where:

Rexist = existing effective whole-assembly thermal resistance value or R-value[323]
= actual recorded

Rnew = new total effective whole-assembly thermal resistance value or R-value[324]
= actual recorded

CDH = Cooling Degree Hours[325].
Dependent on location:

| Location | Cooling Degree Hours (75°F set point) |
|---|---|
| Akron | 3,986 |
| Cincinnati | 7,711 |
| Cleveland | 5,817 |
| Columbus | 4,367 |
| Dayton | 5,934 |
| Toledo | 4,401 |
| Youngtown | 3,689 |

DUA = Discretionary Use Adjustment to account for the fact that people do not always operate their air conditioning system when the outside temperature is greater than 75°F
= 0.75 [326]

Area = Square footage of insulated area
= actual recorded

$\eta$Cool = Efficiency of Air Conditioning equipment
= actual recorded

For example, insulating 1000 square feet of an attic floor from R-5 to R-30, in a Cincinnati home with AC SEER 10:

$\Delta$kWh = ((1/Rexist – 1/Rnew) * CDH * DUA * Area) / 1000 / $\eta$Cool

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323 If uninsulated assembly assume R-5.
324 Include the R-value for the assembly and any existing insulation remaining.
325 Derived by summing the delta between the average outdoor temperature and the base set point of 75 degrees (above which cooling is assumed to be used) each hour of the year. Hourly temperature data obtained from TMY3 data: https://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/
326 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. TRM v7.0 Vol. 3_September 28, 2018_Final

= ((1/5 – 1/30) * 7711 * 0.75 * 1000) / 1000 / 10

= 96 kWh

**Summer Coincident Peak Demand Savings**

ΔkW = ΔkWh / FLHcool *CF

Where:

FLHcool = Full load cooling hours
Dependent on location as below:

| Location | Run Hours[327] |
|---|---|
| Akron | 476 |
| Cincinnati | 664 |
| Cleveland | 426 |
| Columbus | 552 |
| Dayton | 631 |
| Mansfield | 474 |
| Toledo | 433 |
| Youngstown | 369 |

CF = Summer Peak Coincidence Factor for measure
= 0.68 [328]

For example, insulating 1000 square feet of an attic floor from R-5 to R-30, in a Cincinnati home with AC SEER 10:

ΔkW = ΔkWh / FLHcool *CF

= 96 / 664 * 0.68

= 0.1 kW

**Space Heating Savings Calculation**

ΔMMBTU = ((1/Rexist – 1/Rnew) * HDD * 24 * Area) / 1,000,000 / ηHeat

Where:

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327 Based on Full Load Hour assumptions taken from the ENERGY STAR calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xlshttps://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC_bulk.xlshttp://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.”

328 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. TRM v7.0 Vol. 3_September 28, 2018_Final

HDD = Heating Degree Days (65° base temperature) for location[329]

| Location | Heating Degree Days (65°F base temperature) |
|---|---|
| Akron | 6,408 |
| Cincinnati | 5,113 |
| Cleveland | 6,216 |
| Columbus | 5,685 |
| Dayton | 6,045 |
| Toledo | 6,649 |
| Youngtown | 6,719 |

ηHeat = Average Net Heating System Efficiency (Equipment Efficiency * Distribution Efficiency) [330]
= actual recorded

**Note for homes with electric heat (resistance or heat pump), follow the MMBTU formula above and convert to kWh by multiplying by 293.1. For heat pumps the equipment efficiency used in the above algorithm should be the Coefficient Of Performance or COP (i.e., divide HSPF by 3.412; e.g., HSPF 7.7 is COP of 2.26).**

For example, insulating 1000 square feet of an attic floor from R-5 to R-30, in a Cincinnati home with a gas heating system with efficiency of 70%:

ΔMMBTU = ((1/Rexist – 1/Rnew) * HDD * 24 * Area) / 1,000,000 / ηHeat

= ((1/5 – 1/30) * 5,113 * 24 * 1,000) / 1,000,000 / 0.7

= 29 MMBtu

**Water Impact Descriptions and Calculation**

n/a

**Deemed O&M Cost Adjustment Calculation**

n/a

[329] Derived by summing the delta between the average outdoor temperature and the base set point of 65 degrees (below which heating is assumed to be used) each hour of the year. Hourly temperature data obtained from TMY3 data: https://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/

[330] The System Efficiency can be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf) or by performing duct blaster testing.
If there are more than one heating systems, the weighted (by consumption) average efficiency should be used.
If the heating system or distribution is being upgraded within a package of measures together with the insulation upgrade, the new average heating system efficiency should be used.

# VI. Miscellaneous

## Pool Pumps (Time of Sale)

### Description

This measure describes the purchase and installation of an efficient two-speed or variable speed residential pool pump meeting the ENEGY STAR minimum qualifications for either in-ground or above ground pools to replace single speed pool pumps. ENERGY STAR version 2.0 specification takes effect on January 1, 2019 and version 3.0 has an effective date of July 19, 2021.

**Definition of Efficient Equipment**

The high efficiency equipment is a two-speed or variable speed ENERGY STAR residential pool pump.

**Definition of Baseline Equipment**

The baseline efficiency equipment is assumed to be a single speed residential pool pump.

**Deemed Savings for this Measure after January 1, 2019 (ENERGY STAR 2.0)**

| Pump Type | Control Type | Average Annual KWH Savings per unit[331] | Average Summer Coincident Peak kW Savings per unit[332] | Average Annual Fossil Fuel heating fuel savings (MMBTU) per unit | Average Annual Water savings per unit |
|---|---|---|---|---|---|
| Self-Priming (Inground) Pool Pumps | Multi-Speed | 1,776 | 1.211 | n/a | n/a |
| Self-Priming (Inground) Pool Pumps | Variable-Speed | 1,952 | 1.282 | n/a | n/a |
| Non-Self Priming (Aboveground) Pool Pumps | Multi-Speed | 465 | 0.589 | n/a | n/a |
| Non-Self Priming (Aboveground) Pool Pumps | Variable-Speed | 539 | 0.638 | n/a | n/a |

[331] Illinois Statewide TRM V7.0, Measure 5.7.1 High Efficiency Pool Pumps, p. 344
[332] Ibid., p. 345

**after July 19, 2021 (ENERGY STAR 3.0)**

| Pump Type | Control Type | Average Annual KWH Savings per unit[333] | Average Summer Coincident Peak kW Savings per unit[334] | Average Annual Fossil Fuel heating fuel savings (MMBTU) per unit | Average Annual Water savings per unit |
|---|---|---|---|---|---|
| Self-Priming (Inground) Pool Pumps | Multi-Speed | 2,090 | 1.329 | n/a | n/a |
| Self-Priming (Inground) Pool Pumps | Variable-Speed | 2,222 | 1.381 | n/a | n/a |
| Non-Self Priming (Aboveground) Pool Pumps | Multi-Speed | 465 | 0.589 | n/a | n/a |
| Non-Self Priming (Aboveground) Pool Pumps | Variable-Speed | 539 | 0.638 | n/a | n/a |

**Deemed Lifetime of Efficient Equipment**
The estimated useful life for a variable speed pool pump is 10 years.

**Deemed Measure Cost**
The incremental cost is estimated to be $235 for a two speed motor and $549 for a variable speed motor[335].

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

**Coincidence Factor**
The coincidence factor for this measure is assumed to be 0.83[336].

## REFERENCE SECTION

**Calculation of Savings**

**Energy Savings[337]**

$$\Delta kWh = kWh_{Base} - kWh_{Efficient}$$

[333] Illinois Statewide TRM V7.0, Measure 5.7.1 High Efficiency Pool Pumps, p. 344
[334] Ibid., p. 345
[335] ENERGY STAR Pool Pump Calculator
[336] Based on Efficiency Vermont’s coincidence factor for pool pumps; in the absence of empirical evaluation data, this was based on market feedback about the typical run pattern for pool pumps showing that most people will run pump during the day, and set timer to turn pump off during the night.
[337] The Illinois Statewide TRM V7.0 defines the following methodology and assumptions sourced from the ENERGY STAR Pool Pump Calculator and assume a nameplate horsepower of 1.5 and a pool size of 22,000 gallons, with 2.0 turnovers per day in the base case and 1.6 turnovers per day in the efficient case. For above ground pools, the turnover ratios were kept the same with the pool size being 7,540 gallons. The volume of the above ground pool is sourced from the California Urban Water council Evaluation of Potential Best Management Practices for Pools, Spas, and Fountains for the average above ground residential pool.

Where:

$kWh_{Base}$ = ((Hrs/Day$_{base}$ * GPM$_{base}$ * 60)/EF$_{base}$)/1000 * Days

$kWh_{Multi\text{-}Speed}$ = ((Hrs/Day$_{msH}$ * GPM$_{msH}$ * 60) + (Hrs/Day$_{msL}$ * GPM$_{msL}$ * 60))/WEF$_{ms}$/1000 * Days

$kWh_{Variable\text{-}Speed}$ = ((Hrs/Day$_{vsH}$ * GPM$_{vsH}$ * 60) + (Hrs/Day$_{vsL}$ * GPM$_{vsL}$ * 60))/WEF$_{vs}$/1000 * Days

Where:

Hrs/Day$_{base}$ = run hours of single speed pump
= 11.4 hours for in-ground pools
= 7.0 hours for above ground pool

GPM$_{base}$ = flow of single speed pump (gal/min)
= 64.4 gal/min for in-ground pools
= 36 gal/min for above ground pools

60 = minutes per hour

EF$_{base}$ = Energy Factor of baseline single speed pump (gal/WH)
= 2.1

Hrs/Day$_{msL}$ = run hours of two speed pump at low speed
= 15.7 hours for in-ground pools
= 9.6 hours for above ground pools

GPM$_{msL}$ = flow of two speed pump at low speed (gal/min)
= 31 gal/min for in-ground pools
= 17 gal/min for above ground pools

Hrs/Day$_{msH}$ = run hours of two speed pump at high speed
= 2 hours for in-ground pools
= 1.2 hours for above ground pools

GPM$_{msH}$ = flow of two speed pump at high speed (gal/min)
= 56 gal/min for in-ground pools
= 31 gal/min for above ground pools

Hrs/Day$_{vsL}$ = run hours of variable speed pump at low speed
= 16 hours for in-ground pools
= 9.8 hours for above ground pools

GPM$_{vsL}$ = flow of variable speed pump at low speed (gal/min)
= 30.6 gal/min for in-ground pools
= 17 gal/min for above ground pools

Hrs/Day$_{vsH}$ = run hours of variable speed pump at high speed
= 2 hours for in-ground pools
= 1.2 hours for above ground pools

$GPM_{vsH}$ = flow of variable speed pump at high speed (gal/min)
= 50 gal/min for in-ground pools
= 28 gal/min for above ground pools

Days = Number of days per year that the swimming pool is operational
= 125[338]

WEF = Weighted Energy Factor of the efficient pump (gal/WH), dependent on the pool application and motor designation, as detailed in the table below[339]:

| Pump Type | Control Type | ENERGY STAR Version 2.0 WEF (gal/Wh) | ENERGY STAR Version 3.0 WEF (gal/Wh) |
|---|---|---|---|
| Self-Priming (Inground) Pool Pumps | Multi-speed ($WEF_{ms}$) | 5.31 | 8.44 |
| | Variable-speed ($WEF_{vs}$) | 6.6 | 11.05 |
| Non-Self Priming (Aboveground) Pool Pumps | Multi-speed ($WEF_{ms}$) | 3.55 | 3.55 |
| | Variable-speed ($WEF_{vs}$) | 4.21 | 4.21 |

**Summer Coincident Peak Demand Savings[340]**

$\Delta kW = (kW_{Base} - kW_{Efficient}) * CF$

Where:

$kW_{Base} = kWh/day_{base} / Hrs/day_{base}$

$kWh_{Multi\text{-}Speed} = kWh/day_{ms} / Hrs/Days_{ms}$

$kWh_{Variable\text{-}Speed} = kWh/day_{vs} / Hrs/Day_{vs}$

$kWh/Day_{base}$ = daily energy consumption of baseline pump, as defined above
= 20.98 kWh/day for in-ground pools
= 7.19 kWh/day for above ground pools

$Hrs/Day_{base}$ = daily run hours of single speed pump
= 11.4 hours for in-ground pools

[338] Assumes 50% of pools operated from Memorial Day through Labor Day (100 days) and 50% of pools operate for a longer span, typically the 5 month period between May and September (150 days), due to their ability to heat the pool.
[339] Values sourced from Illinois Statewide TRM v7.0 using the following methodology. The Efficient Weighted Energy Factor is sourced from a weighted average of products meeting the ENERGY STAR minimum qualification and listed on their Qualified Products List (QPL), as accessed on 04/26/2018. As pump applications were not designated in the ENERGY STAR QPL, equipment sized and horsepower were assumed similar between aboveground and in-ground pools.
[340] The Illinois Statewide TRM V7.0 defines the following methodology and assumptions sourced from the ENERGY STAR Pool Pump Calculator and assume a nameplate horsepower of 1.5 and a pool size of 22,000 gallons, with 2.0 turnovers per day in the base case and 1.6 turnovers per day in the efficient case.

= 7.0 hours for above ground pools

$kWh/Day_{ms}$ = daily energy consumption of two speed pump, as defined above
= 6.76 and 4.26 kWh/day for in-ground pools for ENERGY STAR 2.0 & 3.0 respectively
= 3.47 kWh/day for above ground pools for ENERGY STAR 2.0 & 3.0

$Hrs/Day_{ms}$ = daily run hours of two speed pump
= 17.7 hours for in-ground pools
= 10.9 hours for above ground pools

$kWh/Day_{vs}$ = daily energy consumption of variable speed pump, as defined above
= 5.36 and 3.20 kWh/day for in-ground pools for ENERGY STAR 2.0 & 3.0 respectively
= 2.88 kWh/day for above ground pools for ENERGY STAR 2.0 & 3.0

$Hrs/Day_{vs}$ = daily run hours for variable speed pump
= 18 hours for in-ground pools
= 11 hours for above ground pools

CF = Summer Peak Coincidence Factor for measure
= 0.83

**Fossil Fuel Impact Descriptions and Calculation**

n/a

**Water Impact Descriptions and Calculation**

n/a

**Deemed O&M Cost Adjustment Calculation**

n/a

## Smart Strip Power Strip (Time of Sale)

**Description**
This measure relates to Tier 1 and Tier 2 Controlled Power Strips (or Smart Strips) installed in home entertainment centers (AV Equipment) and home offices (IT Equipment). Smart Strips are multi-plug power strips with the ability to automatically disconnect specific connected loads when not in active use. This measure applies to smart strips with 5 outlets or more.

Tier 1 smart strips are designed to reduce standby loads based upon the power draw of a control load, also plugged into the strip. Power is disconnected from the switched (controlled) outlets when the control load power draw is reduced below a certain adjustable threshold, thus turning off the appliances plugged into the switched outlets. By disconnecting, the standby load of the controlled devices, the overall load of a centralized group of equipment (i.e. entertainment centers and home office) can be reduced. Uncontrolled outlets are also provided that are not affected by the control device and so are always providing power to any device plugged into it.

Tier 2 smart strips are designed to reduce standby and active loads by monitoring user engagement and disconnecting power to all devices when a set period of inactivity is detect. This is accomplished through multiple technologies including infrared (IR) sensing, motion sensing, or countdown timers in addition to the Tier 1 master switch controls. Tier 2 smart strips save power by also reducing active power when the equipment is not in use in addition to the standby power saved with Tier 1 smart strips. For the purpose of this measure, Tier 2 smart strips apply to entertainment center equipment only.

**Definition of Efficient Equipment**
The efficient case is the use of a Tier 1 or Tier 2 smart strip connected to AV or IT Equipment.

**Definition of Baseline Equipment**
The assumed baseline is a standard power strip that does not control connected loads.

**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 |
|---|---|---|---|---|
| Tier 1 AV Equipment | 75.1[341] | 0.0088 | n/a | n/a |
| Tier 1 IT Equipment | 31[342] | 0.0041 | n/a | n/a |
| Tier 1 Unknown | 57.5[343] | 0.0070 | n/a | n/a |
| Tier 2 AV Equipment | 234[344] | 0.0274 | n/a | n/a |

[341] NYSERDA, Advanced Power Strip Research Report, August 2011, p. 30
[342] Ibid.
[343] Ibid., p.7. Calculated with weighted average where 60% of Tier 1 smart strips are used for AV equipment and 40% for IT equipment.
[344] San Diego Gas & Electric, Tier 2 Advanced Power Strips in Residential and Commercial Applications, April 2015, p. 3

**Deemed Lifetime of Efficient Equipment**
The assumed lifetime of the smart strip is 4 years[345].

**Deemed Measure Cost**
The incremental cost of a smart strip over a standard power strip with surge protection is assumed to be $20 for a Tier 1[346] and $50 for Tier 2 smart strips[347].

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

**Coincidence Factor**
The summer peak coincidence factor for this measure is assumed to be 0.8[348]

## REFERENCE SECTION

**Calculation of Savings**

**Energy Savings**

$\Delta$kWh = Deemed values based on referenced studies

**Summer Coincident Peak Demand Savings**

$\Delta$kW = $\Delta$kWh / Hours * CF

Where:

Hours = Annual number of hours during which the controlled standby loads are turned off by the Smart Strip.
= $6{,}825.5_{\text{AV Equipment}}$[349]
= $6{,}095.5_{\text{IT Equipment}}$[350]

CF = Summer Peak Coincidence Factor for measure
= 0.8

[345] David Rogers, Power Smart Engineering, October 2008; "Smart Strip electrical savings and usability", p22.
[346] NYSERDA, Advanced Power Strip Research Report, August 2011, p. 30. Calculated as incremental over baseline power strip ($35 - $15 = $20)
[347] San Diego Gas & Electric, Tier 2 Advanced Power Strips in Residential and Commercial Applications, April 2015, p. 17 Calculated as incremental over baseline power strip ($65 - $15 = $50)
[348] No source specified – update pending availability and review of applicable references.
[349] NYSERDA, Advanced Power Strip Research Report, August 2011, p. 8 Average of hours for controlled TV (off 18.7 hours per day) and computer from; NYSERDA Measure Characterization for Advanced Power Strips
[350] NYSERDA, Advanced Power Strip Research Report, August 2011, p. 16 Average of hours for controlled computer (off 16.7 hours per day)

$$\Delta kW_{Tier\ 1\ AV} = 75.1 / 6{,}825.5 * 0.8$$

$$= 0.0088\ kW$$

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

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

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

# VII. Whole Building/Comprehensive

## Residential New Construction

**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 September, 2013, the Ohio Building Code is based on the 2009 International Energy Conservation Code (IECC).

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 2009 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 for heating, cooling, lighting, and plug loads 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, savings for water heating shall adjusted linearly based on the number of bedrooms, and savings for appliances should not be adjusted for home size. 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 =

$$((\text{UDRH electric demand} * OF_{UDRH}) - (\text{Rated Home electric demand} * OF_r)) * CF$$

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™

The table below provides a summary of the input values and their data sources.

**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. If a refrigerator or other appliance included in the UDRH is not supplied by the builder, the value defined in the UDRH specifications table below should be used for energy consumption.

**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 September, 2013, the Ohio Building Code is based on the 2009 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 2009 (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 2009 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 the figure and table below shall be used in determining the applicable energy requirements for the UDRH.

**Ohio Climate Zones Map**


**Ohio Climate Zones by County**

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

## Whole-House Residential Retrofit

**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[351] approved rating software
- Software energy simulation performance exceeding the requirements of National Renewable Energy Laboratory's Home Energy Rating System BESTEST[352]
- US DOE Weatherization Assistance Program approval[353]

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.

[351] http://resnet.us
[352] http://www.nrel.gov/docs/legosti/fy96/7332b.pdf
[353] http://www.waptec.org

The software tools must provide outputs that separately account for heating and cooling energy savings so that demand and fuel-related economic savings may be properly addressed.

**Summer Coincident Peak Demand Savings**

Cooling only:

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

Where:

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

| Location | Run Hours[354] |
|---|---|
| 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[355]

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

$\Delta kW \quad = \Delta kWh / FLHcool * CF$
$= 350 / 433 * 0.5$
$= 0.404$ 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.[356]

**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

354 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.”
355 Based on Energy Center of Wisconsin, May 2008 metering study; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research”, p32
356 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.

**This foregoing document was electronically filed with the Public Utilities**

**Commission of Ohio Docketing Information System on**

**11/29/2019 3:35:14 PM**

**in**

**Case No(s). 19-0002-EL-UNC**

Summary: Report 2020 Ohio Technical Reference Manual, Volume II: Residential Market Sector electronically filed by Kristin  DuPree on behalf of PUCO Staff