

**TECHNICAL REFERENCE MANUAL**

**Volume 3:**

**Commercial and Industrial Measures**

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**State of Pennsylvania**

**Act 129** Energy Efficiency and Conservation Program

&

**Act 213** Alternative Energy Portfolio Standards

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# Commercial and Industrial Measures

The following section of the TRM contains savings protocols for commercial and industrial measures.

## Lighting

### Lighting Improvements

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Lighting Equipment |
| **Measure Life** | New Linear Fluorescent Fixture: 15 years  Lamp Only: LED, Screw-in: 15 years  Lamp Only: Induction Lamps: 6 years  Lamp Only: Metal Halide Lamps: 6 years  Lamp Only: High Pressure Sodium Lamps: 12 years  Lamp Only: Mercury Vapor Lamps: 6 years  Lamp Only: T8 Lamps: 10 years  Lamp Only: LED, Linear, Type A: 7 years Source 1  Lamp Only: LED, Linear, Type B: 15 years  Lamp Only: LED, Linear, Type C: 15 years  Permanent Fixture Removal: 13 years  Permanent Lamp Removal: 11 years Source 2 |
| **Measure Vintage** | Early Replacement or Permanent Removal |

Eligibility

Lighting improvements include fixture or lamp and ballast replacement and/or permanent removal in existing commercial and industrial customers’ facilities.[[1]](#footnote-3) Installed and removed lamps and fixtures are broken down into two distinct types based on common load shapes: Screw-based and Other General Service. Screw-based bulbs consist of self-ballasted incandescent, halogen, CFL, and LED bulbs; Other General Service Lighting consists of all other fixture and lamp types, including but not limited to linear fluorescents, metal halides, high intensity discharge lamps, and hardwired/pin-based CFLs and LEDs.

To be eligible for savings from permanent fixture and lamp removal, customer must have permanently removed unneeded, functional light fixtures, lamps, lamp holders, and/or ballasts in accordance with local regulations. The removal of non-operational equipment is not eligible for the defined savings.

Permanent lamp removal includes the permanent removal of existing 8’, 4’, 3’ and 2’ T8 fluorescent lamps. The savings are defined on a per-removed-lamp basis and don’t include savings from lamp replacements.

Note that the Energy Policy Act of 2005 (“EPACT 2005”) and Energy Independence and Security Act (“EISA”) 2007, and subsequent federal rulemakings, introduced new efficacy standards for linear fluorescent bulbs and ballasts, effectively phasing out magnetic ballasts (effective October 1, 2010) and most T-12 bulbs (effective July 14, 2012). This induced a shift in what a participant would have purchased in the absence of the program because T-12 bulbs on magnetic ballasts are no longer viable options and, therefore, adjusts the baseline assumption. With this understanding, standard T-8s became the baseline for all T-12 linear fluorescent retrofits beginning June 1, 2016 (PY8). The comparable baseline for any removed standard T-12 fixture will be the T-8 fixture of the same length and lamp count. The comparable baseline for any removed high-output T-12 fixture will be the T-8 fixture of the same length and lamp count with a ballast factor equal to 0.98. The assumed T-8 baseline fixtures and wattages associated with the most common T-12 fixture configurations are presented in Table 3‑1. For small business direct install programs where wattage of the existing T-12 fixture is known, and the existing fixture was in working condition, wattage of the existing fixture removed by the program may be used as the baseline wattage in lieu of the table below. In such cases, the lighting equipment must be replaced directly by an ICSP and not a lighting trade ally.



Table ‑

: Assumed T-8 Baseline Fixtures for Removed T-12 Fixtures

| **T-12 Lamp Length** | **T-12 Lamp Type** | **T-12 Lamp Count** | **Assumed T-8 Baseline Fixture Code** | **Assumed T-8 Baseline Wattage** |
| --- | --- | --- | --- | --- |
| 24” | Standard | 1 | F21ILL | 20 |
| 24” | Standard | 2 | F22ILL | 33 |
| 24” | Standard | 3 | F23ILL | 47 |
| 24” | Standard | 4 | F24ILL | 61 |
| 36” | Standard | 1 | F31ILL | 26 |
| 36” | Standard | 2 | F32ILL | 46 |
| 36” | Standard | 3 | F33ILL | 67 |
| 36” | Standard | 4 | F34ILL | 87 |
| 48” | Standard | 1 | F41ILL | 31 |
| 48” | Standard | 2 | F42ILL | 59 |
| 48” | Standard | 3 | F43ILL | 89 |
| 48” | Standard | 4 | F44ILL | 112 |
| 48” | Standard | 6 | F46ILL | 175 |
| 48” | Standard | 8 | F48ILL | 224 |
| 60” | Standard | 1 | F51ILL | 36 |
| 60” | Standard | 2 | F52ILL | 72 |
| 72” | Standard | 1 | F61ILL | 55 |
| 72” | Standard | 2 | F62ILL | 111 |
| 96” | Standard | 1 | F81ILL | 58 |
| 96” | Standard | 2 | F82ILL | 109 |
| 96” | Standard | 3 | F83ILL | 167 |
| 96” | Standard | 4 | F84ILL | 219 |
| 96” | Standard | 6 | F86ILL | 328 |
| 96” | High-Output | 1 | F81LHL | 85 |
| 96” | High-Output | 2 | F82LHL | 160 |
| 96” | High-Output | 3 | F83LHL | 253 |
| 96” | High-Output | 4 | F84LHL | 320 |
| 96” | High-Output | 6 | F86LHL | 506 |

Similarly, the EISA “backstop” provision introduced new efficacy standards for general service lamps (effective January 1, 2020) effectively requiring a minimum efficacy of 45 lm/W for most general service lamps. This induced a shift in what a participant would have purchased in the absence of the program because standard and halogen incandescent lamps are no longer viable options and, therefore, adjusts the baseline assumption. With this understanding, a generic general service lamp with an efficacy of 45 lm/W will become the assumed baseline for the majority of incandescent lamp retrofits beginning January 1, 2020.[[2]](#footnote-5) The comparable baseline for any removed incandescent lamps will be a generic general service lamp with similar lumen output. The assumed generic general service lamp baseline lamps/fixtures and wattages associated with the most common incandescent lamp/fixture configurations are presented in Table 3‑2.

: Assumed Generic GSL Baseline Lamps/Fixtures for Removed Incandescent Lamps/Fixtures

| **Removed Lamp/Fixture Description** | **Lamp Count** | **Baseline Fixture Code** | **Assumed Baseline Fixture Wattage** |
| --- | --- | --- | --- |
| Incandescent, (1) 34W lamp | 1 | GSL8/1 | 8 |
| Incandescent, (1) 40W ES lamp | 1 | GSL8/1 | 8 |
| Incandescent, (1) 40W ES/LL lamp | 1 | GSL8/1 | 8 |
| Incandescent, (1) 36W lamp | 1 | GSL8/1 | 8 |
| Incandescent, (1) 40W lamp | 1 | GSL10/1 | 10 |
| Incandescent, (1) 42W lamp | 1 | GSL11/1 | 11 |
| Incandescent, (1) 45W lamp | 1 | GSL11/1 | 11 |
| Incandescent, (1) 50W lamp | 1 | GSL13/1 | 13 |
| Incandescent, (1) 52W lamp | 1 | GSL13/1 | 13 |
| Incandescent, (1) 60W ES lamp | 1 | GSL13/1 | 13 |
| Incandescent, (1) 60W ES/LL lamp | 1 | GSL13/1 | 13 |
| Incandescent, (1) 54W lamp | 1 | GSL14/1 | 14 |
| Incandescent, (1) 55W lamp | 1 | GSL14/1 | 14 |
| Incandescent, (1) 60W lamp | 1 | GSL17/1 | 17 |
| Incandescent, (1) 65W lamp | 1 | GSL18/1 | 18 |
| Incandescent, (1) 67W lamp | 1 | GSL19/1 | 19 |
| Incandescent, (1) 75W ES lamp | 1 | GSL19/1 | 19 |
| Incandescent, (1) 75W ES/LL lamp | 1 | GSL19/1 | 19 |
| Incandescent, (1) 69W lamp | 1 | GSL19/1 | 19 |
| Incandescent, (1) 72W lamp | 1 | GSL20/1 | 20 |
| Incandescent, (1) 75W lamp | 1 | GSL23/1 | 23 |
| Incandescent, (1) 80W lamp | 1 | GSL25/1 | 25 |
| Incandescent, (1) 85W lamp | 1 | GSL26/1 | 26 |
| Incandescent, (1) 100W ES lamp | 1 | GSL28/1 | 28 |
| Incandescent, (1) 100W ES/LL lamp | 1 | GSL28/1 | 28 |
| Incandescent, (1) 90W lamp | 1 | GSL28/1 | 28 |
| Incandescent, (1) 93W lamp | 1 | GSL29/1 | 29 |
| Incandescent, (1) 95W lamp | 1 | GSL30/1 | 30 |
| Incandescent, (1) 100W lamp | 1 | GSL33/1 | 33 |
| Incandescent, (1) 120W lamp | 1 | GSL40/1 | 40 |
| Incandescent, (1) 125W lamp | 1 | GSL44/1 | 44 |
| Incandescent, (1) 135W lamp | 1 | GSL48/1 | 48 |
| Incandescent, (1) 150W ES lamp | 1 | GSL48/1 | 48 |
| Incandescent, (1) 150W ES/LL lamp | 1 | GSL48/1 | 48 |
| Incandescent, (1) 150W lamp | 1 | GSL58/1 | 58 |
| Incandescent, (1) 170W lamp | 1 | GSL66/1 | 66 |
| Incandescent, (2) 34W lamp | 2 | GSL8/2 | 16 |
| Incandescent, (2) 40W lamp | 2 | GSL10/2 | 20 |
| Incandescent, (2) 50W lamp | 2 | GSL13/2 | 26 |
| Incandescent, (2) 52W lamp | 2 | GSL13/2 | 26 |
| Incandescent, (2) 54W lamp | 2 | GSL14/2 | 28 |
| Incandescent, (2) 55W lamp | 2 | GSL14/2 | 28 |
| Incandescent, (2) 60W lamp | 2 | GSL17/2 | 34 |
| Incandescent, (2) 65W lamp | 2 | GSL18/2 | 36 |
| Incandescent, (2) 67W lamp | 2 | GSL19/2 | 38 |
| Incandescent, (2) 75W lamp | 2 | GSL23/2 | 46 |
| Incandescent, (2) 90W lamp | 2 | GSL28/2 | 56 |
| Incandescent, (2) 95W lamp | 2 | GSL30/2 | 60 |
| Incandescent, (2) 100W lamp | 2 | GSL33/2 | 66 |
| Incandescent, (2) 120W lamp | 2 | GSL40/2 | 80 |
| Incandescent, (2) 135W lamp | 2 | GSL48/2 | 96 |
| Incandescent, (2) 150W lamp | 2 | GSL58/2 | 116 |
| Incandescent, (3) 60W lamp | 3 | GSL17/3 | 51 |
| Incandescent, (3) 67W lamp | 3 | GSL19/3 | 57 |
| Incandescent, (3) 75W lamp | 3 | GSL23/3 | 69 |
| Incandescent, (3) 90W lamp | 3 | GSL28/3 | 84 |
| Incandescent, (3) 100W lamp | 3 | GSL33/3 | 99 |
| Incandescent, (4) 60W lamp | 4 | GSL17/4 | 68 |
| Incandescent, (4) 75W lamp | 4 | GSL23/4 | 92 |
| Incandescent, (4) 100W lamp | 4 | GSL33/4 | 132 |
| Incandescent, (5) 60W lamp | 5 | GSL17/5 | 85 |
| Incandescent, (5) 100W lamp | 5 | GSL33/5 | 165 |
| Halogen Incandescent, (1) 35W lamp | 1 | GSL12/1 | 12 |
| Halogen Incandescent, (1) 40W lamp | 1 | GSL14/1 | 14 |
| Halogen Incandescent, (1) 42W lamp | 1 | GSL14/1 | 14 |
| Halogen Incandescent, (1) 45W lamp | 1 | GSL17/1 | 17 |
| Halogen Incandescent, (1) 50W lamp | 1 | GSL19/1 | 19 |
| Halogen Incandescent, (1) 52W lamp | 1 | GSL20/1 | 20 |
| Halogen Incandescent, (1) 55W lamp | 1 | GSL24/1 | 24 |
| Halogen Incandescent, (1) 60W lamp | 1 | GSL26/1 | 26 |
| Halogen Incandescent, (1) 72W lamp | 1 | GSL33/1 | 33 |
| Halogen Incandescent, (1) 75W lamp | 1 | GSL34/1 | 34 |
| Halogen Incandescent, (1) 90W lamp | 1 | GSL41/1 | 41 |
| Halogen Incandescent, (1) 100W lamp | 1 | GSL46/1 | 46 |
| Halogen Incandescent, (1) 150W lamp | 1 | GSL69/1 | 69 |
| Halogen Incandescent, (2) 45W lamp | 2 | GSL17/2 | 34 |
| Halogen Incandescent, (2) 50W lamp | 2 | GSL19/2 | 38 |
| Halogen Incandescent, (2) 55W lamp | 2 | GSL24/2 | 48 |
| Halogen Incandescent, (2) 75W lamp | 2 | GSL34/2 | 68 |
| Halogen Incandescent, (2) 90W lamp | 2 | GSL41/2 | 82 |
| Halogen Incandescent, (2) 150W lamp | 2 | GSL69/2 | 138 |

See Appendix E for general eligibility requirements for solid state lighting products in commercial and industrial applications.

Algorithms

For all lighting fixture improvements (without control improvements), the following algorithms apply:

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |

Definition of Terms

Table ‑: Terms, Values, and References for Lighting Improvements

| **Term** | | **Unit** | **Values** | | **Source** |
| --- | --- | --- | --- | --- | --- |
| , Connected load of the baseline lighting as defined by project classification | | *kW* | See Fixture Identities in Appendix C  Default Permanent Lamp Removal: Table 3‑10 | | Appendix C  3 |
| , Connected load of the post-retrofit or energy–efficient lighting system | | *kW* | See Fixture Identities in Appendix C  For Permanent Fixture and/or Lamp Removal, | | Appendix C |
| *DeltakW*, difference between connected load of baseline and post-retrofit energy efficiency lighting system | *kW* | Default Street Lighting: 0.120  Calculated value | | 4 | | |
| , Savings factor for existing lighting control (percent of time the lights are off) | | *None* | EDC Data Gathering | | EDC Data Gathering |
|  | |  | Default: Table 3‑4 | | Table 3‑4 |
| , Coincidence factor | | *Decimal* | EDC Data Gathering | | EDC Data Gathering |
| Default Screw-based Bulbs: Table 3‑5  Default Other General Service: Table 3‑6 | | Table 3‑5 and Table 3‑6 |
| , Hours of Use – the average annual operating hours of the baseline lighting equipment, which if applied to full connected load will yield annual energy use. | |  | EDC Data Gathering | | EDC Data Gathering |
|  | |  | Default Screw-based Bulbs: Table 3‑5  Default Other General Service: Table 3‑6  Default Street Lighting: Table 3‑7 | | Table 3‑5, Table 3‑6, and Table 3‑7 |
| , Interactive Energy Factor – applies to C&I interior lighting in space that has air conditioning, electric space hating, or refrigeration. This represents the secondary energy impacts which results from the decreased waste heat from efficient lighting. | | *None* | Default: Table 3‑8 and Table 3‑9 | | Table 3‑8 and Table 3‑9 |
| , Interactive Demand Factor – applies to C&I interior lighting in space that has air conditioning or refrigeration only. This represents the secondary demand savings in cooling required which results from the decreased waste heat from efficient lighting. | | *None* | Default: Table 3‑8 and Table 3‑9 | | Table 3‑8 and Table 3‑9 |

Other factors required to calculate savings are shown in Table 3‑4, Table 3‑5, Table 3‑6, Table 3‑7, Table 3‑8, and Table 3‑9. Note that if HOU is stated and verified by logging lighting hours of use groupings, actual hours should be applied. In addition, the site-specific CF must be used to calculate peak demand savings if actual hours are used. The IF factors shown in Table 3‑8 and Table 3‑9 are to be used only when the facilities are air conditioned and only for fixtures in conditioned or refrigerated space. The HOU for refrigerated spaces are to be estimated or logged separately.

Table ‑: Savings Control Factors Assumptions[[3]](#footnote-6)

| **Strategy** | **Definition** | **Technology** | **Savings** | **Source** |
| --- | --- | --- | --- | --- |
| Switch | Manual On/Off Switch | Light Switch | 0% | 5 |
| Occupancy | Adjusting light levels according to the presence of occupants | Occupancy Sensors | 24% |
| Time Clocks | 24% |
| Energy Management System | 24% |
| Daylighting | Adjusting light levels automatically in response to the presence of natural light | Photosensors | 28% |
| Time Clocks | 28% |
| Personal Tuning | Adjusting individual light levels by occupants according to their personal preferences; applies, for example, to private offices, workstation-specific lighting in open-plan offices, and classrooms | Dimmers | 31% |
| Wireless on-off switches | 31% |
| Bi-level switches | 31% |
| Computer based controls | 31% |
| Pre-set scene selection | 31% |
| Institutional Tuning | Adjustment of light levels through commissioning and technology to meet location specific needs or building policies; or provision of switches or controls for areas or groups of occupants; examples of the former include high-end trim dimming (also known as ballast tuning or reduction of ballast factor), task tuning and lumen maintenance | Dimmable ballasts | 36% |
| On-off or dimmer switches for non-personal tuning | 36% |
| Multiple Types | Includes combination of any of the types described above. Occupancy and personal tuning, daylighting and occupancy are most common. | Occupancy and personal tuning/  daylighting and occupancy | 38% |

Table ‑: Lighting HOU and CF by Building Type for Screw-Based Bulbs

| **Building Type** | **HOU** | **CF** | **Source** |
| --- | --- | --- | --- |
| Education | 2,944 | 0.39 | 6 |
| Exterior, Photocell-Controlled (All Building Types) | 4,306 | 0.11 | 7 |
| Exterior, All Other (All Building Types) | 3,604 | 0.11 | 8 |
| Grocery | 7,798 | 0.99 | 6 |
| Health | 2,476 | 0.47 | 6 |
| Industrial Manufacturing – 1 Shift | 2,857 | 0.96 | 8, 9 |
| Industrial Manufacturing – 2 Shift | 4,730 | 0.96 | 8, 9 |
| Industrial Manufacturing – 3 Shift | 6,631 | 0.96 | 8, 9 |
| Institutional/Public Service | 1,456 | 0.23 | 6 |
| Lodging | 2,925 | 0.38 | 6 |
| Miscellaneous/Other | 2,001 | 0.33 | 6 |
| Multi-Family Common Areas | 5,950 | 0.73 | 3 |
| Office | 1,420 | 0.26 | 6 |
| Parking Garages | 8,678 | 0.98 | 8 |
| Restaurant | 3,054 | 0.55 | 6 |
| Retail | 2,383 | 0.56 | 6 |
| Street Lighting[[4]](#footnote-7) | See Table 3‑7 | 0.00 | See Table 3‑7 |
| Warehouse | 2,815 | 0.50 | 6 |

Table ‑: Lighting HOU and CF by Building Type for Other General Service Lighting

| **Building Type** | **HOU** | **CF** | **Source** |
| --- | --- | --- | --- |
| Education | 2,371 | 0.45 | 6 |
| Exterior, Photocell-Controlled (All Building Types) | 4,306 | 0.11 | 7 |
| Exterior (All Building Types) | 3,604 | 0.11 | 8 |
| Grocery | 6,471 | 0.93 | 6 |
| Health | 2,943 | 0.52 | 6 |
| Industrial/Manufacturing - 1 Shift | 2,857 | 0.96 | 8, 9 |
| Industrial/Manufacturing - 2 Shift | 4,730 | 0.96 | 8, 9 |
| Industrial/Manufacturing - 3 Shift | 6,631 | 0.96 | 8, 9 |
| Institutional/Public Service | 1,419 | 0.23 | 6 |
| Lodging | 3,579 | 0.45 | 6 |
| Miscellaneous/Other | 2,830 | 0.58 | 6 |
| Multi-Family Common Areas | 5,950 | 0.73 | 3 |
| Office | 2,294 | 0.48 | 6 |
| Parking Garage | 8,678 | 0.98 | 8 |
| Restaurant | 4,747 | 0.77 | 6 |
| Retail | 2,915 | 0.66 | 6 |
| Street Lighting[[5]](#footnote-8) | See Table 3‑7 | 0.00 | See Table 3‑7 |
| Warehouse | 2,545 | 0.48 | 6 |

Table ‑: Street lighting HOU by EDC

|  |  |  |
| --- | --- | --- |
| **EDC** | **HOU** | **Source** |
| Duquesne | 4,200 | 10 |
| PECO | 4,100 | 11 |
| PPL | 4,300 | 12 |
| Met-Ed | 4,200 | 13 |
| Penelec | 4,200 | 14 |
| Penn Power | 4,070 | 15 |
| West Penn Power | 4,200 | 16 |

Table ‑: Interactive Factors for All Bulb Types

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
|  | *None* | Comfort Cooled = See Table 3‑9 | 6 |
| Freezer spaces (-35 °F – 20 °F) = 0.50 | 17 |
| Medium-temperature refrigerated spaces (20 °F – 40 °F) = 0.29 |
| High-temperature refrigerated spaces (40 °F – 60 °F) = 0.18 |
| Un-cooled space = 0 |
|  | *None* | Comfort Cooled = See Table 3‑9 | 6 |
| Freezer spaces (-35 °F – 20 °F) = 0.50 | 17 |
|  |  | Medium-temperature refrigerated spaces (20 °F – 40 °F) = 0.29 |  |
|  |  | High-temperature refrigerated spaces (40 °F – 60 °F) = 0.18 |  |
|  |  | Un-cooled space = 0 |  |

Table ‑: Interactive Factors for Comfort Cooled Spaces for All Building Types

|  |  |  |
| --- | --- | --- |
| **Heating Fuel** |  |  |
| Non-Electric Heat | 0.031 | 0.192 |
| Electric Heat | -0.142 | 0.192 |
| Unknown | 0.000 | 0.192 |

Table 3‑10: Connected Load of the Baseline Lighting

|  |  |  |
| --- | --- | --- |
| **Lamp Length** | **Wattage Removed (*kWbase*) per Lamp** | **Source** |
| **T8** |
| 8-foot | 0.0386 | 18 |
| 4-foot | 0.0194 |
| 3-foot | 0.0146 |
| 2-foot | 0.0098 |

Default Savings

There are no default savings associated with this measure.

Evaluation Protocols

**Methods for Determining Baseline Conditions**

The following are acceptable methods for determining baseline conditions when verification by direct inspection is not possible as may occur in a rebate program where customers submit an application and equipment receipts only after installing efficient lighting equipment, or for a retroactive project as allowed by Act 129. In order of preference:

* Examination of replaced lighting equipment that is still on site waiting to be recycled or otherwise disposed of
* Examination of replacement lamp and ballast inventories where the customer has replacement equipment for the retrofitted fixtures in stock. The inventory must be under the control of the customer or customer’s agent
* Interviews with and written statements from customers, facility managers, building engineers or others with firsthand knowledge about purchasing and operating practices at the affected site(s) identifying the lamp and ballast configuration(s) of the baseline condition
* Interviews with and written statements from the project’s lighting contractor or the customer’s project coordinator identifying the lamp and ballast configuration(s) of the baseline equipment
* For street lighting projects only, use of the DeltakW as shown in Table 3‑3

**Detailed Inventory Form**

A detailed lighting inventory is required for all lighting improvement projects. The lighting inventory form will use the algorithms presented above to derive the total ΔkW and ΔkWh savings for each installed measure. Within a single project, to the extent there are multiple combinations of control strategies (SVG), hours of use (HOU), coincidence factors (CF) or interactive factors (IF), the will be broken out to account for these different factors. This will be accomplished using Appendix C, a Microsoft Excel inventory form that specifies the lamp and ballast configuration using the “Fixture Identities” sheet and SVG, HOU, CF and IF values for each line entry. The inventory form will also specify the location and number of fixtures for reference and validation.

Appendix C was developed to automate the calculation of energy and demand impacts for retrofit lighting projects, based on a series of entries by the user defining key characteristics of the retrofit project. The "General Information" sheet is provided for the user to identify facility-specific details of the project that have an effect on the calculation of gross savings. Facility-specific details include contact information, electric utility, building area information, and operating schedule. The "Lighting Inventory" sheet is the main worksheet that calculates energy savings and peak demand reduction for the user-specified lighting fixture and controls improvements. This form follows the algorithms presented above and facilitates the calculation of gross savings for implementation and evaluation purposes. Each line item on this tab represents a specific area with common baseline fixtures, retrofit fixtures, controls strategy, space cooling, and space usage.

Baseline and retrofit fixture wattages are determined by selecting the appropriate fixture code from the “Fixture Identities” sheet. The sheet can also be used to find the appropriate code for a particular lamp-ballast combination by using the enabled auto-filter options. Actual wattages of fixtures determined by manufacturer’s equipment specification sheets or other independent sources may not be used unless (1) the manufacturer's cut sheet indicates that the difference in delta-watts of fixture wattages (i.e. difference in delta watts of baseline and “actual” installed efficient fixture wattage and delta watts of baseline and nearest matching efficient fixture in the “Fixture Identities” of Appendix C is more than 10% or (2) the corresponding fixture code is not listed in the “Fixture Identities” list. In these cases, alternate wattages for lamp-ballast combinations can be inputted using the appropriate cells within the “Fixture Identities” tab. Rows 9 through 28 provide a guided custom LED fixture generator to be used with non-self-ballasted LEDs. All other custom cut sheets should be inputted into rows 932 through 981. Documentation supporting the alternate wattages must be provided in the form of manufacturer-provided specification sheets or other industry accepted sources (e.g. ENERGY STAR listing, Design Lights Consortium listing, etc.). Submitted specification sheets must cite test data performed under standard ANSI procedures. These exceptions will be used as the basis for periodically updating the “Fixture Identities” to better reflect market conditions and more accurately represent savings.

Some EDC Implementation CSPs may have developed in-house lighting inventory forms that are used to determine reported savings estimates for projects and calculate rebate amounts. The Appendix C form is the preferred tool for reported and verified savings calculations. However, a ICSP lighting inventory form may be used for program delivery purposes provided it (1) includes all the same functionality, formulas, and calculation steps as the Appendix C form and (2) is approved by the SWE prior to being utilized to calculate reported savings. In the case where an ICSP tool produces a different savings estimate from the Appendix C calculator, the Appendix C result is considered to be the TRM-supported savings value. Appendix C will be updated periodically to include new fixtures and technologies available as may be appropriate. Additional guidance can be found in the “Manual” sheet of Appendix C.

**Custom Hours of Use and Coincidence Factors**

If the project cannot be described by the building type categories listed in Table 3‑5 and Table 3‑6, or if the facility’s actual lighting hours deviate by more than 10% from the tables, or if the project retrofitted only a portion of a facility’s lighting system for which whole building hours of use would not be appropriate, the deemed HOU and CF assumptions can be overridden by inputting custom operating schedules into the Lighting Operation Schedule portion of the “General Information” tab of Appendix C. The custom schedule inputs must be corroborated by an acceptable source such as posted hours, customer interviews, building monitoring system (BMS), or metered data.

For all projects, annual hours are subject to adjustment by EDC evaluators or SWE.

**Metering – Projects with savings below 750,000 kWh**

Metering is encouraged for projects with expected savings below 750,000 kWh but have high uncertainty, i.e. where hours are unknown, variable, or difficult to verify. Exact conditions of “high uncertainty” are to be determined by the EDC evaluation contractors to appropriately manage variance. Metering completed by the implementation contractor maybe leveraged by the evaluation contractor, subject to a reasonableness review. Sampling methodologies within a site are to be either discerned by the EDC evaluation contractor based on the characteristics of the facility in question or performed consistent with guidance the EDC EM&V contractor provides.

**Metering – Projects with savings of 750,000 kWh or higher**

For projects with expected savings of 750,000 kWh or higher, metering is required[[6]](#footnote-11). Installation of light loggers is the accepted method of metering, but trend data from BMS is an acceptable substitute. Metering completed by the implementation contractor may be leveraged by the evaluation contractor, subject to a reasonableness review. Sampling methodologies within a site are to be either discerned by the EDC evaluation contractor or communicated to implementation contractors based on the characteristics of the facility in question or performed consistent with guidance the EDC EM&V contractor provides.

When BMS data is used as a method of obtaining customer-specific data in lieu of metering, the following guidelines should be followed:

* Care should be taken with respect to BMS data, since the programmed schedule may not reflect regular hours of long unscheduled overrides of the lighting system, such as nightly cleaning in office buildings, and may not reflect how the lights were actually used, but only the times of day the common area lighting is commanded on and off by the BMS.
* The BMS trends should represent the actual status of the lights (not just the command sent to the lights), and the ICSP and EC are required to demonstrate that the BMS system is functioning as expected, prior to relying on the data for evaluation purposes.
* The BMS data utilized should be specific to the lighting systems, and should be required to be representative of the building areas included in the lighting project.

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### New Construction Lighting

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Lighting Equipment |
| **Measure Life** | 15 years Source 1 |
| **Measure Vintage** | New Construction |

New Construction incentives are intended to encourage decision-makers in new construction projects to incorporate greater energy efficiency into their building design and construction practices that will result in a permanent reduction in electrical (kWh) usage above baseline practices. See Appendix E for general eligibility requirements for solid state lighting products in commercial and industrial applications.

Eligibility Requirements

New construction applies to new building projects wherein no structure or site footprint presently exists, addition or expansion of an existing building or site footprint, or major tenant improvements that change the use of the space. Eligible lighting equipment and fixture/lamp types include fluorescent fixtures (lamps and ballasts), compact fluorescent lamps, high intensity discharge (HID) lamps, interior and exterior LED lamps and fixtures, cold-cathode fluorescent lamps (CCFL), induction lamps, and lighting controls.

The baseline demand for calculating savings is determined using one of the two methods detailed in IECC 2015. The interior lighting baseline is calculated using either the Building Area Method as shown in Table 3‑12 or the Space-by-Space Method as shown in Table 3‑13. For exterior lighting, the baseline is calculated using the Baseline Exterior Lighting Power Densitiesas shown in Table 3‑14. Table 3‑14 does not distinguish between tradable and non-tradable exterior spaces. When analyzing exterior spaces, all exterior spaces must be included in savings calculations so that energy penalties from any over-lit spaces are properly accounted for in the facility-level savings estimates. The post-installation demand is calculated based on the installed fixtures using the “Fixture Identities” sheet in Appendix C.

Algorithms

For all new construction projects analyzed using the IECC 2015 **Building Area Method**, the following algorithms apply Source 2:

|  |  |
| --- | --- |
|  |  |
|  |  |

For all new construction projects analyzed using the IECC 2015 **Space-by-Space Method**, the following algorithms apply Source 2:

|  |  |
| --- | --- |
|  |  |
|  |  |

Where n is the number of spaces and:

|  |  |
| --- | --- |
|  |  |
|  |  |

Definition of Terms

Table ‑: Terms, Values, and References for New Construction Lighting

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , The baseline space or building connected load as calculated by multiplying the space or building area by the appropriate Lighting Power Density (LPD) values specified in either Table 3‑12 or Table 3‑13 | *kW* | Calculated based on space or building type and size. | Calculated Value |
| , The calculated connected load of the energy efficient lighting | *kW* | Calculated based on specifications of installed equipment using Appendix C | Calculated Value |
| *SVGbase*, Baseline savings factor in accordance with code-required lighting controls (percent of time the lights are off) | *None* | Based on Code | EDC Data Gathering |
|  |  | Default: Table 3‑15 | 1 |
| , Coincidence factor | *Decimal* | Based on Metering[[7]](#footnote-16) | EDC Data Gathering |
|  |  | Default Screw-based Bulbs: Table 3‑5  Default Other General Service: Table 3‑6 | Table 3‑5 and Table 3‑6 |
| , Hours of Use – the average annual operating hours of the facility |  | Based on Metering[[8]](#footnote-17) | EDC Data Gathering |
|  |  | Default Screw-based Bulbs: Table 3‑5  Default Other General Service: Table 3‑6 | Table 3‑5 and Table 3‑6 |
| , Interactive Energy Factor | *None* | Default: Table 3‑8 and Table 3‑9 | Table 3‑8 and Table 3‑9 |
| , Interactive Demand Factor | *None* | Default: Table 3‑8 and Table 3‑9 | Table 3‑8 and Table 3‑9 |

Table ‑: Lighting Power Densities from IECC 2015 Building Area Method Source 2

| **Building Area Type** | **LPD (W/ft**2) | **Building Area Type** | **LPD (W/ft**2) |
| --- | --- | --- | --- |
| Automotive facility | 0.80 | Multifamily | 0.51 |
| Convention center | 1.01 | Museum | 1.02 |
| Courthouse | 1.01 | Office | 0.82 |
| Dining: bar lounge/leisure | 1.01 | Parking garage | 0.21 |
| Dining: cafeteria/fast food | 0.90 | Penitentiary | 0.81 |
| Dining: family | 0.95 | Performing arts theater | 1.39 |
| Dormitory | 0.57 | Police station | 0.87 |
| Exercise center | 0.84 | Post office | 0.87 |
| Fire station | 0.67 | Religious building | 1.00 |
|  | 0.94 | Retail | 1.26 |
| Health care clinic | 0.90 | School/university | 0.87 |
|  | 1.05 | Sports arena | 0.91 |
| / | 0.87 | Town hall | 0.89 |
|  | 1.19 | Transportation | 0.70 |
|  | 1.17 | Warehouse | 0.66 |
| Motion picture theater | 0.76 | Workshop | 1.19 |

Table ‑: Lighting Power Densities from IECC 2015 Space-by-Space Method Source 2

| **Common Space Type** | **LPD (W/ft2)** | **Building Specific Space Types** | **LPD (W/ft2)** |
| --- | --- | --- | --- |
| **Atrium** |  | **Facility for the visually impaired** |  |
| Less than 40 feet in height | 0.03 per foot in total height | In a chapel (and not used primarily by the staff) | 2.21 |
| Greater than 40 feet in height | 0.40 + 0.02 per foot in total height | In a recreation room (and not used primarily by the staff) | 2.41 |
| **Audience seating area** |  | **Automotive (See Vehicle Maintenance Area above)** |  |
| In an auditorium | 0.63 | Convention Center—exhibit space | 1.45 |
| In a convention center | 0.82 | Dormitory—living quarters | 0.38 |
| In a gymnasium | 0.65 | Fire Station—sleeping quarters | 0.22 |
| In a motion picture theater | 1.14 | **Gymnasium/fitness center** |  |
| In a penitentiary | 0.28 | In an exercise area | 0.72 |
| In a performing arts theater | 2.43 | In a playing area | 1.20 |
| In a religious building | 1.53 | **Healthcare facility** |  |
| In a sports arena | 0.43 | In an exam/treatment room | 1.66 |
| Otherwise | 0.43 | In an imaging room | 1.51 |
| Banking activity area | 1.01 | In a medical supply room | 0.74 |
| **Breakroom (See Lounge/Breakroom)** |  | In a nursery | 0.88 |
| **Classroom/lecture hall/training room** |  | In a nurse's station | 0.71 |
| In a penitentiary | 1.34 | In an operating room | 2.48 |
| Otherwise | 1.24 | In a patient room | 0.62 |
| Conference/meeting/multipurpose room | 1.23 | In a physical therapy room | 0.91 |
| Copy/print room | 0.72 | In a recovery room | 1.15 |
| **Corridor** |  |  |  |
| In a facility for the visually impaired (and not used primarily by the staff) | 0.92 | In a reading area | 1.06 |
| In a hospital | 0.79 | In the stacks | 1.71 |
| In a manufacturing facility | 0.41 | **facility** |  |
| Otherwise | 0.66 | In a detailed manufacturing area | 1.29 |
|  | 1.72 | In an equipment room | 0.74 |
| Computer room | 1.71 | In an extra high bay area (greater than 50' floor-to-ceiling height) | 1.05 |
| **Dining area** |  | In a high bay area (25-50' floor-to-ceiling height) | 1.23 |
| In a penitentiary | 0.96 | In a low bay area (less than 25' floor-to-ceiling height) | 1.19 |
| In a facility for the visually impaired (and not used primarily by the staff) | 1.90 |  |  |
| In bar/lounge or leisure dining | 1.07 | In a general exhibition area | 1.05 |
| In cafeteria or fast food dining | 0.65 | In a restoration room | 1.02 |
| In family dining | 0.89 | Performing arts theater—dressing room | 0.61 |
| Otherwise | 0.65 | Post Office—Sorting Area | 0.94 |
| Electrical/mechanical room | 0.95 | **Religious buildings** |  |
| vehicle garage | 0.56 | In a fellowship hall | 0.64 |
| Food preparation area | 1.21 | In a worship/pulpit/choir area | 1.53 |
| Guest room | 0.47 | **Retail facilities** |  |
| **Laboratory** |  | In a dressing/fitting room | 0.71 |
| In or as a classroom | 1.43 | In a mall concourse | 1.10 |
| Otherwise | 1.81 | **Sports arena—playing area** |  |
| Laundry/washing area |  | For a Class I facility | 3.68 |
| Loading dock, interior | 0.47 | For a Class II facility | 2.40 |
| **Lobby** |  | For a Class III facility | 1.80 |
| In a facility for the visually impaired (and not used primarily by the staff) | 1.80 | For a Class IV facility | 1.20 |
| For an elevator |  | **Transportation facility** |  |
| In a hotel | 1.06 | In a baggage/carousel area | 0.53 |
| In a motion picture theater | 0.59 | In an airport concourse | 0.36 |
| In a performing arts theater | 2.00 | At a terminal ticket counter | 0.80 |
| Otherwise | 0.90 | **Warehouse—storage area** |  |
| Locker room | 0.75 | For medium to bulky, palletized items | 0.58 |
| **Lounge/breakroom** |  | For smaller, hand-carried items | 0.95 |
| In a healthcare facility | 0.92 |  |  |
| Otherwise | 0.73 |  |  |
| **Office** |  |  |  |
| Enclosed | 1.11 |  |  |
| Open plan | 0.98 |  |  |
| Parking area, interior |  |  |  |
| area | 1.68 |  |  |
| **Restroom** |  |  |  |
| In a facility for the visually impaired (and not used primarily by the staff) | 1.21 |  |  |
| Otherwise | 0.98 |  |  |
| Sales area | 1.59 |  |  |
| Seating area, general | 0.54 |  |  |
| **Stairway (See space containing stairway)** |  |  |  |
| Stairwell | 0.69 |  |  |
| Storage room | 0.63 |  |  |
| Vehicle maintenance area |  |  |  |
| Workshop | 1.59 |  |  |

Table ‑: Baseline Exterior Lighting Power Densities Source 2

|  | | **Space Description** | | | **Lighting Zones[[9]](#footnote-23)** | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Zone 1** | | **Zone 2** | **Zone 3** | **Zone 4** | |
| Base Site Allowance (Base allowance is usable in tradable or nontradable surfaces.) | 500 W | | 600 W | 750 W | 1300 W | |
| **Uncovered Parking Areas** | | | | | | |
|  | | Parking areas and drives | | | 0.04 W/ft2 | 0.06 W/ft2 | 0.10 W/ft2 | 0.13 W/ft2 |
| **Building Grounds** | | | | | | |
|  | | Walkways less than 10 feet wide | | | 0.7 W/linear foot | 0.7 W/linear foot | 0.8 W/linear foot | 1.0 W/linear foot |
|  | | Walkways 10 feet wide or greater, plaza areas, special feature areas | | | W/ft2 | 0.14 W/ft2 | 0.16 W/ft2 | 0.2 W/ft2 |
|  | | Stairways | | | 0.75 W/ft2 | 1.0 W/ft2 | 1.0 W/ft2 | 1.0 W/ft2 |
| Pedestrian tunnels | 0.15 W/ft2 | | 0.15 W/ft2 | 0.2 W/ft2 | 0.3 W/ft2 | |
| **Building Entrances and Exits** | | | | | | |
|  | | Main entries | | | 20 W/linear foot of door width | 20 W/linear foot of door width | 30 W/linear foot of door width | 30 W/linear foot of door width |
|  | | Other doors | | | 20 W/linear foot of door width | 20 W/linear foot of door width | 20 W/linear foot of door width | 20 W/linear foot of door width |
| Entry canopies | 0.25 W/ft2 | | 0.25 W/ft2 | 0.4 W/ft2 | 0.4 W/ft2 | |
| **Sales Canopies** | | | | | | |
|  | | Free-standing and attached | | | 0.6 W/ft2 | 0.6 W/ft2 | 0.8 W/ft2 | 1.0 W/ft2 |
| **Outdoor Sales** | | | | | | |
|  | | Open areas (including vehicle sales lots) | | | 0.25 W/ft2 | 0.25 W/ft2 | 0.5 W/ft2 | 0.7 W/ft2 |
|  | | Street frontage for vehicle sales lots in addition to “open area” allowance | | | No allowance | 10 W/linear foot | 10 W/linear foot | 30 W/linear foot |
| Building facades | No allowance | | 0.075 W/ft2 of gross above-grade wall area | 0.113 W/ft2 of gross above-grade wall area | 0.15 W/ft2 of gross above-grade wall area | |
| Automated teller machines (ATM) and night depositories | 270 W per location plus 90 W per additional ATM per location | | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location | |
| Entrances and gatehouse inspection stations at guarded facilities | 0.75 W/ft2 of covered and uncovered area | | 0.75 W/ft2 of covered and uncovered area | 0.75 W/ft2 of covered and uncovered area | 0.75 W/ft2 of covered and uncovered area | |
| Loading areas for law enforcement, fire, ambulance and other emergency service vehicles | 0.5 W/ft2 of covered and uncovered area | | 0.5 W/ft2 of covered and uncovered area | 0.5 W/ft2 of covered and uncovered area | 0.5 W/ft2 of covered and uncovered area | |
| Drive-up windows/doors | 400 W per drive-through | | 400 W per drive-through | 400 W per drive-through | 400 W per drive-through | |
| Parking near 24-hour retail entrances | 800 W per main entry | | 800 W per main entry | 800 W per main entry | 800 W per main entry | |

Table ‑: Default Baseline Savings Control Factors Assumptions for New Construction Only[[10]](#footnote-24)

| **Building Type** | **SVGbase** |
| --- | --- |
| Education | 17% |
| Exterior | 0% |
| Grocery | 5% |
| Health | 8% |
| Industrial/Manufacturing – 1 Shift | 0% |
| Industrial/Manufacturing – 2 Shift | 0% |
| Industrial/Manufacturing – 3 Shift | 0% |
| Institutional/Public Service | 12% |
| Lodging | 15% |
| Miscellaneous/Other | 6% |
| Office | 15% |
| Parking Garage | 0% |
| Restaurant | 5% |
| Retail | 5% |
| Warehouse | 14% |
| Custom | Based on Code |

Default Savings

There are no default savings associated with this measure.

Evaluation Protocols

**Detailed Inventory Form**

A detailed inventory of all installed fixtures contributing to general light requirements is mandatory for participation in this measure. Lighting that need not be included in the inventory is as follows:

* 1. Display or accent lighting in galleries, museums, and monuments
  2. Lighting that is integral to:

1. Equipment or instrumentation and installed by its manufacturer,
2. Refrigerator and freezer cases (both open and glass-enclosed),
3. Equipment used for food warming and food preparation,
4. Medical equipment,
5. Advertising or directional signage,
6. Exit signs, or
7. Emergency lighting
8. Lighting specifically designed only for use during medical procedures
9. Lighting used for plant growth or maintenance
10. Lighting used in spaces designed specifically for occupants with special lighting needs
11. Lighting in retail display windows that are enclosed by ceiling height partitions.

A detailed lighting inventory is required for all lighting improvement projects. The lighting inventory form will use the algorithms presented above to derive the total ΔkW and ΔkWh savings for each installed measure. Within a single project, to the extent there are multiple combinations of control strategies (SVG), hours of use (HOU), coincidence factors (CF) or interactive factors (IF), the will be broken out to account for these different factors. This will be accomplished using Appendix C, a Microsoft Excel inventory form that specifies the lamp and ballast configuration using the “Fixture Identities” sheet and SVG, HOU, CF and IF values for each line entry. The inventory form will also specify the location and number of fixtures for reference and validation.

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For all projects, annual hours are subject to adjustment by EDC evaluators or SWE.

**Metering – Projects with savings below 750,000 kWh**

Metering is encouraged for projects with expected savings below 750,000 kWh but have high uncertainty, i.e. where hours are unknown, variable, or difficult to verify. Exact conditions of “high uncertainty” are to be determined by the EDC evaluation contractors to appropriately manage variance. Metering completed by the implementation contractor maybe leveraged by the evaluation contractor, subject to a reasonableness review. Sampling methodologies within a site are to be either discerned by the EDC evaluation contractor based on the characteristics of the facility in question or performed consistent with guidance the EDC EM&V contractor provides.

**Metering – Projects with savings of 750,000 kWh or higher**

For projects with expected savings of 750,000 kWh or higher, metering is required[[11]](#footnote-27). Exceptions may be made and EDC data gathering may be substituted if necessary at the evaluation contractor’s discretion in cases involving early occupancy. Otherwise, installation of light loggers is the accepted method of metering, but trend data from BMS is an acceptable substitute. Metering completed by the implementation contractor maybe leveraged by the evaluation contractor, subject to a reasonableness review. Sampling methodologies within a site are to be either discerned by the EDC evaluation contractor or communicated to implementation contractors based on the characteristics of the facility in question or performed consistent with guidance the EDC EM&V contractor provides.

When BMS data is used as a method of obtaining customer-specific data in lieu of metering, the following guidelines should be followed:

* Care should be taken with respect to BMS data, since the programmed schedule may not reflect regular hours of long unscheduled overrides of the lighting system, such as nightly cleaning in office buildings, and may not reflect how the lights were actually used, but only the times of day the common area lighting is commanded on and off by the BMS.
* The BMS trends should represent the actual status of the lights (not just the command sent to the lights), and the ICSP and EC are required to demonstrate that the BMS system is functioning as expected, prior to relying on the data for evaluation purposes.
* The BMS data utilized should be specific to the lighting systems, and should be required to be representative of the building areas included in the lighting project.

Sources

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. <http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf>
2. International Energy Conservation Code 2015. International Code Council.
3. Pennsylvania Statewide Act 129 2014 Commercial & Residential Lighting Metering Study. Prepared for Pennsylvania Public Utilities Commission. January 13, 2015. <http://www.puc.pa.gov/pcdocs/1340978.pdf>

### Lighting Controls

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Wattage Controlled |
| **Measure Life** | 8 years Source 1 |
| **Measure Vintage** | Retrofit and New Construction |

Eligibility

Lighting controls turn lights on and off automatically, which are activated by time, light, motion, or sound. The measurement of energy savings is based on algorithms with key variables (e.g. coincidence factor (CF), hours of use (HOU) provided through existing end-use metering of a sample of facilities or from other utility programs with experience with these measures (i.e., % of annual lighting energy saved by lighting control). These key variables are listed in Table 3‑16.

If a lighting improvement consists of solely lighting controls, the lighting fixture baseline is the existing fixtures with the existing lamps and ballasts or, if retrofitted, new fixtures with new lamps and ballasts as defined in Lighting Audit and Design Tool shown in Appendix C.

Algorithms

Algorithms for annual energy savings and peak demand savings are shown below.

|  |  |
| --- | --- |
|  |  |
|  |  |

Definition of Terms

Table ‑: Terms, Values, and References for Lighting Controls

| **Term** | **Unit** | **Values** | **Source** | |
| --- | --- | --- | --- | --- |
| , Total lighting load connected to the new control in kilowatts. Savings are per controlled system. The total connected load per controlled system should be collected from the customer | *kW* | Lighting Audit and Design Tool in Appendix C | EDC Data Gathering | |
| , Savings factor for installed lighting control (percent of time the lights are off) | *None* | Based on metering | EDC Data Gathering | |
| Default: Table 3‑4 | 2 | |
| , Baseline savings factor (percent of time the lights are off) | *None* | Retrofit Default: Table 3‑4 | 2 | |
| New Construction Default: Table 3‑15 | 3 | |
| , Coincidence factor | *Decimal* | Based on metering[[12]](#footnote-30) | EDC Data Gathering | |
| By building type and size | Table 3‑5 and Table 3‑6 | |
| , Hours of Use – the average annual operating hours of the baseline lighting equipment (before the lighting controls are in place), which if applied to full connected load will yield annual energy use. |  | Based on metering[[13]](#footnote-31) | EDC Data Gathering | |
|  |  | By building type | Table 3‑5 and Table 3‑6 | |
| , Interactive Energy Factor | *None* | Default: Table 3‑8 and Table 3‑9 | Table 3‑8 and Table 3‑9 | |
| , Interactive Demand Factor | *None* | Default: Table 3‑8 and Table 3‑9 | Table 3‑8 and Table 3‑9 |

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables.

It is noted that if site-specific data is used to determine HOU, then the same data must be used to determine the site-specific CF. Similarly, if the default TRM HOU is used, then the default TRM CF must also be used in the savings calculations. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources



California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table



|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |







### 

1. for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Williams, A., Atkinson, B., Garbesi, K., Rubinstein, F., “A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings”, Lawrence Berkeley National Laboratory, September 2011. https://www.acuitybrands.com/-/media/Files/Acuity/Resources/Regulations%20Codes%20and%20Standards/LBNL%20study.pdf?la=en

### 

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | LED Exit Sign |
|  |  |

|  |  |
| --- | --- |
| **Measure Life** | 15 years Source 1 |
|  |  |

If the exit signs match those listed in Table 3‑17, the default savings value for LED exit signs installed cooled spaces can be used without completing Appendix C.



See Appendix E for general eligibility requirements for solid state lighting products in commercial and industrial applications.

The algorithms shown below can be used to calculate annual energy savings and peak demand savings associated with this measure.

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17: Terms, Values, and References for LED Exit Signs

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Term** | | **Unit** | **Values** | | | **Source** |
| , Connected load of baseline lighting as defined by project classification | | *kW* | Actual Wattage | | | EDC Data Gathering |















|  |  |  |  |
| --- | --- | --- | --- |
|  |  | Single-Sided Incandescent: 0.020  Dual-Sided Incandescent: 0.040  Single-Sided Fluorescent: 0.009  Dual-Sided Fluorescent: 0.020 | Appendix C |
| *,* Connected load of the post-retrofit or energy-efficient lighting | *kW* | Actual Wattage | EDC Data Gathering |
| Single-Sided: 0.002  Dual-Sided: 0.004 | Appendix C |
| *DeltakW*, difference between connected load of baseline and post-retrofit energy efficiency lighting system | *kW* | Default Unknown Type: 0.032 | 2 |
| , Coincidence factor | *Decimal* | 1.0 | 3 |
| , Hours of Use – the average annual operating hours of the baseline lighting equipment. |  | 8,760 | 3 |
| , Interactive Energy Factor | *None* | Default: Table 3‑8 and Table 3‑9 | Table 3‑8 and Table 3‑9 |
| , Interactive Demand Factor | *None* | Default: Table 3‑8 and Table 3‑9 | Table 3‑8 and Table 3‑9 |

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**LED Exit Signs replacing unknown baseline exit signs**

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| --- | --- |
|  |  |
|  |  |

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, [http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018](http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx.%20Accessed%20December%202018).
2. Navigant analysis of Phase III evaluation-verified lighting data across all seven Pennsylvania EDC’s.
3. This assumes operation 24 hours per day, 365 days per year. Additionally, the load shape is assumed to be flat, so the coincidence factor is assumed to be 1.

### 

|  |  |  |
| --- | --- | --- |
| **Target Sector** | Commercial and Industrial Establishments | |
| **Measure Unit** | LED Channel Signage | |
|  |  | |

|  |  |
| --- | --- |
| **Measure Life** | 15 years Source 1 |
|  |  |

Typically,

See Appendix E for general eligibility requirements for solid state lighting products in commercial and industrial applications.

This measure includes the replacement of neon and/or incandescent channel letter signs with efficient LED channel letter signs. Replacement signs cannot use more than 20%

Table 3‑18. Energy interactive effects are not included in the calculations for outdoor applications.

**Indoor applications:**

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| --- | --- |
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**Outdoor applications:**



|  |  |
| --- | --- |
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|  |  |

Table ‑: Terms, Values, and References for LED Channel Signage

| **Term** | | **Unit** | | **Values** | **Source** |
| --- | --- | --- | --- | --- | --- |

|  |  |  |  |
| --- | --- | --- | --- |
| , Sign length | *Linear ft* | EDC Data Gathering | EDC Data Gathering |
| , kW of baseline lighting system | *kW/Linear ft* | EDC Data Gathering  Default: 0.0457 (Red LED systems only) | EDC Data Gathering  1 |
| , kW of post-retrofit or energy-efficient lighting system | *kW/Linear ft* | EDC Data Gathering  Default: 0.00127 (Red LED systems only) | EDC Data Gathering  1 |
| , Coincidence factor | *Decimal* | EDC Data Gathering  Default for Indoor Applications: Table 3‑5  Default for Outdoor Applications: 0[[14]](#footnote-41) | EDC Data Gathering  Table 3‑5 |
| , Annual hours of Use |  | EDC Data Gathering  Default: Table 3‑5 | EDC Data Gathering  Table 3‑5 |
| , Interactive Energy Factor | *None* | Default: Table 3‑8 and Table 3‑9 | Table 3‑8 and Table 3‑9 |
| , Interactive Demand Factor | *None* | Default: Table 3‑8 and Table 3‑9 | Table 3‑8 and Table 3‑9 |
| , Savings factor for existing lighting control (percent of time the lights are off), typically manual switch. | *None* | Default: Table 3‑4 | Table 3‑4 |
| , Savings factor for new lighting control (percent of time the lights are off). | *None* | Default: Table 3‑4 | Table 3‑4 |



Default Savings

There are no default savings for this measure.

Evaluation Protocol

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables.

It is noted that if site-specific data is used to determine HOU, then the same data must be used to determine the site-specific CF. Similarly, if the default TRM HOU is used, then the default TRM CF must also be used in the savings calculations. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Southern California Edison Company, LED Channel Letter Signage (Red), Work Paper SCE13LG052, Revision 1, February 2, 2016.

### LED Refrigeration Display Case Lighting

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Refrigeration Display Case Lighting |
| **Measure Life** | 8 years Source 1 |
| **Measure Vintage** | Early Replacement |

This protocol applies to LED lamps with and without motion sensors installed in vertical display refrigerators, coolers, and freezers replacing T8 or T12 linear fluorescent lamps. The LED lamps produce less waste heat than the fluorescent baseline lamps, decreasing the cooling load on the refrigeration system and energy needed by the refrigerator compressor. Additional savings can be achieved from the installation of motion sensors which dim the lights when the space is unoccupied.

See Appendix E for general eligibility requirements for solid state lighting products in commercial and industrial applications.

Eligibility

This measure is targeted to non-residential customers who install LED case lighting with or without motion sensors on existing refrigerators, coolers, and freezers - specifically on vertical displays. The baseline equipment is assumed to be cases with uncontrolled T8 or T12 linear fluorescent lamps.[[15]](#footnote-43)

Algorithms

Savings and assumptions are based on a per door basis.

|  |  |
| --- | --- |
|  |  |
|  |  |

Definition of Terms

Table ‑: Terms, Values, and References for LED Refrigeration Case Lighting

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Connected wattage of baseline fixtures for each door | *W* | EDC Data Gathering | EDC Data Gathering |
| , Connected wattage of efficient fixtures for each door | *W* | EDC Data Gathering | EDC Data Gathering |
| , Number of doors | *None* | EDC Data Gathering | EDC Data Gathering |
| , Annual operating hours |  | EDC Data Gathering  Default: 6,471 | 1 |
| , Interactive Energy Factor | *None* | Default: Table 3‑8 | Table 3‑8 |
| , Interactive Demand Factor |  | Default: Table 3‑8 | Table 3‑8 |
| , Coincidence factor | *Decimal* | 0.99 | 2 |
| , Conversion factor from watts to kilowatts |  | 1,000 | Conversion Factor |

Default Savings

Default savings may be claimed using the algorithms above and the variable defaults. EDCs may also claim savings using customer specific data.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. Theobald, M. A., Emerging Technologies Program: Application Assessment Report #0608, LED Supermarket Case Lighting Grocery Store, Northern California, Pacific Gas and Electric Company, January 2006. <http://www.etcc-ca.com/images/stories/pdf/ETCC_Report_204.pdf>. Assumes 6,471 annual operating hours and 50,000 lifetime hours. Note that 6,471 is the assumed HOU for general service lighting in grocery settings.
2. Pennsylvania Statewide Act 129 2014 Commercial & Residential Lighting Metering Study. Prepared for Pennsylvania Public Utilities Commission. January 13, 2015. <https://www.puc.pa.gov/pcdocs/1340978.pdf>.

### Lighting Improvements for Midstream Delivery Programs

|  |  |
| --- | --- |
|  |  |
| **Measure Unit** | Lighting Equipment |
| **Measure Life** | Variable[[16]](#footnote-44) |
| **Measure Vintage** | Replace on burnout or Early Replacement |

Mid-Stream Lighting Overview

Significant changes in the lighting industry in recent years, particularly related to LED lamp products, have created an opportunity for utility programs to engage directly with commercial lighting suppliers to increase the adoption of energy efficient lighting technologies. In this new environment, it is imperative that utility programs are accelerating sales of qualifying products and that the program design will support cost-effective energy savings.

Lighting Improvements for Midstream Delivery Programs will offer incentives on eligible products sold to trade allies and customers through commercial sales channels such as distributors of lighting products. This complements other delivery channels (such as downstream rebates to trade allies and customers) by providing incentives to encourage distributors to stock, promote, and sell more efficient lighting. Midstream Delivery Programs should be used for one-for-one fixture replacement; if fixtures are being removed and not replaced, the contractor should go through the downstream program and complete Appendix C.

This protocol applies to efficient lighting delivered through a midstream channel. Code minimum baseline (where applicable) and least efficient readily available (replace on burnout) product were used to determine baseline wattage.

Measures covered by the Lighting Improvements for Midstream Delivery Programs protocol include fixture, lamp, or lamp and ballast replacement, with or without integrated controls, in existing commercial and industrial customers’ facilities. The protocol is used for programs where EDCs pay incentives to qualified midstream participants including but not limited to distributors, for eligible LED lamps and fixtures. Retrofit measures where incentives are paid to customers or trade allies are covered by the Lighting Improvements protocol. New construction measures are covered by the protocol and excluded here. Lamps and fixtures included in this protocol are categorized as follows:

* Omnidirectional, directional, and decorative screw-based lamps
* LED lamps and fixtures
* Highbay and lowbay fixtures
* Highbay and lowbay fixtures with integrated controls
* Exterior area and wall pack fixtures
* Parking garage lighting

See Appendix E for general eligibility requirements for solid state lighting products in commercial and industrial applications.

For all lighting fixture improvements (without control improvements), the following algorithms apply:

|  |  |
| --- | --- |
|  |  |
|  |  |

Table 3‑20: Terms, Values, and References for Lighting Improvements for Midstream Delivery Programs

|  |  |  |  |
| --- | --- | --- | --- |
| , Wattage of baseline lighting | *kW* | Default: Table 3‑21,  Table 3‑22, Table 3‑23, and Table 3‑24 | Table 3‑21,  Table 3‑22, Table 3‑23, and Table 3‑24 |
| , Wattage of incentivized lighting | *kW* | EDC Data Gathering | EDC Data Gathering |
| , Hours of Use – the average annual operating hours of the lighting equipment, which if applied to full connected load will yield annual energy use. |  | Default Screw-based Bulbs: Table 3‑5  Default Other General Service: Table 3‑6  Default Street Lighting: Table 3‑7  EDC Data Gathering  If building type unknown: 2,500 hours | Table 3‑5, Table 3‑6, and Table 3‑7  EDC Data Gathering |
| , Coincidence Factor | *Decimal* | Default Screw-based Bulbs: Table 3‑5  Default Other General Service: Table 3‑6  If building type is unknown: 0.60 | Table 3‑5 and Table 3‑6 |
| , Savings factor for existing lighting control (percent of time the lights are off) | *None* | Default: 3.47% | 17 |
| , Savings factor for integrated lighting control (percent of time the lights are off) | *None* | EDC Data Gathering  Unknown or Manual Switch = 3.47%  Occupancy Sensors = 24%  Photosensors or Time Clocks = 28%  Combination (Occupancy and personal tuning /daylighting, dimming and occupancy) = 38% | 1, 2, 3, 17 |
| , Interactive Energy Factor | *None* | Default: Table 3‑8 and Table 3‑9 | Table 3‑8 and Table 3‑9 |
| , Interactive Demand Factor | *None* | Default: Table 3‑8 and Table 3‑9 | Table 3‑8 and Table 3‑9 |
| *ISR,* In Service Rate, the fraction of incentivized lamps or fixtures that are installed within three years of purchase | *%* | EDC Data Gathering  Default = 98% | 4 |

Table 3‑21, Table 3‑22, Table 3‑23, and Table 3‑24 are arranged by lamp type. When the lamp type is covered by codes or standards, those code/standard wattages apply. For lamps not covered by codes/standards, baseline wattage is the least-efficient, commercially-available, commonly-installed technology. The baseline wattage for LED lamps and fixtures measures is the wattage for the least efficient, standards compliant equipment commonly available in the market.

Efficient product wattages are manufacturer published values as collected by EDCs and ICSPs.

HOU and CF values in Table 3‑5 and Table 3‑6 use building types or EDC data gathering. Building type information must be collected by EDCs and ICSPs for all projects with a change in connected load above 20 KW.

Baseline Wattage, Omnidirectional Lamps

| **Efficient Lamp or Fixture** | **Minimum Lumen** | **Maximum Lumen** | **Incandescent Equivalent (For Reference Only)** | **Wattsbase 2021-2026** | **Source** |
| --- | --- | --- | --- | --- | --- |
| Omnidirectional, General Service Lamp, Screw-based | 250 | 309 | 25 | 25 | 5, 6, 7 |
| 310 | 449 | 25 | 8 |
| 450 | 749 | 40 | 13 |
| 750 | 1,049 | 60 | 20 |
| 1,050 | 1,489 | 75 | 28 |
| 1,490 | 1,999 | 100 | 39 |
| 2,000 | 2,600 | 125 | 51 |
| 2,601 | 3,000 | 150 | 62 |
| 3,001 | 3,300 | 200 | 70 |
| 3,301 | 3,999 | 200 | 200 |
| 4,000 | 6,000 | 300 | 300 |

Table 3‑22: Baseline Wattage, Decorative Lamps

| **Efficient Lamp or Fixture** | **Minimum Lumen** | **Maximum Lumen** | **Incandescent Equivalent (For Reference Only)** | **Wattsbase 2021-2026** | **Source** |
| --- | --- | --- | --- | --- | --- |
| Decorative, Non-Globe, Screw-based | 70 | 89 | 10 | 10 | 5, 6, 7 |
| 90 | 149 | 15 | 15 |
| 150 | 299 | 25 | 25 |
| 300 | 309 | 40 | 29 |
| 310 | 499 | 40 | 9 |
| 500 | 699 | 60 | 13 |
| Decorative, Globe, Screw-based | 250 | 309 | 25 | 25 | 5, 6, 7 |
| 310 | 349 | 25 | 7 |
| 350 | 499 | 40 | 9 |
| 500 | 574 | 60 | 12 |
| 575 | 649 | 75 | 14 |
| 650 | 749 | 100 | 16 |
| 750 | 1,049 | 100 | 20 |
| 1,050 | 1,300 | 150 | 26 |

Table 3‑23: Baseline Wattage, Directional Lamps

| **Efficient Lamp or Fixture** | **Minimum Lumen** | **Maximum Lumen** | **Incandescent Equivalent (For Reference Only)** | **Wattsbase 2021-2026** | **Source** |
| --- | --- | --- | --- | --- | --- |
| Reflector Lamp; R, ER, BR, with screw-based, >=2.25" diameter | 400 | 472 | 40 | 10 | 5, 6, 7 |
| 473 | 524 | 45 | 11 |
| 525 | 714 | 50 | 14 |
| 715 | 937 | 65 | 18 |
| 938 | 1,259 | 75 | 24 |
| 1,260 | 1,399 | 90 | 30 |
| 1,400 | 1,739 | 100 | 35 |
| 1,740 | 2,174 | 120 | 43 |
| 2,175 | 2,624 | 150 | 53 |
| 2,625 | 2,999 | 175 | 62 |
| 3,000 | 3,300 | 200 | 70 |
| 3,301 | 4,500 | 200 | 200 |
| Reflector Lamp; R, ER, BR, with screw-based, diameter <2.25" | 400 | 449 | 40 | 9 | 5, 6, 7 |
| 450 | 499 | 45 | 11 |
| 500 | 649 | 50 | 13 |
| 650 | 1,199 | 65 | 21 |
| ER30, BR30, BR40, or ER40 | 400 | 449 | 40 | 9 | 5, 6, 7 |
| 450 | 499 | 45 | 11 |
| 500 | 649 | 50 | 13 |
| 650 | 1,199 | 65 | 21 |
| R20 | 400 | 449 | 40 | 9 | 5, 6, 7 |
| 450 | 719 | 45 | 13 |
| Reflector Lamp; PAR, MR, MRX | 400 | 472 | Custom[[17]](#footnote-45) | 10 | 5, 6, 7 |
| 473 | 524 | 11 |
| 525 | 714 | 14 |
| 715 | 937 | 18 |
| 938 | 1,259 | 24 |
| 1,260 | 1,399 | 30 |
| 1,400 | 1,739 | 35 |
| 1,740 | 2,174 | 43 |
| 2,175 | 2,624 | 53 |
| 2,625 | 2,999 | 62 |
| 3,000 | 3,300 | 70 |
| 3,301 | 4,500 | 200 |
| All reflector lamps < 400 lumen | 200 | 309 | 20 | 20 | 5, 6, 7 |
| 310 | 399 | 30 | 8 |

Table 3‑24: Baseline Wattage, Linear Lamps & Fixtures, HID Interior and Exterior Fixtures

| **Efficient Lamp or Fixture** | **Minimum Lumen** | **Maximum Lumen** | **Wattsbase** | **Note** | **Source** |
| --- | --- | --- | --- | --- | --- |
| Linear Lamp, 2 ft |  |  | 16.5 | Baseline is standard T8 lamp adjusted for fixture and ballast | Appendix C; 17  4 ft 2 lamp T8 fixture 59 watt/2 = 29.5 watt / lamp |
| Linear Lamp, 3,200 lumen, 4 ft |  |  | 29.5 | Baseline is standard T8 lamp adjusted for fixture and ballast |
| Linear Lamp, 3,200 lumen, 4 ft |  |  | 54 | Baseline is T5 HO |
| Linear Lamp, 5 ft |  |  | 40 | Baseline is standard T8 |
| Linear Lamp, 6 ft |  |  | 65 | Baseline is standard T8 |
| Linear Lamp, 8 ft |  | 4,000 | 59 | Baseline is standard T8 |
| Linear Lamp, 8 ft HO | 4,001 |  | 86 | Baseline is HO T8 |
| Linear LED Fixture, 2 ft | 1,500 | 3,500 | 33 | Baseline is standard 2L T8 | Linear LED Fixture Max Lumen = Number lamps x Lumen Output x Fixture Efficiency x Ballast Factor; where 4' T8 mean lumen = 3,199, fixture efficiency = 74%, ballast factor = 0.90  5, 9, 10 |
| Linear LED Fixture, 2 ft | 3,501 | 5,500 | 61 | Baseline is standard 4L T8 |
| Linear LED Fixture, 4 ft |  | 2,132 | 31 | Baseline is standard 1L T8 |
| Linear LED Fixture, 4 ft | 2,132 | 4,261 | 59 | Baseline is standard 2L T8 |
| Linear LED Fixture, 4 ft | 4,262 | 6,392 | 89 | Baseline is standard 3L T8 |
| Linear LED Fixture, 4 ft | 6,393 | 9,400 | 112 | Baseline is standard 4L T8 |
| Linear LED Fixture, 8 ft |  | 3,290 | 58 | Baseline is standard 1L T8 |
| Linear LED Fixture, 8 ft | 3,291 | 6,580 | 109 | Baseline is standard 2L T8 |
| Linear LED Fixture, 8 ft | 6,581 | 9,870 | 167 | Baseline is standard 3L T8 |
| Linear LED Fixture, 8 ft | 9,871 |  | 219 | Baseline is standard 4L T8 |
| Highbay & Lowbay LED Fixture | 3,850 | 6,550 | 135 | Average 150 watt HID lamp/ T8 HLO | LED Lumen Equivalent = HID Initial Lamp Lumen x HID LLD at 40% rated life x HID Fixture Efficiency HID LLD = 75.8%, HID Fixture Efficiency = 80.4%; survey of manufacturer data, MH, PSMH  9, 11, 12, 13, 14, 15 |
| 6,551 | 9,300 | 168 | Average 175 watt HID lamp/ T8 HLO |
| 9,301 | 11,150 | 198 | Average 200 watt HID lamp/ T8 HLO |
| 11,151 | 12,200 | 236 | Average 250 watt HID lamp/ T8 HLO |
| 12,201 | 15,550 | 289 | Average 320 watt HID lamp/ T8 HLO |
| 15,551 | 20,100 | 367 | Average 400 watt HID lamp/ T8 HLO |
| 20,101 | 34,700 | 634 | Average 750 watt HID lamp/ T8 HLO |
| 34,701 | 57,250 | 901 | Average 1,000 watt HID lamp/ T8 HLO |
| Exterior Fixture (Pole, Wall Pack or Parking Garage) | 250 | 4,650 | 133 | 100 watt HID lamp | LED Lumen Equivalent = HID Initial Lamp Lumen x HID LLD at 40% rated life x HID Fixture Efficiency x DLC adjustment DLC Adjust = 80/70 lumen/watt where 80 is DLC minimum for indoor highbay, 70 for outdoor,  HID LLD = 75.8%, HID Fixture Efficiency = 81.5%; survey of manufacturer data, MH, PSMH, HPS  9, 11, 12, 13, 14, 15, 16 |
| 4,651 | 7,900 | 215 | 175 watt HID lamp |
| 7,901 | 11,050 | 295 | 250 watt HID lamp |
| 11,051 | 24,700 | 462 | 400 watt HID lamp |
| 24,701 | 40,750 | 843 | 750 watt HID lamp |
| 40,751 | 54,650 | 1,090 | 1,000 watt HID lamp |

Default Savings

no default savings associated with this measure.

Evaluation Protocols

All midstream program evaluations should follow the SWE approved method in the EDC EM&V  plan. This includes baseline selection, hours of use determination, and coincident demand calculations.

The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

1. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. <https://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf>
2. Illinois Statewide Technical Reference Manual for Energy Efficiency v7.0, 4.5.4 LED Bulbs and Fixtures. <http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf>.
3. Energy Independence and Security Act (“EISA”) of 2007. <https://www.congress.gov/bill/110th-congress/house-bill/6>. EISA requires all general service lamps sold on or after 1/1/2020 to meet efficacy requirements of 45 lm/W.
4. Energy Conservation Program: Energy Conservation Standards for General Service Lamps. 82 Fed. Reg. 12 (January 19, 2017). Federal Register: The Daily Journal of the United States. Amends the definition of general service lamps to cover the vast majority of screw-base lamps (including incandescent reflectors) with initial lumen output of greater than or equal to 310 lumens and less than or equal to 3,300 lumens.
5. ENERGY STAR® Program Requirements for Lamps (Light Bulbs) V2.1. <https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification.pdf>
6. ENERGY STAR® Lamps Center Beam Intensity Benchmark Tool. <https://www.energystar.gov/sites/default/files/ESLampCenterBeamTool%20rev%202016-09-01.xlsx>
7. Design Lights Consortium, Qualified Products List, [www.designlights.org](https://urldefense.proofpoint.com/v2/url?u=http-3A__www.designlights.org&d=CwMFAg&c=l9ZC4kQDqh9zJlZOaj4GRw&r=gFurZHTQfIEJXopcWiUzvNnY91vlFPKUPOklcZGAcPg&m=qRrDuf08bx7A9AMyBJrsG2tjeWqAlUpmvGfP8yYLet8&s=WtW-ef_m1-vqGhklRlb2SkSIGgbTtZuEvL1EhdzSeGg&e=)
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9. Lamp and Ballast Catalogue, 2014-2015, Osram, [www.osram-americas.com](http://www.osram-americas.com).
10. US Department of Energy, Lumen Maintenance and Light Loss Factors, September 2013, [www.pnnl.gov/main/publications/external/technical\_reports/PNNL-22727.pdf](https://urldefense.proofpoint.com/v2/url?u=http-3A__www.pnnl.gov_main_publications_external_technical-5Freports_PNNL-2D22727.pdf&d=CwMFAg&c=l9ZC4kQDqh9zJlZOaj4GRw&r=gFurZHTQfIEJXopcWiUzvNnY91vlFPKUPOklcZGAcPg&m=qRrDuf08bx7A9AMyBJrsG2tjeWqAlUpmvGfP8yYLet8&s=YS1J54xCVnNL8vF1VD_vVGxrjoF3NT8-9NxRIyHfWrk&e=)
11. GE Lamps and Ballasts Catalogue, 2015-2016, <http://www.gelighting.com/LightingWeb/na/smart-catalog.jsp>.
12. Lithonia, 2016, <http://www.lithonia.com/psg/>.
13. Eaton Cooper, <http://www.cooperindustries.com/content/public/en/lighting.html>.
14. DOE LED Lighting Facts, <http://www.lightingfacts.com/>.
15. The Pennsylvania Statewide Act 129 2018 SWE Commercial and Industrial Baseline study, Table 16. On average, 13% of statewide connected load is controlled by advanced controls (occupancy sensors, photocells, EMS, etc.), resulting in a weighted average 3.47% baseline controls factor.

## HVAC

### HVAC Systems

|  |  |  |
| --- | --- | --- |
| **Target Sector** | Commercial and Industrial Establishments | |
| **Measure Unit** | HVAC System | |
| **Measure Life** | 15 years Source 1 | |
| **Measure Vintage** | Replace on Burnout, New Construction, or Early Replacement | |

Eligibility

The energy and demand savings for Commercial and Industrial HVAC systems is determined from the algorithms listed below. This protocol excludes water source, ground source, and groundwater source heat pumps measures that are covered in Section 3.2.3. All HVAC applications other than comfort cooling and heating, such as process cooling, are defined as non-standard applications and are ineligible for this measure.

Algorithms

**Air Conditioning (central AC, air-cooled DX, split systems, and packaged terminal AC)**

For A/C units < 65,000 , use SEER to calculate and convert SEER to EER to calculate using 11.3/13 as the conversion factor. For units rated in both EER and IEER, use IEER for energy savings calculations.

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**Air Source and Packaged Terminal Heat Pump**

For ASHP units < 65,000 , use SEER to calculate and HSPF to calculate . Convert SEER to EER to calculate using 11.3/13 as the conversion factor. For units rated in both EER and IEER, use IEER for energy savings calculations.

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Definition of Terms

Table ‑: Terms, Values, and References for HVAC Systems

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , Rated cooling capacity of the energy efficient unit |  | Nameplate data (AHRI) | EDC Data Gathering |
| , Rated heating capacity of the energy efficient unit |  | Nameplate data (AHRI) | EDC Data Gathering |
| , Integrated energy efficiency ratio of the baseline unit. |  | Early Replacement: Nameplate data | EDC Data Gathering |
| New Construction or Replace on Burnout: Default values from Table 3‑26 | See Table 3‑26 |
| , Integrated energy efficiency ratio of the energy efficient unit. |  | Nameplate data (AHRI) | EDC Data Gathering |
| , Energy efficiency ratio of the baseline unit. For air-source AC and ASHP units < 65,000 , SEER should be used for cooling savings |  | Early Replacement: Nameplate data | EDC Data Gathering |
| New Construction or Replace on Burnout: Default values from Table 3‑26 | See Table 3‑26 |
| , Energy efficiency ratio of the energy efficient unit. For air-source AC and ASHP units < 65,000 , SEER should be used for cooling savings. |  | Nameplate data (AHRI) | EDC Data Gathering |
| , Seasonal energy efficiency ratio of the baseline unit. For units > 65,000 , EER should be used for cooling savings. |  | Early Replacement: Nameplate data | EDC Data Gathering |
| New Construction or Replace on Burnout: Default values from Table 3‑26 | See Table 3‑26 |
| , Seasonal energy efficiency ratio of the energy efficient unit. For units > 65,000 , EER should be used for cooling savings. |  | Nameplate data (AHRI) | EDC Data Gathering |
| , Coefficient of performance of the baseline unit. For ASHP units < 65,000, HSPF should be used for heating savings. | None | Early Replacement: Nameplate data | EDC Data Gathering |
| New Construction or Replace on Burnout: Default values from Table 3‑26 | See Table 3‑26 |
| , Coefficient of performance of the energy efficient unit. For ASHP units < 65,000 HSPF should be used for heating savings. | None | Nameplate data (AHRI) | EDC Data Gathering |
| , Heating seasonal performance factor of the baseline unit. For units > 65,000 , COP should be used for heating savings. |  | Early Replacement: Nameplate data | EDC Data Gathering |
| New Construction or Replace on Burnout: Default values from Table 3‑26 | See Table 3‑26 |
| , Heating seasonal performance factor of the energy efficiency unit. For units > 65,000 , COP should be used for heating savings. |  | Nameplate data (AHRI) | EDC Data Gathering |
| , Coincidence Factor | *Decimal* | EDC Data Gathering | EDC Data Gathering |
| Default: Table 3‑28 | 2 |
| , Equivalent Full Load Hours for the cooling season – The kWh during the entire operating season divided by the kW at design conditions. |  | EDC Data Gathering | EDC Data Gathering |
| Default: Table 3‑27 | 2 |
| , Equivalent Full Load Hours for the heating season – The kWh during the entire operating season divided by the kW at design conditions. |  | EDC Data Gathering | EDC Data Gathering |
| Default: Table 3‑29 | 2 |
| 11.3/13, Conversion factor from SEER to EER, based on average EER of a SEER 13 unit | *None* |  | 3 |
| 1,000, conversion from watts to kilowatts |  | 1,000 | Conversion Factor |
| 3.412, conversion factor from kWh to kBtu |  | 3.412 | Conversion Factor |

Table ‑: HVAC Baseline Efficiencies

| **Equipment Type and Capacity** | | **Subcategory or Rating Condition** | **Cooling Baseline** | | **Heating Baseline** | | **Source** | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **PY13-PY14** | **PY15-PY17** | **PY13-PY14** | **PY15-PY17** |  | |
| **Air-Source Air Conditioners** | | | | | | | | |
| < 65,000 Btu/h | | Split System | 13.0 SEER | 13.0 SEER | N/A | N/A | 5 | |
| Single Package | 14.0 SEER | 14.0 SEER |
| > 65,000 Btu/h and < 135,000 Btu/h | | Split System and Single Package | 11.2 EER | 11.7 EER | N/A | N/A | 5, 8, 9 | |
| 12.9 IEER | 14.8 EER |
| > 135,000 Btu/h and < 240,000 Btu/h | | Split System and Single Package | 11.0 EER | 11.4 EER | N/A | N/A | 5, 8, 9 | |
| 12.4 IEER | 14.2 EER |
| > 240,000 Btu/h and < 760,000 Btu/h | | Split System and Single Package | 10.0 EER | 10.4 EER | N/A | N/A | 5, 8, 9 | |
| 11.6 IEER | 13.2 EER |
| > 760,000 Btu/h | | Split System and Single Package | 9.7 EER | 9.7 EER | N/A | N/A | 5 | |
| 11.2 IEER | 11.2 IEER |
| **Air-Source Heat Pumps** | | | | | | | | |
| < 65,000 Btu/h | | Split System | 14.0 SEER | 14.0 SEER | 8.2 HSPF | 8.2 HSPF | 5 | |
| Single Package | 14.0 SEER | 14.0 SEER | 8.0 HSPF | 8.0 HSPF |
| > 65,000 Btu/h  and < 135,000 Btu/h | | Split System and Single Package | 11.0 EER | 12.0 EER | 3.3 COP | 3.4 COP | 5, 8, 9 | |
| 12.2 IEER | 14.1 IEER |
| > 135,000 Btu/h and < 240,000 Btu/h | | Split System and Single Package | 10.6 EER | 10.7 EER | 3.2 COP | 3.3 COP | 5, 8, 9 | |
| 11.6 IEER | 13.5 IEER |
| > 240,000 Btu/h | | Split System and Single Package | 9.5 EER | 9.9 EER | 3.2 COP | 3.2 COP | 5, 8, 9 | |
| 10.6 IEER | 12.5 IEER |
| **Packaged Terminal Systems (Nonstandard Size) - Replacement** | | | | | | | | |
| PTAC | | N/A | 10.9 - (0.213 x Cap / 1,000) EER | 10.9 - (0.213 x Cap / 1,000) EER | N/A | N/A | 5 | |
| PTHP | | N/A | 10.8 - (0.213 x Cap / 1,000) EER | 10.8 - (0.213 x Cap / 1,000) EER | 2.9 - (0.026 x Cap / 1,000) COP | 2.9 - (0.026 x Cap / 1,000) COP |
| **Packaged Terminal Systems (Standard Size) – New Construction** | | | | | | | | |
| PTAC | | N/A | 14.0 - (0.300 x Cap / 1,000) EER | 14.0 - (0.300 x Cap / 1,000) EER | N/A | N/A | 5, 8 | |
| PTHP | | N/A | 14.0 - (0.300 x Cap / 1,000) EER | 14.0 - (0.300 x Cap / 1,000) EER | 3.7 - (0.052 x Cap / 1,000) COP | 3.7 - (0.052 x Cap / 1,000) COP |
| **Water-Cooled Air Conditioners** | | | | | | | | |
| < 65,000 Btu/h | | Split System and Single Package | 12.1 EER | 12.1 EER | N/A | N/A | 5 | |
| 12.3 IEER | 12.3 IEER |
| > 65,000 Btu/h  and < 135,000 Btu/h | | Split System and Single Package | 12.1 EER | 12.1 EER | N/A | N/A |
| 13.9 IEER | 13.9 IEER |
| > 135,000 Btu/h and < 240,000 Btu/h | | Split System and Single Package | 12.5 EER | 12.5 EER | N/A | N/A |
| 13.9 IEER | 13.9 IEER |
| > 240,000 Btu/h and < 760,000 Btu/h | | Split System and Single Package | 12.4 EER | 12.4 EER | N/A | N/A |
| 13.6 IEER | 13.6 IEER |
| > 760,000 Btu/h | | Split System and Single Package | 12.2 EER | 12.2 EER | N/A | N/A |
| 13.5 IEER | 13.5 IEER |
| **Evaporatively-Cooled Air Conditioners** | | | | | | | | |
| < 65,000 Btu/h | | Split System and Single Package | 12.1 EER | 12.1 EER | N/A | N/A | 5 | |
|  |  | 12.3 IEER | 12.3 IEER |  |  |  |
| > 65,000 Btu/h  and < 135,000 Btu/h | | Split System and Single Package | 12.1 EER | 12.1 EER | N/A | N/A |  | |
|  |  | 12.3 IEER | 12.3 IEER |  |  |  |
| > 135,000 Btu/h and < 240,000 Btu/h | | Split System and Single Package | 12.0 EER | 12.0 EER | N/A | N/A |  | |
|  |  | 12.2 IEER | 12.2 IEER |  |  |  |
| > 240,000 Btu/h and < 760,000 Btu/h | | Split System and Single Package | 11.9 EER | 11.9 EER | N/A | N/A |  | |
|  |  | 12.1 IEER | 12.1 IEER |  |  |  |
| > 760,000 Btu/h | | Split System and Single Package | 11.7 EER | 11.7 EER | N/A | N/A |  | |
|  |  | 11.9 IEER | 11.9 IEER |  |  |  |

**Notes:** 1) For non-PTAC/PTHP equipment at capacities greater than 65,000 Btu/h, subtract 0.2 from the required baseline efficiency rating value if unit has heating section other than electric resistance. 2) For PTAC and PTHP equipment, “Cap” represents the rated cooling capacity of the product in Btu/h. If the unit’s capacity is less than 7,000 Btu/h, 7,000 Btu/h is used in the calculation. If the unit’s capacity is greater than 15,000 Btu/h, 15,000 Btu/h is used in the Calculation.

Table ‑: Cooling EFLHs for Pennsylvania Cities

| **Space and/or Building Type** | **Allentown** | **Binghamton** | | **Bradford** | **Erie** | **Harrisburg** | | **Philadelphia** | | **Pittsburgh** | | **Scranton** | | **Williamsport** | **Source** | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Education - College/University | 640 | 440 | | 369 | 478 | 657 | | 734 | | 594 | | 533 | | 595 | 2 | |
| Education - Other | 267 | 163 | | 139 | 185 | 310 | | 345 | | 273 | | 217 | | 239 | 2 | |
| Grocery | 654 | 542 | | 542 | 636 | 453 | | 536 | | 638 | | 434 | | 442 | 2 | |
| Health - Hospital | 1,030 | 977 | | 977 | 1,038 | 892 | | 1,059 | | 788 | | 1,022 | | 1,013 | 2 | |
| Health - Other | 477 | 397 | | 350 | 481 | 540 | | 684 | | 511 | | 467 | | 476 | 2 | |
| Industrial Manufacturing | 570 | 361 | | 309 | 411 | 616 | | 682 | | 530 | | 445 | | 478 | 2 | |
| Institutional/Public Service | 753 | 516 | | 455 | 607 | 820 | | 1,087 | | 706 | | 629 | | 685 | 2 | |
| Lodging | 1,386 | 1,205 | | 1,084 | 1,392 | 1,523 | | 1,732 | | 1,478 | | 1,348 | | 1,384 | 2 | |
| Multi-Family (Common Areas) | 1,395 | 654 | | 577 | 769 | 1,482 | | 1,647 | | 1,176 | | 991 | | 1,052 | 6,7 | |
| Office | 458 | 213 | | 323 | 412 | 565 | | 704 | | 721 | | 500 | | 466 | 2 | |
| Restaurant | 550 | 429 | | 374 | 513 | 590 | | 791 | | 632 | | 522 | | 594 | 2 | |
| Retail | 735 | 535 | | 464 | 620 | 742 | | 911 | | 816 | | 603 | | 648 | 2 | |
| Warehouse - Other | 174 | 97 | | 86 | 114 | 235 | | 346 | | 192 | | 130 | | 178 | 2 | |
| Warehouse - Refrigerated | 3,130 | 3,048 | | 3,010 | 3,080 | 3,163 | | 3,200 | | 3,116 | | 3,094 | | 3,135 | 2 | |

Table ‑: Cooling Demand CFs for Pennsylvania Cities

| **Space and/or Building Type** | | **Allentown** | **Binghamton** | **Bradford** | | **Erie** | | **Harrisburg** | | **Philadelphia** | | **Pittsburgh** | | **Scranton** | | **Williamsport** | | **Source** | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Education - College/University | | 0.48 | 0.40 | 0.37 | | 0.38 | | 0.48 | | 0.51 | | 0.48 | | 0.45 | | 0.49 | | 2 | |
| Education - Other | | 0.12 |  | 0.07 | | 0.09 | | 0.18 | | 0.19 | | 0.18 | | 0.13 | | 0.15 | |
| Grocery | | 0.33 | 0.26 | 0.26 | | 0.27 | | 0.24 | | 0.26 | | 0.27 | | 0.21 | | 0.24 | |  | |
| Health - Hospital | | 0.43 |  | 0.34 | | 0.37 | | 0.39 | | 0.44 | | 0.39 | | 0.37 | | 0.42 | |  | |
| Health - Other | | 0.26 | 0.25 | 0.23 | | 0.27 | | 0.30 | | 0.34 | | 0.32 | | 0.28 | | 0.29 | |  | |
| Industrial Manufacturing | | 0.51 | 0.37 | 0.33 | | 0.39 | | 0.55 | | 0.60 | | 0.53 | |  | | 0.48 | |  | |
| Institutional/Public Service | | 0.53 | 0.38 | 0.34 | | 0.45 | | 0.60 | | 0.72 | | 0.56 | | 0.48 | | 0.52 | |  | |
| Lodging | | 0.72 | 0.73 | 0.71 | | 0.77 | | 0.78 | | 0.83 | | 0.83 | | 0.73 | | 0.78 | |  | |
| Multi-Family (Common Areas) | | 0.48 | 0.48 | 0.48 | | 0.48 | | 0.48 | | 0.48 | | 0.48 | | 0.48 | | 0.48 | | 4 | |
| Office |  | 0.32 | 0.16 | 0.26 | | 0.31 | | 0.41 | | 0.27 | | 0.35 | | 0.36 | | 0.37 | | 2 | |
| Restaurant | | 0.38 | 0.36 | 0.33 | | 0.37 | | 0.42 | |  | | 0.49 | | 0.39 | | 0.45 | |  |  |  |
| Retail | | 0.52 | 0.45 | 0.42 | | 0.46 | | 0.53 | | 0.57 | | 0.56 | | 0.47 | | 0.49 | |  | |
| Warehouse - Other | | 0.18 | 0.11 | 0.10 | | 0.13 | | 0.24 | | 0.30 | | 0.23 | | 0.15 | | 0.20 | |  | |
| Warehouse - Refrigerated | | 0.50 |  | 0.45 | | 0.48 | | 0.52 | | 0.53 | | 0.51 | | 0.48 | | 0.51 | |  | |

Table ‑: Heating EFLHs for Pennsylvania Cities

| **Space and/or Building Type** | **Allentown** | **Binghamton** | **Bradford** | | **Erie** | | | **Harrisburg** | | | **Philadelphia** | | | **Pittsburgh** | | | **Scranton** | | **Williamsport** | **Source** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Education - College/University | 719 | 984 | 1,078 | | 857 | | | 552 | | | 464 | | | 651 | | | 824 | | 655 | 2 |
| Education - Other | 636 | 910 |  | | |  | | | 1,018 | | | 666 | | | 741 | | | 646 | 884 | 925 | 655 |  |
| Grocery | 733 | 1,068 | 1,068 | | 534 | | | 1,269 | | | 1,217 | | | 564 | | | 1,737 | | 1,419 |  |
| Health - Hospital | 147 | 81 | 71 | | 95 | | | 361 | | | 345 | | | 418 | | | 106 | | 154 |  |
| Health - Other | 944 | 1,432 | 1,630 | | 1,304 | | | 854 | | | 805 | | | 1,023 | | | 1,193 | | 958 |  |
| Industrial Manufacturing | 406 | 500 | 568 | | 473 | | | 374 | | | 339 | | | 400 | | | 441 | | 346 |  |
| Institutional/Public Service | 1,178 | 1,489 | 1,719 | |  | | |  | | | 1,121 | | | 1,163 | | |  | | 1,066 |  |
| Lodging | 2,371 | 3,219 | 3,846 | | 3,077 | | | 2,159 | | | 2,017 | | | 2,411 | | | 2,591 | | 2,403 |  |
| Multi-Family (Common Areas) | 277 | 320 | 354 | | 322 | | | 263 | | | 259 | | | 264 | | | 281 | | 278 | 6, 7 |
| Office | 321 | 159 | 527 | | 422 | | | 330 | | | 281 | | | 344 | | | 329 | | 340 | 2 |
| Restaurant | 1,151 | 1,865 | 2,109 | | 1,687 | | | 1,040 | | | 993 | | | 1,340 | | | 1,501 | | 1,241 |  |
| Retail | 809 | 1,085 | 1,221 | | 980 | | | 648 | | | 632 | | | 781 | | | 855 | | 675 |  |
| Warehouse - Other | 847 | 1,108 | 1,258 | | 1,114 | | | 843 | | | 900 | | | 978 | | | 1,008 | | 800 |  |
| Warehouse - Refrigerated | 363 | 613 | 668 | | 534 | | | 307 | | | 222 | | | 409 | | | 439 | | 328 |  |

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. <http://www.nrel.gov/docs/fy11osti/49246.pdf>
3. C&I Unitary HVAC Load Shape Project Final Report, Version 1.1, KEMA, 2011. <https://neep.org/sites/default/files/resources/NEEP_HVAC_Load_Shape_Report_Final_August2_0.pdf>
4. International Energy Conservation Code 2015, Table C403.2.3(1).
5. ENERGY STAR Air-Source Heat Pump Calculator. US Department of Energy. Updated July 2011.
6. Connecticut’s 2018 Program Savings Document. Eversource Energy and UIL Holdings Corp. December 15, 2017. The EFLH values reported in this document were adjusted using full load hours (FLH) from Source 6 to account for differences in weather conditions.
7. 10 CFR Part 431. Energy Efficiency Program for Certain Commercial and Industrial Equipment: Subpart F—Commercial Air Conditioners and Heat Pumps. Tables 3, 4, 7.
8. Federal standards do no establish post-1/1/2023 minimum EER requirements for air-source air conditioners and heat pumps. Minimum EER requirements have been estimated using average EER of units meeting minimum IEER requirements, by type and size category, from the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory of Certified Product Performance. Accessed 1/3/2019. https://www.ahridirectory.org/ahridirectory/pages/home.aspx

### Electric Chillers

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Electric Chiller |
|  |  |

|  |  |
| --- | --- |
| **Measure Life** | 15 years Source 1 |
|  |  |

PA Energy Code.These prescriptive algorithms and stipulated values are valid for standard comfort cooling

chillers in industrial applications, chillers using glycol, and heat recovery chillers are defined as non-standard applications and must follow a site-specific custom protocol.

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For Equipment with Efficiency Ratings in EER units

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For Equipment with Efficiency Ratings in kW/ton units

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| --- | --- |
|  |  |
|  |  |

Definition of Terms

Table ‑: Terms, Values, and References for Electric Chillers

| **Term** | **Unit** | | **Values** | | **Source** |
| --- | --- | --- | --- | --- | --- |
| , The capacity of the chiller at site design conditions accepted by the program | *ton* | | Nameplate Data | | EDC Data Gathering |
| 12, conversion factor from tons cooling to kBtu/hr |  | | 12 | | Conversion Factor |
| , Design Rated Efficiency of the baseline chiller. |  | | Early Replacement: Nameplate Data | | EDC Data Gathering |
| New Construction or Replace on Burnout: Default value from Table 3‑31 | | See Table 3‑31 |
| , Design Rated Efficiency of the energy efficient chiller from the manufacturer data and equipment ratings in accordance with AHRI Standards. |  | | Nameplate Data (AHRI Standards 550/590). At minimum, must satisfy standard listed in Table 3‑31 | | EDC Data Gathering |
| , Energy Efficiency Ratio of the baseline unit. |  | | Early Replacement: Nameplate Data | | EDC Data Gathering |
| New Construction or Replace on Burnout: Default value from Table 3‑31 | | See Table 3‑31 |
| , Energy Efficiency Ratio of the efficient unit from the manufacturer data and equipment ratings in accordance with AHRI Standards. |  | | Nameplate Data (AHRI Standards 550/590). At minimum, must satisfy standard listed in Table 3‑31 | | EDC Data Gathering |
| , Integrated Part Load Value of the baseline unit. | or | | Early Replacement: Nameplate Data | | EDC Data Gathering |
| New Construction or Replace on Burnout: See Table 3‑31 | | See Table 3‑31 |
| , Integrated Part Load Value of the efficient unit. | or | | Nameplate Data (AHRI Standards 550/590). At minimum, must satisfy standard listed in Table 3‑31 | | EDC Data Gathering |
| , Coincidence factor | *Decimal* | | See Table 3‑33 | | 2 |
| , Equivalent Full Load Hours – The kWh during the entire operating season divided by the kW at design conditions. The most appropriate EFLH shall be utilized in the calculation. |  | | Based on Logging, BMS data or Modeling[[18]](#footnote-56) | | EDC Data Gathering |
| Default values from Table 3‑32 | | 2 |

Table ‑: Electric Chiller Baseline Efficiencies[[19]](#footnote-57)

| **Chiller Type** | **Size** | **Path A** | **Path B** | **Source** |
| --- | --- | --- | --- | --- |
| Air Cooled Chillers | 150 tons | Full load: 10.100 EER | Full load: 9.700 EER | 3 |
| IPLV: 13.700 EER | IPLV: 15.800 EER |
| 150 tons | Full load: 10.100 EER | Full load: 9.700 EER |
| IPLV: 14.000 EER | IPLV: 16.100 EER |
| Air-Cooled Chiller without Condenser | All capacities | Air-cooled chillers without condensers must be rated with matching condensers and comply with the air-cooled chiller efficiency requirements. | |
| Water Cooled Positive Displacement or Reciprocating Chiller | 75 tons | Full load: 0.750 kW/ton | Full load: 0.780 kW/ton |
| IPLV: 0.600 kW/ton | IPLV: 0.500 kW/ton |
| 75 tons and  150 tons | Full load: 0.720 kW/ton | Full load: 0.750 kW/ton |
| IPLV: 0.560 kW/ton | IPLV: 0.490 kW/ton |
| 150 tons and  300 tons | Full load: 0.660 kW/ton | Full load: 0.680 kW/ton |
| IPLV: 0.540 kW/ton | IPLV: 0.440 kW/ton |
| 300 tons and  600 tons | Full load: 0.610 kW/ton | Full load: 0.625 kW/ton |
| IPLV: 0.520 kW/ton | IPLV: 0.410 kW/ton |
| 600 tons | Full load: 0.560 kW/ton | Full load: 0.585 kW/ton |
| IPLV: 0.500 kW/ton | IPLV: 0.380 kW/ton |
| Water Cooled Centrifugal Chiller | 150 tons | Full load: 0.610 kW/ton | Full load: 0.695 kW/ton |
| IPLV: 0.550 kW/ton | IPLV: 0.440 kW/ton |
| 150 tons and  300 tons | Full load: 0.610 kW/ton | Full load: 0.635 kW/ton |
| IPLV: 0.550 kW/ton | IPLV: 0.400 kW/ton |
| 300 tons and  400 tons | Full load: 0.560 kW/ton | Full load: 0.595 kW/ton |
| IPLV: 0.520 kW/ton | IPLV: 0.390 kW/ton |
| 400 tons and  600 tons | Full load: 0.560 kW/ton | Full load: 0.585 kW/ton |
| IPLV: 0.500 kW/ton | IPLV: 0.380 kW/ton |
| 600 tons | Full load: 0.560 kW/ton | Full load: 0.585 kW/ton |
| IPLV: 0.500 kW/ton | IPLV: 0.380 kW/ton |



Table ‑: Chiller EFLHs for Pennsylvania Cities

| **Space and/or Building Type** | **Allentown** | **Binghamton** | **Bradford** | **Erie** | **Harrisburg** | **Philadelphia** | **Pittsburgh** | **Scranton** | **Williamsport** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Data Center - No Economizer | EDC Data Gathering | | | | | | | | |
| Data Center - With Economizer | EDC Data Gathering | | | | | | | | |
| Education - College/University | 665 | 416 | 368 | 490 | 696 | 770 | 600 | 524 | 619 |
| Education - Other | 275 | 182 | 161 | 214 | 344 | 389 | 282 | 244 | 316 |
| Health - Hospital | 1,240 | 935 | 825 | 1,100 | 1,362 | 1,556 | 1,185 | 1,134 | 1,208 |
| Health - Other | 459 | 347 | 306 | 408 | 520 | 622 | 472 | 418 | 462 |
| Industrial Manufacturing | 708 | 449 | 395 | 527 | 700 | 780 | 631 | 574 | 614 |
| Lodging | 1,397 | 1,178 | 988 | 1,317 | 1,511 | 1,654 | 1,432 | 1,352 | 1,415 |
| Office | 446 | 334 | 295 | 393 | 521 | 586 | 443 | 410 | 453 |
| Retail | 749 | 518 | 457 | 609 | 836 | 897 | 699 | 659 | 742 |



Table ‑: Chiller Demand CFs for Pennsylvania Cities



### 

| **Space and/or Building Type** | **Allentown** | **Binghamton** | **Bradford** | **Erie** | **Harrisburg** | **Philadelphia** | **Pittsburgh** | **Scranton** | **Williamsport** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Data Centers | EDC Data Gathering | | | | | | | | |
| Education - College/University | 0.42 | 0.28 | 0.23 | 0.31 | 0.43 | 0.46 | 0.41 | 0.34 | 0.40 |
| Education - Other | 0.11 | 0.08 | 0.07 | 0.09 | 0.18 | 0.18 | 0.17 | 0.12 | 0.17 |
| Health - Hospital | 0.50 | 0.45 | 0.42 | 0.48 | 0.50 | 0.54 | 0.48 | 0.48 | 0.50 |
| Health - Other | 0.24 | 0.20 | 0.16 | 0.22 | 0.28 | 0.30 | 0.28 | 0.23 | 0.26 |
| Industrial Manufacturing | 0.53 | 0.41 | 0.33 | 0.43 | 0.53 | 0.58 | 0.54 | 0.48 | 0.50 |
| Lodging | 0.62 | 0.59 | 0.54 | 0.61 | 0.68 | 0.69 | 0.71 | 0.60 | 0.68 |
| Office | 0.29 | 0.24 | 0.21 | 0.27 | 0.35 | 0.23 | 0.32 | 0.29 | 0.32 |
| Retail | 0.46 | 0.34 | 0.28 | 0.38 | 0.54 | 0.55 | 0.48 | 0.43 | 0.48 |

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. International Energy Conservation Code 2015. Table C403.2.3(7).

### 

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Geothermal Heat Pump |
| **Measure Life** | 15 years Source 1 |
| **Measure Vintage** | Replace on Burnout, New Construction, or Early Replacement |

This protocol shall apply to ground source, groundwater source, water source heat pumps, and water source and evaporatively cooled air conditioners in commercial applications as further described below. This measure may apply to early replacement of an existing system, replacement on burnout, or installation of a new unit in a new or existing non-residential building for HVAC applications. The base case may employ a different system than the retrofit case.

Eligibility

In order for this characterization to apply, the efficient equipment is a high-efficiency groundwater source, water source, or ground source heat pump system that meets or exceeds the energy efficiency requirements of the International Energy Conservation Code (IECC) 2015, Table 403.2.3(1). The following retrofit scenarios are considered:

* Ground source heat pumps for existing or new non-residential HVAC applications
* Groundwater source heat pumps for existing or new non-residential HVAC applications
* Water source heat pumps for existing or new non-residential HVAC applications

These retrofits reduce energy consumption by the improved thermodynamic efficiency of the refrigeration cycle of new equipment, by improving the efficiency of the cooling and heating cycle, and by lowering the condensing temperature when the system is in cooling mode and raising the evaporating temperature when the equipment is in heating mode as compared to the base case heating or cooling system. It is expected that the retrofit system will use a similar conditioned-air distribution system as the base case system.

This protocol does not apply to heat pump systems coupled with non-heat pump systems such as chillers, rooftop AC units, boilers, or cooling towers. Projects that use unique, combined systems such as these should use a site-specific M&V plan (SSMVP) to describe the particulars of the project and how savings are calculated. All HVAC applications other than comfort cooling and heating, such as process cooling, are defined as non-standard applications and are ineligible for this measure.

Definition of Baseline Equipment

In order for this protocol to apply, the baseline equipment could be a standard-efficiency air source, water source, groundwater source, or ground source heat pump system, or an electric chiller and boiler system, or other chilled/hot water loop system. To calculate savings, the baseline system type is assumed to be an air source heat pump of similar size except for cases where the project is replacing a ground source, groundwater source, or water source heat pump; in those cases, the baseline system type is assumed to be a similar system at code.

Table ‑: Water Source or Geothermal Heat Pump Baseline Assumptions

| **Baseline Scenario** | | **Baseline Efficiency Assumptions** |
| --- | --- | --- |
| New Construction | | Standard efficiency air source heat pump system |
| Retrofit | Replacing any technology besides a ground source, groundwater source, or water source heat pump | Standard efficiency air source heat pump system |
| Replacing a ground source, groundwater source, or water source heat pump | Efficiency of the replaced geothermal system for early replacement only (if known), else code for a similar system |

Algorithms

There are three primary components that must be accounted for in the energy and demand calculations. The first component is the heat pump unit energy and power, the second is the circulating pump in the ground/water loop system energy and power, and the third is the well pump in the ground/water loop system energy and power. For projects where the retrofit system is similar to the baseline system, such as a standard efficiency ground source system replaced with a high efficiency ground source system, the pump energy is expected to be the same for both conditions and does not need to be calculated. The kWh savings should be calculated using the basic equations below. For baseline units rated in both EER and IEER, use IEER in place of EER where listed in the kWh savings calculations below, and use EER for the kW savings calculations.

**For air-cooled base case units with cooling capacities less than 65 kBtu/h:**

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

For air-cooled base case units with cooling capacities equal to or greater than 65 kBtu/h, and all other units:

|  |  |
| --- | --- |
|  |  |
|  |  |
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|  |  |
|  |  |
|  |  |

Definition of Terms[[20]](#footnote-59)

Table ‑: Terms, Values, and References for Geothermal Heat Pumps

| **Term** | **Unit** | **Value** | **Source** |
| --- | --- | --- | --- |
| , Rated cooling capacity of the energy efficient unit |  | Nameplate data (AHRI) | EDC Data Gathering |
| , Rated heating capacity of the energy efficient unit |  | Nameplate data (AHRI)  Use if the heating capacity is not known | EDC Data Gathering |
| , the cooling SEER of the baseline unit |  | Early Replacement: Nameplate data | EDC Data Gathering |
| New Construction or Replace on Burnout: Default values from Table 3‑26 and Table 3‑38 | See Table 3‑26 and Table 3‑38 |
| , Integrated energy efficiency ratio of the baseline unit. |  | Early Replacement: Nameplate data | EDC Data Gathering |
|  |  | Default: Table 3‑26 | See Table 3‑26 |
| , the cooling EER of the baseline unit |  | Early Replacement: Nameplate data  = SEERbase X (11.3/13) if EER not available[[21]](#footnote-60) | EDC Data Gathering |
|  |  | New Construction or Replace on Burnout: Default values from Table 3‑26 and Table 3‑38 | See Table 3‑26 and Table 3‑38 |
| , Heating Season Performance Factor of the baseline unit |  | Early Replacement: Nameplate data | EDC Data Gathering |
|  |  | New Construction or Replace on Burnout: Default values from Table 3‑26 and Table 3‑38 | See Table 3‑26 and Table 3‑38 |
| , Coefficient of Performance of the baseline unit | *None* | Early Replacement: Nameplate data | EDC Data Gathering |
|  |  | New Construction or Replace on Burnout: Default values from Table 3‑26 and Table 3‑38 | See Table 3‑38 |
| , the cooling EER of the new ground source, groundwater source, or water source heat pump being installed |  | Nameplate data (AHRI)  = SEERee X (11.3/13) if EER not available[[22]](#footnote-61) | EDC Data Gathering |
| , Coefficient of Performance of the new ground source, groundwater source, or water source heat pump being installed | *None* | Nameplate data (AHRI) | EDC Data Gathering |
| , Cooling annual Equivalent Full Load Hours EFLH for Commercial HVAC for different occupancies |  | Based on Logging, BMS data or Modeling[[23]](#footnote-62) | EDC Data Gathering |
|  |  | Default values from Table 3‑27 | 3 |
| , Heating annual Equivalent Full Load Hours EFLH for Commercial HVAC for different occupancies |  | Based on Logging, BMS data or Modeling27 | EDC Data Gathering |
| Default values from Table 3‑29 | 3 |
| , Coincidence factor for Commercial HVAC | *Decimal* | See Table 3‑28 | 3 |
| , Coincidence factor for ground source loop pump | *Decimal* | If unit runs 24/7/365, CF=1.0;  If unit runs only with heat pump unit compressor, See Table 3‑28 | 3 |
| , Horsepower of base case ground loop pump motor | *HP* | Ground source, groundwater source, or water source heat pump baseline: Nameplate  ASHP baseline: 0 | EDC Data Gathering |
| , Load factor of the base case ground loop pump motor; ratio of the peak running load to the nameplate rating of the pump motor. | *None* | Based on spot metering and nameplate | EDC Data Gathering |
|  |  | Default: 75% | 2 |
| , efficiency of base case ground loop pump motor | *None* | Nameplate | EDC Data Gathering |
|  |  | If unknown, assume the federal minimum efficiency requirements in Table 3‑36 | 4 |
| , efficiency of base case ground loop pump at design point | *None* | Nameplate | EDC Data Gathering |
| If unknown, assume program compliance efficiency in Table 3‑37 | See Table 3‑37 |
| , Run hours of base case ground loop pump motor | *Hours* | Based on Logging, BMS data or Modeling[[24]](#footnote-64) | EDC Data Gathering |
|  |  | [[25]](#footnote-65)  Default values from Table 3‑27 and Table 3‑29 | 3 |
| , Horsepower of retrofit case ground loop pump motor | *HP* | Nameplate | EDC Data Gathering |
| , Load factor of the retrofit case ground loop pump motor; Ratio of the peak running load to the nameplate rating of the pump motor. | *None* | Based on spot metering and nameplate | EDC Data Gathering |
|  |  | Default: 75% | 2 |
| , efficiency of retrofit case ground loop pump motor | *None* | Nameplate | EDC Data Gathering |
|  |  | If unknown, assume the federal minimum efficiency requirements in Table 3‑36 | Table 3‑36 |
| , efficiency of retrofit case ground loop pump at design point | *None* | Nameplate | EDC Data Gathering |
| If unknown, assume program compliance efficiency in Table 3‑37 | See Table 3‑37 |
| , Run hours of retrofit case ground loop pump motor | *Hours* | Based on Logging, BMS data or Modeling29 | EDC Data Gathering |
| 28  Default values from Table 3‑27 and Table 3‑29 | 3 |
| 3.412, conversion factor from kWh to kBtu |  | 3.412 | Conversion Factor |
| 0.746, conversion factor from horsepower to kW |  | 0.746 | Conversion Factor |
| *GSER*, Factor used to determine the SEER of a GSHP based on its EER | *None* | 1.02 | 5 |

Table ‑: Federal Baseline Motor Efficiencies for NEMA Design A and NEMA Design B Motors

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Motor HP** | **Motor Nominal Full-Load Efficiencies (percent)** | | | | | | | |
| **2 Poles** | | **4 poles** | | **6 Poles** | | **8 Poles** | |
| **Enclosed** | **Open** | **Enclosed** | **Open** | **Enclosed** | **Open** | **Enclosed** | **Open** |
| 1 | 77.0 | 77.0 | 85.5 | 85.5 | 82.5 | 82.5 | 75.5 | 75.5 |
| 1.5 | 84.0 | 84.0 | 86.5 | 86.5 | 87.5 | 86.5 | 78.5 | 77.0 |
| 2 | 85.5 | 85.5 | 86.5 | 86.5 | 88.5 | 87.5 | 84.0 | 86.5 |
| 3 | 86.5 | 85.5 | 89.5 | 89.5 | 89.5 | 88.5 | 85.5 | 87.5 |
| 5 | 88.5 | 86.5 | 89.5 | 89.5 | 89.5 | 89.5 | 86.5 | 88.5 |
| 7.5 | 89.5 | 88.5 | 91.7 | 91.0 | 91.0 | 90.2 | 86.5 | 89.5 |
| 10 | 90.2 | 89.5 | 91.7 | 91.7 | 91.0 | 91.7 | 89.5 | 90.2 |
| 15 | 91.0 | 90.2 | 92.4 | 93.0 | 91.7 | 91.7 | 89.5 | 90.2 |
| 20 | 91.0 | 91.0 | 93.0 | 93.0 | 91.7 | 92.4 | 90.2 | 91.0 |

Table ‑: Ground/Water Loop Pump and Circulating Pump Efficiency[[26]](#footnote-68)

|  |  |
| --- | --- |
| **HP** | **Minimum Pump Efficiency at Design Point (ηpump)** |
| 1.5 | 65% |
| 2 | 65% |
| 3 | 67% |
| 5 | 70% |
| 7.5 | 73% |
| 10 | 75% |
| 15 | 77% |
| 20 | 77% |

Table ‑: Default Baseline Equipment Efficiencies

| **Equipment Type and Capacity** | **Cooling Baseline** | **Heating Baseline** | **Source** |
| --- | --- | --- | --- |
| **Water to Air: Water Loop** | | | |
| 17,000 | 12.2 EER  (860 F entering water) | 4.3 COP (680 F entering water) | 6 |
| 17,000 and 65,000 | 13.0 EER  (860 F entering water) | 4.3 COP (680 F entering water) |
| 65,000 and 135,000 | 13.0 EER  (860 F entering water) | 4.3 COP (680 F entering water) |  |
| **Water to Air: Ground Water** | | | |
| 135,000 | 18.0 EER  (590 F entering water) | 3.7 COP (500 F entering water) | 6 |
| **Brine to Air: Ground Loop** | | | |
| 135,000 | 14.1 EER  (770 F entering fluid) | 3.2 COP (320 F entering fluid) | 6 |
| **Water to Water: Water Loop** | | | |
| 135,000 | 10.6 EER  (860 F entering water) | 3.7 COP (680 F entering water) | 6 |
| **Water to Water: Ground Water** | | | |
| 135,000 | 16.3 EER  (590 F entering water) | 3.1 COP (500 F entering water) | 6 |
| **Brine to Water: Ground Loop** | | | |
| 135,000 | 12.1 EER  (770 F entering fluid) | 2.5 COP (320 F entering fluid) | 6 |

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Extrapolation of manufacturer data.

### 

1. International Energy Conservation Code 2015. Table C403.2.3(7).

### 

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Ductless Heat Pump |
|  |  |

|  |  |
| --- | --- |
| **Measure Life** | 15 years Source 1 |
|  |  |

15/12.5 and 8.5, respectively, or greater.

This protocol documents the energy savings attributed to ENERGY STAR ductless mini-split heat pumps with energy-efficiency performance of 15/12.5 SEER/EER and 8.5 HSPF or greater with inverter technology.Source 2 The baseline heating system could be an existing electric resistance, a lower-efficiency ductless heat pump system, a ducted heat pump, packaged terminal heat pump (PTHP), electric furnace, or a non-electric fuel-based system. The baseline cooling system could be a standard efficiency heat pump system, central air conditioning system, packaged terminal air conditioner (PTAC), or room air conditioner. The DHP could be a new device in an existing space, a new device in a new space, or could replace an existing heating/cooling device. The DHP systems could be installed as a single-zone system (one indoor unit, one outdoor unit) or a multi-zone system (multiple indoor units, one outdoor unit). In addition, the old systems should be de-energized, completely uninstalled and removed in order to ensure that the full savings is realized. All HVAC applications other than comfort cooling and heating, such as process cooling, are defined as non-standard applications and are ineligible for this measure.

Algorithms

The savings depend on three main factors: baseline condition, usage, and the capacity of the indoor unit. The algorithms, shown below, are separated into two calculations: single zone and multi-zone ductless heat pumps.

Single Zone:

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |
|  |  |

Multi-Zone:

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |
|  |  |

Definition of Terms

Table ‑: Terms, Values, and References for DHP

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , The cooling capacity of the indoor unit, given in as appropriate for the calculation. This protocol is limited to units < 65,000 (5.4 tons)  , The heating capacity of the indoor unit, given in as appropriate for the calculation. |  | Nameplate | EDC Data Gathering |
| , Equivalent Full Load Hours for cooling , Equivalent Full Load Hours for heating |  | Based on Logging, BMS data or Modeling | EDC Data Gathering  3 |
| Default: Table 3‑27 and Table 3‑29 |
| , Heating Seasonal Performance Factor, heating efficiency of the baseline unit[[27]](#footnote-72) |  | Standard DHP: 8.2  Electric resistance: 3.412  ASHP: 8.2  PTHP (Replacements): 2.9 - (0.026 x Cap / 1,000) COP  PTHP (New Construction): 3.7 - (0.052 x Cap / 1,000) COP  Electric furnace: 3.241  For new space, no heat in an existing space, or non-electric heating in an existing space: use electric resistance: 3.412 | 4, 5, 7, 8, 9 |
| , Seasonal Energy Efficiency Ratio cooling efficiency of baseline unit[[28]](#footnote-74) |  | DHP, ASHP, or central AC: 14  Room AC: 11.3  PTAC (Replacements): 10.9 - (0.213 x Cap / 1,000) EER  PTAC (New Construction): 14.0 - (0.300 x Cap / 1,000) EER  PTHP (Replacements): 10.8 - (0.213 x Cap / 1,000) EER  PTHP (New Construction): 14.0 - (0.300 x Cap / 1,000) EER  For new space or no cooling in an existing space: use Room AC: 11.3 | 5, 6, 7 |
| , Heating Seasonal Performance Factor, heating efficiency of the installed DHP |  | Based on nameplate information. Should be at least ENERGY STAR. | EDC Data Gathering |
| , Seasonal Energy Efficiency Ratio cooling efficiency of the installed DHP |  | Based on nameplate information. Should be at least ENERGY STAR. | EDC Data Gathering |
| , Coincidence factor | *Decimal* | Default: Table 3‑28 | 3 |

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. ENERGY STAR Air Source Heat Pumps and Central Air Conditioners Key Product Criteria. <http://www.energystar.gov/index.cfm?c=airsrc_heat.pr_crit_as_heat_pumps>
3. Based on Nexant’s eQuest modeling analysis 2014.
4. COP = HSPF/3.412. HSPF = 3.412 for electric resistance heating, HSPF = 8.2 for standard DHP. Electric furnace COP typically varies from 0.95 to 1.00 and thereby assumed a COP 0.95 (HSPF = 3.241).
5. Air-Conditioning, Heating, and Refrigeration Institute (AHRI); the directory of the available ductless mini-split heat pumps and corresponding efficiencies (lowest efficiency currently available). Accessed 12/01/2018. <https://www.ahridirectory.org/ahridirectory/pages/home.aspx>
6. Code of Federal Regulations at 10 CFR 430.32(b). Assumes 10,000 Btu/hr unit with louvered sides. Note: As of 1/1/2014, room air conditioners are rated with the Combined Energy Efficiency Ratio (CEER) which incorporated the impact of standby power consumption. Because this metric is not comparable to SEER, the previous EER requirement is assumed and converted to SEER.
7. If the unit’s capacity is less than 7,000 , use 7,000 in the calculation. If the unit’s capacity is greater than 15,000 , use 15,000 in the calculation.

### 

1. International Energy Conservation Code 2015. Table C403.2.3(2).
2. U.S. Department of Energy. 10 CFR Part 431. Energy Efficiency Program for Certain Commercial and Industrial Equipment: Subpart F—Commercial Air Conditioners and Heat Pumps. Table 7.

### 

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Gas, Propane or Oil Heater |
| **Measure Life** | 15 years Source 1 |
| **Measure Vintage** | Replace on Burnout, Early Retirement, or New Construction |

Eligibility

The energy and demand savings for small commercial fuel switching for heating systems is determined from the algorithms listed below. This protocol excludes water source, ground source, and groundwater source heat pumps.

The baseline for this measure is an existing commercial facility with an electric primary heating source. The heating source can be electric baseboards, packaged terminal heat pump (PTHP) units, electric furnace, or electric air source heat pump. The retrofit condition for this measure is the installation of a new standard efficiency natural gas, propane, or oil furnace or boiler. This algorithm does not apply to combination space and water heating units. This protocol applies to furnace measures with input rating of less than 225,000 and boiler measures with input rating of less than 300,000 .



EDCs may provide incentives for equipment with efficiencies greater than or equal to the applicable ENERGY STAR requirement per the following table.

Table ‑: ENERGY STAR Requirements for Furnaces and Boilers

|  |  |  |
| --- | --- | --- |
| **Equipment** | **ENERGY STAR Requirements** | **Source** |
| Gas Furnace | AFUE rating of 95% or greater  Furnace fan must have electronically commutated fan motor (ECM)  Less than or equal to 2.0% air leakage | 2 |
| Oil Furnace | AFUE rating of 85% or greater  Furnace fan must have electronically commutated fan motor (ECM)  Less than or equal to 2.0% air leakage |
| Gas Boiler | AFUE rating of 90% or greater | 3 |
| Oil Boiler | AFUE rating of 87% or greater |  | |

Algorithms

The energy savings are the full energy consumption of the electric heating source minus the energy consumption of the fossil fuel furnace blower motor. The energy savings are obtained through the following formulas shown below. EDCs may use billing analysis using program participant data to claim measure savings, in lieu of using the defaults provided in this measure protocol. Billing analysis should be conducted using at least 12 months of billing data (pre- and post-retrofit).

Electric furnace or air source heat pump

For ASHP units < 65,000 , use HSPF instead of COP to calculate .

|  |  |
| --- | --- |
|  |  |
|  |  |

Baseboard heating, packaged terminal heat pump

|  |  |
| --- | --- |
|  |  |

The motor consumption of a gas furnace is subtracted from the savings for a baseboard or PTHP heating system, as these existing systems do not require a fan motor while the replacement furnace does (the electric furnace and air source heat pumps require fan motors with similar consumption as a gas furnace and thus there is no significant change in motor load). For boilers, the annual pump energy consumption is negligible (<50 kWh per year) and not included in this calculation.[[29]](#footnote-79)

There are no peak demand savings as it is a heating only measure.

Although there are significant electric savings, there is also an associated increase in fossil fuel energy consumption. While this fuel consumption does not count against PA Act 129 energy savings, it is expected to be used in the program TRC test. The increased fossil fuel energy is obtained through the following formula:

Fuel consumption with fossil fuel furnace or boiler:

|  |  |
| --- | --- |
|  |  |

Definition of Terms

Table ‑: Terms, Values, and References for Fuel Switching

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , Rated heating capacity of the new fossil fuel unit |  | Nameplate data (AHRI) | EDC Data Gathering |
| , Rated heating capacity of the existing electric unit |  | Nameplate data (AHRI)  Default: set equal to | EDC Data Gathering |
| , Efficiency rating of the baseline unit. For ASHP units < 65,000 Btu/hr, HSPF should be used for heating savings | *None* | Early Replacement: Nameplate data | EDC Data Gathering |
|  |  | New Construction or Replace on Burnout: Default values from Table 3‑26 | See Table 3‑26 |
| , Heating seasonal performance factor of the baseline unit. For units >65,000 Btu/hr, COP should be used for heating savings |  | Early Replacement: Nameplate data | EDC Data Gathering |
|  |  | New Construction or Replace on Burnout: Default values from Table 3‑26 | See Table 3‑26 |
| , Annual Fuel Utilization Efficiency rating of the fossil fuel unit | *None* | Default: Table 3‑40 | 2, 3 |
| Nameplate data (AHRI) | EDC Data Gathering |
| , Equivalent Full Load Hours for the heating season – The kWh during the entire operating season divided by the kW at design conditions |  | Based on Logging, EMS data or Modeling[[30]](#footnote-81) | EDC Data Gathering |
|  |  | Default: Table 3‑29 | 4 |
| , Gas furnace blower motor horsepower | *HP* | Default: ½ HP for furnace | Average blower motor capacity for gas furnace (typical range = ¼ HP to ¾ HP) |
| Nameplate | EDC Data Gathering |
| , Efficiency of furnace blower motor | *None* | From nameplate | EDC Data Gathering |
|  |  | Default: 0.50 for furnace | Typical efficiency of ½ HP blower motor for gas furnace |



1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. ENERGY STAR Program Requirements for Furnaces. <https://www.energystar.gov/sites/default/files/Furnaces%20Version%204.1_Program%20Requirements.pdf>
3. ENERGY STAR Program Requirements for Boilers. <https://www.energystar.gov/sites/default/files/specs/Boilers%20Program%20Requirements%20Version%203%200.pdf>
4. The Equivalent Full Load Hours (EFLH) for Pennsylvania are calculated based on Nexant’s eQuest modeling analysis 2014.

### Small C&I HVAC Refrigerant Charge Correction

|  |  |  |
| --- | --- | --- |
| **Target Sector** | Commercial and Industrial Establishments | |
| **Measure Unit** | Tons of Refrigeration Capacity | |
| **Measure Life** | 10 years Source 1 | |
| **Measure Vintage** | Retrofit | |

This protocol describes the assumptions and algorithms used to quantify energy savings for refrigerant charging on packaged AC units and heat pumps operating in small commercial applications. The protocol herein describes a partially deemed energy savings and demand reduction estimation.

Eligibility

This protocol is applicable for small commercial and industrial customers, and applies to documented tune-ups for package or split systems up to 20 tons. All HVAC applications other than comfort cooling and heating, such as process cooling, are defined as non-standard applications and are ineligible for this measure.

Algorithms

This section describes the process of creating energy savings and demand reduction calculations.

Air Conditioning

For A/C units < 65,000 , use SEER to calculate and convert SEER to EER to calculate using 11.3/13 as the conversion factor. For A/C units > 65,000 , if rated in both EER and IEER, use IEER for energy savings calculations.

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Heat Pumps

For Heat Pump units < 65,000 , use SEER to calculate and HSPF instead of COP to calculate . Convert SEER to EER to calculate using 11.3/13 as the conversion factor. For Heat Pump units > 65,000 , if rated in both EER and IEER, use IEER to calculate .

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Definition of Terms

Table ‑: Terms, Values, and References for Refrigerant Charge Correction

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , Unit capacity for cooling |  | From nameplate | EDC Data Gathering |
| , Unit capacity for heating |  | From nameplate | EDC Data Gathering |
| EER, Energy Efficiency Ratio. For A/C and heat pump units < 65,000 , SEER should be used for cooling savings. |  | From nameplate | EDC Data Gathering |
| Default: Table 3‑26 | See Table 3‑26 |
| IEER, Integrated energy efficiency ratio of the baseline unit. |  | From nameplate | EDC Data Gathering |
|  |  | Default: Table 3‑26 | See Table 3‑26 |
| SEER, Seasonal Energy Efficiency Ratio. For A/C and heat pump units > 65,000 , EER should be used for cooling savings. |  | From nameplate | EDC Data Gathering |
|  |  | Default: Table 3‑26 | See Table 3‑26 |
| HSPF, Heating Seasonal Performance Factor. For heat pump units > 65,000 , COP should be used for heating savings. |  | From nameplate | EDC Data Gathering |
|  |  | Default: Table 3‑26 | See Table 3‑26 |
| COP,Coefficient of Performance. For heat pump units < 65,000 , HSPF should be used for heating savings. | *None* | From nameplate | EDC Data Gathering |
|  |  | Default: Table 3‑26 | See Table 3‑26 |
| , Equivalent Full-Load Hours for mechanical cooling |  | Default: Table 3‑27 | 2 |
|  |  | Based on Logging, BMS data or Modeling[[31]](#footnote-85) | EDC Data Gathering |
| , Equivalent Full-Load Hours for Heating |  | See Table 3‑29 | 2 |
| RCF, COP Degradation Factor for Cooling | *None* | See Table 3‑43 | 3 |
| , Coincidence factor | *Decimal* | See Table 3‑28 | 2 |
| 1,000, convert from watts to kilowatts |  |  | Conversion Factor |
| 11.3/13, Conversion factor from SEER to EER, based on average EER of a SEER 13 unit | *None* |  | 4 |

**Table 3‑43: Refrigerant charge correction COP degradation factor (RCF) for various relative charge adjustments for both TXV metered and non-TXV units**

| **% of nameplate charge added (removed)** | **RCF (TXV)** | **RCF (Non-TVX)** | **% of nameplate charge added (removed)** | **RCF (TXV)** | **RCF (Non-TVX)** | **% of nameplate charge added (removed)** | **RCF (TXV)** | **RCF (Non-TVX)** | **Source** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 60% | 68% | 13% | 28% | 95% | 83% | (4%) | 100% | 100% | 3 |
| 59% | 70% | 16% | 27% | 96% | 84% | (5%) | 100% | 99% |
| 58% | 71% | 19% | 26% | 96% | 85% | (6%) | 100% | 99% |
| 57% | 72% | 22% | 25% | 97% | 87% | (7%) | 99% | 99% |
| 56% | 73% | 25% | 24% | 97% | 88% | (8%) | 99% | 99% |
| 55% | 74% | 28% | 23% | 97% | 89% | (9%) | 99% | 98% |
| 54% | 76% | 31% | 22% | 98% | 90% | (10%) | 99% | 98% |
| 53% | 77% | 33% | 21% | 98% | 91% | (11%) | 99% | 97% |
| 52% | 78% | 36% | 20% | 98% | 92% | (12%) | 99% | 97% |
| 51% | 79% | 39% | 19% | 98% | 92% | (13%) | 99% | 96% |
| 50% | 80% | 41% | 18% | 99% | 93% | (14%) | 98% | 96% |
| 49% | 81% | 44% | 17% | 99% | 94% | (15%) | 98% | 95% |
| 48% | 82% | 46% | 16% | 99% | 95% | (16%) | 98% | 95% |
| 47% | 83% | 48% | 15% | 99% | 95% | (17%) | 98% | 94% |
| 46% | 84% | 51% | 14% | 99% | 96% | (18%) | 98% | 93% |
| 45% | 85% | 53% | 13% | 100% | 97% | (19%) | 98% | 93% |
| 44% | 86% | 55% | 12% | 100% | 97% | (20%) | 97% | 92% |
| 43% | 86% | 57% | 11% | 100% | 98% | (21%) | 97% | 91% |
| 42% | 87% | 60% | 10% | 100% | 98% | (22%) | 97% | 90% |
| 41% | 88% | 62% | 9% | 100% | 98% | (23%) | 97% | 90% |
| 40% | 89% | 64% | 8% | 100% | 99% | (24%) | 97% | 89% |
| 39% | 89% | 65% | 7% | 100% | 99% | (25%) | 96% | 88% |
| 38% | 90% | 67% | 6% | 100% | 99% | (26%) | 96% | 87% |
| 37% | 91% | 69% | 5% | 100% | 100% | (27%) | 96% | 86% |
| 36% | 91% | 71% | 4% | 100% | 100% | (28%) | 96% | 85% |
| 35% | 92% | 73% | 3% | 100% | 100% | (29%) | 95% | 84% |
| 34% | 92% | 74% | 2% | 100% | 100% | (30%) | 95% | 83% |
| 33% | 93% | 76% | 1% | 100% | 100% | (31%) | 95% | 82% |
| 32% | 94% | 77% | (0%) | 100% | 100% | (32%) | 95% | 81% |
| 31% | 94% | 79% | (1%) | 100% | 100% | (33%) | 95% | 80% |
| 30% | 95% | 80% | (2%) | 100% | 100% | (34%) | 94% | 78% |
| 29% | 95% | 82% | (3%) | 100% | 100% | (35%) | 94% | 77% |

**Note:** In the table above, “% of nameplate charge added (removed)” is the independent variable.

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Nexant’s eQuest modeling analysis 2014.
3. Small HVAC Problems and Potential Savings Report, California Energy Commission, 2003. <http://www.energy.ca.gov/2003publications/CEC-500-2003-082/CEC-500-2003-082-A-25.PDF>
4. Average EER for SEER 13 units as calculated by EER = -0.02 × SEER² + 1.12 × SEER based on U.S. DOE Building America House Simulation Protocol, Revised 2010.

### ENERGY STAR Room Air Conditioner

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Room Air Conditioner |
| **Measure Life** | 9 years Source 1 |
| **Measure Vintage** | Replace on Burnout, Early Retirement, or New Construction |

Eligibility

This protocol is for ENERGY STAR Version 4.1 room air conditioner units installed in small commercial spaces. All HVAC applications other than comfort cooling and heating, such as process cooling, are defined as non-standard applications and are ineligible for this measure. Only ENERGY STAR units qualify for this protocol.

Algorithms

for annual energy savings and peak demand savings are shown below.

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Definition of Terms

Table ‑: Terms, Values, and References for ENERGY STAR Room Air Conditioners

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Rated cooling capacity of the energy efficient unit |  | Nameplate data (AHRI) | EDC Data Gathering |
| , Combined Energy Efficiency ratio of the baseline unit |  | New Construction or Replace on Burnout: Default Federal Standard values from Table 3‑45 to Table 3‑47 | 3, 4 |
| Early Replacement: Nameplate data | EDC Data Gathering |
| , Combined Energy Efficiency ratio of the energy efficiency unit |  | Nameplate data (AHRI) | EDC Data Gathering |
| , Coincidence factor | *Fraction* | Default: Table 3‑28 | 2 |
| , Equivalent Full Load Hours for the cooling season – kWh during the entire operating season divided by kW at design conditions. |  | Based on Logging, BMS data or Modeling[[32]](#footnote-88) | EDC Data Gathering |
| Default: Table 3‑27 | 2 |
| *,* RAC ELFH to Central Air Conditioner (CAC) ELFH conversion | *Fraction* | 0.31 | 5 |

Table 3‑45 lists the minimum federal efficiency standards for room air conditioners and minimum ENERGY STAR efficiency standards for RAC units of various capacity ranges, with and without louvered sides. Units without louvered sides are also referred to as “through the wall” units or “built-in” units. Note that the new federal standards are based on the Combined Energy Efficiency Ratio metric (CEER), which is a metric that incorporates energy use in all modes, including standby and off modes.

Table ‑: RAC Federal Minimum Efficiency and ENERGY STAR Version 4.1 Standards

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Capacity  (Btu/h)** | **Federal Standard CEER, with louvered sides** | **ENERGY STAR CEER, with louvered sides** | **Federal Standard CEER, without louvered sides** | **ENERGY STAR CEER, without louvered sides** |
| 6,000 | 11.0 | 12.1 | 10.0 | 11.0 |
| 6,000 to 7,999 |
| 8,000 to 10,999 | 10.9 | 12.0 | 9.6 | 10.6 |
| 11,000 to 13,999 | 9.5 | 10.5 |
| 14,000 to 19,999 | 10.7 | 11.8 | 9.3 | 10.2 |
| 20,000 to 24,999 | 9.4 | 10.3 | 9.4 | 10.3 |
| 25,000 to 27,999 | 9.4 |
| 28,000 | 9.0 | 9.9 | 9.4 |

Table 3‑46 lists the minimum federal efficiency standards and minimum ENERGY STAR efficiency standards for casement-only and casement-slider RAC units. Casement-only refers to a RAC designed for mounting in a casement window with an encased assembly with a width of ≤ 14.8 inches and a height of ≤ 11.2 inches. Casement-slider refers to a RAC with an encased assembly designed for mounting in a sliding or casement window with a width of ≤ 15.5 inches.

Table ‑: Casement-Only and Casement-Slider RAC Federal Minimum Efficiency and ENERGY STAR Version 4.1 Standards

|  |  |  |
| --- | --- | --- |
| **Casement** | **Federal Standard CEER** | **ENERGY STAR CEER** |
| Casement-only | 9.5 | 10.5 |
| Casement-slider | 10.4 | 11.4 |

Table 3‑47 lists the minimum federal efficiency standards and minimum ENERGY STAR efficiency standards for reverse-cycle RAC units.

Table ‑: Reverse-Cycle RAC Federal Minimum Efficiency Standards and ENERGY STAR Version 4.1 Standards

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Capacity  (Btu/h)** | **Federal Standard CEER, with louvered sides** | **ENERGY STAR EER, with louvered sides** | **Federal Standard CEER, without louvered sides** | **ENERGY STAR EER, without louvered sides** |
| 14,000 | N/A | N/A | 9.3 | 10.2 |
| 14,000 | 8.7 | 9.6 |
| 20,000 | 9.8 | 10.8 | N/A | N/A |
| 20,000 | 9.3 | 10.2 |

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, [http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018](http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx.%20Accessed%20December%202018).
2. Based on Nexant’s eQuest Modeling Analysis 2014.
3. Federal standards: U.S. Department of Energy. Federal Register. 164th ed. Vol. 76, August 24, 2011. <http://www.gpo.gov/fdsys/pkg/FR-2013-07-16/pdf/FR-2013-07-16.pdf>
4. ENERGY STAR Program Requirements Product Specification for Room Air Conditioners. [https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%204.1%20Room%20Air%20Conditioners%20Specification.pdfhttps://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%204.1%20Room%20Air%20Conditioners%20Specification.pdf](https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%204.1%20Room%20Air%20Conditioners%20Specification.pdfhttps:/www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%204.1%20Room%20Air%20Conditioners%20Specification.pdf)
5. 2019 Illinois Statewide Technical Reference Manual for Energy Efficiency Version 7.0. Volume 2: Commercial and Industrial Measures. September 28, 2018. [http://ilsagfiles.org/SAG\_files/Technical\_Reference\_Manual/Version\_7/Final\_9-28-18/IL-TRM\_Effective\_010119\_v7.0\_Vol\_2\_C\_and\_I\_092818\_Final.pdf](http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf%20)

### Controls: Guest Room Occupancy Sensor

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Occupancy Sensor |
| **Measure Life** | 15 years Source 1 |
| **Measure Vintage** | Retrofit |

This protocol applies to the installation of a control system in hotel guest rooms to automatically adjust the temperature setback during unoccupied periods. Savings are based on the management of the guest room’s set temperatures and controlling the HVAC unit for various occupancy modes. The savings are per guestroom controlled, rather than per sensor, for multi-room suites.

Eligibility

This measure is targeted to hotel customers whose guest rooms are equipped with energy management thermostats replacing manual heating/cooling temperature set-point and fan On/Off/Auto thermostat controls. Acceptable baseline conditions are hotel guest rooms with manual heating/cooling temperature set-point and fan On/Off/Auto thermostat controls. Efficient conditions are hotel/motel guest rooms with energy management controls of the heating/cooling temperature set-points and operation state based on occupancy modes.

Algorithms

Energy savings estimates are deemed using the tables below. Estimates were derived using an EnergyPlus model of a motel.Source 2 Model outputs were normalized to the installed capacity and reported here as kWh/Ton and coincident peak kW/Ton. Motels and hotels show differences in shell performance, number of external walls per room and typical heating and cooling efficiencies, thus savings values are presented for hotels and motels separately. Savings also depend on the size and type of HVAC unit, and whether housekeeping staff are directed to set-back/turn-off the thermostats when rooms are unrented.

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Definition of Terms

Table ‑: Terms, Values, and References for Guest Room Occupancy Sensors

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| *,* Cooling capacity of controlled unit in tons | *ton* | EDC Data Gathering | EDC Data Gathering |
| *,* Energy savings factor |  | See Table 3‑49 and Table 3‑50 | 2 |
| *,* Demand savings factor |  | See Table 3‑51 and Table 3‑52 | 2 |

Table ‑: Energy Savings for Guest Room Occupancy Sensors – Motels

|  |  |  |
| --- | --- | --- |
| **HVAC Type** | **Baseline** | **ESF (kWh/ton)** |
| PTAC with Electric Resistance Heating | Housekeeping Setback | 559 |
| No Housekeeping Setback | 1,877 |
| PTAC with Gas Heating | Housekeeping Setback | 85 |
| No Housekeeping Setback | 287 |
| PTHP | Housekeeping Setback | 260 |
| No Housekeeping Setback | 1,023 |

Table ‑: Energy Savings for Guest Room Occupancy Sensors – Hotels

|  |  |  |
| --- | --- | --- |
| **HVAC Type** | **Baseline** | **ESF (kWh/ton)** |
| PTAC with Electric Resistance Heating | Housekeeping Setback | 322 |
| No Housekeeping Setback | 1,083 |
| PTAC with Gas Heating | Housekeeping Setback | 259 |
| No Housekeeping Setback | 876 |
| PTHP | Housekeeping Setback | 283 |
| No Housekeeping Setback | 1,113 |
| Central Hot Water Fan Coil with Electric Resistance Heating | Housekeeping Setback | 245 |
| No Housekeeping Setback | 822 |
| Central Hot Water Fan Coil with Gas Heating | Housekeeping Setback | 182 |
| No Housekeeping Setback | 615 |

Table ‑: Peak Demand Savings for Guest Room Occupancy Sensors – Motels

|  |  |  |
| --- | --- | --- |
| **HVAC Type** | **Baseline** | **DSF (kW/ton)** |
| PTAC with Electric Resistance Heating | Housekeeping Setback | 0.10 |
| No Housekeeping Setback | 0.28 |
| PTAC with Gas Heating | Housekeeping Setback | 0.10 |
| No Housekeeping Setback | 0.28 |
| PTHP | Housekeeping Setback | 0.10 |
| No Housekeeping Setback | 0.28 |

Table ‑: Peak Demand Savings for Guest Room Occupancy Sensors – Hotels

|  |  |  |
| --- | --- | --- |
| **HVAC Type** | **Baseline** | **DSF (kW/ton)** |
| PTAC with Electric Resistance Heating | Housekeeping Setback | 0.04 |
| No Housekeeping Setback | 0.10 |
| PTAC with Gas Heating | Housekeeping Setback | 0.03 |
| No Housekeeping Setback | 0.08 |
| PTHP | Housekeeping Setback | 0.03 |
| No Housekeeping Setback | 0.09 |
| Central Hot Water Fan Coil with Electric Resistance Heating | Housekeeping Setback | 0.03 |
| No Housekeeping Setback | 0.08 |
| Central Hot Water Fan Coil with Gas Heating | Housekeeping Setback | 0.02 |
| No Housekeeping Setback | 0.06 |

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. S. Keates, ADM Associates Workpaper: “Suggested Revisions to Guest Room Energy Management (PTAC & PTHP)”, 11/14/2013 and spreadsheet summarizing the results: ‘GREM Savings Summary\_IL TRM\_1\_22\_14.xlsx.’ Five cities in IL were part of this study. Values in this protocol are based on the model for the city of Belleville, IL due to the similarity in the weather heating and cooling degree days with the city of Philadelphia, PA.

### Controls: Economizer

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Economizer |
| **Measure Life** | 10 years Source 1 |
| **Measure Vintage** | Replace on Burnout, New Construction, or Retrofit |

Dual enthalpy economizers regulate the amount of outside air introduced into the ventilation system based on the relative temperature and humidity of the outside and return air. If the enthalpy (latent and sensible heat) of the outside air is less than that of the return air when space cooling is required, then outside air is allowed in to reduce or eliminate the cooling requirement of the air conditioning equipment. Since the economizers will not be saving energy during peak hours, the demand savings are zero.

Eligibility

This measure is targeted to non-residential establishments whose HVAC equipment is not equipped with a functional economizer. The baseline condition is an HVAC unit with no economizer installed or with a non-functional/disabled economizer. The efficient condition is an HVAC unit with an economizer and dual enthalpy (differential) control. New construction installations are only eligible when not already required by IECC 2015 energy code.

Algorithms

**Replace on Burnout or New Construction**

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**Retrofit**

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Definition of Terms

Table ‑: Terms, Values, and References for Economizers

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Savings factor; Annual cooling load savings per unit area of conditioned space in the building when compared with a baseline HVAC system with no economizer. |  | 0.002 | 2 |
| , Area of conditioned space served by controlled unit | *ft2* | EDC Data Gathering | EDC Data Gathering |
| , Free cooling hours with outdoor temperature between 60 F and 70 F. Typical operating hour conditions are defined below with standard climate zones for PA. |  | See Table 3‑54 | 3 |
| , Efficiency of existing HVAC equipment. Depending on the size and age, this will either be the SEER, IEER, or EER (use EER only if SEER or IEER are not available) |  | EDC Data Gathering  Default: Table 3‑26 | See Table 3‑26 |
| , Efficiency of existing HVAC equipment. Depending on the size and age, this will either be the SEER, IEER, or EER (use EER only if SEER or IEER are not available) |  | EDC Data Gathering | EDC Data Gathering |
| 10.7 | 4 |

Table ‑: FCHr for PA Climate Zones and Various Operating Conditions

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Location** | **FCHr by Operating Schedule** | | | |
| **1 Shift, 5 days per week** | **2 Shift, 5 days per week** | **3 Shift, 5 days per week** | **24/7** |
| Allentown | 444 | 691 | 1,119 | 1,787 |
| Binghamton | 396 | 615 | 997 | 1,643 |
| Bradford | 354 | 550 | 892 | 1,469 |
| Erie | 406 | 641 | 1,033 | 1,652 |
| Harrisburg | 402 | 645 | 1,066 | 1,861 |
| Philadelphia | 432 | 663 | 1,098 | 1,772 |
| Pittsburgh | 422 | 635 | 997 | 1,708 |
| Scranton | 487 | 738 | 1,169 | 1,870 |
| Williamsport | 407 | 642 | 1,066 | 1,786 |



Default Savings

Default savings may be claimed using the algorithms above and the variable defaults along with required EDC data gathering of customer data.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Bell Jr., Arthur A., 2007. *HVAC Equations, Data, and Rules of Thumb*, second edition, pages 51-52. Assuming 500 CFM/ton (total heat of 300-500 cfm/ton @20F delta) and interior supply flow of 1 CFM/Sq Ft as rule of thumb for all spaces, divide 1 by 500 to get 0.002 ton/Sq Ft savings factor used. This is the assumed cooling load per sq ft of a typical space and what the economizer will fully compensate for during free cooling temperatures.
3. Hours calculated based on local TMY weather data with outdoor temperature between 60°F and 70°F.
4. Pennsylvania Act 129 2018 Non-Residential Baseline Study, <http://www.puc.pa.gov/Electric/pdf/Act129/SWE-Phase3_NonRes_Baseline_Study_Rpt021219.pdf>

### Computer Room Air Conditioner

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Computer Room Air Conditioner unit |
| **Measure Life** | 15 years Source 1 |
| **Measure Vintage** | Replace on Burnout, New Construction, or Early Replacement |

This protocol builds upon the existing HVAC Systems protocol to include computer room air conditioners, given their specific baseline efficiency requirements.

The energy and demand savings for Commercial and Industrial HVAC systems are determined from the algorithms shown below. Newly-installed computer room air conditioner (CRAC) systems that exceed the baseline efficiencies (in SCOP) outlined in Table 3‑56 are eligible for this measure. VFDs and other CRAC measures can be found in other sections of the TRM.

SCOP is the only recognized efficiency metric for data center equipment. Energy and demand savings should be calculated according to the specifications of the newly-installed equipment and the mandated baseline efficiencies listed in Table 3‑56.

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Table 3‑55: Terms, Values, and References for Computer Room Air Conditioners

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , Rated cooling capacity of the energy efficient unit |  | Nameplate data (AHRI) | EDC Data Gathering |
| , Sensible Coefficient of Performance of the baseline unit. | None | Early Replacement: Nameplate data | EDC Data Gathering |
| New Construction or Replace on Burnout: Default values from Table 3‑56 | 2 |
| , Sensible Coefficient of Performance of the energy efficient unit. | None | Nameplate data (AHRI) | EDC Data Gathering |
| , Coincidence factor | *Decimal* | Default = 1.0 or EDC Data Gathering | 3 |
| , Equivalent Full Load Hours for the cooling season – the kWh during the entire operating season divided by the kW at design conditions |  | Based on Logging, BMS data or Modeling | EDC Data Gathering |
| 1,000, conversion from kilowatts to watts |  | 1,000 | Conversion Factor |
| , conversion from Btu to watt-hours |  |  | Conversion Factor |

Table 3‑56: Computer Room Air Conditioner Baseline Efficiencies

| **Equipment Type** | **Net Sensible Cooling Capacitya** | **Minimum SCOP-127b Efficiency Downflow units / Upflow units** |
| --- | --- | --- |
| Air conditioners, air-cooled | 65,000 | 2.20 / 2.09 |
| 65,000 and 240,000 | 2.10 / 1.99 |
| 240,000 | 1.90 / 1.79 |
| Air conditioners, water-cooled | 65,000 | 2.60 / 2.49 |
| 65,000 and 240,000 | 2.50 / 2.39 |
| 240,000 | 2.40 / 2.29 |
| Air conditioners, water-cooled with fluid economizer | 65,000 | 2.55 / 2.44 |
| 65,000 and 240,000 | 2.45 / 2.34 |
| 240,000 | 2.35 / 2.24 |
| Air conditioners, glycol-cooled (rated at 40% propylene glycol) | 65,000 | 2.50 / 2.39 |
| 65,000 and 240,000 | 2.15 / 2.04 |
| 240,000 | 2.10 / 1.99 |
| Air conditioners, glycol-cooled (rated at 40% propylene glycol) with fluid economizer | 65,000 | 2.45 / 2.34 |
| 65,000 and 240,000 | 2.10 / 1.99 |
| 240,000 | 2.05 / 1.94 |
| a) Net sensible cooling capacity. The total gross cooling capacity less the latent cooling less the energy to the air movement system. (Total Gross – Latent – Fan Power) b) Sensible coefficient of performance (SCOP-127): a ratio calculated by dividing the net sensible cooling capacity in watts by the total power input in watts (excluding re-heaters and humidifiers) at conditions defined in ASHRAE Standard 127. The net sensible cooling capacity is the gross sensible capacity minus the energy dissipated into the cooled space by the fan system. | | |

Default Savings

this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Phase II Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, [http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018](http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx.%20Accessed%20December%202018).
2. U.S. Department of Energy. 10 CFR Part 431. Energy Efficiency Program for Certain Commercial and Industrial Equipment: Subpart F—Commercial Air Conditioners and Heat Pumps. Table 12.
3. Xcel Energy, Data Center Efficiency Deemed Savings 2016. <https://www.xcelenergy.com/staticfiles/xe/PDF/Regulatory/CO-DSM/CO-Rates-and-Reg-DSM-Data-Center-Efficiency-Deemed-Savings-2016.pdf>

### Computer Room Air Conditioner/Handler Electronically Commutated Plug Fans

|  |  |
| --- | --- |
|  |  |
| **Measure Unit** | Fan Size (HP) Installed |
| **Measure Life** | 15 years Source 1 |
| **Measure Vintage** | Replace on Burnout, Early Replacement, Retrofit, New Construction |

Data centers have significant cooling loads, due to the large internal heat gains from IT equipment. Cooling for these spaces is typically provided by computer room air conditioners (CRAC) or computer room air handlers (CRAH). CRAH units differ from CRAC units by supplying cooling via chilled water instead of direct-expansion.

Since CRAH units lack compressors and condensers, fan energy comprises the majority of their energy usage.Source 2 This document is concerned with installing or replacing the existing fans with electronically commutated (EC) plug fans. The term “plug fan” refers to a fan with no housing, typically utilizing an airfoil, backward inclined or backward curved impeller design.Source 3

Baseline fans are typically centrifugal, belt-driven fans mounted in the CRAC unit, powered by three-phase AC motors. The proposed upgrade is to replace these with EC plug fans which are direct-driven and can be mounted in-unit or underfloor. Underfloor mounting offers additional energy savings by providing a more efficient airflow path and reducing resistance on the blower.

This measure requires the installation of EC plug fans in CRAC and CRAH units. This applies to new construction applications where EC plug fans were specified instead of belt-driven fans or retrofit applications in which conventional, belt-driven fans were replaced with EC plug fans.

Installing any mechanism that could potentially modify the airflow of the supply fan on a DX system has potential to freeze the coil. Installation of any ECM on a CRAC unit should be verified with the manufacturer.

The annual energy and peak demand savings are obtained through the following formulas shown below. These formulas are adopted from Xcel Energy’sDeemed Savings Technical Assumptions for the Data Center Efficiency Program.Source 4

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |
|  |  |

Table 3‑57: Terms, Values, and References for CRAC/CRAH EC Plug Fans

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Efficiency of baseline centrifugal, forward-curved fans | None | EDC Data Gathering  Default = 53.81% | 4 |
| , Efficiency of baseline belt | None | EDC Data Gathering  Default = 95% | 6 |
| , Efficiency of baseline AC motor | None | EDC Data Gathering  Default = 91.18% | 4 |
| , Efficiency of EC plug fan | None | EDC Data Gathering  Default = 65.97% | 4 |
| , Efficiency of EC motor drive | None | EDC Data Gathering  Default = 99.5% | 4 |
| , Efficiency of EC motor | None | EDC Data Gathering  Default = 88.96% | 4 |
| , Underfloor distribution savings factor | None | If fans are located:  In Unit = 0%  Underfloor = 12.7% | 5 |
| , Comparison Load Factor. This term compares the baseline and EC system efficiencies and accounts for underfloor location (if applicable) to provide an estimate of the load on the EC system. | None | Calculated | 4 |
| , Fan power reduction | kW | Calculated | 4 |
| , Fan power replaced | HP | EDC Data Gathering | - |
| , % of CRAC/CRAH units in use | None | EDC Data Gathering  Default = 83% | 7 |
| , Efficiency of cooling system | kW/ton | EDC Data Gathering  Default = 0.95 | \* |
| , Annual hours of fan operation | Hours/year | EDC Data Gathering  Default = 8,760 | \*\* |
| kilowatt to hp conversion factor | kW/HP | 0.746 | - |
| Btu to kWh conversion factor | Btu/kWh | 3,413 | - |
| Btu to ton (cooling) conversion factor | Btu/ton | 12,000 | - |
| Coincidence factor | None | EDC Data Gathering  Default = 1.0 | \*\* |
| \* Assumes an average of air-cooled chillers and DX (all sizes) and water-cooled DX efficiencies. Water-cooled chillers were excluded from the average since they are assumed to be baseline for data centers greater than 1 MW. Source 7, pages 32, 36 and 38. \*\* Assumes data center CRAC/CRAH fans operates continuously. This is consistent with the HVAC hours for data center applications. Additionally, the CRAC/CRAH fans are assumed to operating regardless of economizer operation. | | | |

Default Savings

Table 3‑58: Default ‘per HP’ Savings for CRAC/CRAH EC Plug Fans

|  |  |  |
| --- | --- | --- |
| **Location of Plug Fan** | **Energy Savings (kWh/HP)** | **Peak Demand Reduction (kW/HP)** |
| In Unit | 1,390 | 0.1587 |
| Underfloor | 2,306 | 0.2633 |
| If Unknown | 1,848 | 0.2110 |

1. Department of Energy, Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment, December 2013. <https://energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf>
2. Emerson Network Power, Technical Note: Using EC Plug Fans to Improve Energy Efficiency of Chilled Water Cooling Systems in Large Data Centers, <http://shared.liebert.com/SharedDocuments/White%20Papers/PlugFan_Low060608.pdf>
3. ASHRAE, 2016 ASHRAE Handbook: HVAC Systems and Equipment.
4. Xcel Energy Data Center Efficiency Program,Deemed Savings Technical Assumptions*,* <https://www.xcelenergy.com/staticfiles/xe/PDF/Regulatory/CO-DSM/CO-Rates-and-Reg-DSM-Data-Center-Efficiency-Deemed-Savings-2016.pdf>
5. Technical Note: Using EC Plug Fans to Improve Energy Efficiency of Chilled Water Cooling Systems in Large Data Centers, by Emerson Power Network (<http://shared.liebert.com/SharedDocuments/White%20Papers/PlugFan_Low060608.pdf>) [UDSF value derived from EC Plug Fans vs. VFD savings table on page 5, savings from base at 100% speed.]
6. U.S. Department of Energy, Replace V-Belts with Notched or Synchronous Belt Drives, November 2012. <http://www.nrel.gov/docs/fy13osti/56012.pdf>
7. Integral Group, Energy Efficiency Baselines for Data Centers, March 1, 2013. <http://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/hightech/data_center_baseline.pdf> (Usage factor assumes 5 of 6 units operating, based on a “Redundancy = N+1” and “Safety factor on capacity = design load \* 1.20”)

### Computer Room Air Conditioner/Handler VSD on AC Fan Motors

|  |  |
| --- | --- |
|  |  |
| **Measure Unit** | Size (HP) of Fan |
| **Measure Life** | 15 years Source 1 |
| **Measure Vintage** | Retrofit, New Construction |

Data centers have significant cooling loads, due to the large internal heat gains from IT equipment. Cooling for these spaces is typically provided by computer room air conditioners (CRAC) or computer room air handlers (CRAH). CRAH units differ from CRAC units by supplying cooling via chilled water instead of direct-expansion.

Since CRAH units lack compressors and condensers, fan energy comprises the majority of their energy usage.Source 2 In addition to saving fan energy, cooling load is also reduced, resulting from the decreased energy consumption by motors within the conditioned space. This measure protocol is concerned with installing orupgrading to variable speed drives (VSDs) on existing CRAC or CRAH units.

This measure requires the installation of a VSD to control AC fan motors in CRAC and CRAH units. This applies to new construction and retrofit applications where constant speed AC fan motors are retrofitted with VSD controls.

Installing any mechanism that could potentially modify the airflow of the supply fan on a DX system has potential to freeze the coil. Installation of any VSD on a CRAC unit should be verified with the manufacturer.

The annual energy and peak demand savings are obtained through the following formulas:

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |
|  |  |

Table 3‑59: Terms, Values, and References for CRAC/CRAH VSD on AC Fan Motors

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
| , Fan motor power | HP | EDC Data Gathering | - |
| , Load factor of fan motor | None | EDC Data Gathering  Default = 75% | 4 |
| , Efficiency of AC motor | None | EDC Data Gathering  Default = 91.18% | 4 |
| 0.746, HP to kW conversion factor | kW/HP | 0.746 | - |
| , Annual hours of fan operation | Hours/year | 8,760 | 4 |
| Energy savings factor | None | 0.40 | 5 |
| , % of CRAC/CRAH units in use (usage factor) | None | EDC Data Gathering  Default = 83% | 4 |
| , conversion factor from BTU/hr to kW | BTU/hr-kW | 3,143 | - |
| conversion factor from BTUs/hr to tons of cooling | BTU/hr-ton | 12,000 | - |
| Coincidence factor | None | EDC Data Gathering  Default = 1 | 4 |
| Efficiency of cooling system | kW/ton | EDC Data Gathering  Default = 0.95 | 3 |

Default Savings

Default savings for this measure are shown in the table below.

Table 3‑60: Default Savings for CRAC/CRAH VSD on AC Fan Motors

|  |  |
| --- | --- |
| **Annual Energy Savings (kWh/HP)** | **Peak Demand Reduction (kW/HP)** |
| 2,267 | 0.2588 |

1. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. (15 years is given for non-process VSDs.) <https://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf>
2. *Technical Note: Using EC Plug Fans to Improve Energy Efficiency of Chilled Water Cooling Systems in Large Data Centers*, Emerson Network Power. Page 2. <http://shared.liebert.com/SharedDocuments/White%20Papers/PlugFan_Low060608.pdf>
3. Integral Group, Energy Efficiency Baselines for Data Centers, March 1, 2013. <http://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/hightech/data_center_baseline.pdf> (Usage factor derived from an assumption that 5 of 6 units operating, based on a “Redundancy = N+1” and “Safety factor on capacity = design load \* 1.20”. Cooling system efficiency assumes an average of air-cooled chillers and DX (all sizes) and water-cooled DX efficiencies. Water-cooled chillers were excluded from the average since they are assumed to be baseline for data centers greater than 1 MW.)
4. Xcel Energy Data Center Efficiency Program,Deemed Savings Technical Assumptions*,* <https://www.xcelenergy.com/staticfiles/xe/PDF/Regulatory/CO-DSM/CO-Rates-and-Reg-DSM-Data-Center-Efficiency-Deemed-Savings-2016.pdf>
5. Electric Power Research Institute. Energy savings factor comes from a conservative estimate based on reducing fan speed to approximately 85% (0.853= 0.61 under ideal conditions). Supported by EPRI case study: EPRI “was able to reduce is fan power use by 77%.” <http://www.datacenterknowledge.com/archives/2011/11/21/focus-on-fans-delivers-cost-savings-on-cooling/>

### Circulation Fan: High-Volume Low-Speed

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Number of Fans Installed |
| **Measure Life** | 15 years Source 1 |
| **Measure Vintage** | Replace on Burnout, Early Replacement, Retrofit, New Construction |

This protocol covers energy and demand savings associated with the installation of high-volume low-speed (HVLS) circulating fans to replace conventional circulating fans. HVLS fans generally range from 8 feet to 24 feet in diameter and move more cubic feet of air per Watt than conventional circulating fans.Source 2 This measure is for use in Commercial and Industrial applications only. For Agricultural applications, please refer to TRM Measure 4.1.5 High Volume Low Speed Fans.

Until recently, there was not a practical standard for determining performance (airflow rate, power consumption, efficiency, thrust or efficacy) of HVLS fans.Source 3 *ANSI/AMCA Standard 230-15 Laboratory Methods of Testing Air Circulating Fans for Rating and Certification* now provides a uniform testing procedure that includes HVLS fans. However, based on a late-2018 review of product specifications the results of this standard are not yet incorporated into product documentation.

This measure requires the installation of HVLS fans (diameters ranging from 8 to 24 feet) in either new construction or retrofit applications where conventional circulating fans are replaced.

The annual energy and peak demand savings are obtained through the following formulas:

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |
|  |  |

Table 3‑61: Terms, Values, and References for HVLS Fans

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Conventional fan wattage | *W* | EDC Data Gathering | 4 |
| Default values in Table 3‑62 |
| , HVLS fan wattage | *W* | EDC Data Gathering | 4 |
| Default values in Table 3‑62 |
| , Annual hours of fan operation | *Hours/year* | EDC Data Gathering | 5 |
| Default values in Table 3‑63 |
| *,* Conversion factor |  | 1,000 | - |
| , Coincidence factor | *None* | Default values in Table 3‑28 | 5 |

Table 3‑62: Default Values for Conventional and HVLS Fan Wattages

|  |  |  |
| --- | --- | --- |
| **Fan Diameter (ft)** |  |  |
| ≥ 8 and < 10 | 2,227 | 377 |
| ≥ 10 and < 12 | 2,784 | 471 |
| ≥ 12 and < 14 | 3,341 | 565 |
| ≥ 14 and < 16 | 3,898 | 659 |
| ≥ 16 and < 18 | 4,497 | 761 |
| ≥ 18 and < 20 | 5,026 | 850 |
| ≥ 20 and < 24 | 5,555 | 940 |
| ≥ 24 | 6,613 | 1,119 |

Table 3‑63: Default Hours of Use by Building Type and Region

| **Space and/or Building Type** | **Allentown** | **Binghamton** | **Bradford** | **Erie** | **Harrisburg** | **Philadelphia** | **Pittsburgh** | **Scranton** | **Williamsport** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Education - College/University | 1,359 | 1,424 | 1,447 | 1,335 | 1,208 | 1,198 | 1,244 | 1,356 | 1,250 |
| Education - Other | 902 | 1,073 | 1,158 | 851 | 1,051 | 991 | 1,157 | 1,142 | 894 |
| Grocery | 1,387 | 1,610 | 1,610 | 1,170 | 1,722 | 1,753 | 1,202 | 2,171 | 1,861 |
| Health - Hospital | 1,177 | 1,058 | 1,048 | 1,133 | 1,253 | 1,404 | 1,206 | 1,128 | 1,167 |
| Health - Other | 1,421 | 1,829 | 1,980 | 1,785 | 1,394 | 1,489 | 1,534 | 1,660 | 1,434 |
| Industrial Manufacturing | 976 | 861 | 876 | 884 | 989 | 1,021 | 929 | 886 | 824 |
| Institutional/Public Service | 1,931 | 2,005 | 2,174 | 2,044 | 1,918 | 2,208 | 1,869 | 2,030 | 1,751 |
| Lodging | 3,757 | 4,424 | 4,930 | 4,469 | 3,682 | 3,749 | 3,889 | 3,939 | 3,787 |
| Multi-Family (Common Areas) | 1,672 | 974 | 931 | 1,091 | 1,745 | 1,906 | 1,440 | 1,272 | 1,330 |
| Office | 778 | 372 | 850 | 834 | 895 | 984 | 1,064 | 828 | 806 |
| Restaurant | 1,701 | 2,294 | 2,483 | 2,200 | 1,630 | 1,784 | 1,972 | 2,023 | 1,835 |
| Retail | 1,544 | 1,620 | 1,686 | 1,600 | 1,390 | 1,543 | 1,597 | 1,458 | 1,323 |
| Warehouse - Other | 1,021 | 1,205 | 1,344 | 1,228 | 1,078 | 1,246 | 1,170 | 1,138 | 978 |
| Warehouse - Refrigerated | 3,493 | 3,661 | 3,678 | 3,614 | 3,470 | 3,422 | 3,525 | 3,533 | 3,463 |

Default Savings

There are no default savings for this measure.

Evaluation Protocols

1. State of Wisconsin. Focus on Energy Evaluation, Business Program: Measure Life Study Final Report: August 25, 2009. Appendix B, Pages 65-66. <https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf>
2. Survey of available HVLS fans from the following manufacturers: Big Ass Fans, Go Fan Yourself, Kelley, MacroAir, Patterson Fan Company and Rite-Hite.
3. Taber, Christian. *The Thrust of ANSI/AMCA Standard 230-15, Circulator Fan Performance Testing Standards.* ASHRAE Journal, September 2015. <http://bookstore.ashrae.biz/journal/download.php?file=2015Sept_028-039_Taber.pdf>
4. The wattage information for fan diameters of 8 feet through 14 feet have been extrapolated from existing wattage data in *IPL Energy Efficiency Programs 2009 Evaluation*, KEMA Inc. Appendix H, Table H-17. February 14, 2012.
5. Hours of use are assumed to match the HOU of Circulating fans (the sum of EFLHHeat and EFLHCool). EFLHs and CFs for Pennsylvania are calculated based on Nexant’s eQuest modeling analysis 2014.

## Motors and VFDs

### 

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Motor |
| **Measure Life** | 15 years Source 1 |
| **Measure Vintage** | Replace on Burnout, New Construction, or Early Replacement |

Eligibility

For constant speed and uniformly loaded motors, the prescriptive measurement and verification protocols described below apply to the replacement of old motors with new energy efficient motors of the same rated horsepower and for New Construction. Replacements where the old motor and new motor have different horsepower ratings are considered custom measures. Motors with variable speeds, variable loading, or industrial-specific applications are also considered custom measures.

Note that the Coincidence Factor (CF) and Run Hours of Use (RHRS) for motors specified below do not take into account systems with multiple motors serving the same load, such as duplex motor sets with a lead-lag setup. Under these circumstances, a custom measure protocol is required.

Algorithms

The energy and demand savings for this measure depend on the size and efficiency of the efficient motor, calculated according to the following algorithms:

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

Definition of Terms

Table ‑: Terms, Values, and References for Premium Efficiency Motors

| **Term** | **Unit** | **Value** | **Source** |
| --- | --- | --- | --- |
| , Rated horsepower of the baseline and energy efficient motor | *HP* | Nameplate | EDC Data Gathering |
| , Conversion factor for HP to kWh | *kWh/HP* | 0.746 | Conversion factor |
| , Annual run hours of the motor |  | Based on logging, panel data or modeling[[33]](#footnote-100) | EDC Data Gathering |
| Default: Table 3‑67 to Table 3‑71 | 2 |
| 37, Load Factor. Ratio between the actual load and the rated load. Variable loaded motors should use custom measure protocols. | *None* | Based on spot metering and nameplate | EDC Data Gathering |
| Default, fans: 0.76  Default, pumps: 0.79 | 3 |
| , Efficiency of the baseline motor. If a new motor was purchased as an alternative to rewinding an old motor, the nameplate efficiency of the old motor may be used as the baseline. | *None* | Early Replacement: Nameplate | EDC Data Gathering |
| New Construction or Replace on Burnout: Default comparable standard motor.  See  Table 3‑65 and Table 3‑66 | 4 |
| , Efficiency of the energy-efficient motor | *None* | Nameplate | EDC Data Gathering |
| Coincidence factor | *Decimal* | EDC Data Gathering | EDC Data Gathering |
| Table 3‑67 to Table 3‑71 | 2 |

Table ‑: Baseline Efficiencies for NEMA Design A and NEMA Design B Motors

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Motor HP** | **Motor Nominal Full-Load Efficiencies (percent)** | | | | | | | |
| **2 Pole (3600 RPM)** | | **4 pole (1800 RPM)** | | **6 Pole (1200 RPM)** | | **8 Pole (900 RPM)** | |
| **Enclosed** | **Open** | **Enclosed** | **Open** | **Enclosed** | **Open** | **Enclosed** | **Open** |
| 1 | 77.0 | 77.0 | 85.5 | 85.5 | 82.5 | 82.5 | 75.5 | 75.5 |
| 1.5 | 84.0 | 84.0 | 86.5 | 86.5 | 87.5 | 86.5 | 78.5 | 77.0 |
| 2 | 85.5 | 85.5 | 86.5 | 86.5 | 88.5 | 87.5 | 84.0 | 86.5 |
| 3 | 86.5 | 85.5 | 89.5 | 89.5 | 89.5 | 88.5 | 85.5 | 87.5 |
| 5 | 88.5 | 86.5 | 89.5 | 89.5 | 89.5 | 89.5 | 86.5 | 88.5 |
| 7.5 | 89.5 | 88.5 | 91.7 | 91.0 | 91.0 | 90.2 | 86.5 | 89.5 |
| 10 | 90.2 | 89.5 | 91.7 | 91.7 | 91.0 | 91.7 | 89.5 | 90.2 |
| 15 | 91.0 | 90.2 | 92.4 | 93.0 | 91.7 | 91.7 | 89.5 | 90.2 |
| 20 | 91.0 | 91.0 | 93.0 | 93.0 | 91.7 | 92.4 | 90.2 | 91.0 |
| 25 | 91.7 | 91.7 | 93.6 | 93.6 | 93.0 | 93.0 | 90.2 | 91.0 |
| 30 | 91.7 | 91.7 | 93.6 | 94.1 | 93.0 | 93.6 | 91.7 | 91.7 |
| 40 | 92.4 | 92.4 | 94.1 | 94.1 | 94.1 | 94.1 | 91.7 | 91.7 |
| 50 | 93.0 | 93.0 | 94.5 | 94.5 | 94.1 | 94.1 | 92.4 | 92.4 |
| 60 | 93.6 | 93.6 | 95.0 | 95.0 | 94.5 | 94.5 | 92.4 | 93.0 |
| 75 | 93.6 | 93.6 | 95.4 | 95.0 | 94.5 | 94.5 | 93.6 | 94.1 |
| 100 | 94.1 | 93.6 | 95.4 | 95.4 | 95.0 | 95.0 | 93.6 | 94.1 |
| 125 | 95.0 | 94.1 | 95.4 | 95.4 | 95.0 | 95.0 | 94.1 | 94.1 |
| 150 | 95.0 | 94.1 | 95.8 | 95.8 | 95.8 | 95.4 | 94.1 | 94.1 |
| 200 | 95.4 | 95.0 | 96.2 | 95.8 | 95.8 | 95.4 | 94.5 | 94.1 |
| 250 | 95.8 | 95.0 | 96.2 | 95.8 | 95.8 | 95.8 | 95.0 | 95.0 |
| 300 | 95.8 | 95.4 | 96.2 | 95.8 | 95.8 | 95.8 | N/A | N/A |
| 350 | 95.8 | 95.4 | 96.2 | 95.8 | 95.8 | 95.8 | N/A | N/A |
| 400 | 95.8 | 95.8 | 96.2 | 95.8 | N/A | N/A | N/A | N/A |
| 450 | 95.8 | 96.2 | 96.2 | 96.2 | N/A | N/A | N/A | N/A |
| 500 | 95.8 | 96.2 | 96.2 | 96.2 | N/A | N/A | N/A | N/A |

Table ‑: Baseline Motor Efficiencies for NEMA Design C Motors

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Motor HP** | **Motor Nominal Full-Load Efficiencies (percent)** | | | | | |
| **4 Pole (1800 RPM)** | | **6 Pole (1200 RPM)** | | **8 Pole (900 RPM)** | |
| **Enclosed** | **Open** | **Enclosed** | **Open** | **Enclosed** | **Open** |
| 1 | 85.5 | 85.5 | 82.5 | 82.5 | 75.5 | 75.5 |
| 1.5 | 86.5 | 86.5 | 87.5 | 86.5 | 78.5 | 77.0 |
| 2 | 86.5 | 86.5 | 88.5 | 87.5 | 84.0 | 86.5 |
| 3 | 89.5 | 89.5 | 89.5 | 88.5 | 85.5 | 87.5 |
| 5 | 89.5 | 89.5 | 89.5 | 89.5 | 86.5 | 88.5 |
| 7.5 | 91.7 | 91.0 | 91.0 | 90.2 | 86.5 | 89.5 |
| 10 | 91.7 | 91.7 | 91.0 | 91.7 | 89.5 | 90.2 |
| 15 | 92.4 | 93.0 | 91.7 | 91.7 | 89.5 | 90.2 |
| 20 | 93.0 | 93.0 | 91.7 | 92.4 | 90.2 | 91.0 |
| 25 | 93.6 | 93.6 | 93.0 | 93.0 | 90.2 | 91.0 |
| 30 | 93.6 | 94.1 | 93.0 | 93.6 | 91.7 | 91.7 |
| 40 | 94.1 | 94.1 | 94.1 | 94.1 | 91.7 | 91.7 |
| 50 | 94.5 | 94.5 | 94.1 | 94.1 | 92.4 | 92.4 |
| 60 | 95.0 | 95.0 | 94.5 | 94.5 | 92.4 | 93.0 |
| 75 | 95.4 | 95.0 | 94.5 | 94.5 | 93.6 | 94.1 |
| 100 | 95.4 | 95.4 | 95.0 | 95.0 | 93.6 | 94.1 |
| 125 | 95.4 | 95.4 | 95.0 | 95.0 | 94.1 | 94.1 |
| 150 | 95.8 | 95.8 | 95.8 | 95.4 | 94.1 | 94.1 |
| 200 | 96.2 | 95.8 | 95.8 | 95.4 | 94.5 | 94.1 |

Table ‑: Default RHRS and CFs for Supply Fan Motors in Commercial Buildings[[34]](#footnote-103)

| **Facility Type** | **Parameter** | **Allentown** | | **Binghamton** | | **Bradford** | | **Erie** | | | **Harrisburg** | | | **Philadelphia** | | | **Pittsburgh** | | | **Scranton** | | | **Williamsburg** | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Education - College / University | CF | 0.43 | | 0.30 | | 0.24 | | 0.32 | | | 0.44 | | | 0.47 | | | 0.42 | | | 0.38 | | | 0.44 | | | |
| Run Hours | 6,042 | | 6,054 | | 6,126 | | 6,139 | | | 5,860 | | | 5,966 | | | 5,982 | | | 5,876 | | | 5,905 | | | |
| Education - Other | CF | 0.12 | | 0.08 | | 0.07 | | 0.09 | | | 0.17 | | | 0.18 | | | 0.18 | | | 0.12 | | | 0.15 | | | |
|  | Run Hours | 4,380 | | 4,583 | | 4,718 | | 4,572 | | | 4,313 | | | 4,384 | | | 4,415 | | | 4,490 | | | 4,377 | | | |
| Grocery | CF | 0.24 | | 0.21 | |  | | | 0.19 | | | 0.22 | | | 0.24 | | | 0.26 | | | 0.29 | | | | 0.21 | | | 0.24 | | |
|  | Run Hours | 6,708 | | 6,764 | | 6,810 | | 6,738 | | | 6,692 | | | 6,669 | | | 6,718 | | | 6,725 | | | 6,710 | | | |
| Health - Hospital | CF | 0.43 | | 0.24 | | 0.29 | | 0.39 | | | 0.45 | | | 0.51 | | | 0.45 | | | 0.40 | | | 0.41 | | | |
| Run Hours | 8,760 | | 8,760 | | 8,760 | | 8,760 | | | 8,760 | | | 8,760 | | | 8,760 | | | 8,760 | | | 8,760 | | | |
| Health - Other | CF | 0.24 | | 0.21 | | 0.17 | | 0.23 | | | 0.29 | | | 0.31 | | | 0.29 | | | 0.25 | | | 0.28 | | | |
| Run Hours | 8,760 | | 8,760 | | 8,760 | | 8,760 | | | 8,760 | | | 8,760 | | | 8,760 | | | 8,760 | | | 8,760 | | | |
| Industrial Manufacturing | CF | 0.48 | | 0.34 | | 0.28 | | 0.38 | | | 0.53 | | | 0.57 | | | 0.50 | | | 0.43 | | | 0.46 | | | |
| Run Hours | 3,831 | | 3,981 | | 4,080 | | 3,977 | | | 3,769 | | | 3,838 | | | 3,869 | | | 3,902 | | | 3,829 | | | |
| Institutional / Public Service | CF |  | | 0.38 | | 0.34 | | 0.45 | | | 0.60 | | | 0.72 | | | 0.56 | | | 0.47 | | |  | | | | |  | | |  | |  | | | 0.52 |
| Run Hours | 5,188 | | 5,223 | | 5,248 | | 5,217 | | | 5,172 | | | 5,186 | | | 5,201 | | | 5,207 | | | 5,184 | | | |
| Lodging | CF | 0.64 | | 0.64 | |  | | 0.65 | | | 0.71 | | | 0.71 | | | 0.73 | | | 0.65 | | | 0.71 | | | |
|  | 8,760 | |  | |  | |  | | | 8,760 | | | 8,760 | | | 8,760 | | | 8,760 | | | 8,760 | | | |
| Office | CF | 0.30 | | 0.26 | | 0.21 | | 0.28 | | | 0.37 | | | 0.39 | | | 0.35 | | | 0.32 | | | 0.34 | | | |  | | | |  | |  | |
| Run Hours | 4,195 | | 4,473 | | 4,699 | | 4,441 | | | 4,087 | | | 4,063 | | | 4,240 | | | 4,228 | | | 4,139 | | | |
| Restaurant | CF |  |  | |  | |  | | |  | | | 0.38 | | | 0.19 | | | 0.28 | | |  | | | | 0.42 | | | | 0.50 | |  | | 0.39 | | 0.45 |
| Run Hours | 6,282 | | 2,680 | | 6,487 | | 6,365 | | | 6,252 | | | 6,226 | | | 6,300 | | | 6,315 | | | 6,286 | | | |  | | | |  | |
| Retail | CF | 0.50 | | 0.40 | | 0.36 | | 0.44 | | | 0.53 | | | 0.56 | | | 0.54 | | | 0.45 | | | 0.49 | | | |
| Run Hours | 5,137 | | 5,188 | | 5,234 | | 5,158 | | | 5,108 | | | 5,092 | | | 5,146 | | | 5,149 | | | 5,134 | | | |
| Warehouse - Other | CF | 0.18 | | 0.11 | | 0.10 | | 0.13 | | | 0.24 | | | 0.30 | | | 0.23 | | | 0.15 | | | 0.20 | | | |
|  | Run Hours | 5,037 | | 5,189 | | 5,259 | | 5,222 | | | 4,980 | | | 5,168 | | | 5,110 | | | 5,188 | | | 5,028 | | | |
| Warehouse - Refrigerated | CF | 0.50 | | 0.46 | | 0.43 | | 0.48 | | | 0.52 | | | 0.53 | | | 0.51 | | | 0.48 | | | 0.51 | | | |
| Run Hours | 4,041 | | 4,041 | | 4,041 | | 4,041 | | | 4,041 | | | 4,041 | | | 4,041 | | | 4,041 | | | 4,041 | | | |

Table ‑: Default RHRS and CFs for Chilled Water Pump (CHWP) Motors in Commercial Buildings[[35]](#footnote-104)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Facility Type** | **Parameter** | **Allentown** | **Binghamton** | **Bradford** | **Erie** | | **Harrisburg** | | | **Philadelphia** | | **Pittsburgh** | | | **Scranton** | | **Williamsburg** | | |
| Education – College / University | CF | 0.41 | 0.27 | 0.23 | 0.30 | | 0.42 | | | 0.45 | | 0.40 | | | 0.33 | | 0.40 | | |
| Run Hours | 4,007 | 3,436 | 3,096 | 3,641 | | 4,057 | | | 4,311 | |  | | | 3,828 | | 3,872 | | |
| Education - Other | CF | 0.10 | 0.08 | 0.07 | 0.09 | | 0.18 | | | 0.18 | | 0.17 | | | 0.12 | | 0.16 | | |
| Run Hours |  | 2,721 | 1,849 | | 1,631 | | 2,175 | | | 2,730 | | 3,505 | | 2,676 | | | 2,310 | | | 2,573 | | |
| Health - Hospital | CF | 0.46 |  |  |  | | 0.38 | | | 0.31 | | 0.42 | | 0.50 | | 0.54 | | | 0.48 | | | | 0.44 | |  |
| Run Hours | 5,588 | 4,801 | 4,167 | 5,109 | | 5,717 | | | 6,086 | | 5,593 | | | 5,266 | | 5,628 | | |
| Health - Other | CF | 0.24 | 0.20 | 0.16 | 0.22 | | 0.28 | | | 0.30 | | 0.28 | | | 0.23 | | 0.26 | | |
| Run Hours | 3,892 | 3,093 | 2,592 | 3,456 | | 4,104 | | | 4,535 | | 3,900 | | | 3,710 | | 3,818 | | |
| Industrial Manufacturing | CF | 0.53 | 0.40 | 0.32 | 0.43 | | 0.53 | | | 0.58 | | 0.54 | | | 0.48 | | 0.50 | | |
|  | Run Hours | 1,735 | 1,306 | 1,086 | 1,448 | | 1,742 | | | 1,891 | | 1,606 | | | 1,558 | | 1,633 | | |
| Lodging | CF | 0.61 | 0.58 | 0.53 | 0.60 | | 0.66 | | | 0.67 | | 0.69 | | | 0.59 | | 0.66 | | |
| Run Hours |  | 5,042 | 4,444 | 5,198 | |  | | |  | | 5,686 | | | 5,655 | | 5,776 | | |
| Office | CF | 0.29 | 0.25 | 0.20 | 0.27 | | 0.35 | | | 0.36 | |  | | | 0.33 | | | 0.29 | | | 0.32 | | |
| Run Hours | 1,789 | 1,402 | 1,189 | 1,585 | | 1,804 | | | 2,036 | | 1,739 | | | 1,638 | | 1,711 | | |
| Retail | CF | 0.46 |  | 0.33 | |  | | | |  | | 0.28 | | 0.38 | | 0.53 | | | 0.54 | | | |  | | 0.42 | 0.47 |
| Run Hours | 2,957 | 2,416 | 2,012 | 2,653 | | 3,085 | | | 3,225 | | 2,795 | | | 2,735 | | 2,898 | | |

Table ‑: Default RHRS and CFs for Cooling Tower Fan (CTF) Motors in Commercial Buildings[[36]](#footnote-105)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Facility Type** | **Parameter** | **Allentown** | **Binghamton** | **Bradford** | **Erie** | | **Harrisburg** | | **Philadelphia** | **Pittsburgh** | | **Scranton** | | **Williamsburg** | | |
| Education – College / University | CF | 0.41 | 0.26 | 0.23 | 0.30 | | 0.42 | | 0.45 | 0.40 | | 0.33 | | 0.39 | | |
| Run Hours | 4,006 | 3,435 | 3,096 | 3,641 | | 4,057 | | 4,309 | 3,914 | | 3,827 | | 3,871 | | |
| Education - Other | CF | 0.11 | 0.08 | 0.07 | 0.09 | | 0.18 | | 0.18 | 0.17 | | 0.12 | | 0.17 | | |
| Run Hours | 2,742 | 1,851 | 1,634 | 2,178 | |  | | 3,517 | 2,685 | | 2,313 | | 2,604 | | |
| Health - Hospital | CF | 0.45 | 0.37 |  |  | |  | | 0.31 | 0.41 |  | | 0.54 | | |  | | | |  | | 0.46 |
| Run Hours | 5,587 | 4,798 | 4,165 | 5,107 | | 5,714 | | 6,084 | 5,591 | | 5,263 | | 5,626 | | |
| Health - Other | CF | 0.24 | 0.20 | 0.16 | 0.22 | | 0.28 | | 0.30 | 0.28 | | 0.23 | | 0.26 | | |
| Run Hours | 3,894 | 3,093 | 2,593 | 3,457 | | 4,106 | | 4,537 | 3,902 | | 3,711 | | 3,819 | | |
| Industrial Manufacturing | CF | 0.53 | 0.40 | 0.32 | 0.43 | | 0.54 | | 0.59 | 0.54 | | 0.48 | | 0.50 | | |
| Run Hours | 1,735 | 1,306 | 1,086 | 1,448 | | 1,742 | | 1,891 | 1,606 | | 1,558 | | 1,633 | | |
| Lodging | CF | 0.61 | 0.58 | 0.53 | 0.61 | | 0.67 | | 0.68 | 0.70 | | 0.59 | | 0.66 | | |  | | | |  | |
| Run Hours |  | 5,039 | 4,442 | 5,197 | |  | | 6,159 |  | |  | | 5,773 | | |
| Office | CF | 0.29 | 0.25 | 0.20 | 0.27 | | 0.35 | | 0.36 |  | | 0.33 | | | 0.29 | | | 0.32 | | |
| Run Hours | 1,789 | 1,402 | 1,189 | 1,585 | | 1,804 | | 2,036 | 1,739 | | 1,638 | | 1,711 | | |
| Retail | CF | 0.46 |  | | 0.33 | |  | |  | 0.28 | 0.38 | | 0.53 | | |  | | | |  | |  | 0.47 |
| Run Hours | 2,957 | 2,416 | 2,012 | 2,653 | | 3,085 | | 3,226 | 2,795 | | 2,736 | | 2,898 | | |

Table ‑: Default RHRS and CFs for Heating Hot Water Pump (HHWP) Motors in Commercial Buildings[[37]](#footnote-106)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Facility Type** | | **Parameter** | **Allentown** | | **Binghamton** | | **Bradford** | | **Erie** | **Harrisburg** | | **Philadelphia** | | | **Pittsburgh** | | | **Scranton** | | | **Williamsburg** | |
| Education – College / University | | CF | 0.01 | | 0.01 | | 0.01 | | 0.01 | 0.00 | | 0.00 | | | 0.01 | | | 0.01 | | | 0.01 | |
| Run Hours | 4,548 | | 5,271 | | 5,900 | | 5,036 | 4,250 | | 4,014 | | | 4,572 | | | 4,638 | | | 4,487 | |  | |
| Education - Other | | CF | 0.00 | | 0.00 | | 0.00 | | 0.00 | 0.00 | | 0.00 | | | 0.00 | | | 0.00 | | | 0.00 | |
| Run Hours | 3,651 | |  | | 4,251 | | 4,722 | | 4,080 | |  | | | 3,341 | | | 3,705 | | | 3,830 | |  |
| Health - Hospital | | CF | 0.09 | | 0.09 | | 0.09 | | 0.09 | 0.09 | | 0.09 | | | 0.09 | | | 0.09 | | | 0.09 | |
| Run Hours | 8,760 | | 8,760 | | 8,760 | | 8,760 | 8,760 | | 8,760 | | | 8,760 | | | 8,760 | | | 8,760 | |
| Health - Other | | CF | 0.00 | | 0.00 | | 0.00 | | 0.00 | 0.00 | | 0.00 | | | 0.00 | | | 0.00 | | | 0.00 | |
| Run Hours |  | | 6,627 | | 7,170 | | 6,280 |  | |  | | | 5,991 | | | 6,223 | | | 6,045 | |
| Industrial Manufacturing | | CF | 0.00 | | 0.00 | | 0.00 | | 0.00 | 0.00 | | 0.00 | | | 0.00 | | | 0.00 | | | 0.00 | |
| Run Hours | 1,258 | | 1,684 | | 1,944 | | 1,555 | 1,184 | | 1,028 | | | 1,287 | | | 1,393 | | | 1,277 | |
| Lodging | | CF | 0.00 | | 0.00 | | 0.00 | | 0.00 | 0.00 | | 0.00 | | | 0.00 | | | 0.00 | | | 0.00 | |
|  | 6,469 | | 7,072 | | 7,587 | | 6,829 | 6,155 | | 6,077 | | | 6,574 | | | 6,628 | | | 6,387 | |
| Office | | CF | 0.00 | | 0.00 | | 0.00 | | 0.00 | 0.00 | | 0.00 | | | 0.00 | | | 0.00 | | | 0.00 | |
| Run Hours | 3,214 | | 3,876 | | 4,446 | | 3,611 | 3,014 | | 2,690 | | | 3,246 | | | 3,336 | | | 3,169 | |
| Retail | | CF | 0.00 | | 0.00 | | 0.00 | | 0.00 | 0.00 | | 0.00 | | | 0.00 | | | 0.00 | | | 0.00 | |
|  | | Run Hours | 2,676 | | 3,183 | | 3,568 | | 2,960 | 2,561 | | 2,398 | | | 2,908 | | | 2,841 | | | 2,660 | |

Table ‑: Default RHRS and CFs for Condenser Water Pump Motors in Commercial Buildings[[38]](#footnote-107)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Facility Type** | | **Parameter** | **Allentown** | | **Binghamton** | | **Bradford** | | **Erie** | **Harrisburg** | | **Philadelphia** | | **Pittsburgh** | | **Scranton** | | | **Williamsburg** | |
| Education - College / University | | CF | 0.41 | | 0.26 | | 0.20 | | 0.30 | 0.42 | | 0.45 | | 0.40 | | 0.33 | | | 0.39 | |
| Run Hours | 3,527 | | 2,938 | | 2,466 | | 3,063 | 3,602 | | 4,030 | | 3,749 | | 3,500 | | | 3,489 | |
| Education - Other | | CF | 0.11 | | 0.08 | | 0.07 | | 0.09 | 0.18 | | 0.18 | | 0.17 | | 0.12 | | | 0.17 | |
| Run Hours | 2,448 | | 1,733 | | 1,529 | | 2,039 | 2,539 | | 3,346 | |  | | 2,164 | | | 2,423 | |  | |  | |
| Health - Hospital | | CF | 0.45 | |  | | 0.29 | | 0.41 | 0.49 | | 0.54 | | 0.47 | | 0.44 | | | 0.46 | |
| Run Hours | 3,950 | | 3,546 | | 3,293 | | 3,698 | 3,687 | | 4,168 | | 4,093 | | 3,713 | | | 3,670 | |
| Health - Other | | CF | 0.24 | | 0.20 | | 0.16 | | 0.22 | 0.28 | | 0.30 | | 0.28 | | 0.23 | | | 0.26 | |
| Run Hours | 3,675 | | 3,100 | | 2,585 | | 3,394 | 3,725 | | 4,304 | | 3,571 | | 3,687 | | | 3,722 | |
| Industrial Manufacturing | | CF | 0.53 | | 0.40 | | 0.32 | | 0.43 | 0.54 | | 0.59 | | 0.54 | | 0.48 | | | 0.50 | |
| Run Hours | 1,735 | | 1,305 | | 1,084 | | 1,445 | 1,737 | | 1,889 | | 1,602 | | 1,558 | | | 1,632 | |
| Lodging | | CF | 0.61 | | 0.58 | | 0.53 | | 0.61 | 0.67 | | 0.68 | | 0.70 | | 0.59 | | | 0.66 | |  | |  | |
| Run Hours | 5,544 | | 4,591 | | 3,939 | | 4,766 | 5,569 | | 5,886 | | 5,239 | | 5,353 | | |  | |
| Office | | CF | 0.29 | | 0.25 | | 0.20 | | 0.27 |  | | 0.36 | |  | | 0.33 | | | 0.29 | | 0.32 | |
| Run Hours | 1,781 | | 1,389 | | 1,177 | | 1,569 | 1,792 | | 2,027 | | 1,730 | | 1,631 | | | 1,702 | |
| Retail | | CF | 0.46 | |  | | 0.33 | |  | |  | | 0.28 | | 0.38 | | 0.53 | | |  | | 0.47 | |  | | 0.47 |
| Run Hours | 2,889 | | 2,381 | | 1,986 | | 2,616 | 3,025 | | 3,185 | | 2,757 | | 2,702 | | | 2,847 | |

Default Savings

There are no default savings for this measure.

Evaluation Protocols

Motor projects achieving expected kWh savings of 250,000 kWh or higher must[[39]](#footnote-108) be metered to calculate *ex ante* and/or *ex post* savings. Metering is not mandatory where the motors in question are constant speed and hours can be easily verified through a building automation system schedule that clearly shows motor run time.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Phase II SWE team modeling, described in the 2015 Tentative Order Section E.3.c, [http://www.puc.pa.gov/pcdocs/1311852.docx. Accessed December 2018](http://www.puc.pa.gov/pcdocs/1311852.docx.%20Accessed%20December%202018).
3. Regional Technical Forum. *Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors.* November 5, 2012. Appendix C, Table 6.
4. “Energy Conservation Program: Energy Conservation Standards for Commercial and Industrial Electric Motors; Final Rule,” 79 Federal Register 103 (29 May 2014). <https://www.gpo.gov/fdsys/pkg/FR-2014-05-29/html/2014-11201.htm>

### Variable Frequency Drive (VFD) Improvements

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Variable Frequency Drive |
| **Measure Life** | 15 years Source 1 |
| **Measure Vintage** | New Construction or Retrofit |

The following protocol for the measurement of energy and demand savings applies to the installation of Variable Frequency Drives (VFDs) in standard commercial building applications – supply and return fans, cooling tower fans, chilled water pumps, and heating water pumps. The baseline condition is a motor without a VFD control. The efficient condition is a motor with a VFD control.

Installations of new equipment with VFDs which are required by energy codes adopted by the State of Pennsylvania are not eligible for incentives



The energy and demand savings associated with this measure depend on the size of the affected motor and the motor’s load profile. Savings are calculated using the following algorithms:

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

of Terms

Table ‑: Terms, Values, and References for VFDs

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , Rated horsepower of the motor | *HP* | Nameplate | EDC Data Gathering |
| , Conversion factor for HP to kWh | *kWh/HP* | 0.746 | Conversion factor |
| [[40]](#footnote-110)Annual run hours of the baseline motor |  | Based on logging, panel data, or modeling | EDC Data Gathering |
| Default: Table 3‑67 to Table 3‑71 | 2 |
| Load Factor. Ratio between the actual load and the rated load. | *None* | Based on spot metering and nameplate | EDC Data Gathering |
| Default for fans: 0.76  Default for pumps: 0.79 | 3 |
| , Motor efficiency at the full-rated load. For VFD installations, this can be either an energy efficient motor or standard efficiency motor. | *Percent* | Nameplate | EDC Data Gathering |
| , Percentage of runtime spent within a given flow fraction range | *Percent* | Based on logging, panel data, or modeling | EDC Data Gathering |
| Default: Table 3‑73 | 4 |
| , Part load ratio for a given flow fraction range based on the baseline flow control type | *Percent* | Default: Table 3‑74 to Table 3‑75 | 4 |
| , Part load ratio for a given flow fraction range with installed VFD | *Percent* | Default: Table 3‑74 to Table 3‑75 | 4 |
| , Part load ratio for the average flow fraction during the peak period on the baseline flow control type | *Percent* | Based on logging, panel data, or modeling | EDC Data Gathering |
| Default: | 5 |
| , Part load ratio for the average flow fraction during the peak period on the efficient flow control type | *Percent* | Based on logging, panel data, or modeling | EDC Data Gathering |
| Default: | 5 |

Table 3‑73: Default Load Profiles for HVAC Fans and Pumps

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Equipment Type** | **Flow Fraction (%)** | | | | | | | | | | |
| **0** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** |
| HVAC Fan | 0% | 0% | 0% | 0% | 0% | 10% | 20% | 30% | 20% | 15% | 5% |
| HVAC Pump | 0% | 0% | 0% | 5% | 10% | 20% | 30% | 20% | 10% | 5% | 0% |



Table ‑74: Supply/Return and Cooling Tower Fan Power Part Load Ratios

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Control Type** | **Flow Fraction (%)** | | | | | | | | | | |
| **0** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** |
| Constant Volume | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Two-Speed | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Air Foil/Backward Incline | 0.56 | 0.53 | 0.53 | 0.57 | 0.64 | 0.72 | 0.80 | 0.89 | 0.96 | 1.02 | 1.05 |
| Air Foil/Backward Incline with Inlet Guide Vanes | 0.47 | 0.53 | 0.56 | 0.57 | 0.59 | 0.60 | 0.62 | 0.67 | 0.74 | 0.85 | 1.00 |
| Forward Curved | 0.20 | 0.22 | 0.26 | 0.30 | 0.37 | 0.45 | 0.54 | 0.65 | 0.77 | 0.91 | 1.06 |
| Forward Curved with Inlet Guide Vanes | 0.20 | 0.21 | 0.22 | 0.23 | 0.26 | 0.31 | 0.39 | 0.49 | 0.63 | 0.81 | 1.04 |
| Variable Frequency Drive | 0.05 | 0.05 | 0.05 | 0.08 | 0.13 | 0.20 | 0.30 | 0.43 | 0.60 | 0.80 | 1.03 |

Table 3‑75: HVAC Pump Power Part Load Ratios

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Control Type** | **Flow Fraction (%)** | | | | | | | | | | |
| **0** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** |
| Constant Volume | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Throttle Valve | 0.55 | 0.61 | 0.67 | 0.73 | 0.78 | 0.82 | 0.87 | 0.90 | 0.94 | 0.97 | 1.00 |
| Variable Frequency Drive | 0.27 | 0.19 | 0.14 | 0.13 | 0.15 | 0.21 | 0.30 | 0.43 | 0.60 | 0.79 | 1.03 |

**Methods for Determining Baseline Conditions**

The following are acceptable methods for determining baseline motor control conditions when verification by direct inspection is not possible as may occur in a rebate program where customers submit an application and equipment receipts only after installing the variable frequency drive(s), or for a retroactive project as allowed by Act 129. In order of preference:

* Examination of disengaged baseline motor control equipment or equipment that has been removed but is still on site waiting to be recycled or otherwise disposed of
* Interviews with and written statements from customers, facility managers, building engineers or others with firsthand knowledge about operating practices at the affected site(s) identifying the baseline motor control strategy
* Interviews with and written statements from the project’s mechanical contractor identifying the baseline motor control strategy

**Appendix D: and VFD Calculator**

Appendix D: Motor and VFD Calculator was developed to automate the calculation of energy and demand impacts for retrofit VFD projects, based on a series of entries by the user defining key characteristics of the retrofit project. The "General Information" sheet is provided for the user to identify facility-specific details of the project that have an effect on the calculation of gross savings. Facility-specific details include contact information, electric utility, and facility type. The "VFD Inventory" sheet is the main worksheet that calculates energy savings and peak demand reduction for the user-specified motors and motor control improvements. This form follows the algorithms presented above and facilitates the calculation of gross savings for implementation and evaluation purposes. Each line item on this tab represents a single type of motor.



**Custom Load Profiles**

Default fan and pump load profiles as defined in Table 3‑73 are included in the calculator, but users may also customize the load profile to reflect site specific conditions. Annual motor run hours may also be customized. For all projects, annual hours are subject to adjustment by EDC evaluators or SWE.

**Metering**

VFD projects achieving expected kWh savings of 250,000 kWh or higher must[[41]](#footnote-115) be metered to calculate *ex ante* and/or *ex post* savings. Metering should be conducted using standalone power logging equipment and/or trend data from a BMS or other control system. Metering completed by the implementation contractor may be leveraged by the evaluation contractor, subject to a reasonableness review. Additional descriptions of the metering requirements for projects exceeding the 250,000 kWh savings threshold are described in Section 1.3.3.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Phase II SWE team modeling, described in the 2015 Tentative Order Section E.3.c, <http://www.puc.pa.gov/pcdocs/1311852.docx>. Accessed December 2018.
3. Regional Technical Forum. *Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors.* November 5, 2012. Appendix C, Table 6.
4. California Municipal Utilities Association. *Savings Estimation Technical Reference Manual* 2016.
5. 2019 Illinois Statewide Technical Reference Manual for Energy Efficiency Version 7.0. Volume 2: Commercial and Industrial Measures.September 28, 2018. <http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf>

### ECM Circulating Fan

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | ECM Circulating Fan |
| **Measure Life** | 15 years Source 1 |
| **Measure Vintage** | Early Replacement |

This protocol covers energy and demand savings associated with retrofit of existing shaded-pole (SP) or permanent-split capacitor (PSC) circulator fan motors in an air handling unit with an electronically commutated motor (ECM).

Eligibility

This measure is targeted to non-residential customers whose air handling equipment currently uses a SP or PSC fan motor rather than an ECM. This measure applies only to circulating fan motors of 1 HP or less. Motors larger than 1 HP are governed by NEMA standards and would see little to no efficiency benefit by adding an ECM. Additionally, new construction and replace-on-burnout vintages are not eligible to participate, as ECM technology is required in new equipment by federal efficiency standards.Source 2

The targeted fan can supply heating, cooling, ventilation, or any combination of these. A default savings option is offered if motor input wattage is not known. However, these parameters should be collected by EDCs for greatest accuracy. Acceptable baseline conditions are an existing circulating fan with a SP or PSC fan motor 1 HP or less. Efficient conditions are a circulating fan with an ECM.

Algorithms

The energy and demand savings associated with this measure depend on the wattage of the baseline and efficient motor.



motor wattages can be estimated using the motor efficiency values listed in

Table 3‑77. Savings are calculated using the following algorithms:

|  |  |
| --- | --- |
|  |  |
|  |  |

Heating

|  |  |
| --- | --- |
|  |  |
|  |  |

**Cooling**

Interactive factors should be applied for motors that supply cooling to account for the reduced cooling load associated with the lower wattage ECM motor. Interactive factors do not apply if the motor is located outside of the conditioned air pathway.

|  |  |
| --- | --- |
|  |  |
|  |  |

**Ventilation**

Fans that provide ventilation, such as introduction of outdoor air, may operate continuously or may follow a building occupancy schedule, regardless of heating or cooling requirements. Default hours and coincidence factor are not provided for this type of fan usage. EDCs must collect fan hours of operation to calculate savings for fans providing only ventilation. If a fan provides ventilation as well as either heating or cooling, then any heating or cooling hours should be removed from the calculation of operating hours for ventilation only.

|  |  |
| --- | --- |
|  |  |
|  |  |

**Motor Wattage**

Motor wattage may be estimated if unknown using this algorithm.

|  |  |
| --- | --- |
|  |  |

Table ‑: Terms, Values, and References for ECM Circulating Fans

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Term** | | | **Unit** | **Values** | **Source** | |
| , Baseline watts | | | *W* | Nameplate data | EDC Data Gathering | |
| , Energy efficient watts | | | *W* | Nameplate data | EDC Data Gathering | |
| , Load factor | | | *None* | Default: 0.9 | 3 | |
| , Equivalent Full-Load Hours for heating only | | |  | Based on logging, panel data, or modeling | EDC Data Gathering | |
| Default: Table 3‑29 | 4 | |
| , Equivalent Full-Load Hours for cooling only | | |  | Based on logging, panel data, or modeling | EDC Data Gathering | |
| Default: Table 3‑27 | 4 | |
| , Hours for ventilation only, separate from cooling or heating operation | | |  | Based on logging, panel data, or modeling | EDC Data Gathering | |
| Default: 0 | n/a | |
| *CFcool*, Coincidence Factor | | | *Decimal* | Based on logging, panel data, or modeling | EDC Data Gathering | |
| Default: Table 3‑28 | 4 | |
| *CF­­vent*, Coincidence Factor | | | *Decimal* | Based on logging, panel data, or modeling | EDC Data Gathering | |
| Default: 0 | n/a | |
| , Energy Interactive Factor | | | *None* | Default: 26.2% | 5 | |
| , Demand Interactive Factor | | | *None* | Default: 30% | 6 | |
| , Rated horsepower of the motor | | | *HP* | Nameplate | EDC Data Gathering | |
| , Default motor efficiency for motor type. | | | *Percent* | Default: Table 3‑77 | 7 | |
| , Conversion factor for HP to kWh | | | *kWh/HP* | 0.746 | Conversion factor | |

Table ‑: Default Motor Efficiency by Motor Type

|  |  |  |
| --- | --- | --- |
| **Motor Type** | | **Assumed Efficiency** |
| SP | | 0.40 |
| PSC | | 0.50 |
| ECM | | 0.70 |

Default Savings

Default savings may be claimed using the algorithms above and the variable defaults. EDCs may also claim savings using customer specific data.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Federal standards: U.S. Department of Energy, Federal Register. 164th ed. Vol. 79, July 3, 2014. <https://www.govinfo.gov/content/pkg/FR-2014-07-03/pdf/FR-2014-07-03.pdf>
3. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Residential Multi-Family, and Commercial/Industrial Measures. Version 6. April 16, 2018.
4. Phase II SWE team modeling, described in the 2015 Tentative Order Section E.3.c, <http://www.puc.pa.gov/pcdocs/1311852.docx>. Accessed December 2018.
5. Assuming that the waste heat is within the conditioned air stream, then the energy associated with removing the waste heat during the year is approximated as the inverse of the COP, or 3.412/SEER = 0.30 if one uses 13 as a default value for cooling system SEER.
6. Assuming that the waste heat is within the conditioned air stream, then the energy associated with removing the waste heat during peak times is approximated as the inverse of the COP, or 3.412/EER = 0.30 if one uses 11.3 as a default value for cooling system EER.
7. DOE Building Technologies Office. *Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment.* <https://www.energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf>. Accessed December 2018.

### VSD on Kitchen Exhaust Fan

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | VSD on Kitchen Exhaust Fan |
| **Measure Life** | 15 years Source 1 |
| **Measure Vintage** | New Construction or Retrofit |

Installation of variable speed drives (VSD) on commercial kitchen exhaust fans allows the variation of ventilation based on cooking load and/or time of day.

Eligibility

This measure is targeted to non-residential customers whose kitchen exhaust fans are equipped with a VSD that varies the exhaust rate of kitchen ventilation based on the energy and effluent output from the cooking appliances (i.e., the more heat and smoke/vapors generated, the more ventilation needed). This involves installing a temperature sensor in the hood exhaust collar and/or an optic sensor on the end of the hood that sense cooking conditions which allows the system to automatically vary the rate of exhaust to what is needed by adjusting the fan speed.

The baseline equipment is kitchen ventilation that has a constant speed ventilation motor.

The energy efficient condition is a kitchen ventilation system equipped with a VSD and demand ventilation controls and sensors.

Algorithms

Annual energy and demand savings values are based on monitoring results from five different types of sites, as summarized in the PG&E work paper.Source 2 The sites included an institutional cafeteria, a casual dining restaurant, a hotel kitchen, a supermarket kitchen, and a university dining facility. Units are based on savings per total exhaust fan rated horsepower. Savings values are applicable to new and retrofit units.

|  |  |
| --- | --- |
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|  |  |

Table ‑: Terms, Values, and References for VSD on Kitchen Exhaust Fans

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Term** | **Unit** | | **Values** | | **Source** | |
| , Annual energy savings per total exhaust fan horsepower |  | | 4,423 | | 2 | |
| , Coincident peak demand savings per total exhaust fan horsepower |  | | 0.55 | | 3 | |
| , Horsepower rating of the exhaust fan | *HP* | | Nameplate data | | EDC Data Gathering | |

Default Savings

Savings for this measure are partially deemed based on motor horsepower.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. PGE Workpaper, Commercial Kitchen Demand Ventilation Controls, PGECOFST116. June 30, 2014
3. SDGE Workpaper, Work Paper WPSDGENRCC0019, Commercial Kitchen Demand Ventilation Controls, Revision 2. December 24, 2016.

### ECM Circulator Pump

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Per Pump |
| **Measure Life** | 15 years Source 1 |
| **Measure Vintage** | Replace on Burnout, Early Replacement, Retrofit, New Construction |

This protocol covers energy and demand savings associated with replacing single-speed induction motor circulator pumps with electronically commutated motor (ECM)—also called brushless permanent magnet (BPM) motor—circulator pumps. Circulator pumps are used to circulate water for space heating in residential and commercial buildings. Typical applications include baseboard and radiant floor heating systems that utilize a primary/secondary loop system in multifamily residences and small commercial buildings. Circulator pumps for domestic hot water applications are commonly used in multifamily and commercial buildings to shorten the amount of time it takes for hot water to reach the occupants on upper floors and those with long piping runs. These recirculator pumps can be operated continuously or be controlled by a timer or an aquastat, which turns on the pump only when the temperature of the return line falls below a certain set point.Source 1 Circulator pumps that use ECMs are more efficient because they lack brushes that add friction to the motor and have the ability to modulate their speed to match the load.

This measure targets non-residential customers who purchase and install an ECM or BPM circulator pump, replacing single-speed induction motor circulator pumps in space heating and hot water applications. For all vintages except New Construction, the baseline pump control is the existing pump control, whether continuously running or controlled by a timer or aquastat. For New Construction, the baseline pump control method is the same as the energy efficient pump control method as installed.

Algorithms

are defined for heating circulation pumps and domestic hot water recirculation pumps separately. Both algorithms depend on the wattage of the ECM motor.

**Heating Circulation Pumps**

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**DHW Recirculation Pumps**

Some DHW recirculation pumps incorporate aquastat controls, so replacing the singe-speed motor may also result in a reduction in hours of use. The following algorithm allows for hours of use that differ between the baseline and energy efficient scenarios.

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |

**ECM Motor Wattage**

ECM motor wattage may be estimated if unknown using this algorithm.

|  |  |
| --- | --- |
|  |  |

Table 3‑79: Terms, Values, and References for ECM Circulator Pumps

|  |  |  |  |
| --- | --- | --- | --- |
| , Energy efficient watts | *W* | Nameplate data | EDC Data Gathering |
| , Baseline watts | *W* | Calculated | N/A |
| , Savings factor | *None* | 18% | 2 |
| , Equivalent Full-Load Hours for heating only |  | Based on logging, panel data, or modeling | EDC Data Gathering |
| Default: Table 3‑29 | 3 |
| , Load Factor. Ratio between the actual load and the rated load. | *None* | Default: 0.90 | 4 |
| , Average annual pump run hours for baseline DHW recirculating pump |  | Based on logging, panel data, or modeling | EDC Data Gathering |
| For continuously running pump: 8,760  For timer or aquastat-controlled pumps: 2,190 | 5 |
| , Average annual pump run hours for ECM DHW recirculating pump |  | Based on logging, panel data, or modeling | EDC Data Gathering |
| For continuously running pump: 8,760  For timer or aquastat-controlled pumps: 2,190 | 5 |
| , Coincidence factor for baseline DHW recirculating pump |  | Based on logging, panel data, or modeling | EDC Data Gathering |
| For continuously running pump: 1.0  For timer or aquastat-controlled pumps: 0.25 | 5 |
| , Coincidence factor for ECM DHW recirculating pump |  | Based on logging, panel data, or modeling | EDC Data Gathering |
| For continuously running pump: 1.0  For timer or aquastat-controlled pumps: 0.25 | 5 |
| , Rated horsepower of the motor | *HP* | Nameplate | EDC Data Gathering |
| , Conversion factor for HP to kWh | *kWh/HP* | 0.746 | Conversion factor |
| , Efficiency of ECM motor | *Percent* | 85% | 6 |

Default Energy Savings

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Cadmus. Impact Evaluation of the 2011–2012 ECM Circulator Pump Pilot Program. Table 2. Pump Spot Measurements. October 18, 2012.
3. Phase II SWE team modeling, described in the 2015 Tentative Order Section E.3.c, [http://www.puc.pa.gov/pcdocs/1311852.docx. Accessed December 2018](http://www.puc.pa.gov/pcdocs/1311852.docx.%20Accessed%20December%202018).
4. Regional Technical Forum. *Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors.* November 5, 2012. Appendix C, Table 6. Average of values for 1, 1.5, and 2 hp pumps.
5. DHW Recirculation System Control Strategies. Final Report 99-13-30. January 1999. Hours of use for pumps with an aquastat control in multifamily applications.
6. Average efficiency levels for ECM fans calculated using a market average for the product category.

### High Efficiency Pumps

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments, Agricultural |
| **Measure Unit** | Pump |
| **Measure Life** | 13.3 years Source 1 |
| **Measure Vintage** | Replace on Burnout, New Construction, or Early Replacement |

All pumps manufactured after January 27, 2020 must comply with the DOE’s energy conservation standard as described in 10 CFR 431 Subpart Y.Source 2 This standard is applicable to the following cleanwater pump types:

* End Suction Closed Coupled (ESCC)
* End Suction Frame Mounted (ESFM)
* In-Line (IL)
* Radially Split Multi-Stage In-Line Diffuser Casing (RSV)
* Submersible Turbine (ST)

This measure does not apply to dedicated-purpose pool pumps or circulator pumps. Savings for dedicated pool pumps should follow the guidance in Section 1.16 of this TRM. This standard requires that pumps tested for compliance with the standard and labeled with a Pump Energy Index (PEI). Compliant pumps will achieve a PEI of 1.0 or less. Pumps that achieve lower PEI values will save energy.

Conversions from constant speed to variable speed pumping are not covered under this measure. Default hours of use and coincidence factor values are provided for chilled water, heating water, and condenser water pumps only.

The energy and demand savings for this measure depend on the size and efficiency of the motor driving the pump, as well as the pump PEI. Savings are calculated according to the following algorithms:

|  |  |
| --- | --- |
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|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

Table 3‑80: Terms, Values, and References for Premium Efficiency Motors

| **Term** | **Unit** | **Value** | **Source** |
| --- | --- | --- | --- |
| , Rated horsepower of the baseline and energy efficient motor | *HP* | Nameplate | EDC Data Gathering |
| , Conversion factor for HP to kWh | *kWh/HP* | 0.746 | Conversion factor |
| , Annual run hours of the motor |  | Based on logging, panel data or modeling[[42]](#footnote-121) | EDC Data Gathering |
| Default: Table 3‑68, Table 3‑69, Table 3‑71 | 3 |
| , Load Factor. Ratio between the actual load and the rated load. Variable loaded motors should use custom measure protocols. | *None* | Based on spot metering and nameplate | EDC Data Gathering |
| Default: 0.79 for pumps | 4 |
| , Efficiency of the motor. PEI values for pump packages include motor efficiency. | *None* | Motor nameplate or 1.0 for pump packages | EDC Data Gathering |
| Default: Table 3‑65 and Table 3‑66 | 5 |
| , Baseline pump energy index. | *None* | Default: Table 3‑81 | 1 |
| , Rated pump energy index of installed high efficiency pump or pumping package. | *None* | Nameplate | EDC Data Gathering |
| Coincidence factor | *Decimal* | EDC Data Gathering | EDC Data Gathering |
| Default: Table 3‑68, Table 3‑69, Table 3‑71 | 3 |

Table 3‑81: Baseline Pump Energy Indices

|  |  |  |
| --- | --- | --- |
| **Pump Type** | **PEIbase** | |
| **Constant Speed** | **Variable Speed** |
| ESCC, 1800 RPM | 1.00 | 0.49 |
| ESCC, 3600 RPM | 0.96 | 0.51 |
| ESFM, 1800 RPM | 0.98 | 0.49 |
| ESFM, 3600 RPM | 0.99 | 0.51 |
| IL | 0.99 | 0.50 |
| RSV | 0.98 | 0.50 |
| ST | 0.96 | 0.60 |

Default Energy Savings

There are no default savings for this measure.

1. Regional Technical Forum. UES Measure – Efficient Pumps. Commercial/Industrial/Agricultural Pumps v1.1 Workbook. <https://rtf.nwcouncil.org/measure/efficient-pumps>. Accessed January 2019.
2. U.S. Department of Energy. 10 CFR Part 431. Energy Efficiency Program for Certain Commercial and Industrial Equipment: Subpart Y—Pumps.
3. Phase II SWE team modeling, described in the 2015 Tentative Order Section E.3.c, [http://www.puc.pa.gov/pcdocs/1311852.docx. Accessed December 2018](http://www.puc.pa.gov/pcdocs/1311852.docx.%20Accessed%20December%202018).
4. Regional Technical Forum. *Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors.* November 5, 2012. Appendix C, Table 6.
5. “Energy Conservation Program: Energy Conservation Standards for Commercial and Industrial Electric Motors; Final Rule,” 79 Federal Register 103 (29 May 2014). <https://www.gpo.gov/fdsys/pkg/FR-2014-05-29/html/2014-11201.htm>

## Domestic Hot Water

### Heat Pump Water Heaters

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Heat Pump Water Heater |
| **Measure Life** | 10 years Source 1 |
| **Measure Vintage** | New Construction, Replace on Burnout, Early Retirement |

Heat pump water heaters take heat from the surrounding air and transfer it to the water in the tank, unlike conventional electrical water heaters which use resistive heating coils to heat the water.

This protocol documents the energy savings attributed to heat pump water heaters with uniform energy factors meeting the minimum ENERGY STAR criteria.Source 2 However, uniform energy factors that exceed the ENERGY STAR minimums are accommodated with the partially deemed scheme. The measure described here involves the installation of a heat pump water heater instead of a code minimum electric water heater. It is important to note that federal standards require efficiency levels only achievable by heat pump water heaters at certain tank sizes. Therefore, the baseline condition is effectively an electric resistance water heater at smaller tank sizes and code minimum heat pump water heater for larger tank sizes. It does not cover systems where the heat pump is a pre-heater or is combined with other water heating sources. More complicated installations can be treated as custom projects.

Mid-Stream Domestic Hot Water Overview

Commercial Heat Pump Water Heaters for Midstream Delivery Programs will offer incentives on eligible products sold to trade allies and customers through commercial sales channels such as distributors of heat pump water heating products. This complements other delivery channels (such as downstream rebates to trade allies and customers) by providing incentives to encourage distributors to stock, promote, and sell more-efficient systems. In a Midstream Delivery program, less information is available about the business and installation setting so additional default values are required to calculate energy and peak demand savings.

Algorithms

The energy savings calculation compares performance ratings for heat pump and code minimum water heaters and uses typical hot water usages. The energy savings are obtained through the following formula:

|  |  |
| --- | --- |
|  |  |

The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage between 2PM and 6PM on summer weekdays to the total annual energy usage (ETDF), and discounted by the resistive discount factor.

|  |  |
| --- | --- |
|  |  |

The Energy to Demand Factor uses hourly load data for specific types of buildings to create loadshapes.Source 3 Pennsylvania’s summer peak is defined as non-holiday weekdays from 2PM to 6PM for June, July, and August. From those load shapes, the ETDF is calculated as follows and provided in Table 3‑82:

|  |  |
| --- | --- |
|  |  |

Gallons Per Year per square foot estimates are provided in Table 3‑82. Multiplying GPY per square foot for the appropriate building type times the square footage of the area served by the water heater will provide the needed GPY.

|  |  |
| --- | --- |
|  |  |

Table ‑: Typical water heating Gallons per Year and Energy to Demand Factors

|  |  |  |  |
| --- | --- | --- | --- |
| **Commercial Prototype Building** | **GPY per Square Foot** | **ETDF** |  |
| Education - Other | 3.81 | 0.0002545 |  |
| Health - Hospital | 4.97 | 0.0002011 |  |
| Health - Other | 3.09 | 0.0003020 |
| Institutional/Public Service | 5.90 | --- |
| Lodging | 17.33 | 0.0001210 |  |
| Miscellaneous/Other | 2.04 | 0.0002590 |
| Office | 1.33 | 0.0002490 |  |
| Restaurant | 94.04 | 0.0001525 |  |
| Retail | 0.80 | 0.0002560 |  |
| Warehouse - Refrigerated | 0.22 | 0.0003018 |  |

Heat pump performance is temperature and humidity dependent. The Uniform Energy Factors are determined from a DOE testing procedure that is carried out at 57°F wet bulb temperature. However, the average outdoor wet bulb temperature in PA is closer to 43°F Source 4, while the average wet bulb temperature in conditioned spaces typically ranges from 50°F to 80°F.

Figure 3‑1 below shows relative coefficient of performance (COP) compared to the COP at rated conditions.Source 5 According to the plotted profile, the following adjustments provided in Table 3‑83 are recommended. For midstream delivery programs, the heat pump water heater placement location will be unknown. The Pennsylvania 2018 baseline study did not report on water heater installation location, and a wider investigation did not reveal any other research with this detailed breakdown of data. Due to the lack of information, the midstream delivery program will use a COP Adjustment Factor value of 1.0 (e.g., no adjustment).

Table ‑: COP Adjustment Factors, Fadjust

|  |  |  |
| --- | --- | --- |
| **Heat Pump Placement** | **Typical WB Temperature °F** | **COP Adjustment Factor (Fadjust)** |
| Unconditioned Space | 43 | 0.77 |
| Conditioned Space | 68 | 1.16 |
| Kitchen | 85 | 1.45 |
| Unknown (Midstream Delivery) | 57 | 1.00 |

Figure ‑: Dependence of COP on Outdoor Wet Bulb Temperature

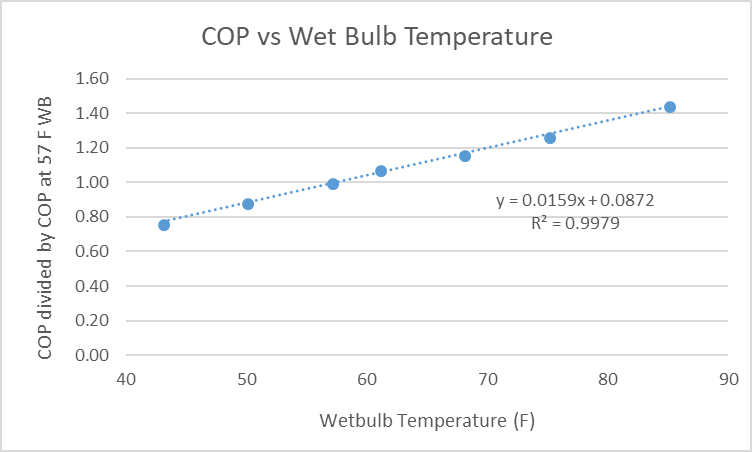
****

Table ‑: Terms, Values, and References for Heat Pump Water Heaters

| **Term** | **Unit** | | **Values** | | | **Source** |
| --- | --- | --- | --- | --- | --- | --- |
| , Uniform Energy Factor of baseline water heater | *None* | | See Table 3‑85 | | | 6 |
| , Uniform Energy Factor of proposed efficient water heater | *None* | | Default:  ≤ 55 Gallons: 2.0  > 55 Gallons: 2.2 | | | 2 |
| Nameplate | | | EDC Data Gathering |
| , Temperature of hot water | *°F* | | 119 | | | 9 |
| , Temperature of cold water supply | *°F* | | 52 | | | 8 |
| , Energy to Demand Factor | None | | Default: Table 3‑82 | | | 3 |
| , COP Adjustment factor | *None* | | Default: Table 3‑83 | | | 5, 10 |
| , Square footage |  | | Default Unknown/Midstream: 4,000 | | | 7 |
| EDC Data Gathering | | | EDC Data Gathering |
| , Average annual gallons per year | *Gallons* | | Default: Table 3‑82 | | | Calculation |
| EDC Data Gathering | | | EDC Data Gathering |



Energy Factors Based on Storage Volume

For water heaters delivered through midstream channels, the storage volume of the baseline system will be assumed to be the same as that of the proposed system. The storage volume can be determined from the manufacturer and model number of the incented heat pump water heater.

The current Federal Standards for electric water heater Uniform Energy Factors vary based on draw pattern. This standard, which went into effect at the end of 2016, replaces the old federal standard equal to 0.96 – (0.0003\*Rated Storage Volume in Gallons) for tanks equal to or smaller than 55 gallons and 2.057 – (0.00113\*Rated Storage Volume) for tanks larger than 55 gallons. The following table shows the Uniform Energy Factors for various storage volumes. Formulas provided assume a medium draw pattern.

Table ‑: Minimum Baseline Uniform Energy Factor Based on Storage Volume

|  |  |  |  |
| --- | --- | --- | --- |
| **Rated Storage Volume (Vr)** | | **Uniform Energy Factor** | |
| ≥ 20 gal and ≤ 55 gal | | 0.9307 − (0.0002 × Vr) | |
| > 55 gal and ≤ 120 gal | | 2.1171 − (0.0011 × Vr) | |

Default Savings

The default savings presented below represent the installation of heat pump electric water heaters in the case that the business type, square footage, and location are unknown, and the Uniform Energy Factor is the Energy Star minimum. For 55 gallons, default savings assume a 40-gallon tank. For 55 gallons, default savings assume an 80-gallon tank. Remaining default values used in this calculation can be found in Table 3‑84.

Table ‑: Default Energy Savings



| Location Installed | Storage Volume (gallons) |  |
| --- | --- | --- |
| Unknown (Midstream Delivery) | ≤ 55 | 776.4 |
| > 55 | 50.9 |

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed November 13, 2018
2. ENERGY STAR Product Specifications for Residential Water Heaters Version 3.2. Effective April 16, 2015. <https://www.energystar.gov/sites/default/files/Water%20Heaters%20Final%20Version%203.2_Program%20Requirements_0.pdf>
3. GPY per square foot is found in the Technical Support Document: Energy Efficiency Program For Consumer Products And Commercial And Industrial Equipment: Commercial Water Heating Equipment. Table 7.3.1, p.186. ETDF values are calculated from load data provided in Appendix 7B, p. 230. April 18, 2016
4. SWE analysis of TMY3 data for PA weather stations.
5. The performance curve is developed using the NREL’s Heat Pump Water Heater Technology Assessment Based on Laboratory Research and Energy Simulation Models’. Methodology can be seen: <https://www.nrel.gov/docs/fy12osti/51433.pdf>. Values are more easily viewed: <https://www.nrel.gov/docs/fy14osti/52635.pdf> The performance curve is developed using the NREL’s The COP adjustment values are an average of COP adjustment for Unit A, B, D, and E, where values are taken from the average tank temperature at 57 degrees F.
6. U.S. Federal Standards for Residential Water Heaters. Current as of November 23, 2018. <https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8>
7. Pennsylvania Act 129 2018 Non-Residential Baseline Study. <http://www.puc.pa.gov/Electric/pdf/Act129/SWE-Phase3_NonRes_Baseline_Study_Rpt021219.pdf>
8. Natural Resources Conservation Service. October 6, 2018. <https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PA>
9. 2014 End Use & Saturation Study. April 4, 2014. <http://www.puc.pa.gov/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Non-Residential_EndUse_Saturation_Study.pdf>
10. Assuming a 45% relative humidity, atmospheric pressure at the sea level value of 29.9 inHg, and the ground temperature calculation of 52 degrees F (Source 8), unconditioned wet bulb temperature is estimated to be 43 degrees F.

### Low Flow Pre-Rinse Sprayers for Retrofit Programs and Time of Sale Programs

|  |  |  |
| --- | --- | --- |
| **Target Sector** | Commercial and Industrial Establishments | |
| **Measure Unit** | Pre-Rinse Sprayer | |
| **Measure Life** | 8 years Source 1 | |
| **Measure Vintage** | Retrofit, Early Replacement, or Replace on Burnout | |

This protocol documents the energy savings and demand reductions attributed to efficient low flow pre-rinse sprayers in grocery and food service applications including fast food restaurants, full service restaurants, and other. The most likely areas of application are kitchens in restaurants and hotels. Only premises with electric water heating may qualify for this incentive. In addition, the replacement pre-rinse spray nozzle must use less than 1.6 gallons per minute.Source 2 Low flow pre-rinse sprayers reduce hot water usage and save energy associated with water heating.

The baseline for the Retrofit/Early Replacement vintage is assumed to be a 2.25 GPM and 2.15 GPM for food service and grocery applications respectively.Source 3 The baseline for the Replace on Burnout (Time of Sale) vintage is assumed to be 1.6 GPM.Source 2

Algorithms

The energy savings and demand reduction are calculated through the protocols documented below.

|  |  |  |
| --- | --- | --- |
|  |  | |

The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage between 2PM and 6PM on summer weekdays to the total annual energy usage.

|  |  |
| --- | --- |
|  |  |

The Energy to Demand Factor uses hourly load data for specific types of buildings to create loadshapes.Source 4 Pennsylvania’s summer peak is defined as non-holiday weekdays from 2PM to 6PM for June, July, and August. From those load shapes, the ETDF is calculated as follows and provided in Table 3‑87:

|  |  |
| --- | --- |
|  |  |

Table ‑87: Typical Energy to Demand Factors

|  |  |
| --- | --- |
| **Commercial Prototype Building** | **ETDF** |
| Quick-service Restaurant | 0.000186 |
| Full-service Restaurant | 0.0001189 |
| Standalone Retail (Grocery) | 0.000237 |
| Default - Unknown | 0.000259 |

The parameters in the above equation are listed in Table 3‑88 below.

Table ‑: Terms, Values, and References for Low Flow Pre-Rinse Sprayers

| **Term** | **Unit** | | **Values** | | **Source** |
| --- | --- | --- | --- | --- | --- |
| , Baseline flow rate of sprayer | *GPM* | | EDC Data Gathering | | EDC Data Gathering |
| Default: Table 3‑89 | | 2, 3 |
| , Post measure flow rate of sprayer | *GPM* | | EDC Data Gathering | | EDC Data Gathering |
| Default: Table 3‑89 | | 2, 3 |
| , Baseline water usage duration |  | | EDC Data Gathering | | EDC Data Gathering |
| Default: Table 3‑89 | | 5 |
| , Post measure water usage duration |  | | EDC Data Gathering | | EDC Data Gathering |
| Default: Table 3‑89 | | 5 |
| , Temperature of hot water | *°F* | | Default: 127.5 | | 6 |
| , Incoming cold water temperature | *°F* | | 52 | | 9 |
| , Uniform energy factor of existing electric water heater system | *None* | | EDC Data Gathering | | EDC Data Gathering |
| 0.9 | | 7 |
| ETDF, Energy to demand factor | *None* | | Default: Table 3‑87 | | 4 |
| Days per year pre-rinse spray valve is used at the site | Days | | 365 | | 3 |
| Specific mass in pounds of one gallon of water |  | | 8.3 | | 8 |
| Specific heat of water |  | | 1.0 | | 8 |
| Btu per kWh |  | | 3,412 | | Conversion Factor |

Table 3‑89: Flow Rate and Usage Duration by Program

| **Program: Application** | **Flow Rate (GPM)** | | **Usage Duration (min/day)** | |
| --- | --- | --- | --- | --- |
| **Fbase** | **Fee** | **Ubase** | **Uee** |
| Retrofit: Food service applications | 2.25 | 1.12 | 32.4 | 43.8 |
| Retrofit: Grocery or Unknown | 2.15 | 1.12 | 4.8 | 6 |
| Time of Sale: Limited Service (Fast Food) Restaurant | 1.6 | 1.12 | 32.4 | 43.8 |
| Time of Sale: Full Service Restaurant | 1.6 | 1.12 | 32.4 | 43.8 |
| Time of Sale: Other or Unknown | 1.6 | 1.12 | 26.4 | 36 |



Default Savings

For retrofit programs, the default savings for the installation of a low flow pre-rinse sprayer compared to a standard efficiency sprayer is 268 kWh/year for pre-rinse sprayers installed in grocery stores and 1,776 kWh/year for pre-rinse sprayers installed in food service building typessuch as restaurants. The deemed demand reductions for the installation of a low flow pre-rinse sprayer compared to a standard efficiency sprayer is 0.06 kW for pre-rinse sprayers installed in grocery stores and 0.27 kW for pre-rinse sprayers installed in food service building types such as restaurants.

The default savings for the installation of a low flow pre-rinse sprayer compared to a standard efficiency sprayer for all Pre-Rinse Sprayer programs are listed in Table 3‑90. In the case of unknown installation setting, “Grocery” defaults can be used for Retrofit and “Other” defaults can be used for Time of Sale programs. The chosen ETDF values for the default demand savings depend on the application but can be obtained from Table 3‑87. Specifically, Retrofit: Groceries and Time of Sale: Other use the Default: Unknown ETDF estimate; Time of Sale: Full Service and Limited Service use their respective ETDF values; and Retrofit Food Service uses a simple average of the Full and Quick service ETDF values

90: Low Flow Pre-Rinse Sprayer Default Savings

|  |  |  |
| --- | --- | --- |
| **Application** |  |  |
| Retrofit: Food Service | 1,776 | 0.27 |
| Retrofit: Groceries or Unknown | 268 | 0.06 |
| Time of Sale: Limited Service (Fast Food) Restaurant | 207 | 0.04 |
| Time of Sale: Full Service Restaurant | 207 | 0.02 |
| Time of Sale: Other or Unknown | 143 | 0.04 |

Evaluation Protocol

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. Impact Evaluation of Massachusetts Prescriptive Gas Pre-Rinse Spray Valve Measure, DNV-GL, 2014. <http://ma-eeac.org/wordpress/wp-content/uploads/Prescriptive-Gas-Pre-Rinse-Spray-Valve-Measure-Impact-Evaluation.pdf>
2. <http://www.psc.state.ga.us/electric/federal/EPA/EPA2005.pdf>
3. *Impact and Process Evaluation Final Report for California Urban Water Conservation Council 2004-5 Pre-Rinse Spray Valve Installation Program (Phase 2),* SBW Consulting, 2007, Table 3-4, p. 23.
4. Technical Support Document: Energy Efficiency Program For Consumer Products And Commercial And Industrial Equipment: Commercial Water Heating Equipment. ETDF values are calculated from load data provided in Appendix 7B, p. 230. April 18, 2016
5. *Impact and Process Evaluation Final Report for California Urban Water Conservation Council 2004-5 Pre-Rinse Spray Valve Installation Program (Phase 2),* SBW Consulting, 2007, Table 3-6, p. 24. <http://www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=976>
6. *Impact and Process Evaluation Final Report for California Urban Water Conservation Council 2004-5 Pre-Rinse Spray Valve Installation Program (Phase 2),* SBW Consulting, 2007, Table 3-5, p. 23. <http://www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=976>
7. Pennsylvania Act 129 2018 Non-Residential Baseline Study. <http://www.puc.pa.gov/Electric/pdf/Act129/SWE-Phase3_NonRes_Baseline_Study_Rpt021219.pdf>

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | |  | | |



















1. Natural Resources Conservation Service. October 6, 2018. <https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PA>
2. Hours based on PG&E savings estimates, algorithms, sources (2005), Food Service Pre-Rinse Spray Valves with review of 2010 Ohio Technical Reference Manual and Act on Energy Business Program Technical Resource Manual Rev05. <http://s3.amazonaws.com/zanran_storage/amppartners.org/ContentPages/2464316647.pdf>

### Fuel Switching: Electric Resistance Water Heaters to Gas/Propane

|  |  |  |
| --- | --- | --- |
| **Target Sector** | Commercial and Industrial Establishments | |
| **Measure Unit** | Water Heater | |
| **Measure Life** | Tankless: 20 years  ≤ 75,000 Btu/h: 11 years  >75,000 Btu/h: 15 years Source 1 | |
| **Measure Vintage** | Early Replacement or Replace on Burnout | |

Eligibility

Natural gas and propane water heaters generally offer the customer lower costs compared to standard electric water heaters. Additionally, they typically see an overall energy savings when looking at the source energy of the electric unit versus the fossil fuel unit.

This protocol documents the energy savings attributed to converting from a standard electric tank water heater to an ENERGY STAR natural gas water heater. If a customer submits a rebate for a product that has applied for ENERGY STAR Certification but has not yet been certified, the savings will be counted for that product contingent upon its eventual certification as an ENERGY STAR measure. If at any point the product is rejected by ENERGY STAR, the product is then ineligible for the program and savings will not be counted.

Algorithms

The energy savings calculation utilizes average performance data for available small commercial standard electric and natural gas water heaters and typical water usage. Because there is little electric energy associated with a natural gas or propane water heater, the energy savings are the full energy utilization of the electric water heater. The energy savings are obtained through the following formula:

|  |  |
| --- | --- |
|  |  |

|  |  |
| --- | --- |
|  |  |



Where changes depending on the fossil fuel used by the water heater.

For resistive water heaters, the demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage between 2PM and 6PM on summer weekdays to the total annual energy usage.

|  |  |
| --- | --- |
|  |  |

The Energy to Demand Factor uses hourly load data for specific types of buildings to create loadshapes.Source 2 Pennsylvania’s summer peak is defined as non-holiday weekdays from 2PM to 6PM for June, July, and August. From those load shapes, the ETDF is calculated as follows and provided in Table 3‑82:

|  |  |
| --- | --- |
|  |  |

Gallons Per Year per square foot estimates are provided in Table 3‑82. Multiplying GPY per square foot for the appropriate building type times the square footage of the area served by the water heater will provide the needed GPY.

|  |  |
| --- | --- |
|  |  |

The parameters in the above equations are listed in Table 3‑91.

Table ‑: Terms, Values, and References for Commercial Water Heater Fuel Switching

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , Uniform energy factor of baseline electric water heater | *None* | Default: 0.9 | 3 |
| Nameplate | EDC Data Gathering |
| , Uniform energy factor of installed natural gas water heater | *None* | Default: Table 3‑92 | 4, 5 |
| Nameplate | EDC Data Gathering |
| , Square Footage |  | Default: 4,000 | 3 |
| EDC Data Gathering | EDC Data Gathering |
| , Average annual gallons per year | *Gallons* | Default: Table 3‑82 | 2 |
| EDC Data Gathering | EDC Data Gathering |
| , Temperature of hot water | *°F* | 119 | 6 |
| , Temperature of cold water supply | *°F* | 52 | 7 |
| ETDF, Energy To Demand Factor | *None* | Default: Table 3‑82 | 2 |



Table ‑: Minimum Baseline Uniform Energy Factor for Gas Water Heaters

|  |  |  |
| --- | --- | --- |
|  | **Rated Storage Volume or Type** | **Uniform Energy Factor** |
| ≤ 75,000 Btu/h | ≤ 55 gal | ≥ 0.67 |
| > 55 gal | ≥ 0.77 |
| Tankless | ≥ 0.90 |
| > 75,000 Btu/h | Storage or Tankless | ≥ 0.94 |



The default savings for the replacement of an electric water heater with a fossil fuel unit in various applications are listed below. For the default savings, the algorithm uses default values provided in Table 3‑91 for baseline UEF and Typical Square Feet, and Gallons per Year per Square Foot from Table 3‑82.

Table ‑: Water Heating Fuel Switch Energy Savings Algorithms



|  |  |  |
| --- | --- | --- |
| **Building Type** |  | **Fuel Consumption (MMBtu)** |
| Unknown (Midstream Delivery) | 1,475.1 | 4.53 \* |

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed November 13, 2018
2. GPY per square foot is found in the Technical Support Document: Energy Efficiency Program For Consumer Products And Commercial And Industrial Equipment: Commercial Water Heating Equipment. Table 7.3.1, p.186. ETDF values are calculated from load data provided in Appendix 7B, p. 230. April 18, 2016
3. Pennsylvania Act 129 2018 Non-Residential Baseline Study. <http://www.puc.pa.gov/Electric/pdf/Act129/SWE-Phase3_NonRes_Baseline_Study_Rpt021219.pdf>
4. ENERGY STAR Program Requirements Produce Specification for Commercial Water Heaters Version 2.0. <https://www.energystar.gov/sites/default/files/Program%20Requirements_Commercial%20Water%20Heaters_Final%20Version%202.0_12%2029%2017.pdf>
5. Commission Order page 30 of the 2016 TRC Test Final Order requires fuel switching to ENERGY STAR measures, not standard efficiency measures. The Uniform Energy Factor has therefore been updated to reflect the Energy Star standard for natural gas or propane storage water heaters. ENERGY STAR Product Specification for Residential Water Heaters Version 3.2. <https://www.energystar.gov/sites/default/files/Water%20Heaters%20Final%20Version%203.2_Program%20Requirements_0.pdf>
6. 2014 SWE Residential Baseline Study. <http://www.puc.pa.gov/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf>
7. Natural Resources Conservation Service. October 6, 2018. <https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PA>

## Refrigeration

### ENERGY STAR Refrigeration/Freezer Cases

|  |  |  |
| --- | --- | --- |
| **Target Sector** | | Commercial and Industrial Establishments |
| **Measure Unit** | | Refrigeration/Freezer Case |
| **Measure Life** | | 12 years Source 1 |
| **Measure Vintage** | | Replace on Burnout |



































|  |  |
| --- | --- |
|  |  |

Eligibility

This protocol estimates savings for installing high efficiency refrigeration and freezer cases that exceed ENERGY STAR efficiency standards. Eligible refrigerators and freezers are self-contained with vertical-closed transparent or solid doors. The measurement of energy and demand savings is based on algorithms with volume as the key variable.

Algorithms

Annual energy savings and peak demand savings calculations are shown below.

|  |  |
| --- | --- |
|  |  |
|  |  |

Table ‑: Terms, Values, and References for High-Efficiency Refrigeration/Freezer Cases

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , The unit energy consumption of a standard unit |  | See Table 3‑95 | 2 |
| , The unit energy consumption of the ENERGY STAR-qualified unit |  | See Table 3‑95 | 3 |
| , Internal Volume |  | EDC data gathering | EDC data gathering |
| , days per year |  | EDC data gathering  Default: 365 | Conversion Factor |

Table ‑: Refrigeration & Freezer Case Efficiencies

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Refrigerators** | | | | | | |
| **Volume** | **Transparent Door** | | | **Solid Door** | | |
|  |  | |  |  | |
| V < 15 | 0.095\*V + 0.445 | 0.10\*V + 0.86 | | 0.022\*V + 0.97 | 0.05\*V + 1.36 | |
| 15 ≤ V < 30 | 0.05\*V + 1.12 | 0.066\*V + 0.31 |
| 30 ≤ V < 50 | 0.076\*V + 0.34 | 0.04\*V + 1.09 |
| 50 ≤ V | 0.105\*V – 1.111 | |  | 0.024\*V + 1.89 | |  |
| **Freezers** | | | | | | |
| **Volume** | **Transparent Door** | | | **Solid Door** | | |
|  | |  |  | |  |
| V < 15 | 0.232\*V + 2.36 | 0.29\*V + 2.95 | | 0.021\*V + 0.9 | 0.22\*V + 1.38 | |
| 15 ≤ V < 30 |  | |  | 0.12\*V + 2.248 | |  |
| 30 ≤ V < 50 |  | |  | 0.285\*V – 2.703 | |  |
| 50 ≤ V |  | |  | 0.142\*V + 4.445 | |  |

Default Savings











There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Energy Conservation Program: Energy Conservation Standards for Commercial Refrigeration Equipment. Final Rule. Table I.1. <https://www.regulations.gov/document?D=EERE-2010-BT-STD-0003-0104>
3. ENERGY STAR Program Requirements for Commercial Refrigerators and Freezers. Version 4.0 <https://www.energystar.gov/sites/default/files/Commercial%20Refrigerators%20and%20Freezers%20V4%20Spec%20Final%20Version_0.pdf>

### High-Efficiency Evaporator Fan Motors for Walk-In or Reach-In Refrigerated Cases

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Evaporator Fan Motor |
| **Measure Life** | 15 years Source 1 |
| **Measure Vintage** | Early Replacement |

Eligibility

This protocol covers energy and demand savings associated with the replacement of existing shaded-pole (SP) evaporator fan motors or Permanent Split Capacitor (PSC) motors in walk-in or reach-in refrigerated display cases with an Electronically Commutated motor (ECM) or a Permanent Magnet Synchronous (PMS) motor. The baseline condition assumes the evaporator fan motor is uncontrolled (i.e., it runs continuously). This measure is not applicable for new construction or replace on burnout projects. Savings are calculated per motor replaced.

There are two sources of energy and demand savings through this measure:

1. The direct savings associated with replacement of an inefficient motor with a more efficient one;
2. The indirect savings of a reduced cooling load on the refrigeration unit due to less heat gain from the more efficient evaporator fan motor in the air-stream.

Algorithms

The algorithms below are adapted from the Commercial Refrigeration Loadshape Project, a research effort from NEEP, Cadmus, and the Demand Management Institute.Source 2 The report notes that savings show minimal variation with the time of day or day type, thus peak demand savings are simply annual energy savings divided by 8,760.

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |
|  |  |

Table 3‑96: Terms, Values, and References for High-Efficiency Evaporator Fan Motors

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Term** | | **Unit** | **Values** | **Source** |
| , Input wattage of the baseline motor | *kW* | | Nameplate | EDC Data Gathering |
| Calculated value | Calculated value |
| , Input wattage of the efficient motor | *kW* | | Nameplate | EDC Data Gathering |
| Calculated value | Calculated value |
| , Effective runtime of the motor without controls | % | | EDC Data Gathering | EDC Data Gathering |
| Default: 97.8% | 2 |
|  | , Operating hours per year |  | 8,760 | Conversion factor |
| , Waste heat factor for energy; represents the increased savings due to reduced waste heat from motors that must be rejected by the refrigeration equipment | | None | SP Base, : 1.38  PSC Base, Cooler: 1.19  SP Base, Freezer 1.76  PSC Base, Freezer: 1.38 | 3 |
| , Rated horsepower of the baseline motor | | *HP* | Nameplate | EDC Data Gathering |
| , Rated horsepower of the efficient motor | *HP* | | Nameplate | EDC Data Gathering |
| , Motor efficiency of the baseline motor | % | | Default for SP: 30%  Default for PSC: 60% | 4 |
| , Motor efficiency of the efficient motor | % | | Default for ECM: 70%  Default for PMS: 73% | 4, 5 |
| , Load factor. Ratio between the actual load and the rated load. | *%* | | Based on spot metering and nameplate  Default: 0.9 | EDC Data Gathering  6 |
| , Conversion factor | kW/HP | | 0.746 | Conversion factor |

|  |  | |  | |  | |
| --- | --- | --- | --- | --- | --- | --- |

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Commercial Refrigeration Loadshape Project, Northeast Energy Efficiency Partnerships, October 2015. <https://neep.org/commercial-refrigeration-loadshape-report-10-2015-0>. Average wattage per rated horsepower (0.758 kW/HP) is based on an average of 66 ECMs. This represents a conservative estimate for PMS motors, as they are slightly more efficient than ECMs.
3. In cases where the baseline is an SP motor, waste heat factor is calculated by dividing the annual energy savings (kWh/HP) for “Equipment and Interactive” (shown in Table 43 of the report referenced in Source 2) by annual energy savings (kWh/HP) for the “Equipment Only” equipment type (also shown in Table 43). According to the DOE report noted in Source 4, PSC motors are approximately twice as efficient as SP motors. Thus, PSC motors will create less waste heat. The default waste heat factors for PSC motor baselines suppose PSC motors create half as much waste heat as SP motors.
4. Department of Energy. “Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment.” December 2013. Motor efficiencies for the baseline motors are drawn from Table 2.1, which provides peak efficiency ranges for a variety of motors. The motor efficiency for an ECM is drawn from the discussion in 2.4.3. <https://www.energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf>
5. Fricke, B. and B. Becker, Oak Ridge National Laboratory. “Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits.” ORNL/TM-2015/466. 2015. PMS motor efficiency estimated to be 0.73. See Table 1. <http://info.ornl.gov/sites/publications/files/Pub58600.pdf>.











New York Standard Approach for Estimating Energy Savings

|  |  |
| --- | --- |
| from |  |























1. Energy Efficiency Programs – Residential Multi-Family, and Commercial/Industrial Measures. Version 6. April 16, 2018.

### 

### 

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Evaporator Fan Controller |
| **Measure Life** | 15 years Source 1 |
| **Measure Vintage** | Retrofit |

This measure is for the installation of evaporator fan controls in walk-in coolers or freezers with no pre-existing controls. An evaporator fan controller is a device or system that lowers airflow across an evaporator when there is no refrigerant flow through the evaporator (i.e., when the compressor is in an off-cycle). Evaporator fans run constantly to provide cooling when the compressor is running, and to provide air circulation when the compressor is not running. The equations specified in the Algorithms section are for fans that are turned off and/or cycled.

A fan controller saves energy by reducing fan usage, by reducing the refrigeration load resulting from the heat given off by the fan and by reducing compressor energy resulting from the electronic temperature control. This protocol documents the energy savings attributed to evaporator fan controls.

Eligibility

This protocol documents the energy savings attributed to installation of evaporator fan controls in medium-temperature walk-in or reach-in coolers and low temperature walk-in or reach-in freezers. The baseline case is assumed to be a shaded pole (SP) motor without controls or an electronically-commutated motor (ECM) without controls.

Algorithms











The algorithms used in this section are adapted from NEEP’s Commercial Refrigeration Loadshape Project.Source 2

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |

Table ‑: Terms, Values, and References for Evaporator Fan Controllers

| **Term** | | **Unit** | **Values** | | | **Source** |
| --- | --- | --- | --- | --- | --- | --- |
| , Input wattage of the SP or ECM motor | | *kW* | Nameplate | | | EDC Data Gathering |
| Calculated value | | | Calculated value |
| , Effective runtime of the uncontrolled motor | | *None* | EDC Data Gathering  Default: 97.8% | | | EDC Data Gathering  2 |
| , Effective runtime of the controlled motor | | *None* | EDC Data Gathering  Unknown control style: 66.5%  ON/OFF control style: 63.6%  Micropulse control style: 69.2% | | | EDC Data Gathering  2 |
| 8,760, Numbers of operating hours per year | | *Hours* | 8,760 | | | Conversion factor |
| , Waste heat factor for energy; represents the increased savings due to reduced waste heat from motors that must be rejected by the refrigeration equipment | | *None* | Cooler: 1.38  Freezer 1.76 | | | 3 |
| , Rated horsepower of the motor | | *HP* | Nameplate | | | EDC Data Gathering |
| , Motor efficiency of the SP or ECM motor | | None | Default for SP: 30%  Default for ECM: 70% | | | 4 |
| , Load factor. Ratio between the actual load and the rated load. | | *%* | Based on spot metering and nameplate  Default: 0.9 | | | EDC Data Gathering  5 |
| , Conversion factor | | kW/HP | 0.746 | | | Conversion factor |
| , Coincidence factor | | *None* | Unknown control style: 0.094  ON/OFF control style: 0.087  Micropulse control style: 0.102 | | | 6 |

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Commercial Refrigeration Loadshape Project, Northeast Energy Efficiency Partnerships, October 2015. <https://neep.org/commercial-refrigeration-loadshape-report-10-2015-0>. The average kW per rated HP values are taken from Table 28. The effective runtime values are taken from Table 34.
3. Waste heat factor is calculated by dividing the annual energy savings (kWh/HP) for “Equipment and Interactive” (shown in Table 43 of the report referenced in Source 2) by annual energy savings (kWh/HP) for the “Equipment Only” equipment type (also shown in Table 43).
4. Department of Energy. “Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment.” December 2013. Motor efficiency for SP motors is drawn from Table 2.1, which provides peak efficiency ranges for a variety of motors. The motor efficiency for an ECM is drawn from the discussion in 2.4.3. <https://www.energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf>
5. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Residential Multi-Family, and Commercial/Industrial Measures. Version 6. April 16, 2018.
6. Coincidence factors are developed by dividing the PJM summer peak kW/HP savings for evaporator fan controls (shown in Table 47 of the report referenced in Source 2) by the average annual energy savings (kWh/HP) for evaporator fan controls (shown in Table 43 of the report referenced in Source 2).

### Controls: Floating Head Pressure Controls

|  |  |  |
| --- | --- | --- |
| **Target Sector** | Commercial and Industrial Establishments | |
| **Measure Unit** | Floating Head Pressure Control | |
| **Measure Life** | 15 years Source 1 | |
| **Measure Vintage** | Retrofit | |

Installers conventionally design a refrigeration system to condense at a set pressure-temperature point, typically 90 ºF. By installing a floating head pressure control[[43]](#footnote-167) (FHPCs) condenser system, the refrigeration system can change condensing temperatures in response to different outdoor temperatures. This means that the minimum condensing head pressure from a fixed setting (180 psig for R-22) is lowered to a saturated pressure equivalent at 70 ºF or less. Either a balanced-port or electronic expansion valve that is sized to meet the load requirement at a 70 ºF condensing temperature must be installed. Alternatively, a device may be installed to supplement the refrigeration feed to each evaporator attached to a condenser that is reducing head pressure.

Eligibility

This protocol documents the energy savings attributed to FHPCs applied to a single-compressor refrigeration system in commercial applications. The baseline case is a refrigeration system without FHPC whereas the efficient case is a refrigeration system with FHPC. FHPCs must have a minimum Saturated Condensing Temperature (SCT) programmed for the floating head pressure control of ≤ 70 ºF. The use of FHPC would require balanced-port expansion valves, allowing satisfactory refrigerant flow over a range of head pressures. The compressor must be 1 HP or larger.

Algorithms

There are no peak savings associated with this measure. Annual energy savings algorithms are shown below.

|  |  |
| --- | --- |
|  |  |

If the refrigeration system is rated in tonnage:

|  |  |
| --- | --- |
|  |  |

Definition of Terms

Table ‑: Terms, Values, and References for Floating Head Pressure Controls

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , Rated horsepower (HP) per compressor | *HP* |  | EDC Data Gathering |
| , Annual savings per HP |  | See Table 3‑99, Table 3‑100 | 2, 3, 4 |
| , Coefficient of Performance | *None* | Based on design conditions | EDC Data Gathering |
| Default:  Condensing Unit;  Refrigerator (Medium Temp: 28 °F – 40 °F): 2.51  Freezer (Low Temp: -20 °F – 0 °F): 1.30  Remote Condenser;  Refrigerator (Medium Temp: 28 °F – 40 °F): 2.50  Freezer (Low Temp: -20 °F – 0 °F): 1.46 | 5 |
| , Refrigeration tonnage of the system | *ton* | EDC Data Gathering | EDC Data Gathering |
| , Conversion factor to convert from ton to HP |  | Engineering Estimate | 6 |

Table ‑: Annual Savings kWh/HP by Location

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Climate Zone** | **Condensing Unit (kWh/HP)** | | | **Remote Condenser (kWh/HP)** | | |
| **Refrigerator (Medium Temp)** | **Freezer (Low Temp)** | **Default(Temp Unknown)** | **Refrigerator (Medium Temp)** | **Freezer (Low Temp)** | **Default (Temp Unknown)** |
| Allentown | 630 | 767 | 672 | 467 | 639 | 520 |
| Binghamton | 728 | 835 | 761 | 495 | 674 | 551 |
| Bradford | 765 | 860 | 794 | 511 | 686 | 565 |
| Erie | 681 | 802 | 719 | 482 | 657 | 536 |
| Harrisburg | 585 | 737 | 632 | 440 | 623 | 497 |
| Philadelphia | 546 | 710 | 597 | 435 | 609 | 489 |
| Pittsburgh | 617 | 759 | 661 | 470 | 634 | 521 |
| Scranton | 686 | 806 | 723 | 479 | 659 | 535 |
| Williamsport | 663 | 790 | 702 | 468 | 651 | 525 |

Table ‑: Default Condenser Type Annual Savings kWh/HP by Location

|  |  |  |  |
| --- | --- | --- | --- |
| **Climate Zone** | **Unknown Condenser Type Default (kWh/HP)** | | |
| **Refrigerator (Medium Temp)** | **Freezer (Low Temp)** | **Temp Unknown** |
| Allentown | 549 | 703 | 596 |
| Binghamton | 612 | 755 | 656 |
| Bradford | 638 | 773 | 680 |
| Erie | 582 | 730 | 628 |
| Harrisburg | 513 | 680 | 565 |
| Philadelphia | 491 | 660 | 543 |
| Pittsburgh | 544 | 697 | 591 |
| Scranton | 583 | 733 | 629 |
| Williamsport | 566 | 721 | 614 |

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. Floating Head Pressure Controls for Single Compressor Systems, V1.6. Accessed from RTF website <https://rtf.nwcouncil.org/measure/floating-head-pressure-controls-single-compressor-systems> on October 26, 2018.
2. Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Grocery Floating Head Pressure Controls for Single Compressor Systems, FY2010, V1. Using RTF Deemed saving estimates for the NW climate zone, data was extrapolated to Pennsylvania climate zones by using cooling degree days comparison based on the locale. <https://rtf.nwcouncil.org/measure/floating-head-pressure-controls-single-compressor-systems>
3. Default based on the Pennsylvania Act 129 2018 Non-Residential Baseline Study (<http://www.puc.pa.gov/Electric/pdf/Act129/SWE-Phase3_NonRes_Baseline_Study_Rpt021219.pdf>), which found a split of roughly 69% medium temperature displays and 31% low temperature displays.
4. No data available to predict if condensing units or remote condensers will be more prevalent, assumed 50/50 split, based on discussion with Portland Energy Conservation, Inc. (PECI) GrocerySmart staff.
5. The given COP values are averaged based on the data from Grocery Floating Head Pressure Controls for Single Compressor Systems, December 2016, V1.6
6. Conversion factor for compressor horsepower per ton: <http://www.engineeringtoolbox.com/refrigeration-formulas-d_1695.html>

### Controls: Anti-Sweat Heater Controls

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Case door |
| **Measure Life** | 12 years Source 1 |

|  |  |
| --- | --- |
|  |  |

Anti-sweat door heaters (ASDH) prevent condensation on cooler and freezer doors. Anti-sweat heater (ASH) controls sense the humidity in the store outside of reach-in, glass door refrigerated cases and turn off anti-sweat heaters during periods of low humidity. Without controls, anti-sweat heaters run continuously whether they are necessary or not.

There are two commercially available control strategies – (1) ON/OFF controls and (2) micro pulse controls that respond to a call for heating, which is typically determined using either a door moisture sensor or an indoor air temperature and humidity sensor to calculate the dew point. In the first strategy, the ON/OFF controls turn the heaters on and off for minutes at a time, resulting in a reduction in run time. In the second strategy, the micro pulse controls pulse the door heaters for fractions of a second, in response to the call for heating. Savings are realized from the reduction in energy used by not having the heaters running at all times. In addition, secondary savings result from reduced cooling load on the refrigeration unit when the heaters are off.

The baseline condition is assumed to be a commercial glass door cooler or refrigerator with heaters running 24 hours a day, seven days per week (24/7). Non-glass doors are not eligible. The savings given below are based on adding controls to doors with uncontrolled heaters utilizing either ON/OFF or micro pulse controls. The savings calculated from these algorithms is on a per door basis for two temperatures: Refrigerator/Coolers and Freezers. A default value to be used when the case service control strategies are unknown is also calculated.

Algorithms

Algorithms for annual energy savings and peak demand savings are shown below.

|  |  |  |
| --- | --- | --- |
|  | |  |
|  | |  |

Definition of Terms

Table 3‑101: Terms, Values, and References for Anti-Sweat Heater Controls

| **Term** | **Unit** | **Values** | | **Source** |
| --- | --- | --- | --- | --- |
|  | , Number of reach-in refrigerator or freezer doors controlled by sensors | | *Doors* | # of doors | | | EDC Data Gathering |
| , Connected load kW per connected door |  | EDC Data Gathering  Default: 0.13 | | 2 |
| , Effective runtime of uncontrolled ASDH | *None* | EDC Data Gathering  Default: 90.7% | | 2 | |
| , Effective runtime of ASDH with controls | *None* | Unknown control style: 45.6%  ON/OFF control style: 58.9%  Micropulse control style: 42.8% | | 2 | |
| 8,760, Hours in a year | *Hours* | 8,760 | | Conversion Factor | |
| , Waste heat factor for energy; represents the increased savings due to reduced waste heat from heaters that must be rejected by the refrigeration equipment | *None* | Cooler: 1.26  Freezer 1.51 | | 3 | |
| , Waste heat factor for energy; represents the increased savings due to reduced waste heat from heaters that must be rejected by the refrigeration equipment | *None* | Cooler: 1.26  Freezer 1.51 | | 3 | |
| , Coincidence factor | *None* | Unknown control style:  ON/OFF control style: 0.32  Micropulse control style: 0.45 | | 4 | |

Default Savings

Table 3‑102: Per Door Savings with ASDH

|  |  |  |  |
| --- | --- | --- | --- |
| **Description** | **Unknown Control** | **On/Off Control** | **Micropulse Control** |
| **Refrigerator/Cooler** |  |  |  |
| Energy Impact (kWh/door) | 642 | 453 | 682 |
| Peak Demand Impact (kW/door) | 0.072 | 0.052 | 0.073 |
| **Freezer** |  |  |  | |
| Energy Impact (kWh/door) | 770 | 543 | 818 | |
| Peak Demand Impact (kW/door) | 0.086 | 0.062 | 0.088 | |







1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Commercial Refrigeration Loadshape Project, Northeast Energy Efficiency Partnerships, October 2015. <https://neep.org/commercial-refrigeration-loadshape-report-10-2015-0>
3. Waste heat factor is calculated by dividing the PJM Summer Peak kW equipment and interactive savings for ASDH by the equipment savings from Table 52 of the report referenced in Source 2.
4. Coincidence factors developed by dividing the PJM Summer Peak kW Savings for ASDH Controls from Table 52 of the referenced report (0.057 kW/door for unknown control style, 0.041 kW/door for on/off controls, and 0.058 kW/door for micropulse controls) by the average wattage of ASDH per connected door (0.13 kW).

### Controls: Evaporator Coil Defrost Control

|  |  |  |
| --- | --- | --- |
| **Target Sector** | Commercial and Industrial Establishments | |
| **Measure Unit** | Evaporator Coil Defrost Control | |
| **Measure Life** | 10 years Source 1 | |
| **Measure Vintage** | Retrofit | |

This protocol applies to electric defrost control on small commercial walk-in cooler and freezer systems. A freezer refrigeration system with electric defrost is set to run the defrost cycle periodically throughout the day. A defrost control uses temperature and pressure sensors to monitor system processes and statistical modeling to learn the operation and requirements of the system. When the system calls for a defrost cycle, the controller determines if it is necessary and skips the cycle if it is not.

Eligibility

This measure is targeted to non-residential customers whose equipment uses electric defrost controls on small commercial walk-in freezer systems. Acceptable baseline conditions are existing small commercial walk-in coolers or freezers without defrost controls. Efficient conditions are small commercial walk-in coolers or freezers with defrost controls installed.

Algorithms

Algorithms for annual energy savings and peak demand savings are shown below.

|  |  |
| --- | --- |
|  |  |
|  |  |

Definition of Terms

Table ‑: Terms, Values, and References for Evaporator Coil Defrost Controls

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Number of evaporator fans | *Fan* | EDC Data Gathering | EDC Data Gathering |
| , kW of defrost element | *kW* | EDC Data Gathering  Default: 0.9 | EDC Data Gathering,  2 |
| , Savings percentage for reduced defrost cycles | *None* | 30% | 3 |
| , Savings factor for reduced cooling load from eliminating heat generated by the defrost element | *None* | Coolers: 1.3  Freezers: 1.67 | 4 |
| , Average annual full load defrost hours |  | EDC Data Gathering  Default: 487 | EDC Data Gathering,  5 |



Default Savings

Default savings may be claimed using the algorithms above and the variable defaults. EDCs may also claim savings using customer specific data.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. Vermont Technical Reference User Manual (TRM), March 16, 2015171. This is a conservative estimate is based on a discussion with Heatcraft based on the components expected life. <https://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf>
2. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. Pg. 170. The total Defrost Element kW is proportional to the number of evaporator fans blowing over the coil. The typical wattage of the defrost element is 900W per fan. <https://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf>
3. Smart defrost kits claim 30-40% savings (with 43.6% savings by third party testing by Intertek Testing Service). MasterBilt Demand defrost claims 21% savings for northeast. Smart Defrost Kits are more common so the assumption of 30% is a conservative estimate. <https://www.heatcraftrpd.com/PDF/Sales%20Brochures/SB-IN-SMARTDEFROST.pdf>
4. ASHRAE Handbook 2014 Refrigeration, Section 15.14 Figure 24.
5. Demand Defrost Strategies in Supermarket Refrigeration Systems, Oak Ridge National Laboratory, 2011. The refrigeration system is assumed to be in operation every day of the year, while savings from the evaporator coil defrost control will only occur during set defrost cycles. This is assumed to be (4) 20-minute cycles per day, for a total of 487 hours.  
   <https://info.ornl.gov/sites/publications/files/pub31296.pdf>

### Variable Speed Refrigeration Compressor

|  |  |  |
| --- | --- | --- |
| **Target Sector** | Commercial and Industrial Establishments | |
| **Measure Unit** | VSD Refrigeration Compressor | |
| **Measure Life** | 15 years Source 1 | |
| **Measure Vintage** | Retrofit | |

Variable speed drive (VSD) compressors are used to control and reduce the speed of the compressor during times when the refrigeration system does not require the motor to run at full capacity. VSD control is an economical and efficient retrofit option for existing compressor installations. The performance of variable speed compressors can more closely match the variable refrigeration load requirements thus minimizing energy consumption.

Eligibility

This measure, VSD control for refrigeration systems and its eligibility targets applies to retrofit construction in the commercial and industrial building sectors; it is most applicable to grocery stores or food processing applications with refrigeration systems. This protocol is for a VSD control system replacing a slide valve control system.

Algorithms

The savings algorithms are shown below. There are two distinct sets of algorithms – one for if the refrigeration system is rated in tonnage, and another for if the refrigeration system is rated in horsepower.

If the refrigeration system is rated in tonnage:

|  |  |
| --- | --- |
|  |  |
|  |  |

If the refrigeration system is rated in horsepower:

|  |  |
| --- | --- |
|  |  |
|  |  |

Definition of Terms

Table ‑: Terms, Values, and References for VSD Compressors

| **Term** | **Unit** | **Values** | **Sources** |
| --- | --- | --- | --- |
| , Refrigeration tonnage of the system | *ton* | EDC Data Gathering | EDC Data Gathering |
| , Rated horsepower per compressor | *HP* | EDC Data Gathering | EDC Data Gathering |
| , Energy savings value in kWh per ton |  | 1,696 | 2 |
| , Demand savings value in kW per ton |  | 0.22 | 2 |
| , Conversion factor to convert from HP to ton |  | 0.212 | 3 |
| COP, Coefficient of performance | None | EDC Data Gathering  Default for reach-in coolers = 2.04  Default for reach-in freezers = 1.25  Default for reach-in unknown = 1.80  Default for walk-in coolers = 3.42  Default for walk-in freezers = 1.00  Default for walk-in unknown = 2.67 | 4 |

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. 2005 DEER (Database for Energy Efficiency Resources). This measure considered the associated savings by vintage and by climate zone for compressors. The deemed value was an average across all climate zones and all vintages (excluding new construction). <http://www.deeresources.com/index.php/deer2005>
3. Conversion factor for HP to ton is 0.212. From <https://www.advancedconverter.com/unit-conversions/power-conversion/tons-to-horsepower>
4. Navigant Consulting Inc., “*Energy Savings Potential and R&D Opportunities for Commercial Refrigeration,*” U.S. Department of Energy, September 2009. Table 4-4. <https://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf>. The defaults for the “unknown” case represent a weighted average of the cooler and freezer COPs. A split of 69/31 (coolers to freezers) is assumed based on the Pennsylvania Act 129 Non-Residential Baseline Study.

### Strip Curtains for Walk-In Freezers and Coolers

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Walk-in unit door |
| **Measure Life** | 4 years Source 1 |
| **Measure Vintage** | Retrofit |

Strip curtains are used to reduce the refrigeration load associated with the infiltration of non-refrigerated air into the refrigerated spaces of walk-in coolers or freezers.

The primary cause of air infiltration into walk-in coolers and freezers is the air density difference between two adjacent spaces of different temperatures. The total refrigeration load due to infiltration through the main door into the unit depends on the temperature differential between the refrigerated and non-refrigerated airs, the door area and height, and the duration and frequency of door openings. The avoided infiltration depends on the efficacy of the newly installed strip curtains as infiltration barriers.[[44]](#footnote-176) The calculation of the refrigeration load due to air infiltration and the energy required to meet that load is rather straightforward, but relies on critical assumptions regarding the aforementioned operating parameters. Algorithms and assumptions in this protocol are drawn from a Strip Curtains measure maintained by the RTF, which calculates savings using the formulas outlined in ASHRAE's Refrigeration Handbook for calculating refrigeration load from infiltration by air exchange.Source 2

Eligibility

This protocol documents the energy savings attributed to strip curtains applied on walk-in cooler and freezer doors in commercial applications. The most likely areas of application are large and small grocery stores, supermarkets, restaurants, and refrigerated warehouses. The baseline case is a walk-in cooler or freezer that previously had no strip curtain installed. The efficient equipment is a strip curtain added to a walk-in cooler or freezer. Strip curtains must be at least 0.06 inches thick. Low temperature strip curtains must be used on low temperature applications.







Algorithms for annual energy savings and peak demand savings are shown below.

|  |  |
| --- | --- |
|  |  |
|  |  |



Table ‑: Terms, Values, and References for Strip Curtains

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , Average annual kWh savings per square foot of infiltration barrier |  | Default: Table 3‑107 | 2 |
| , Average kW savings per square foot of infiltration barrier |  | Default: Table 3‑107 | 2 |
| , Doorway area |  | EDC Data Gathering  Default: Table 3‑106 | 2 |

106: Doorway Area Assumptions

|  |  |
| --- | --- |
| **Type** | **Doorway Area,** |
| Grocery - Cooler | 21 |
| Grocery - Freezer | 21 |
| Convenience Store - Cooler | 21 |
| Convenience Store - Freezer | 21 |
| Restaurant - Cooler | 21 |
| Restaurant - Freezer | 21 |
| Refrigerated Warehouse - Cooler | 120 |

Default Savings

The default savings values, per square foot, are listed in Table 3‑107. Default square footage values by facility type are listed in Table 3‑106. The defaults are drawn from a Strip Curtains measure maintained by the RTF.

Table ‑: Default Energy Savings and Demand Reductions for Strip Curtains per Square Foot

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Type** |  | **Energy Savings,** | | **Demand Savings,** |
| Grocery - Cooler | | 123 |  | 0.0160 |
| Grocery - Freezer | | 535 |  | 0.0659 |
| Convenience Store - Cooler | | 19 |  | 0.0025 |
| Convenience Store - Freezer | | 31 |  | 0.0038 |
| Restaurant - Cooler | | 24 |  | 0.0031 |
| Restaurant - Freezer | | 129 |  | 0.0158 |
| Refrigerated Warehouse - Cooler | | 410 |  | 0.0532 |











|  | |  |  | | |  | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |

Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings according to store type. The strip curtains are not expected to be installed directly. As such, the program tracking / evaluation effort must capture the following key information:

* Fraction of strip curtains installed in each of the categories (e.g. freezer / cooler and store type)
* Doorway area

The rebate forms should track the above information. During the M&V process, interviews with site contacts should track this fraction, and savings should be adjusted accordingly.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Database for UES Measures, Regional Technical Forum. Strip Curtains, version 1.7. December 2016. <https://rtf.nwcouncil.org/measure/strip-curtains>

### Night Covers for Display Cases

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Display Case |
| **Measure Life** | 5 years Source 1 |
| **Measure Vintage** | Retrofit |

|  |  |
| --- | --- |
| Night covers are deployed during the facility’s unoccupied hours in order to reduce refrigeration energy consumption. |  |

Eligibility

This measure documents the energy savings associated with the installation of night covers on existing open-type refrigerated display cases. These types of display cases can be found in small and medium to large size grocery stores. The air temperature is below 0 °F for low-temperature display cases, between 0 °F to 30 °F for medium-temperature display cases, and between 35 °F to 55 °F for high-temperature display cases.Source 2 It is recommended that these covers have small, perforated holes to decrease moisture buildup.

Algorithms



There are no demand savings for this measure because the covers will not be in use during the peak period. The annual energy savings are obtained through the calculation shown below.Source 3

|  |  |
| --- | --- |
|  |  |

Table ‑: Terms, Values, and References for Night Covers

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| W, Width of the opening that the night covers protect | *ft* | EDC Data Gathering | EDC Data Gathering |
| SF, Savings factor based on the temperature of the case |  | Default: Table 3‑109 | 3 |
| HOU, Annual hours that the night covers are in use |  | EDC Data Gathering  Default = 2,190 | EDC Data Gathering  4 |

Table ‑: Savings Factors

|  |  |
| --- | --- |
| **Cooler Case Temperature** | **Savings Factor** |
| Low Temperature (-35 F to -5 F) | 0.03 kW/ft |
| Medium Temperature (0 F to 30 F) | 0.02 kW/ft |
| High Temperature (35 F to 55 F) | 0.01 kW/ft |
| Unknown | 0.01 kW/ft |

The demand and energy savings assumptions are based on analysis performed by Southern California Edison (SCE). SCE conducted this test at its Refrigeration Technology and Test Center (RTTC). The RTTC’s sophisticated instrumentation and data acquisition system provided detailed tracking of the refrigeration system’s critical temperature and pressure points during the test period. These readings were then utilized to quantify various heat transfer and power related parameters within the refrigeration cycle. The results of SCE’s test focused on three typical scenarios found mostly in supermarkets.

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.

Massachusetts Technical Reference Manual, October 2015, pg. 261. <http://ma-eeac.org/wordpress/wp-content/uploads/2016-2018-Plan-1.pdf>

1. CL&P Program Savings Documentation for 2016 Program Year (2015). Pg. 96. Factors based on Southern California Edison (1997). *Effects of the Low Emissive Shields on Performance and Power Use of a Refrigerated Display Case*.

<https://neep.org/sites/default/files/2015_10_01_2016%20Program%20Savings%20Document.pdf>

1. The default is based on 6 hours per night, 365 days per year. The SCE paper noted in Source 3 assumes covers are deployed for 6 hours daily.

### Auto Closers

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Walk-in Cooler and Freezer Door |
| **Measure Life** | 8 years Source 1 |
| **Measure Vintage** | Retrofit |

The auto-closer should be applied to the main insulated opaque door(s) of a walk-in cooler or freezer. Auto-closers on freezers and coolers can reduce the amount of time that doors are open, thereby reducing infiltration and refrigeration loads. These measures are for retrofit of doors not previously equipped with auto-closers, and assume the doors have strip curtains.

Eligibility

This protocol documents the energy savings attributed to installation of auto closers in walk-in coolers and freezers. The auto-closer must be able to firmly close the door when it is within one inch of full closure. The walk-in door perimeter must be ≥ 16 feet.

Algorithms

The energy and demand savings for this measure were developed based on an SCE working paper regarding refrigerated storage auto closers.Source 2 The paper notes that, “energy savings were determined through building simulation in eQUEST 3.65 Refrigeration. Only the Grocery building type was simulated, and its savings were used for other building types because walk-in coolers and freezers generally have the same characteristics regardless of building type.” Additionally, it is noted that peak demand savings were calculated by averaging the demand during the DEER peak period. This period varies by California climate zone. The working paper provided savings values for each of California’s 16 climate zones. For Pennsylvania, energy savings were extrapolated via a regression model that predicted energy savings based on HDD and CDD (using data from the 16 California climate zones). Average HDD and CDD for the nine Pennsylvania weather cities were plugged into the regression model. Peak demand savings from the SCE study could not be modeled as a function of HDD and CDD, so the peak demand savings from the California climate zone most similar to the Pennsylvania weather cities (in terms of CDD and HDD) were chosen (zone 16).

**Main Cooler Doors**

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**Main Freezer Doors**

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Definition of Terms

Table ‑: Terms, Values, and References for Auto Closers

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Annual kWh savings for main cooler doors |  | Table 3‑111 | 2 |
| , Summer peak kW savings for main cooler doors |  | Table 3‑111 | 2 |
| , Annual kWh savings for main freezer doors |  | Table 3‑111 | 2 |
| , Summer peak kW savings for main freezer doors |  | Table 3‑111 | 2 |

Default Savings

Table ‑: Refrigeration Auto Closers Default Savings

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Reference City** | | **Cooler/Unknown** | | | **Freezer** | | |
|  |  | **kWhcooler** | | **kWcooler** | **kWhfreezer** | | **kWfreezer** |
| All PA cities | | 737 |  | 0.463 | 1,997 | | 0.488 |

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Southern California Edison, “Refrigerated Storage Auto Closer”, Workpaper SCE17RN024, Measure R79 (Cooler) & R80 (Freezer). <http://www.deeresources.net/workpapers>.

### Door Gaskets for Walk-in and Reach-in Coolers and Freezers

|  |  |  |
| --- | --- | --- |
| **Target Sector** | | Commercial and Industrial Establishments |
| **Measure Unit** | | Door Gasket |
| **Measure Life** | | 4 years Source 1 |
| **Measure Vintage** | | Replace on Burnout |

The following protocol for the measurement of energy and demand savings is applicable to commercial refrigeration and applies to the replacement of worn-out gaskets with new better-fitting gaskets. Applicable gaskets include those located on the doors of walk-in and/or reach-in coolers and freezers.

Tight fitting gaskets inhibit infiltration of warm, moist air into the cold refrigerated space, thereby reducing the cooling load. Aside from the direct reduction in cooling load, the associated decrease in moisture entering the refrigerated space also helps prevent frost on the cooling coils. Frost build-up adversely impacts the coil’s, heat transfer effectiveness, reduces air passage (lowering heat transfer efficiency), and increases energy use during the defrost cycle. Therefore, replacing defective door gaskets reduces compressor run time and improves the overall effectiveness of heat removal from a refrigerated cabinet.

Eligibility

This protocol applies to the main doors of both low temperature (“freezer” – below 32 °F) and medium temperature (“cooler” – above 32 °F) walk-ins and reach-ins.

Algorithms

The demand and energy savings assumptions are based on analysis performed by Southern California Edison. The energy savings and demand reduction are obtained through the following calculations:

|  |  |
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Table ‑: Terms, Values, and References for Door Gaskets

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Annual energy savings per gasket door |  | Table 3‑113 | 2 |
| , Demand savings per gasket door |  | Table 3‑113 | 2 |
| Doors, Total number of gasket doors replaced | *Doors* | As Measured | EDC Data Gathering |

Default Savings

The default savings values below are drawn from a door gasket replacement measure maintained by the RTF.Source 2 Energy and demand savings are derived from a mixture of logger data and a direct impact evaluation. Savings for freezers are less than savings for coolers for reach-ins but not walk-ins – this is largely due to HVAC interactions captured in the study.

Table ‑: Door Gasket Savings Per Door for Walk-in and Reach-in Coolers and Freezers

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Type** | **Coolers** | | | **Freezers** | | | | |
|  | |  |  | | |  | |
| Reach-in | 0.032 | | 248 | 0.032 | | | 243 | |
| Walk-in | 0.027 | | 204 | 0.045 | | | 347 | |

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Database for UES Measures, Regional Technical Forum. Door Gasket Replacement, version 1.5. December 2016. <https://rtf.nwcouncil.org/measure/door-gasket-replacement>

### Special Doors with Low or No Anti-Sweat Heat for Reach-In Freezers and Coolers

|  |  |  |
| --- | --- | --- |
| **Target Sector** | | Commercial and Industrial Establishments |
| **Measure Unit** | | Per Door |
| **Measure Life** | | 12 years Source 1 |
| **Measure Vintage** | | Retrofit |

Traditional clear glass display case doors consist of two-pane glass (three-pane in low and medium temperature cases) and aluminum doorframes and door rails. Glass heaters may be included to eliminate condensation on the door or glass. The door heaters are traditionally designed to overcome the highest humidity conditions as cases are built for nation-wide applications. New low heat/no heat door designs incorporate heat reflective coatings on the glass, gas inserted between the panes, non-metallic spacers to separate the glass panes, and/or non-metallic frames (such as fiberglass). Using low-heat or no-heat doors can reduce the energy consumption of the case by using lower wattage heaters or a reduced number of total heaters per door. The savings results from reduced electric energy consumed by the heaters, and from the reduced cooling load on the refrigeration system.

This protocol documents the energy savings attributed to the installation of special glass doors with low/no anti-sweat heaters for reach-in coolers or freezers. The primary focus of this rebate measure is on new cases to incent customers to specify advanced doors when they are purchasing refrigeration cases.

Eligibility

For this measure, a no-heat/low-heat clear glass door must be installed on an upright display case. It is limited to door heights of 57 inches or more. Doors must have either heat reflective treated glass, be gas filled, or both. The baseline is assumed to be standard energy doors.

Algorithms

The energy savings and demand reduction are obtained through the following calculations adopted from the Wisconsin Focus on Energy 2018 TRM.Source 2







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Table ‑: Terms, Values, and References for Special Doors with Low or No Anti-Sweat Heat

| **Term** | | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- | --- |
| , Conversion from watts to kW | |  |  | Conversion factor |
| , Wattage of standard door heaters | | *W* | Nameplate Input Wattage | EDC Data Gathering |
| , Wattage of low-heat or no-heat doors | | *W* | Nameplate Input Wattage | EDC Data Gathering |
| , Coefficient of performance | | *None* | Coolers: 2.04  Freezers: 1.25 | 3 |
| , Annual hours of use | | *Hours* | EDC Data Gathering  Default: 8,760 | Conversion factor |

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Wisconsin Focus on Energy 2018 Technical Reference Manual, Refrigeration: Energy-Efficient Case Doors. Page 577. <https://www.focusonenergy.com/sites/default/files/TRM%202018%20Final%20Version%20Dec%202017_1.pdf>
3. Navigant Consulting Inc., “*Energy Savings Potential and R&D Opportunities for Commercial Refrigeration,*” U.S. Department of Energy, September 2009. Table 4-4. <https://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf>

### Suction Pipe Insulation for Walk-In Coolers and Freezers

|  |  |  |  |
| --- | --- | --- | --- |
| **Target Sector** | | Commercial and Industrial Establishments | |
| **Measure Unit** | | Per Linear Foot of Insulation | |
| **Measure Life** | | 11 years Source 1 | |
| **Measure Vintage** | | Retrofit | |

This measure applies to the installation of insulation on existing bare suction lines (the larger diameter lines that run from the evaporator to the compressor) that are located outside of the refrigerated space for walk-in coolers and freezers. Insulation impedes heat transfer from the ambient air to the suction lines, thereby reducing undesirable system superheat. This decreases the load on the compressor, resulting in decreased compressor operating hours, and energy savings.

Eligibility

This protocol documents the energy savings attributed to insulation of bare refrigeration suction pipes. The following are the eligibility requirements:

* Must insulate bare refrigeration suction lines 1-5/8 inches in diameter or less on existing equipment only;
* Medium temperature lines require 3/4 inch of flexible, closed-cell, nitrite rubber or an equivalent insulation;
* Low temperature lines require 1-inch of insulation that is in compliance with the specifications above; and
* Insulation exposed to the outdoors must be protected from the weather (i.e. jacketed with a medium-gauge aluminum jacket). Source 2

Algorithms

The demand and energy savings assumptions are based analysis performed by Southern California Edison (SCE).Source 1 Measure savings per linear foot of insulation installed on bare suction lines in Restaurants and Grocery Stores are provided in Table 3‑116. These savings were extrapolated via a regression model that predicted the savings for each of California’s 16 climate zones based on CDD. Average CDD for the nine Pennsylvania weather cities was plugged into the regression models.



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Table ‑: Terms, Values, and References for Insulate Bare Refrigeration Suction Pipes

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Annual energy savings per linear foot of insulation |  | Default: Table 3‑116 | 1 |
| , Demand savings per linear foot of insulation |  | Default: Table 3‑116 | 1 |
| L, Total insulation length | *ft* | As Measured | EDC Data Gathering |

Default Savings

Table 3‑116 shows default savings *per linear foot* for this measure. To calculate annual energy savings and peak demand savings, multiply the values shown in Table 3‑116 by the total insulation length ().

Table ‑: Insulate Bare Refrigeration Suction Pipes Savings per Linear Foot

| **City** |  | **Medium-Temperature Walk-in Coolers** | | **Low-Temperature Walk-in Freezers** | |
| --- | --- | --- | --- | --- | --- |
|  | **ΔkW/ft** | **ΔkWh/ft** | **ΔkW/ft** | **ΔkWh/ft** |
| All PA cities |  | 0.005 | 24.8 | 0.016 | 85.5 |

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. Southern California Edison Company, “Insulation of Bare Refrigeration Suction Lines”, Work Paper SCE13RN003. <http://www.deeresources.net/workpapers>
2. Commonwealth Edison Refrigeration Incentives Worksheet 2018. https://www.comed.com/WaysToSave/ForYourBusiness/Documents/RefrigerationWorksheet.pdf

### Refrigerated Display Cases with Doors Replacing Open Cases

|  |  |  |
| --- | --- | --- |
| **Target Sector** | Commercial and Industrial Establishments | |
| **Measure Unit** | Refrigerated Display Case | |
| **Measure Life** | 12 years Source 1 | |
| **Measure Vintage** | Early Replacement | |

This measure considers the replacement of existing vertical open display cases with new closed display cases. The baseline equipment is an average existing medium temperature vertical open display case. The doors on the new cases must be no sweat (also known as zero heat). The display cases should be medium temperature (typically for dairy, meats, or beverages) as opposed to low temperature (typically for frozen food and ice cream). This calculation quantifies the infiltration savings seen by the compressor. Lighting or other upgrades should be considered as separate projects.

Eligibility

The eligible equipment is a new case with no sweat doors that meets federal standard requirements. If a lighting retrofit is included with the new case, it must consume the same amount of energy or less than the old lighting. Upgrades to lighting or other system components should be processed separately. Horizontal cases are not eligible and should be processed as custom.

Algorithms

Deemed energy savings per linear foot of case are based on a project that compared a typical open refrigerated display case line-up to a typical glass-doored refrigerated display case line-up.Source 2

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Definition of Terms

Table ‑: Terms, Values, and References for Refrigerated Display Cases with Doors Replacing Open Cases

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | | **Source** | |
| *,* Deemed energy savings per linear foot of case |  | 404.4 | | 2 | |
| , Width of case opening in feet | ft | EDC Data Gathering | | EDC Data Gathering | |

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Fricke, Brian and Becker, Bryan, "Energy Use of Doored and Open Vertical Refrigerated Display Cases" (2010). International Refrigeration and Air Conditioning Conference. Paper 1154. Values derived from Table 1 and the relative width of the display cases used in the study (without anti-sweat heaters). Energy savings assume 365.25 days of annual operation. Demand savings assume flat energy savings throughout the day. <http://docs.lib.purdue.edu/iracc/1154>

### Adding Doors to Existing Refrigerated Display Cases

|  |  |  |
| --- | --- | --- |
| **Target Sector** | Commercial and Industrial Establishments | |
| **Measure Unit** | Refrigerated Display Case | |
| **Measure Life** | 12 years Source 1 | |
| **Measure Vintage** | Retrofit | |

This measure considers adding doors to existing vertical open display cases. The baseline equipment is an existing vertical display case of medium temperature with no doors. The display cases should be medium temperature (typically for dairy, meats, or beverages) as opposed to low temperature (typically for frozen food and ice cream). The added doors may be no sweat (also known as zero heat) or they may contain anti-sweat heaters. This calculation quantifies infiltration savings which are realized at the compressor due to reduced load. Lighting or other upgrades should be considered as separate projects.

Eligibility

The eligible retrofit equipment is either no sweat doors or doors with anti-sweat heaters. If a lighting retrofit is included with the new doors, it must consume the same amount of energy or less energy than the old lighting. Upgrades to lighting or other system components should be processed separately. Horizontal cases are not eligible and should be processed as custom.

Algorithms

Algorithms for annual energy savings and peak demand savings are shown below. Demand savings assume flat energy savings throughout the day.

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Table ‑: Terms, Values, and References for Adding Doors to Refrigerated Display Cases

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| *,* Energy savings factor. Percent of baseline energy consumption saved by adding doors. |  | Default without anti-sweat heaters: 87%  Default with anti-sweat heaters: 52% | 2, 3 |
| , Width of case opening in feet | ft | EDC Data Gathering | EDC Data Gathering |
| , Average daily compressor energy usage per linear foot of display case |  | EDC Data Gathering  Default = 1.76 | 3 |
| , Annual days of operation |  | EDC Data Gathering  Default = 365.25 | EDC Data Gathering |

There are no default savings for this measure.

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Faramarzi, R.T., Coburn, B.A., Sarhadian, R., 2002, Performance and Energy Impact of Installing Glass Doors on an Open Vertical Deli/Dairy Display Case, *ASHRAE Trans.*, vol. 108, no. 1: p. 673-679. The authors conclude that installing glass doors on an open vertical refrigerated display case results in an 87% reduction in compressor power demand.
3. Fricke, Brian and Becker, Bryan, "Energy Use of Doored and Open Vertical Refrigerated Display Cases" (2010). International Refrigeration and Air Conditioning Conference. Paper 1154. For a 24-ft open display case line-up, average daily compressor energy consumption was 42.20 kWh (Table 1), or 1.76 kWh/ft. Average daily energy consumption of anti-sweat heaters is estimated to be 0.61 kWh/ft – about 35% of baseline compressor energy usage. The ESF is then estimated to be 52% (87% - 35%) in cases where anti-sweat heaters are added. <http://docs.lib.purdue.edu/iracc/1154>

### Air-Cooled Refrigeration Condenser

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Refrigeration Condenser |
| **Measure Life** | 15 years Source 1 |
| **Measure Vintage** | Replace on Burnout, Early Replacement, Retrofit, New Construction |

This measure involves installing an efficient, close-approach (“Approach” or “TD” refers to the temperature difference between the design condensing temperature and the design ambient outdoor temperature.) air-cooled refrigeration system condenser, which saves energy by reducing condensing temperatures and improving the efficiency of the condenser fan system.

Eligibility

This protocol documents energy savings attributed to providing an efficient air-cooled refrigeration system condenser for commercial and industrial refrigeration applications. This measure requires new equipment with an approach temperature of 13ºF or less on low-temperature applications and an approach temperature of 8ºF or less on medium-temperature applications. Specific fan power must be greater than or equal to 85 Btu/hr of heat rejection capacity per watt of fan power.

The baseline condition is assumed to be a standard efficiency air-cooled refrigeration system condenser with a 20ºF approach temperature on low-temperature applications and a 15ºF approach temperature on medium-temperature applications. The baseline equipment incorporates a fan with 45 Btu/hr of heat rejection capacity per watt of fan power. The unit energy savings and peak demand reduction are obtained through the following formulas:

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Table 3‑119: Terms, Values, and References for Air-Cooled Refrigeration Condensers

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Capacity of refrigeration system compressor | Tons | EDC Data Gathering | - |
| , Change in unit energy consumption | kWh/ton | Default: Table 3‑120 | 2 |
| , Change in unit power demand | kW/ton | Default: Table 3‑120 | 2 |

Default Savings

The unit energy and peak demand savings per ton of compressor capacity were approximated for Pennsylvania cities based on an extrapolation from New York state data, calculated from a DOE-2.2 simulation of a prototypical grocery store, which include refrigerated and non-refrigerated food sales convenience stores and specialty food sales.Source 2 The New York TRM assumes that grocery stores and convenience stores are the primary application for this measure, which is a reasonable assumption for applications in Pennsylvania as well. The energy savings were modified using proxy variables for outdoor air temperature, which has a direct effect on the energy savings that can be achieved with this measure using a linear regression model. The proxy variables, chosen as heating and cooling equivalent full-load hours (EFLH, as defined Table 3‑27), were used to approximate the relationship between the projected energy savings in New York cities and the outdoor temperature in those cities. Using a linear regression analysis, data was extrapolated to estimate the energy savings that can be achieved in Pennsylvania cities. For peak demand reduction, a similar methodology was used, applying EFLH cooling data only, as peak demand reduction occurs during cooling season. The unit energy and peak demand savings per ton of capacity for seven different cities (grocery/convenience stores only) in Pennsylvania are shown below. The EDC should use the system capacity data collected to derive the final savings estimate.

Table 3‑120: Default Savings for Air-Cooled Refrigeration Condensers

|  |  |  |
| --- | --- | --- |
| **City** | **Annual Energy Savings per Ton of Capacity ()** | **Peak Demand Savings per Ton of Capacity ()** |
| Allentown | 1,307 | 0.1252 |
| Binghamton | 1,290 | 0.1430 |
| Bradford | 1,296 | 0.1429 |
| Erie | 1,318 | 0.1244 |
| Harrisburg | 1,318 | 0.1171 |
| Philadelphia | 1,312 | 0.1204 |
| Pittsburgh | 1,308 | 0.1245 |
| Scranton | 1,318 | 0.1164 |
| Williamsport | 1,323 | 0.1167 |

for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Residential, Multi-family, and Commercial/Industrial Measures. Version 3. New York State Department of Public Service. June 1, 2015. <http://www3.dps.ny.gov/W/PSCWeb.nsf/ca7cd46b41e6d01f0525685800545955/06f2fee55575bd8a852576e4006f9af7/$FILE/TRM%20Version%203%20-%20June%201,%202015.pdf>

### Refrigerated Case Light Occupancy Sensors

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Per watt of controlled lighting |
| **Measure Life** | 8 years Source 1 |
| **Measure Vintage** | Replace on Burnout, Early Replacement, Retrofit, or New Construction |

installing occupancy sensors to control LED refrigerated case lighting. Energy savings can be achieved from the installation of sensors which dim or turn off the lights when the space or aisle is unoccupied. Energy savings result from a combination of reduced lighting energy as well reduced cooling load within the case.

This measure requires the installation of motion-based lighting controls that allow the LED case lighting to be dimmed or turned off completely during unoccupied conditions.

Algorithms

The algorithm shown below shall be used to calculate the annual energy savings for this measure. There are no peak demand savings associated with this measure, as the savings are assumed to occur off-peak.

|  |  |
| --- | --- |
|  |  |

Table 3‑121: Terms, Values, and References for Refrigerated Case Light Occupancy Sensors

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Term** | | **Unit** | **Values** | **Source** |
| , Connected wattage of controlled refrigerated lighting fixtures | | W | EDC Data Gathering | EDC Data Gathering |
| , Annual operating hours | Hours/year | EDC Data Gathering  Default = 6,205 | | 4 | |
| , Interactive effects factor for energy to account for cooling savings from offset refrigeration load | None | Refrigerator and cooler = 0.29  Freezer = 0.50 | | 3 | |
| , Runtime reduction factor | None | EDC Data Gathering  24-hr facilities =  18-hr facilities = 0.29 | | 2 | |
| , Conversion factor | W/kW | 1,000 | | Conversion factor | |

Default Savings

Default savings per controlled watt are shown below.

122: Default energy and demand savings values, per watt of controlled lighting

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Value** | **Medium-Temp Applications** | | **Low-Temp Applications** | |
| **24 hr/day facilities** | **18 hr/day facilities** | **24 hr/day facilities** | **18 hr/day facilities** |
| Annual kWh savings per controlled watt | 3.1 | 2.3 | 3.6 | 2.7 |
| Peak kW savings per controlled watt | 0.0003 | 0.0003 | 0.0004 | 0.0004 |

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Database for UES Measures, Regional Technical Forum, Display Case Motion Sensors, v3.3. <https://nwcouncil.box.com/s/brl01usbhxvtrjbp0i2xcqk016lndfd1>
3. 2021 Pennsylvania TRM. Table 3‑8: Interactive Factors for All Bulb Types.
4. Theobald, M. A., Emerging Technologies Program: Application Assessment Report #0608, LED Supermarket Case Lighting Grocery Store, Northern California, Pacific Gas and Electric Company, January 2006.<http://www.etcc-ca.com/sites/default/files/OLD/images/stories/pdf/ETCC_Report_204.pdf>

### Refrigeration Economizers

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Economizer |
| **Measure Life** | 15 years Source 1 |
| **Measure Vintage** | Retrofit |

Eligibility

This measure applies to economizers installed on a walk-in refrigeration system. Economizers bring in outside air when weather conditions allow, rather than operating the compressor, thereby saving energy. This measure includes economizers with evaporator fan controls plus a circulation fan and without a circulation fan.

Walk-in refrigeration system evaporator fans run 24 hours per day (except during active defrost) for 365 days per year to provide cooling when the compressor is running and air circulation when the compressor is not running. However, evaporator fans are inefficient for air circulation, and it is more efficient to install an evaporator fan control system to turn off the evaporator fans when the compressor is not running and turn on an efficient 35-watt fan to provide air circulation.

**With Fan Control Installed**

|  |  |
| --- | --- |
|  |  |
|  |  |

**Without Fan Control Installed**

|  |  |
| --- | --- |
|  |  |
|  |  |

Definition of Terms

Table 3‑123: Terms, Values, and References for Refrigeration Economizers

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| *,* Horsepower of the compressor | *HP* | Nameplate | EDC Data Gathering |
| , Condensing unit savings, per hp | kWh/HP | Default values from Table 3‑124 | 2 |
| , Connected load kW of each evaporator fan | kW | Nameplate Input Wattage | EDC Data Gathering |
| Default: 0.123 kW | 3 |
| , Number of fans | *None* | EDC Data Gathering | EDC Data Gathering |
| , Connected load of the circulating fan | kW | EDC Data Gathering | EDC Data Gathering |
| Default: 0.035 kW | 4 |
| , Annual hours that the economizer operates |  | Default values from Table 3‑124 | 5 |
| , Duty cycle of the compressor | *None* | 50% | 6 |
| , bonus factor for reduced cooling load from running the evaporator fan less | *None* | Default: 1.29 | 7 |
| , Connected load of the economizer fan | kW | Nameplate Input Wattage | EDC Data Gathering |
| Default: 0.227 kW | 8 |
| , Duty cycle of the economizer fan on days that are cool enough for the economizer to be working | *None* | EDC Data Gathering | EDC Data Gathering |
| Default: 63% | 9 |

Default values for and are shown in Table 3‑124. If the type of compressor is unknown, EDCs may assume the “Discus” option for .

Table 3‑124: Hours and kWh Savings per HP for Refrigeration Economizers

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **City** | **Hours** | **Condensing unit savings, per HP** | | |
| **Hermetic / Semi-Hermetic** | **Scroll** | **Discus/Unknown** |
| Allentown | 1,674 | 835 | 737 | 698 |
| Binghamton | 2,254 | 1,098 | 969 | 918 |
| Bradford | 2,721 | 1,306 | 1,153 | 1,092 |
| Eerie | 1,931 | 955 | 842 | 799 |
| Harrisburg | 1,458 | 766 | 676 | 641 |
| Philadelphia | 1,223 | 625 | 551 | 523 |
| Pittsburg | 1,614 | 819 | 723 | 685 |
| Scranton | 1,860 | 924 | 816 | 773 |
| Williamsport | 1,741 | 852 | 752 | 713 |

Default Savings

There are no default savings for this measure.

Evaluation Protocol

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

1. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. “Refrigeration Economizer” measure, page 129. <https://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf>. Accessed December 2018.
2. Analysis based on TMY3 weather bin data for each location. Assume 5HP compressor size used to develop kWh/HP value. No floating head pressure controls and compressor is located outdoors.
3. Illinois Statewide Technical Reference Manual v7.0, 4.6.8 Refrigeration Economizers. Based on a weighted average of 80% shaded pole motors at 132 watts and 20% PSC motors at 88 watts. <http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf>. Accessed December 2018.
4. Wattage of fan used by Freeaire and Cooltrol. This fan is used to circulate air in the cooler when the evaporator fan is turned off. As such, it is not used when fan control is not present.
5. Economizer hours are based on a 38° F cooler setpoint, with a 5-degree economizer deadband. They were calculated by using TMY3 weather bin data for each location (number of hours < 33° F at each location is the Hours value).
6. A 50% duty cycle is assumed based on examination of duty cycle assumptions from Richard Travers (35%-65%), Cooltrol (35%-65%), Natural Cool (70%), Pacific Gas & Electric (58%). Also, manufacturers typically size equipment with a built-in 67% duty factor and contractors typically add another 25% safety factor, which results in a 50% overall duty factor (as referenced by the Efficiency Vermont, Technical Reference User Manual).
7. Navigant Consulting Inc., “*Energy Savings Potential and R&D Opportunities for Commercial Refrigeration,*” U.S. Department of Energy, September 2009. Table 4-4. <https://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf>. Compressor COP for walk-in coolers is 3.42 The bonus factor is calculated as (1 + 1/COP).
8. The 227 watts for an economizer is calculated from the average of three manufacturers: Freeaire (186 Watts), Cooltrol (285 Watts), and Natural Cool (218 Watts).
9. Average of two manufacturer estimates of 50% and 75%.

## Appliances

### ENERGY STAR Clothes Washer

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Clothes Washer |
| **Measure Life** | 11.3 years for Multifamily; 7.1 years for Laundromats Source 1 |
| **Measure Vintage** | Replace on Burnout |

This protocol discusses the calculation methodology and the assumptions regarding baseline equipment, efficient equipment, and usage patterns used to estimate annual energy savings expected from the replacement of a standard clothes washer with an ENERGY STAR clothes washer with a minimum Modified Energy Factor (MEFJ2) of ≥ 2.2 .Source 2 The Federal efficiency standard is ≥ 1.35 for Top Loading washers and ≥ 2.0 for Front Loading washers.Source 1

Eligibility

This protocol documents the energy savings attributed to efficient clothes washers meeting ENERGY STAR or better in small commercial applications. This protocol is limited to clothes washers in laundry rooms of multifamily complexes and commercial Laundromats.

Algorithms

The general form of the equation for the ENERGY STAR Clothes Washer measure savings algorithm is:

|  |  |
| --- | --- |
|  |  |

To determine resource savings, the per-unit estimates in the algorithms will be multiplied by the number of clothes washers.

Per unit energy and demand savings are obtained through the following calculations:

|  |  |
| --- | --- |
|  |  |
|  |  |

**Where:**

|  |  |
| --- | --- |
|  |  |
| RMC |  |
|  |  |

The algorithms used to calculate energy savings are taken from the Energy Conservation Program: Test Procedures for Clothes Washers; Final rule.Source 3 Commercial clothes washer per-cycle energy consumption is composed of three components: water-heating energy, machine energy, and drying energy. DOE established the annual energy consumption of commercial clothes washers by multiplying the per-cycle energy and water use by the number of cycles per year.

In the above equations, MEFJ2 is the Modified Energy Factor, which is the energy performance metric for clothes washers. MEFJ2 is defined as:

*MEFJ2 is the quotient of the capacity of the clothes container, C, divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, M, the hot water energy consumption, E, and the energy required for removal of the remaining moisture in the wash load, D. The higher the value, the more efficient the clothes washer is. The equation is shown below and the metric units are ft3/kWh/cycle:*

*.* Source 2

The following steps should be taken to determine per-cycle energy consumption for top-loading and front-loading commercial clothes washers for both old and new clothes washers. Per-cycle energy use is disaggregated into water heating, machine, and clothes drying.

1. Calculate the remaining moisture content (RMC) based on the relationship between RMC and MEF.
2. Calculate the per-cycle clothes-drying energy use using the equation that determines the per-cycle energy consumption for the removal of moisture.
3. Use the per-cycle machine energy use value of 0.133 for MEFs up to 1.40 and 0.114 for MEFs greater than 1.40.Source 1
4. With the per-cycle clothes dryer and machine energy known, determine the per-cycle water-heating energy use by first determining the total per-cycle energy use (the clothes container volume divided by the MEF) and then subtracting from it the per-cycle clothes-drying and machine energy.

The utilization factor, (UF) is equal to the average energy usage between noon and 8PM on summer weekdays to the annual energy usage. The utilization rate is derived as follows:

1. Obtain normalized, hourly load shape data for residential clothes washing.
2. Smooth the load shape by replacing each hourly value with a 5-hour average centered about that hour. This step is necessary because the best available load shape data exhibits erratic behavior commonly associated with metering of small samples. The smoothing out effectively simulates diversification.
3. Take the UF to be the average of all load shape elements corresponding to the hours between noon and 8PM on weekdays from June to September.

The value is obtained using the June-September, weekday noon to 8 PM average of the normalized load shape values associated with residential clothes washers. As an example the following example if provided from PG&E service territory (northern CA). Although Northern CA is far from PA, the load shape data is the best available at the time and the temporal dependence of washer usage is not expected to have a strong geographical dependency. Figure 3‑2 shows the utilization factor for each hour of a sample week in July. Because the load shape data derived from monitoring of in-house clothes washers is being imputed to multifamily laundry room washers (which have higher utilization rates), it is important to check that the resulting minutes of usage per hour is significantly smaller than 60. If the minutes of usage per hour approaches 60, then it should be assumed that the load shape for multi-family laundry room clothes washers must be different than the load shape for in-house clothes washers. The maximum utilization per hour is 36.2 minutes.Source 4

Figure ‑: Utilization factor for a sample week in July[[45]](#footnote-216)



Table ‑: Terms, Values, and References for Commercial Clothes Washers

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | | **Source** |
| , Base Federal Standard Modified Energy Factor | *None* | Front loading: 2.0 | | 1 |
| , Modified Energy Factor of ENERGY STAR Qualified Washing Machine | *None* | Nameplate | | EDC Data Gathering |
| *None* | Default: 2.2 | | 2 |
| , Per-cycle water heating consumption |  | Calculation | | Calculation |
| , Per-cycle energy consumption for removal of moisture i.e. dryer energy consumption |  | Calculation | | Calculation |
| , Per-cycle machine electrical energy consumption |  | 0.14 | | 3 |
| , Capacity of efficient clothes washer |  | Nameplate | | EDC Data Gathering |
| Default: 3.44 | | 5 |
| , Capacity of baseline clothes washer |  | *Capee* | | EDC Data Gathering |
| Default: 3.44 | | 5 |
| , Load adjustment factor | *None* | 0.52 | | 3 |
| , Nominal energy required for clothes dryer to remove moisture from clothes |  | 0.5 | | 1 |
| , Dryer usage factor, percentage of washer loads dried in a clothes dryer | *None* | 0.91 | | 3 |
| , Maximum test-load weight |  | 14.1 | | 3 |
| , Remaining moisture content |  | Calculation | | Calculation |
| , Number of cycles per year | *Cycle* | Multifamily: 1,074  Laundromats: 1,483 | | 1 |
| , Utilization Factor | *None* | 0.0002382 | | 4 |

Default Savings

The default savings for the installation of a washing machine with a MEFJ2 of 2.2 or higher is dependent on the energy source for the washer. Table 3‑127 and Table 3‑128 show savings for ENERGY STAR washing machines with different combinations of water heater and dryer types in multifamily buildings and laundromats. The values are based on the difference between the baseline front loading clothes washer meeting federal efficiency standards and that of a front loading washer[[46]](#footnote-221) which meets ENERGY STAR standards of ≥ 2.2.

For clothes washers where fuel mix is unknown, calculate default savings using the algorithms below and EDC specific saturation values. For EDCs where saturation information is not accessible, use “Default values” described in through Table 3‑128.

|  |  |
| --- | --- |
|  |  |

**Where:**

|  |  |
| --- | --- |
|  | = Energy savings for clothes washers with gas water heater and non-electric dryer fuel from tables below |
|  | = Energy savings for clothes washers with gas water heater and electric dryer fuel from tables below |
|  | = Energy savings for clothes washers with electric water heater and non-electric dryer fuel from tables below |
|  | = Energy savings for clothes washers with electric water heater and electric dryer fuel from tables below |
|  | = Percent of clothes washers with gas water heater and non-electric dryer fuel |
|  | = Percent of clothes washers with gas water heater and electric dryer fuel |
|  | = Percent of clothes washers with electric water heater and non-electric dryer fuel |
|  | = Percent of clothes washers with electric water heater and electric dryer fuel |

Table ‑: Fuel Shares for Water Heaters and Dryers

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Equipment Type** | **Electric** | | **Non-Electric** |  |  |
| Water Heaters Source 6 | 34% | | 66% |  |
| Clothes Dryers Source 7 | 52% | | 48% |  |

Table ‑: Default Savings for Replacing Front-Loading Clothes Washer in Multifamily Buildings with ENERGY STAR Clothes Washer

|  |  |  |  |
| --- | --- | --- | --- |
| **Fuel Source** | **Cycles/ Year** | **Energy Savings (kWh)** | **Peak Demand Savings (kW)** |
| Electric Hot Water Heater, Electric Dryer | 1,074 | 168 | 0.04 |
| Electric Hot Water Heater, Gas Dryer | 1,074 | 113 | 0.027 |
| Gas Hot Water Heater, Electric Dryer | 1,074 | 55 | 0.013 |
| Gas Hot Water Heater, Gas Dryer | 1,074 | 0 | 0 |
| Default (34% Electric WH 40% Electric Dryer) | 1,074 | 67 | 0.016 |

Table ‑: Default Savings for Replacing Front-Loading Clothes Washer in Laundromats with ENERGY STAR Clothes Washer

|  |  |  |  |
| --- | --- | --- | --- |
| **Fuel Source** | **Cycles/ Year** | **Energy Savings (kWh)** | **Peak Demand Savings (kW)** |
| Electric Hot Water Heater, Electric Dryer | 1,483 | 232 | 0.055 |
| Electric Hot Water Heater, Gas Dryer | 1,483 | 155 | 0.037 |
| Gas Hot Water Heater, Electric Dryer | 1,483 | 77 | 0.018 |
| Gas Hot Water Heater, Gas Dryer | 1,483 | 0 | 0 |
| Default (0% Electric WH 0% Electric Dryer) | 1,483 | 0 | 0 |







Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. Energy Conservation Program: Energy Conservation Standards for Commercial Clothes Washers; Final Rule. <https://www.regulations.gov/document?D=EERE-2012-BT-STD-0020-0037>
2. Energy Star Clothes Washers Key Product Criteria. <https://www.energystar.gov/products/appliances/clothes_washers/key_product_criteria>
3. Energy Conservation Program: Test Procedures for Clothes Washers; Final rule. <https://www.regulations.gov/document?D=EERE-2013-BT-TP-0009-0009>
4. Annual hourly load shapes taken from Energy Environment and Economics (E3), Reviewer2: <http://www.ethree.com/cpuc_cee_tools.html>. The average normalized usage for the hours noon to 8 PM, Monday through Friday, June 1 to September 30 is 0.000243
5. Based on the average commercial clothes washer volume of all units meeting ENERGY STAR criteria listed in the ENERGY STAR database of certified products accessed on 11/15/2018. <https://www.energystar.gov/productfinder/product/certified-commercial-clothes-washers/results>.
6. Pennsylvania Act 129 2018 Non-Residential Baseline Study, <http://www.puc.pa.gov/Electric/pdf/Act129/SWE-Phase3_NonRes_Baseline_Study_Rpt021219.pdf>
7. Pennsylvania Act 129 2018 Residential Baseline Study, <http://www.puc.pa.gov/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf>

### ENERGY STAR Bathroom Ventilation Fan in Commercial Applications

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Number of Fans Installed |
| **Measure Life** | 12 years Source 1 |
| **Measure Vintage** | Replace on Burnout, Early Replacement, Retrofit, New Construction |

This protocol covers the energy and demand savings associated with installing ENERGY STAR certified bathroom ventilation fans to replace conventional bathroom ventilation fans in a non-residential application. ENERGY STAR certifies ventilation fans based on minimum efficacy (CFM/W) and maximum allowable sound level (sones). This certification may include fans that are appropriate for light commercial applications but does not include whole-house fans or attic ventilators.Source 2

Eligibility

This measure requires the installation of an ENERGY STAR certified bathroom ventilation fan in a commercial or industrial facility. See Table 3‑129 for minimum efficacy and maximum sound level eligibility requirements.

Table 3‑129: Criteria for ENERGY STAR Certified Bathroom Ventilation Fans Source 2

|  |  |  |  |
| --- | --- | --- | --- |
| **Product Type** | **Rated Airflow Range (CFM)** | **Minimum Efficacy Level (CFM/W)\*** | **Maximum Allowable Sound Level (Sones)\*** |
| Bathroom and Utility Room Fans | 10 – 89 | 2.8 | 2.0 |
| 90 – 200 | 3.5 | 2.0 |
| 201 - 500 | 4.0 | 3.0 |
| \*Products will meet requirements at all speeds, based on static pressure reference measurement as specified in Section 4.C. of the ENERGY STAR specification.Source 2 | | | |

Algorithms

The annual energy and peak demand savings are obtained through the following formulas:

|  |  |
| --- | --- |
|  |  |
|  |  |

Table 3‑130: Terms, Values, and References for ENERGY STAR Bathroom Ventilation Fans

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Nominal capacity of the exhaust fan | CFM | EDC Data Gathering | 3 |
| Default ranges in Table 3‑131 |
| , Baseline fan efficacy | CFM/W | EDC Data Gathering | 4 |
| Default = 2.6 |
| , ENERGY STAR fan efficacy | CFM/W | EDC Data Gathering | 4 |
| Default = 5.1 |
| , Annual hours of use | Hours/year | EDC Data Gathering | 5 |
| Default = 2,870 |
| *,* watts to kilowatt conversion factor |  |  | Conversion factor |
| , Coincidence factor | None | EDC Data Gathering | 6 |
| Default = 0.62 |

Default Savings

Table 3‑131: Default Savings for ENERGY STAR Bathroom Ventilation Fans in Commercial Applications

|  |  |  |  |
| --- | --- | --- | --- |
| **Capacity Range (CFM)** | **Assumed Capacity (CFM)** | **Energy Savings (kWh)** | **Peak Demand Reduction (kW)** |
| 10 – 89 | 70 | 37.9 | 0.0082 |
| 90 – 150 | 110 | 59.5 | 0.0129 |
| 151 – 250 | 175 | 94.7 | 0.0205 |
| 251 – 500 | 350 | 189.4 | 0.0409 |

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. Analysis of Standard Options for Residential Exhaust Fans, Page 3. Davis Energy Group. April 27, 2004. <http://www.energy.ca.gov/appliances/2003rulemaking/documents/case_studies/CASE_Res_Exhaust_Fans.pdf>
2. ENERGY STAR® Program Requirements Product Specification for Residential Ventilating Fans, Eligibility Criteria Version 4.0. Effective October 1, 2015. <https://www.energystar.gov/sites/default/files/asset/document/Vent%20Fans%20V4%200%20Specification_Clarification_0.pdf>
3. Efficiency Vermont, Technical Reference User Manual (TRM), March 16, 2015. Pages 52-53. Typical sizes assumed within the ranges given in Table 3‑131.
4. Default fan efficacies are based on average values for non-ENERGY STAR and ENERGY STAR, 10-500 CFM Bathroom Exhaust Fans from the Home Ventilating Institute’s *HVI-Certified Products Directory*. Updated November 1, 2016. <http://hvi.org/proddirectory/index.cfm> Accessed November 10, 2016.
5. Efficiency Vermont, Technical Reference User Manual (TRM), March 16, 2015. Page 52. Median run-hours of fans installed through Efficiency Vermont custom projects 2008-2011.
6. 0.62 represents the simple average of all coincidence factors listed in the 2015 Mid-Atlantic TRM. Estimated assuming coincidence factors from EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014 weighted by building type floor space for the Northeast census region from the Commercial Building Energy Consumption Survey, US Energy Information Administration, 2003.

## Food Service Equipment

### ENERGY STAR Ice Machines

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Ice Machine |
| **Measure Life** | 8 Years Source 1 |
| **Measure Vintage** | Replace on Burnout |

Eligibility

This measure applies to the installation of a high-efficiency ice machine as either a new item or replacement for an existing unit. The machine must be air-cooled batch-type or continuous ice makers to qualify, which can include self-contained, ice-making heads, or remote-condensing units. The baseline equipment is a commercial ice machine that meets federal equipment standards. The efficient machine must conform to the minimum ENERGY STAR efficiency requirements and meet the ENERGY STAR requirements for water usage given under the same criteria.

Algorithms

The energy savings are dependent on the capacity of ice produced on a daily basis and the duty cycle. A machine’s capacity is generally reported as an ice harvest rate, or amount of ice produced each day.

|  |  |
| --- | --- |
|  |  |
|  |  |

The reference values for each component of the energy impact algorithm are shown in Table 3‑132. A default duty cycle (D) is provided as based on referenced values from several studies, however, EDC data gathering may be used to adjust the duty cycle for custom applications.

Table ‑: Terms, Values, and References for

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Baseline ice machine energy usage per 100 lbs. of ice |  | Table 3‑133, Table 3‑134 | 2 |
| , High-efficiency ice machine energy usage per 100 lbs. of ice |  | Table 3‑135, Table 3‑136 | 3 |
| , Ice harvest rate per 24 hrs. |  | Manufacturer Specs | EDC Data Gathering |
| , Duty cycle of ice machine expressed as a percentage of time machine produces ice | *None* | Custom | EDC Data Gathering |
|  |  | Default: 0.57 | 4 |
| 365, Days per year |  | 365 | Conversion Factor |
| 100, Conversion to obtain energy per pound of ice |  | 100 | Conversion Factor |
| 8760, Hours per year |  | 8,760 | Conversion Factor |
| Ice Machine Type | *None* | Manufacturer Specs | EDC Data Gathering |
| , Coincidence Factor | *Decimal* | 0.937 | 4 |

Table ‑: Batch-Type Ice Machine Baseline Efficiencies

|  |  |  |
| --- | --- | --- |
| **Ice Machine Type** | **Ice Harvest Rate (H)** | **Baseline Energy Use per 100 lbs. of Ice** |
| Ice-Making Head | < 300 | 10 - 0.01233\*H |
| ≥ 300 and < 800 | 7.05 - 0.0025\*H |
|  | ≥ 800 and < 1,500 | 5.55 - 0.00063\*H |
|  | ≥ 1,500 and < 4,000 | 4.61 |
| Remote-Condensing w/out remote compressor | ≥ 50 and < 1,000 | 7.97 - 0.00342\*H |
| ≥ 1,000 and < 4,000 | 4.55 |
| Remote-Condensing with remote compressor | < 942 | 7.97 - 0.00342\*H |
| ≥ 942 and < 4,000 | 4.75 |
| Self-Contained | < 110 | 14.79 - 0.0469\*H |
| ≥ 110 and < 200 | 12.42 - 0.02533\*H |
|  | ≥ 200 and < 4,000 | 7.35 |

Table ‑: Continuous Type Ice Machine Baseline Efficiencies

| **Ice Machine Type** | **Ice Harvest Rate (H)** | **Baseline Energy Use per 100 lbs. of Ice** |
| --- | --- | --- |
| Ice-Making Head | < 310 | 9.19 - 0.00629\*H |
|  | ≥ 310 and < 820 | 8.23 - 0.0032\*H |
|  | ≥ 820 and < 4,000 | 5.61 |
| Remote-Condensing w/out remote compressor | < 800 | 9.7 - 0.0058\*H |
|  | ≥ 800 and < 4,000 | 5.06 |
| Remote-Condensing with remote compressor | < 800 | 9.9 - 0.0058\*H |
|  | ≥ 800 and < 4,000 | 5.26 |
| Self-Contained | < 200 | 14.22 - 0.03\*H |
|  | ≥ 200 and < 700 | 9.47 - 0.00624\*H |
|  | ≥ 700 and < 4,000 | 5.1 |

Table ‑: Batch-Type Ice Machine ENERGY STAR Efficiencies

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Ice Machine Type** | | **Ice Harvest Rate (H)** | | **Baseline Energy Use per 100 lbs. of Ice** |
| Ice-Making Head | | H < 300 | | ≤ 9.20 – 0.01134H |
| 300 ≤ H ≤ 800 | | ≤ 6.49 – 0.0023H |
| 800 ≤ H ≤ 1,500 | | ≤ 5.11 – 0.00058H |
| 1,500 ≤ H ≤ 4,000 | | ≤ 4.24 |
| Remote-Condensing Unit | | H < 988 | | ≤ 7.17 – 0.00308H |
| 988 ≤ H ≤ 4,000 | | ≤ 4.13 |
| Self-Contained (SCU) | | H < 110 | | ≤ 12.57 – 0.0399H |
| 110 ≤ H ≤ 200 | | ≤ 10.56 – 0.0215H |
| 200 ≤ H ≤ 4,000 | | ≤ 6.25 |

Table ‑: Continuous Type Ice Machine ENERGY STAR Efficiencies

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Ice Machine Type** | | **Ice Harvest Rate (H)** | | **Baseline Energy Use per 100 lbs. of Ice** |
| Ice-Making Head | | H < 310 | | ≤ 7.90 – 0.005409H |
| 310 ≤ H ≤ 820 | | ≤ 7.08 – 0.002752H |
| 820 ≤ H ≤ 4,000 | | ≤ 4.82 |
| Remote-Condensing Unit | | H < 800 | | ≤ 7.76 – 0.00464H |
| 800 ≤ H ≤ 4,000 | | ≤ 4.05 |
| Self-Contained (SCU) | | H < 110 | | ≤ 12.37 – 0.0261H |
| 200 ≤ H ≤ 700 | | ≤ 8.24 – 0.005492H |
| 700 ≤ H ≤ 4,000 | | ≤ 4.44 |

There are no default savings associated with this measure.



ENERGY STAR

1. . US Environmental Protection Agency and US Department of Energy. ENERGY STAR Commercial Kitchen Equipment Calculator.



1. Energy Conservation Program: Energy Conservation Standards for Automatic Commercial Ice Makers; Final Rule. Federal Register / Vol. 80, No. 18. January 28, 2015. <https://www.ecfr.gov/cgi-bin/text-idx?SID=b9d042311709dd0d507363e4f54ba2f2&pitd=20150128&pitd=20150128&node=20150128y1.16>
2. Commercial Ice Maker Key Product Criteria Version 3.0. <https://www.energystar.gov/index.cfm?c=comm_ice_machines.pr_crit_comm_ice_machines>
3. Illinois Statewide Technical Reference Manual v7.0 cites a default duty cycle of 57%. <http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf>. Accessed December 2018.

### Controls: Beverage Machine Controls

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Machine Control |
| **Measure Life** | 5 years Source 1 |
| **Measure Vintage** | Retrofit |

Eligibility

This measure is intended for the addition of control systems to existing, non-ENERGY STAR, beverage vending machines. The applicable machines contain refrigerated, non-perishable beverages that are kept at an appropriate temperature. The control systems are intended to reduce energy consumption due to lighting and refrigeration during times of lower customer sales. Typical control systems contain a passive infrared occupancy sensor to shut down the machine after a period of inactivity in the area. The compressor will power on for one to three hour intervals, sufficient to maintain beverage temperature, and when powered on at any time will be allowed to complete at least one cycle to prevent excessive wear and tear. This measure should not be applied to ENERGY STAR qualified vending machines, as they already have built-in controls

The baseline equipment is taken to be an existing standard refrigerated beverage vending machine that does not contain control systems to shut down the refrigeration components and lighting during times of low customer use.

Algorithms

Energy savings are dependent on decreased machine lighting and cooling loads during times of lower customer sales. The savings will be dependent on the machine environment, noting that machines placed in locations such as day-use offices will result in greater savings than those placed in high-traffic areas such as hospitals that operate around the clock. The algorithm below takes into account varying scenarios and can be taken as representative of a typical application.

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There are no peak demand savings because this measure is aimed to reduce demand during times of low beverage machine use, which will typically occur during off-peak hours.

Table ‑: Terms, Values, and References for Beverage Machine Controls

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , Wattage of beverage machine | *W* | EDC Data Gathering  Default for refrigerated beverage vending machine: 400  Default for glass front refrigerated cooler: 460 | EDC Data Gathering  1 |
| , Annual hours of operation |  | EDC Data Gathering  Default: 8,760 | EDC Data Gathering |
| , Energy savings factor | *None* | EDC Data Gathering  Default for refrigerated beverage vending machine: 46%  Default for glass front refrigerated cooler: 30% | EDC Data Gathering  1 |



Default Savings

The decrease in energy consumption due to the addition of a control system will depend on the number of hours per year during which lighting and refrigeration components of the beverage machine are powered down. The average decrease in energy use from refrigerated beverage vending machines with control systems installed is 46%.Source 1 It should be noted that various studies found savings values ranging between 30-65%, most likely due to differences in customer occupation.

The default annual energy savings is shown below. Where it is determined that the default energy saving factor (ESF) or default baseline energy consumption is not representative of specific applications, EDC data gathering can be used to determine an application-specific energy savings factor (ESF) and/or baseline energy consumption for use in the Energy Savings algorithm.

Table ‑: Default Savings for Beverage Machine Controls

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Equipment Type** | | **Annual Energy Savings (** | **Peak Demand Savings ()** |  |
| Refrigerated beverage vending machine |  | 1,611.8 | 0 | |
| Glass front refrigerated cooler |  | 1,208.9 | 0 | |



Sources

1. Illinois Statewide Technical Reference Manual v7.0, September 28, 2018, 4.6.2 Beverage and Snack Machine Controls, which sources USA Technologies Energy Management Product Sheets, July 2006; cited September 2009. <http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf>

### Controls: Snack Machine Controls

|  |  |  |
| --- | --- | --- |
| **Target Sector** | Commercial and Industrial Establishments | |
| **Measure Unit** | Machine Control | |
| **Measure Life** | 5 years Source 1 | |
| **Measure Vintage** | Retrofit | |

A snack machine controller is an energy control device for non-refrigerated snack vending machines. The controller turns off the machine’s lights based on times of inactivity. This protocol is applicable for conditioned indoor installations.

Eligibility

This measure is targeted to non-residential customers who install controls to non-refrigerated snack vending machines. Acceptable baseline conditions are non-refrigerated snack vending machines. Efficient conditions are non-refrigerated snack vending machines with controls.

Algorithms

The energy savings for this measure result from reduced lighting operation.

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Definition of Terms

Table ‑: Terms, Values, and References for Snack Machine Controls

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , Wattage of vending machine | *W* | EDC Data Gathering  Default: 85 | EDC Data Gathering  2 |
| , Annual hours of operation |  | EDC Data Gathering  Default: 8,760 | EDC Data Gathering |
| , Energy savings factor | *None* | 46% | 2 |

Default Savings

Default energy savings for this measure are 342.5 kWh.

1. Measure Life Study, prepared for the Massachusetts Joint Utilities, Energy & Resource Solutions, November 2005.
2. Illinois Statewide Technical Reference Manual v7.0, September 28, 2018. Hours of operation assume operation 24 hours per day, 365 days per year. <http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf>. Accessed December 2018.

### ENERGY STAR Electric Steam Cooker

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Electric Steam Cooker |
| **Measure Life** | 12 years Source 1 |
| **Measure Vintage** | Replace on Burnout |

Eligibility

This measure applies to the installation of electric ENERGY STAR steam cookers as either a new item or replacement for an existing unit. Gas steam cookers are not eligible. The steam cookers must meet minimum ENERGY STAR efficiency requirements. A qualifying steam cooker must meet a minimum cooking efficiency of 50 percent and meet idle energy rates specified by pan capacity.

The baseline equipment is a unit with efficiency specifications that do not meet the minimum ENERGY STAR efficiency requirements.

Algorithms

The savings depend on three main factors: pounds of food steam cooked per day, pan capacity, and cooking efficiency.

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Definition of Terms

Table ‑: Terms, Values, and References for ENERGY STAR Electric Steam Cookers

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , Pounds of food cooked per day in the steam cooker |  | EDC Data Gathering | EDC Data Gathering |
| Default values in Table 3‑141 | *2* |
| , ASTM energy to food ratio; energy (kilowatt-hours) required per pound of food during cooking |  | 0.0308 | 1 |
| , Cooking energy efficiency of the new unit | *None* | Nameplate | EDC Data Gathering |
| Default values in Table 3‑141 | 1 |
| , Cooking energy efficiency of the baseline unit | *None* | See Table 3‑141 | 1 |
| , Idle power of the baseline unit |  | See Table 3‑141 | 4 |
| , Idle power of the new unit |  | Nameplate | EDC Data Gathering |
| Default values in Table 3‑141 | 4 |
| , assumed daily hours of operation | *Hours* | EDC Data Gathering | EDC Data Gathering |
| 12 hours | 1 |
| , Percentage of idle time per day the steamer is in continuous steam mode instead of timed cooking. The power used in this mode is the same as the power in cooking mode. | *None* | 40% | 1 |
| , Production capacity per pan of the baseline unit |  | See Table 3‑141 | 1 |
| , Production capacity per pan of the new unit |  | See Table 3‑141 | 1 |
| , Quantity of pans in the unit | *None* | Nameplate | EDC Data Gathering |
| , Equivalent full load hours per year |  | 4,380 | 1 |
| , Coincidence factor | *Decimal* | 0.9 | 3 |

Default Savings

Table ‑: Default Values for Electric Steam Cookers by Number of Pans

| **# of Pans** | **Parameter** | **Baseline Model** | **Efficient Model** | **Savings** |
| --- | --- | --- | --- | --- |
| 3 | (kW) | 1.000 | 0.40 | --- |
|  | 23.3 | 16.7 | --- |
|  | 100 | 100 | --- |
|  | 30% | 50% | --- |
|  | --- | --- | 9,504 |
|  | --- | --- | 1.95 |
| 4 | (kW) | 1.325 | 0.53 | --- |
|  | 23.3 | 16.7 | --- |
|  | 128 | 128 | --- |
|  | 30% | 50% | --- |
|  | --- | --- | 12,619 |
|  | --- | --- | 2.59 |
| 5 | (kW) | 1.675 | 0.67 | --- |
|  | 23.3 | 16.7 | --- |
|  | 160 | 160 | --- |
|  | 30% | 50% | --- |
|  | --- | --- | 15,801 |
|  | --- | --- | 3.25 |
| 6 | (kW) | 2.000 | 0.80 | --- |
|  | 23.3 | 16.7 | --- |
|  | 192 | 192 | --- |
|  | 30% | 50% | --- |
|  | --- | --- | 18,497 |
|  | --- | --- | 3.89 |

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

1. ENERGY STAR. US Environmental Protection Agency and US Department of Energy. ENERGY STAR Commercial Kitchen Equipment Calculator. <https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx>
2. Food Service Technology Center (FSTC) 2012, *Commercial Cooking Appliance Technology Assessment*. Pounds of Food Cooked per Day based on the default value for a 3 pan steam cooker (100 lbs from FSTC) and scaled up based on the assumption that steam cookers with a greater number of pans cook larger quantities of food per day.
3. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs v6, effective date January 1, 2019
4. Illinois Statewide Technical Reference Manual v7.0, September 28, 2018. <http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf>. Accessed December 2018.

### ENERGY STAR Combination Oven

|  |  |  |
| --- | --- | --- |
| **Target Sector** | Commercial and Industrial Establishments | |
| **Measure Unit** | Number of Ovens Installed | |
| **Measure Life** | 12 years Source 1 | |
| **Measure Vintage** | Replace on Burnout, Early Replacement, Retrofit, New Construction | |

A combination oven is a convection oven that includes the added capability to inject steam into the oven cavity and typically offers at least three distinct cooking modes.

Eligibility

To qualify for this measure, the installed equipment must be a new electric combination oven that meets the ENERGY STAR idle rate and cooking efficiency requirements as specified in Table 3‑142.Source 2*P* represents the pan capacity of the oven.

Table 3‑142: Combination Oven Eligibility Requirements

|  |  |  |  |
| --- | --- | --- | --- |
| **Fuel Type** | **Operation** | **Idle Rate (kW)** | **Cooking-Energy Efficiency (%)** |
| Electric | Steam Mode Convection Mode | ≤ 0.133P + 0.6400 ≤ 0.080P + 0.4989 | ≥ 55 ≥ 76 |



Algorithms

The following algorithms are used to quantify the annual energy and coincident peak demand savings, accounting for the convection-mode cooking energy, the steam-mode cooking energy, and the idle-mode energy consumption.

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**Where:**

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Table ‑: Terms, Values, and References for ENERGY STAR Combination Ovens

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| *P,* Pan capacity - The number of steam table pans the combination oven is able to accommodate as per the ASTM F-1495-05 standard specification. | Pans | EDC Data Gathering | EDC Data Gathering |
| , change in total daily cooking energy consumed by electric oven in convection mode | Wh/day | Calculated | 1 |
| , change in total daily cooking energy consumed by electric oven in steam mode | Wh/day | Calculated | 1 |
| , change in total daily idle energy consumed by electric oven in convection mode | Wh/day | Calculated | 1 |
| , change in total daily idle energy consumed by electric oven in convection mode | Wh/day | Calculated | 1 |
| , average daily operating hours | Hours/day | EDC Data Gathering  Default = 12 hours | 1 |
| , annual days of operation | Days/yr | EDC Data Gathering  Default = 365 | 1 |
| , energy absorbed by food product for electric oven in convection mode | W-hr/lb | EDC Data Gathering  Default = 73.2 | 1 |
| , estimated mass of food cooked per day for electric oven | lbs/day | EDC Data Gathering  Default = 200 (If P < 15) or 250 (If P ≥ 15) | 1 |
| , cooking energy efficiency of electric oven | % | EDC Data Gathering  Default: Table 3‑144 | 1 |
| , percentage of time in convection mode | % | EDC Data Gathering  Default = 50 | 1 |
| , energy absorbed by food product for electric oven in steam mode | W-hr/lb | EDC Data Gathering  Default = 30.8 | 1 |
| , percentage of time in steam mode | % |  | 1 |
| , Idle energy rate of baseline electric oven in convection mode | W | EDC Data Gathering  Default: Table 3‑145 | 1 |
| , Idle energy rate of baseline electric oven in steam mode | W | EDC Data Gathering  Default: Table 3‑145 | 1 |
| , production capacity of baseline electric oven in convection mode | lbs/hr | EDC Data Gathering  Default: Table 3‑146 | 1 |
| , production capacity of baseline electric oven in steam mode | lbs/hr | EDC Data Gathering  Default: Table 3‑146 | 1 |
| , Idle energy rate of ENERGY STAR electric oven in convection mode | W |  | 1 |
| , Production capacity of ENERGY STAR electric oven in convection mode | lbs/hr | EDC Data Gathering  Default: Table 3‑147 | 1 |
| , Production capacity of ENERGY STAR electric oven in steam mode | lbs/hr | EDC Data Gathering  Default: Table 3‑147 | 1 |
| , Idle energy rate of ENERGY STAR electric oven in steam mode | W |  | 1 |
| , W to kW conversion factor | kW/W |  | 1 |
| , Coincidence factor | None | EDC Data Gathering  Default = 0.9 | 3 |



Table ‑: Default Baseline and Efficient-Case Values for ElecEFF

|  |  |  |
| --- | --- | --- |
| **Value** | **Base** | **EE** |
| ElecEFFConv | 72% | 76% |
| ElecEFFSteam | 49% | 55% |

Table 3‑145: Default Baseline Values for ElecIDLE

|  |  |  |
| --- | --- | --- |
| **Pan Capacity** | **Convection Mode (ElecIDLEConvBase)** | **Steam Mode (ElecIDLESteamBase)** |
| < 15 | 1,320 | 5,260 |
| ≥ 15 | 2,280 | 8,710 |

Table 3‑146: Default Baseline Values for ElecPC

|  |  |  |
| --- | --- | --- |
| **Pan Capacity** | **Convection Mode (ElecPCConvBase)** | **Steam Mode (ElecPCSteamBase)** |
| < 15 | 79 | 126 |
| ≥ 15 | 166 | 295 |

Table 3‑147: Default Efficient-Case Values for ElecPC

|  |  |  |
| --- | --- | --- |
| **Pan Capacity** | **Convection Mode (ElecPCConvEE)** | **Steam Mode (ElecPCSteamEE)** |
| < 15 | 119 | 177 |
| ≥ 15 | 201 | 349 |

There are no default



savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. ENERGY STAR, Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>.
2. ENERGY STAR, Program Requirements Product Specification for Commercial Ovens Eligibility Criteria Version 2.2, <https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens/key_product_criteria>.
3. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs v6, effective date January 1, 2019

### ENERGY STAR Commercial Convection Oven

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Number of Convection Ovens Installed |
| **Measure Life** | 12 years Source 1 |
| **Measure Vintage** | Replace on Burnout, Early Replacement, Retrofit, New Construction |

Commercial convection ovens that meet ENERGY STAR requirementsSource 2 utilize improved gaskets for faster and more uniform cooking processes to achieve higher heavy load cooking efficiencies and lower idle energy rates, making them on average about 20 percent more efficient than standard models. The baseline equipment is assumed to be a standard efficiency convection oven with a heavy load efficiency of 65% for both full size (i.e., a convection oven that is capable of accommodating full-size sheet pans measuring 18 x 26 x 1-inch) and 68% for half size (i.e., a convection oven that is capable of accommodating half-size sheet pans measuring 18 x 13 x 1-inch) electric ovens.

Eligibility

This measure targets non-residential customers who purchase and install an electric convection oven that meets ENERGY STAR specifications rather than a non-ENERGY STAR unit. The energy efficient convection oven can be new or rebuilt.

Algorithms

The annual energy savings calculation utilizes the idle energy rate of an ENERGY STAR electric convection oven and a typical electric convection oven, along with estimated annual hours of operation for cooking activities. The energy savings and peak demand reductions are obtained through the following formulas shown below.Source 1, 2

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Table 3‑148: Terms, Values, and References for ENERGY STAR Commercial Electric Convection Ovens

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Either “base” or “ee” depending on whether the calculation of energy consumption is being performed for the baseline or efficient case, respectively. | None | EDC Data Gathering | --- |
| , Annual energy usage of the baseline equipment calculated using baseline values | kWh/yr | Calculated | --- |
| , Annual energy usage of the efficient equipment calculated using efficient values | kWh/yr | Calculated | --- |
| , Daily cooking energy consumption | kWh/day | Calculated | --- |
| , Daily idle energy consumption | kWh/day | Calculated | --- |
| , Average daily operating hours | Hours/day | EDC Data Gathering  Default = 12 | 1 |
| , Annual days of operation | Days/yr | EDC Data Gathering  Default = 365 | 1 |
| , ASTM energy to food; amount of energy absorbed by the food per pound during cooking | kWh/lb | EDC Data Gathering  Default = 0.0732 | 1 |
| , Pounds of food cooked per day | lbs/day | EDC Data Gathering  Default = 100 | 1 |
| , Heavy load cooking energy efficiency | % | EDC Data Gathering  Default: Table 3‑149 | 1, 2 |
| , Idle demand rate | kW | Default: Table 3‑149 | 1, 2 |
| , Production capacity | lbs/hr | EDC Data Gathering  Default: Table 3‑149 | 1, 2 |
| , Coincidence factor | None | EDC Data Gathering  Default = 0.9 | 3 |

Table 3‑149: Electric Oven Performance Metrics: Baseline and Efficient Default Values

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **Half Size** | | **Full Size** | |
| **Baseline Model** | **Efficient Model** | **Baseline Model** | **Efficient Model** |
| IDLE | 1.03 | 1.0 | 2.0 | 1.6 |
| EFF | 68% | 71% | 65% | 71% |
| PC | 45 | 50 | 90 | 90 |

Default Savings

150: Default Unit Savings and Demand Reduction for ENERGY STAR Commercial Electric Convection Ovens.

|  |  |  |
| --- | --- | --- |
| **Parameter** | **ENERGY STAR Convection Oven Savings** | |
|  |  |
| Half Size | 192 | 0.040 |
| Full Size | 1,937 | 0.398 |

Sources

1. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>
2. ENERGY STAR Commercial Ovens Version 2.2 Specification. <https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens/key_product_criteria>
3. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs v6, effective date January 1, 2019

### ENERGY STAR Commercial Fryer

|  |  |
| --- | --- |
| **Target Sector** | Commercial Establishments |
| **Measure Unit** | Number of Commercial Fryers Installed |
| **Measure Life** | 12 years Source 1 |
| **Measure Vintage** | Replace on Burnout, Early Replacement, Retrofit, New Construction |

Commercial fryers that meet ENERGY STAR specifications offer shorter cook times and higher production rates through advanced burner and heat exchanger designs. Standard sized fryers that have earned the ENERGY STAR are about 14 percent more energy efficient than standard models and large vat commercial fryers that have earned the ENERGY STAR are up to 35 percent more energy efficient than non-certified models.

Eligibility

This measure applies to electric ENERGY STAR fryers installed in a commercial kitchen. To qualify for this measure, the customer must install a commercial electric fryer that has earned the ENERGY STAR label.

The annual energy savings calculation utilizes the idle energy rate of ENERGY STAR electric fryers and a typical electric fryer, along with estimated annual hours of operation for cooking activities. Energy savings estimates are provided for both standard and large vat fryers. The unit energy savings and peak demand reduction are obtained through the following formulas:

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Table 3‑151: Terms, Values, and References for ENERGY STAR Commercial Fryers

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Either “base” or “ee” depending on whether the calculation of energy consumption is being performed for the baseline or efficient case, respectively. | None | EDC Data Gathering | --- |
| , Annual energy usage of the baseline equipment calculated using baseline values | kWh/year | Calculated | --- |
| , Annual energy usage of the efficient equipment calculated using efficient values | kWh/year | Calculated | --- |
| , Daily cooking energy consumption | kWh/day | Calculated | --- |
| , Daily idle energy consumption | kWh/day | Calculated | --- |
| , Average daily operating hours | Hours/day | EDC Data Gathering  See Table 3‑152 | 1 |
| , Annual days of operation | Days/year | EDC Data Gathering  Default = 365 | 1 |
| , ASTM energy to food; amount of energy absorbed by the food per pound during cooking | kWh/lb | EDC Data Gathering  Default = 0.167 | 1 |
| , Pounds of food cooked per day | lb/day | EDC Data Gathering  Default = 150 | 1 |
| , Heavy load cooking energy efficiency | % | See Table 3‑152 | 2 |
| , Idle energy rate | kW | See Table 3‑152 | 2 |
| , Production capacity | lb/hr | See Table 3‑152 | 1 |
| , Coincidence factor | None | EDC Data Gathering  Default: 0.9 | 3 |

152: Electric Fryer Performance Metrics: Baseline and Efficient Default Values

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **Standard Fryer** | | **Large Vat Fryer** | |
| **Baseline Model** | **Energy Efficient Model** | **Baseline Model** | **Energy Efficient Model** |
|  | 16 | 16 | 12 | 12 |
|  | 1.05 | 0.80 | 1.35 | 1.10 |
|  | 75% | 83% | 70% | 80% |
|  | 65 | 70 | 100 | 110 |

Default Savings

153: Default for ENERGY STAR Commercial Electric Fryers

|  |  |  |
| --- | --- | --- |
| **Equipment Type** |  |  |
| Standard Fryer | 2,376 | 0.37 |
| Large Vat Fryer | 2,536 | 0.52 |

1. ENERGY STAR, Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>.
2. US EPA. Effective October 1, 2016. ENERGY STAR® Program Requirements Product Specification for Commercial Fryers Eligibility Criteria. <https://www.energystar.gov/products/commercial_food_service_equipment/commercial_fryers/key_product_criteria>
3. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs v6, effective date January 1, 2019.

### ENERGY STAR Commercial Hot Food Holding Cabinet

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Number of Hot Food Holding Cabinets Installed |
| **Measure Life** | 12 years Source 1 |
| **Measure Vintage** | Replace on Burnout, Early Replacement, Retrofit, New Construction |

Commercial electric hot food holding cabinet models that meet ENERGY STAR requirements incorporate better insulation to reduce heat loss and may also offer additional energy saving devices such as more precise controls, full-perimeter door gaskets, magnetic door handles, or dutch doors. The insulation of the cabinet also offers better temperature uniformity within the cabinet from top to bottom. This means that qualified hot food holding cabinets are more efficient at maintaining food temperature while using less energy. The baseline equipment is assumed to be a standard efficiency hot food holding cabinet that is not ENERGY STAR certified.

Eligibility

This measure targets non-residential customers who purchase and install a hot food holding cabinet that meets ENERGY STAR specifications rather than a non-ENERGY STAR unit. The energy efficient hot food holding cabinet can be new or rebuilt. It can include glass or solid door cabinets (fully closed compartment with one or more doors).

The annual energy savings calculation utilizes idle energy rates of ENERGY STAR hot food holding cabinet and a typical hot food holding cabinet, along with estimated annual hours of operation. The unit energy savings and peak demand reduction are obtained through the following formulas:

|  |  |
| --- | --- |
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Definition of Terms

Table 3‑154: Terms, Values, and References for ENERGY STAR Commercial Hot Food Holding Cabinets

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Idle energy rate of the baseline equipment | Watts | EDC Data Gathering (see Table 3‑155  Default = 600 | 1, 2 |
| , Idle energy rate of the efficient equipment | Watts | EDC Data Gathering (see Table 3‑155)  Default = 284 | 1, 2 |
| , Conversion of W to kW | kW/W | 0.001 | Conversion Factor |
| , Average daily operating hours | Hours/day | EDC Data Gathering  Default = 15 | 1 |
| , annual days of operation | Days/Year | EDC Data Gathering  Default = 365 | 1 |
| *V*, the internal volume of the holding cabinet | ft3/unit | EDC Data Gathering  Default = 1.5 | EDC Data Gathering  1 |
| , Coincidence factor | None | 0.9 | 3 |

Table 3‑155: Hot Food Holding Cabinet Performance Metrics: Default Baseline and Efficient Value Equations

|  |  |  |
| --- | --- | --- |
| **Internal Volume** | **Product Idle Energy Consumption Rate** | |
| **Baseline Model (IDLEbase)** | **Efficient Model (IDLEee)** |
| 0 < V < 13 | 40 x V | 21.5 x V |
| 13 ≤ V < 28 | 40 x V | 2.0 x V + 254.0 |
| 28 ≤ V | 40 x V | 3.8 x V + 203.5 |

Default Savings

The default annual energy savings value for ENERGY STAR Commercial Hot Food Holding Cabinet is 1,730 kWh and the default peak demand savings value is 0.28 kW.

1. ENERGY STAR, Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>.
2. ENERGY STAR® Program Requirements Product Specification for Commercial Hot Food Holding Cabinets Eligibility Criteria Version 2.0, effective October 1, 2011 <https://www.energystar.gov/products/commercial_food_service_equipment/commercial_hot_food_holding_cabinets/key_product_criteria>
3. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs v6, effective date January 1, 2019.

### ENERGY STAR Commercial Dishwasher

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Dishwasher |
| **Measure Life** | 10 years Source 1 |
| **Measure Vintage** | Replace on Burnout or New Construction |

This measure describes the energy savings from installing an ENERGY STAR commercial dishwasher in applicable commercial settings. The measure includes stationary rack machines (undercounter; single tank door-type; pot, pan, and utensil; and glasswashing) and conveyor machines (rack and rackless/flight type, multi and single tank). Products must meet idle energy rate and water consumption limits, as determined by both machine type and sanitation approach (chemical/low temp versus high temp).

A high temp machine is defined as a machine applies hot water to the surfaces of dishes to achieve sanitization. A low temp machine is defined as a machine that applies a chemical sanitizing solution to the surfaces of dishes to achieve sanitization.Source 2

Eligibility

To be eligible, commercial dishwashers must meet the Version 2.0 ENERGY STAR Program Requirements for Commercial Dishwashers, effective February 1, 2013.Source 3

Electric energy savings are composed of three parts: electric energy savings from the building water heater, electric energy savings from the booster water heater, and idle electric energy savings. Note that if a building only has a natural gas water heater, then there will still be savings from reduction in idle energy.

|  |  |
| --- | --- |
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|  |  |

Table 3‑156: Terms, Values, and References for ENERGY STAR Commercial Dishwashers

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , Water use per rack of baseline dishwasher, varies by machine type and sanitation method | *Gallons* | EDC Data Gathering | EDC Data Gathering |
| Default: Table 3‑157 | 4 |
| , Water use per rack of ENERGY STAR dishwasher, varies by machine type and sanitation method | *Gallons* | EDC Data Gathering | EDC Data Gathering |
| Default: Table 3‑157 | 4 |
| , Number of racks washed per day, varies by machine type and sanitation method |  | EDC Data Gathering | EDC Data Gathering |
| Default: Table 3‑157 | 4 |
| , Annual days of dishwasher consumption per year |  | EDC Data Gathering | EDC Data Gathering |
| Default = 365 | 4 |
| , Temperature rise in water delivered by building water heater or booster water heater, value varies by type of water heater source | *°F* | EDC Data Gathering | EDC Data Gathering |
| Building WH = 70  Booster WH = 40 | 4 |
| , Recovery efficiency of electric water heater | Decimal | 0.98 | 4 |
| , Idle power draw of baseline dishwasher, varies by machine type and sanitation method | *kW* | EDC Data Gathering | EDC Data Gathering |
| Default: Table 3‑157 | 4 |
| *,* Hours per day of dishwasher operation |  | EDC Data Gathering | EDC Data Gathering |
| Default = 18 | 4 |
| , Wash time per dishwasher, varies by machine type and sanitation method | *Minutes* | EDC Data Gathering | EDC Data Gathering, |
| Default: Table 3‑157 | 4 |
| *,* Idle power draw of ENERGY STAR dishwasher, varies by machine type and sanitation method | *kW* | EDC Data Gathering | EDC Data Gathering |
| Default: Table 3‑157 | 4 |
| Density of Water | *lb/gallon* | 8.207 | 5 |
| , Coincidence factor | *None* | 0.9 | 6 |

Table 3‑157 shows the default values for water user per rack, racks washed per day, wash time per dishwasher, and idle power draws by machine type and sanitation method.

157: Default Inputs for ENERGY STAR Commercial Dishwasher

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Machine Type** | **WUbase** | **WUee** | **RW** | **WT** | **kWbase** | **kWee** |
| **Low Temperature** | | | | | | |
| Under Counter | 1.73 | 1.19 | 75 | 2.0 | 0.50 | 0.50 |
| Stationary Single Tank Door | 2.10 | 1.18 | 280 | 1.5 | 0.60 | 0.60 |
| Single Tank Conveyor | 1.31 | 0.79 | 400 | 0.3 | 1.60 | 1.50 |
| Multi Tank Conveyor | 1.04 | 0.54 | 600 | 0.3 | 2.00 | 2.00 |
| **High Temperature** | | | | | | |
| Under Counter | 1.09 | 0.86 | 75 | 2.0 | 0.76 | 0.50 |
| Stationary Single Tank Door | 1.29 | 0.89 | 280 | 1.0 | 0.87 | 0.70 |
| Single Tank Conveyor | 0.87 | 0.70 | 400 | 0.3 | 1.93 | 1.50 |
| Multi Tank Conveyor | 0.97 | 0.54 | 600 | 0.2 | 2.59 | 2.25 |
| Pot, Pan, and Utensil | 0.70 | 0.58 | 280 | 3.0 | 1.20 | 1.20 |

Default Savings

Using the defaults provided above, the savings per component are shown in Table 3‑158.

Default Annual Energy and Peak Demand Savings for ENERGY STAR Commercial Dishwashers

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Machine Type** | **∆kWhWaterHeater** | **∆kWhBoosterHeater** | **∆kWhIdle** | **∆kWh (if Electric Water Heater and Booster Water Heater)** | **∆kWpeak** |
| **Low Temperature** | | | | | |
| Under Counter | 2,540 | N/A | 0 | 2,540 | 0.35 |
| Stationary Single Tank Door | 16,153 | N/A | 0 | 16,153 | 2.21 |
| Single Tank Conveyor | 13,042 | N/A | 584 | 13,626 | 1.87 |
| Multi Tank Conveyor | 18,811 | N/A | 0 | 18,811 | 2.58 |
| **High Temperature** | | | | | |
| Under Counter | 1,082 | 618 | 1,471 | 3,171 | 0.43 |
| Stationary Single Tank Door | 7,023 | 4,013 | 827 | 11,863 | 1.63 |
| Single Tank Conveyor | 4,264 | 2,436 | 2,511 | 9,212 | 1.26 |
| Multi Tank Conveyor | 16,178 | 9,244 | 1,986 | 27,408 | 3.75 |
| Pot, Pan, and Utensil | 2,107 | 1,204 | 0 | 3,311 | 0.45 |

Evaluation Protocol

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. <https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf>
2. ENERGY STAR Program Requirements for Commercial Dishwashers: Partner Commitments. [https://www.energystar.gov/ia/partners/product\_specs/program\_reqs/Commercial\_Dishwasher\_Pr ogram\_Requirements.pdf](https://www.energystar.gov/ia/partners/product_specs/program_reqs/Commercial_Dishwasher_Pr%20ogram_Requirements.pdf)
3. ENERGY STAR® Program Requirements Product Specification for Commercial Dishwashers Eligibility Criteria Version 2.0, effective February 1, 2013 <https://www.energystar.gov/products/commercial_food_service_equipment/commercial_dishwashers/key_product_criteria>
4. ENERGY STAR, Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>.
5. Dishwasher inlet temperature assumed at 140 degrees F. <https://water.usgs.gov/edu/density.html>
6. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs v6, effective date January 1, 2019

### ENERGY STAR Commercial Griddle

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Electric Griddle |
| **Measure Life** | 12 years Source 1 |
| **Measure Vintage** | Replace on Burnout |

Eligibility

This measure applies to the installation of electric ENERGY STAR griddles as either a new item or replacement for an existing unit. The griddles must meet minimum ENERGY STAR efficiency requirements and be on the ENERGY STAR qualified products list. Commercial griddles that are ENERGY STAR qualified are about 10% to 11% more energy efficient than standard models, due to the use of highly conductive or reflective plate materials, improved thermostatic controls, and strategic placement of thermocouples.

The baseline equipment is a unit with efficiency specifications that do not meet the minimum ENERGY STAR efficiency requirements.

Algorithms

Energy savings for griddles come from increased efficiency during three modes: cooking, idle, and preheating. Algorithms for annual energy savings and peak demand savings are shown below.

|  |  |
| --- | --- |
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Definition of Terms

Table 3‑159: Terms, Values, and References for ENERGY STAR Griddles

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| *,* Operating days per year | *Days/year* | EDC Data Gathering | EDC Data Gathering |
| Default = 365 | 2 |
| , Pounds of food cooked per day | *lbs* | EDC Data Gathering | EDC Data Gathering |
| Default = 100 | 2 |
| , ASTM energy to food |  | Default = 139 | 2 |
| , Baseline cooking efficiency | *%* | EDC Data Gathering | EDC Data Gathering |
| Default = 65% | 2 |
| , ENERGY STAR cooking efficiency | *%* | EDC Data Gathering | EDC Data Gathering |
| Default = 70% | 2 |
| , Baseline idle energy rate |  | EDC Data Gathering | EDC Data Gathering |
| Default = 400 | 2 |
| , ENERGY STAR idle energy rate |  | EDC Data Gathering | EDC Data Gathering |
| Default = 320 | 3 |
| , Area of griddle |  | EDC Data Gathering | EDC Data Gathering |
| Default = 2ft x 3ft = 6ft2 | 2 |
| , Operating hours per day |  | EDC Data Gathering | EDC Data Gathering |
| Default = 12 | 2 |
| , Baseline production capacity |  | EDC Data Gathering | EDC Data Gathering |
| Default = 5.83 | 2 |
| , ENERGY STAR production capacity |  | EDC Data Gathering | EDC Data Gathering |
| Default = 6.67 | 2 |
| , Number of preheats per day |  | EDC Data Gathering | EDC Data Gathering |
| Default = 1 | 4 |
| , Time to preheat |  | EDC Data Gathering | EDC Data Gathering |
| Default = 15 | 4 |
| , Baseline preheat rate |  | EDC Data Gathering | EDC Data Gathering |
| Default = 2,667 | 4 |
| , ENERGY STAR preheat rate |  | EDC Data Gathering | EDC Data Gathering |
| Default = 1,333 | 4 |
| , Coincidence factor | *None* | 0.9 | 5 |

Default Savings

Table 3‑160 provides the default savings, using the default values in Table 3‑159.

Table 3‑160: Default Savings for ENERGY STAR Griddles

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **∆WhCooking** | **∆WhIdle** | **∆WhPreHeat** | **Energy Savings (kWh)** | **Peak Demand Savings (kW)** |
| 1,527 | 3,583 | 2,001 | 2,596 | 0.533 |

Evaluation Protocol

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. ENERGY STAR, Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>.
3. ENERGY STAR Commercial Griddles Specification Tier 2 specifications effective January 1, 2011. https://www.energystar.gov/products/commercial\_food\_service\_equipment/commercial\_griddles/key\_products\_criteria
4. Illinois Statewide Technical Reference Manual v7.0, September 28, 2018. <http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf>. Accessed December 2018.
5. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs v6, effective date January 1, 2019

## Building Shell

### Wall and Ceiling Insulation

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Wall and Ceiling Insulation |
| **Measure Life** | 15 years Source 1 |
| **Measure Vintage** | New Construction or Retrofit |

Wall and ceiling insulation is one of the most important aspects of the energy system of a building.

An R-value indicates the insulation’s resistance to heat flow – the higher the R-value, the greater the insulating effectiveness. The R-value depends on the type of insulation and its material, thickness, and density. When calculating the R-value of a multilayered installation, add the R-values of the individual layers.

Eligibility

This measure applies to non-residential buildings or common areas in multifamily complexes heated and/or cooled using electricity. Existing construction buildings are required to meet or exceed the code requirement. New construction buildings must exceed the code requirement. Eligibility may vary by PA EDC. Buildings with Central AC systems or Air Source Heat Pumps (ASHP) are eligible. Buildings cooled with other systems (e.g., chilled water systems) are not eligible.

Algorithms

The savings depend on the area and R-value of baseline and upgraded walls/ceilings, heating and/or cooling system type and size, and location.

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Definition of Terms

Table ‑: Terms, Values, and References for Wall and Ceiling Insulation

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , Area of the ceiling/attic insulation that was installed |  | EDC Data Gathering | EDC Data Gathering |
| , Area of the wall insulation that was installed |  | EDC Data Gathering | EDC Data Gathering |
| , Heating degree days with a 65 degree base |  | See Table 7 in Appendix A | 2 |
| , Cooling degree days with a 65 degree base |  | See Table 7 in Appendix A | 2 |
| , Hours per day |  | 24 | Conversion Factor |
| , Watts per kilowatt |  | 1,000 | Conversion Factor |
| Btu per kWh |  | 3,412 | Conversion Factor |
| , the R-value of the ceiling insulation and support structure before the additional insulation is installed |  | Default: Table 3‑162 | EDC Data Gathering; 3 |
| , the R-value of the wall insulation and support structure before the additional insulation is installed |  | Default: Table 3‑162 | EDC Data Gathering; 3, |
| , Total R-value of all ceiling/attic insulation after the additional insulation is installed |  | EDC Data Gathering | EDC Data Gathering |
| , Total R-value of all wall insulation after the additional insulation is installed |  | EDC Data Gathering | EDC Data Gathering |
| , Equivalent full load cooling hours |  | Based on Logging, BMS data or Modeling[[47]](#footnote-252) | EDC Data Gathering |
|  |  | Default: Table 3‑27 | 4 |
| , Coincidence factor | *Decimal* | Default: Table 3‑28 | 4 |
| , Efficiency of existing cooling equipment. Depending on the size and age, this will either be the SEER, IEER, or EER (use EER only if SEER or IEER are not available)[[48]](#footnote-253) |  | EDC Data Gathering | EDC Data Gathering |
| Default: Table 3‑26 | Table 3‑26 |
| , Efficiency of the heating system | *None* | EDC Data Gathering | EDC Data Gathering |
| Default: Table 3‑26 | Table 3‑26 |

Table ‑: Initial R-Values

|  |  |  |  |
| --- | --- | --- | --- |
| **Structure and Type** | | **Ri-Value  (New Construction)** | **Ri-Value  (Existing)** |
| **Ceilings** | |  |  |
| Insulation entirely above roof deck | R-30ci1 | EDC Data Gathering |
| Metal buildings | R-19 + R-11 LS2 |
| Attic and other | R-38 |
| **Walls** | | |
| Mass | R-11.4ci | EDC Data Gathering |
| Metal building | | R-13 + R-13ci |  |
| Metal framed | R-13 + R-7.5ci |  |
| Wood framed and other | | R-13 + R-3.8ci OR R-20 |  |
| Below-grade wall | R-7.5ci |  |
| 1 ci = Continuous insulation  2 LS = Liner system | | |



Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018. Capped based on the requirements of the Pennsylvania Technical Reference Manual.
2. SWE analysis of TMY3 data for PA weather stations.
3. The initial R-value for new construction buildings is based on IECC 2015 code for climate zone 5. <https://codes.iccsafe.org/content/IECC2015/chapter-4-ce-commercial-energy-efficiency>
4. Based on results from Nexant’s eQuest modeling analysis 2014.

## Consumer Electronics

### ENERGY STAR Office Equipment

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Office Equipment |
| **Measure Life** | See Table 3‑164 |
| **Measure Vintage** | Replace on Burnout |

Eligibility

This protocol estimates savings for installing ENERGY STAR office equipment compared to standard efficiency equipment. The measurement of energy and demand savings is based on a deemed savings value multiplied by the quantity of the measure.

Algorithms

The general form of the equation for the ENERGY STAR Office Equipment measure savings’ algorithms is:

To determine resource savings, the per unit estimate in the algorithms will be multiplied by the number of units. Per unit savings are primarily derived from the ENERGY STAR calculator for office equipment.

**ENERGY STAR Desktop Computer**

|  |  |
| --- | --- |
|  |  |
|  |  |

**ENERGY STAR Laptop Computer**

|  |  |
| --- | --- |
|  |  |
|  |  |

**ENERGY STAR Fax Machine**

|  |  |
| --- | --- |
|  |  |
|  |  |

**ENERGY STAR Copier**

|  |  |
| --- | --- |
|  |  |
|  |  |

**ENERGY STAR Printer**

|  |  |
| --- | --- |
|  |  |
|  |  |

**ENERGY STAR Multifunction**

|  |  |
| --- | --- |
|  |  |
|  |  |

**ENERGY STAR Monitor**

|  |  |
| --- | --- |
|  |  |
|  |  |

**ENERGY STAR Desktop Phone**

|  |  |
| --- | --- |
|  |  |
|  |  |

**ENERGY STAR Conference Phone**

|  |  |
| --- | --- |
|  |  |
|  |  |

Table ‑: Terms, Values, and References for ENERGY STAR Office Equipment

| **Term** | | **Unit** | | **Values** | | **Source** |
| --- | --- | --- | --- | --- | --- | --- |
| , Electricity savings per purchased ENERGY STAR desktop computer  , Electricity savings per purchased ENERGY STAR laptop computer  , Electricity savings per purchased ENERGY STAR fax machine  , Electricity savings per purchased ENERGY STAR copier  , Electricity savings per purchased ENERGY STAR printer  , Electricity savings per purchased ENERGY STAR multifunction machine  , Electricity savings per purchased ENERGY STAR monitor  , Electricity savings per purchased ENERGY STAR desktop phone  , Electricity savings per purchased ENERGY STAR conference phone | | kWh | | See Table 3‑165 | | 1 |
| , Summer demand savings per purchased ENERGY STAR desktop computer  , Summer demand savings per purchased ENERGY STAR laptop computer  , Summer demand savings per purchased ENERGY STAR fax machine  , Summer demand savings per purchased ENERGY STAR copier  , Summer demand savings per purchased ENERGY STAR printer  , Summer demand savings per purchased ENERGY STAR multifunction machine  , Summer demand savings per purchased ENERGY STAR monitor  , Summer demand savings per purchased ENERGY STAR desktop phone  , Summer demand savings per purchased ENERGY STAR conference phone | | kW | | See Table 3‑165 | | 2 |

Measures lives for ENERGY STAR office equipment are shown in Table 3‑164.

Table ‑: ENERGY STAR Office Equipment Measure Life

|  |  |  |
| --- | --- | --- |
| **Equipment** | **Commercial Life (years)** | **Source** |
| **Desktop Computer** | **4** | **1** |
| **Laptop Computer** | **4** |
| **Monitor** | **7** |
| **Desktop Phone** | **7** |
| **Conference Phone** | **7** |
| **Fax** | **6** |
| **Multifunction Device** | **6** |
| **Printer** | **6** |
| **Copier** | **6** |

Default



Savings

Table ‑: ENERGY STAR Office Equipment Energy and Demand Savings Values

| **Measure** | **Energy Savings (ESav)** | **Summer Peak**  **Demand Savings (DSav)** | **Source** |
| --- | --- | --- | --- |
| Desktop Computer | 124 | 0.0167 | 1, 2 |
| Laptop Computer | 37 | 0.0050 | 1, 2 |
| Fax Machine (laser) | 16 | 0.0022 | 1, 2 |
| Copier (monochrome) | | |  | |  | 1, 2 |
| 1-25 images/min | 73 | 0.0098 |  |
| 26-50 images/min | 151 | 0.0203 |  |
| 51+ images/min | 162 | 0.0218 |  |
| Printer (laser, monochrome) | | |  | |  | 1, 2 |
| 1-10 images/min | 26 | 0.0035 |  |
| 11-20 images/min | 73 | 0.0098 |  |
| 21-30 images/min | 104 | 0.0140 |  |
| 31-40 images/min | 156 | 0.0210 |  |
| 41-50 images/min | 133 | 0.0179 |  |
| 51+ images/min | 329 | 0.0443 |  |
| Multifunction (laser, monochrome) | | |  | |  | 1, 2 |
| 1-10 images/min | 78 | 0.0105 |  |
| 11-20 images/min | 147 | 0.0198 |  |
| 21-44 images/min | 253 | 0.0341 |  |
| 45-99 images/min | 422 | 0.0569 |  |
| 100+ images/min | 730 | 0.0984 |  |
| Monitor | | |  | |  | 1, 2 |
| Less than 12 inches | 5 | 0.0007 |  |
| 12.0 – 16.9 inches | 6 | 0.0008 |  |
| 17.0 – 22.9 inches | 9 | 0.0012 |  |
| 23.0 – 24.9 inches | 8 | 0.0011 |  |
| 25.0 – 60.9 inches | 22 | 0.0030 |  |
| Desktop Phone | 11 | 0.0015 | 1, 2 |
| Conference Phone | 12 | 0.0016 | 1, 2 |

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. ENERGY STAR Qualified Office Equipment Savings Calculator (Referenced latest version released in October 2016). Default values were used. As of December 1, 2018, the published ENERGY STAR Office Equipment Calculator does not reflect the current specification for computers (ENERGY STAR® Program Requirements Product Specification for Computers Eligibility Criteria Version 7.1). V7.1 introduced modest improvements to both desktop and laptop computer efficiency. As a result, the savings values for computers presented in this measure entry reflect savings for V6-compliant models. This characterization should be updated when an updated ENERGY STAR Office Equipment Calculator becomes available.
2. Using a commercial office equipment load shape, the percentage of total savings that occur during the PJM peak demand period was calculated and multiplied by the energy savings.

### Office Equipment – Network Power Management Enabling

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | One copy of licensed software installed on a PC workstation |
| **Measure Life** | 5 years Source 1 |
| **Measure Vintage** | Retrofit |

A number of strategies are available to save energy in desktop computers. One class of products uses software implemented at the network level for desktop computers that manipulates the internal power settings of the central processing unit (CPU) and of the monitor. These power settings are an integral part of a computer’s operating system (most commonly, Microsoft Windows) including “on”, “standby”, “sleep”, and “off” modes and can be set by users from their individual desktops.

Most individual computer users are unfamiliar with these energy-saving settings, hence settings are normally set by an IT administrator to minimize user complaints related to bringing the computer back from standby, sleep, or off modes. However, these default settings use a large amount of energy during times when the computer is not in active use. Studies have shown that energy consumed during non-use periods is large and is often the majority of total energy consumed.

Qualifying software must control desktop computer and monitor power settings within a network from a central location.

Eligibility

The default savings reported in Table 3‑167 are applicable to any software that manages workstations in a networked environment. Such softwares should be capable of the following:

* The software should have wake-on-LAN capability to allow networked workstations to be remotely wakened from or placed into any power-saving mode and to remotely boot or shut down ACPI-compliant workstations.
* The software should have the capability to give the IT administrator easily-accessible central control over the power management settings of networked workstations that optionally overrides settings made by users.
* The software should be capable of applying specific power management policies to network groups, utilizing existing network grouping capabilities.
* The software should be compatible with multiple operating systems and hardware configurations on the same network.
* The software should have the capability to monitor workstation keyboard, mouse, CPU and disk activity in determining workstation idleness.



Algorithms

The general form of the equation for the Network Power Management measure savings algorithms is:

To determine resource savings, the per unit estimate in the algorithms will be multiplied by the number of units. Per unit savings are primarily derived from the ENERGY STAR calculator for office equipment.

**Network Power Management:** **Workstation with** **Desktop Computer and Monitor**

|  |  |
| --- | --- |
|  |  |
|  |  |

**Network Power Management:** **Workstation with Laptop Computer and Monitor**

|  |  |
| --- | --- |
|  |  |
|  |  |

Table 3‑166: Terms, Values, and References for ENERGY STAR Office Equipment

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , Electricity savings per purchased ENERGY STAR desktop computer | kWh | See Table 3‑167 | 2 |
| , Electricity savings per purchased ENERGY STAR laptop computer | kWh | See Table 3‑167 | 2 |
| , Summer demand savings per purchased ENERGY STAR desktop computer | kW | See Table 3‑167 | 3 |
| , Summer demand savings per purchased ENERGY STAR laptop computer | kW | See Table 3‑167 | 3 |

Default Savings

The energy savings per unit includes the power savings from the PC as well as the monitor. Default savings are based on the Low Carbon IT Savings Calculator sourced from the ENERGY STAR website and assumes the absence of an enabled network power management as the baseline condition.

Table 3‑167: Network Power Controls, Per Unit Summary Table

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure** | **Unit** | **Energy Savings**  **()** | **Peak Demand**  **Savings ()** |
| Network PC Plug Load Power Management Software | Workstation – Desktop Computer with Monitor | 392 | 0.0527 |
| Network PC Plug Load Power Management Software | Workstation – Laptop Computer with Monitor1 | 237 | 0.0319 |
| 1Savings assume workstation includes desktop monitor, laptop computer with laptop screen in use. Please refer to ENERGY STAR Low Carbon IT Savings Calculator for different workstation configurations. | | | |

and requirements for evaluation procedures.

Illinois Statewide Technical Reference Manual v7.0, <http://www.ilsag.info/technical-reference-manual.html>. The reference uses 10 years, however, given the rapid changes in the technology industry, there is quite a lot of uncertainty about the measure life and a more conservative value was used (i.e. half the published measure life): Table VI.1:



1. Luedtke, J. S., & Seiden, K. (2005). Surveyor Network Energy Manager: Market Progress Evaluation Report, No. 2 (Northwest Energy Efficiency Alliance report #E05-136). Portland, OR: Quantec, LLC).
2. ENERGYSTAR calculator: Low Carbon IT Savings Calculator: <https://www.energystar.gov/sites/default/files/asset/document/LowCarbonITSavingsCalc.xlsx>
3. Using a commercial office equipment load shape, the percentage of total savings that occur during the PJM peak demand period was calculated and multiplied by the energy savings.

### Advanced Power Strips

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Per Advanced Power Strip |
| **Measure Life** | 5 years Source 1 |
| **Measure Vintage** | Retrofit |

Plug and process loads (PPLs) are building electrical loads that are not related to lighting, heating, ventilation, cooling, and water heating, and typically do not provide comfort to the occupants. PPLs in commercial buildings account for almost 33% of U.S. commercial building electricity use. Minimizing PPLs is a critical part of the design and operation of an energy-efficient building.

Advanced Power Strips (APS) are surge protectors that contain a number of power-saver sockets. There are two types of APS: Tier 1 and Tier 2.

Tier 1 APS have a master control socket arrangement and will shut off the items plugged into the controlled power-saver sockets when they sense that the appliance plugged into the master socket has been turned off. Conversely, the appliance plugged into the master control socket has to be turned on and left on for the devices plugged into the power-saver sockets to function.

Tier 2 APS deliver additional functionality beyond that of a Tier 1 unit, as Tier 2 units manage both standby and active power consumption. The Tier 2 APS manage standby power consumption by turning off devices from a control event. Active power consumption is managed by the Tier 2 unit by monitoring a user’s engagement or presence in the workstation area by either localized motion detection or the use of installed software to monitor keyboard strokes and mouse movement. If after a period of user absence or inactivity, the Tier 2 unit will shut off all items plugged into the controlled outlets, thus saving energy.

Eligibility

This protocol documents the energy savings attributed to the installation of APS. The protocol considers usage of APS with office workstations.

The annual energy savings are calculated for office workstations for both Tier 1 strips and Tier 2 strips. If the presence of power management either at the local-level or network-level is not known, the average energy reduction percentage shall be used.

**Tier 1** **Advanced Power Strip:**

|  |  |
| --- | --- |
|  |  |

**Tier 2 Advanced Power Strip:**

|  |  |
| --- | --- |
|  |  |

Definition of Terms

Table 3‑168: Terms, Values, and References for

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Value** | **Source** |
| , Annual consumption of workstation | *kWh* | 543 kWh | 2 |
| , Energy Reduction Percent | % | Default: Table 3‑169 | 2, 3 |

Table 3‑169: Impact Factors for APS Strip Types

|  |  |  |
| --- | --- | --- |
| **Strip Type** | **End-Use** | **ERP** |
| Tier 1 | Workstation | 24.7% |
| Tier 1 | Workstation with power management (network or local) | 4.0% |
| Tier 1 | Workstation with unknown power management | 14.3% |
| Tier 2 | Workstation | 30.0% |
| Tier 2 | Workstation with power management (network or local) | 4.0% |
| Tier 2 | Workstation with unknown power management | 17.0% |

Default Savings

The default savings calculated based on the parameters identified above are provided in Table 3‑170.

Table 3‑170: Default Savings for APS Strip Types

|  |  |  |
| --- | --- | --- |
| **Strip Type** | **Use** | **Energy Savings (kWh)** |
| Tier 1 | Workstation | 134 |
| Tier 1 | Workstation with power management (network or local) | 22 |
| Tier 1 | Workstation with unknown power management | 78 |
| Tier 2 | Workstation | 163 |
| Tier 2 | Workstation with power management (network or local) | 22 |
| Tier 2 | Workstation with unknown power management | 92 |

Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. NREL/TP-5500-51708, “Selecting a Control Strategy for Plug and Process ”, September 2012, <https://www.nrel.gov/docs/fy12osti/51708.pdf>
3. Acker, B., Duarte, C., and Wymelenberg, K., “Office Space Plug Load Profiles and Energy Savings Interventions”. University of Idaho. 2012. <https://aceee.org/files/proceedings/2012/data/papers/0193-000277.pdf>

### 

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Variable |
| **Measure Life** | 4 years Source 1 |
| **Measure Vintage** | Replace on Burnout |

According to energystar.gov, data centers consume approximately 2% of the electricity in the United States. Servers and mainframes in these data centers provide the email service, information storage, and other information technology services to the businesses that run them. A large proportion (40%) of servers and mainframes are located not in large data centers, but in closets within individual businesses. ENERGY STAR certified servers and mainframes can cut energy usage by 30% on average, and each watt saved at the server or mainframe level can translate to 1.9 watts saved when interactive effects are included.

Eligibility

On average, ENERGY STAR servers are 30% more efficient than standard servers. To qualify for this measure, the installed equipment must be a server system or mainframe that has earned the ENERGY STAR label.Source 2

Algorithms

Annual energy savings and peak demand savings can be calculated using the algorithms shown below. The demand reduction associated with this measure is assumed to be constant since the servers operate 24 hours per day, 365 days per year.







|  |  |
| --- | --- |
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Definition of Terms

Table ‑: Terms, Values, and References for ENERGY STAR Servers

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Term** | **Unit** | | **Values** | | **Source** | |



## 

### 

|  |  |  |  |
| --- | --- | --- | --- |
| , Active power draw of ENERGY STAR server | *kW* | EDC Data Gathering  Calculated value | EDC Data Gathering  Calculated value |
| , Power draw of ENERGY STAR server in idle mode | *kW* | EDC Data Gathering | 3 |
| *,* Utilization of ENERGY STAR server | *None* | EDC Data Gathering  Default: Table 3‑172 | EDC Data Gathering  4, 5, 6 |
| , Percentage ENERGY STAR server is more efficient than “standard” or “typical” unit | *None* | Fixed = 30% or most current ENERGY STAR specification | 7 |
| , Ratio of idle power to full load power for an ENERGY STAR server | *None* | EDC Data Gathering  Default: Table 3‑173 | EDC Data Gathering  8 |
| , Number of ENERGY STAR servers | *Servers* | EDC Data Gathering | EDC Data Gathering |

Table 3‑172: ENERGY STAR Server Utilization Default Assumptions

|  |  |  |
| --- | --- | --- |
| **Server Category** | **Installed Processors** | **(%)** |
| A, B | 1 | 15% |
| C, D | 2 | 40% |

Table 3‑173

|  |  |  |  |
| --- | --- | --- | --- |
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|  |  |  |  |

* Idle power draws of servers, , should be confirmed in the “Idle Power Typical or Single Configuration (W)” on the ENERGY STAR qualified product list.Source 3
* If not using the default values listed in Table 3‑172, utilization rates should be confirmed by examining the data center’s server performance software.

Sources

1. The three International Data Corporation (IDC) studies indicate organizations replace their servers once every three to five years.

IDC (February 2012). “The Cost of Retaining Aging IT Infrastructure.” Sponsored by HP. Online. <http://mjf.ie/wp-content/uploads/white-papers/IDC-White-Paper_the-cost-of-retaining-aging-IT-infrastructure.pdf>

* 1. DC (August 2012). “Analyst Connection: Server Refresh Cycles: The Costs of Extending Life Cycles.” Sponsored by HP/Intel. Online. <http://resources.itworld.com/ccd/assets/31122/detaill>

1. ENERGY STAR Program Requirements for Enterprise Servers Version 2.0 Specifications. <https://www.energystar.gov/ia/partners/prod_development/revisions/downloads/computer_servers/Program_Requirements_V2.0.pdf>
2. variable used in the algorithms.
3. This data should be used, instead of the default values listed in Table 3‑173, when possible.
4. This article cited to sources of average utilization rates between 6 to 12%.
5. Stakeholders interviewed during the development of the ENERGY STAR server specification reported that the average utilization rate for servers with 1 processor is approximately 20%.
6. The estimated utilization of the ENERGY STAR server for servers with two processors was based on the average of two sources, as follows.
7. The ratios listed in Table 3‑173 are based on the average idle to full load ratios for all ENERGY STAR qualified servers in each server category.

### Server Virtualization

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Per server |
| **Measure Life** | 4 years Source 1 |
| **Measure Vintage** | Replace on Burnout |

According to energystar.gov, data centers consume approximately 2% of the electricity in the United States. Servers in these data centers provide the email service, information storage, and other information technology services to the businesses that run them. Most servers are installed for one specific function, for example email. This leads to up to 90% of servers in the US running at 5-10% utilization. Server virtualization allows companies to consolidate excess servers performing multiple tasks into a single physical server, saving the associated energy of the servers removed.

Eligibility

To qualify for this rebate, servers must be consolidated to increase utilization of the remaining servers, and the virtualized servers must be either a) removed or b) physically disconnected from power.

Algorithms

Annual energy savings and peak demand savings can be calculated using the algorithms shown below. The demand reduction associated with this measure is assumed to be constant since the servers operate 24 hours per day, 365 days per year.

|  |  |
| --- | --- |
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|  |  |
|  |  |

Definition of Terms

Table 3‑174: Terms, Values, and References for Server Virtualization

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Single application servers, number 1 to *n* | Servers | EDC Data Gathering | EDC Data Gathering |
| , Power draw of virtualized server in idle mode | kW | EDC Data Gathering | 2 |
| *,* Average annual utilization of single application server, number 1 to *n* | None | EDC Data Gathering  Default: Table 3‑175 | EDC Data Gathering  3, 4, 5 |
| *,* Virtual host server (virtualized + remaining), number 1 to *m* | Servers | EDC Data Gathering (max = 4 for type A, B, max = 1 for type C, D) | EDC Data Gathering |
| *,* Average annual virtual host server utilization | None | EDC Data Gathering  Default: *m* \* utilization in Table 3‑175 | EDC Data Gathering  3, 4, 5 |
| , Power draw of virtualized server in idle mode | kW | EDC Data Gathering | 2 |
| , Ratio of idle power to full load power for server | None | EDC Data Gathering  Default: Table 3‑176 | EDC Data Gathering  6 |

Table 3‑175: Server Utilization Default Assumptions

|  |  |  |
| --- | --- | --- |
| **Server Category** | **Installed Processors** | **(%)** |
| A, B | 1 | 15% |
| C, D | 2 | 40% |

As noted, these Utilization numbers are likely higher than standard server utilizations; however, the post-virtualization server utilization will likely be higher.

Table 3‑176: ENERGY STAR Server Ratio of Idle Power to Full Load Power Factors

|  |  |  |  |
| --- | --- | --- | --- |
| **Server Category** | **Installed Processors** | **Managed Server[[49]](#footnote-261)** | **Ratio of ES Idle/ES Full Load (b)** |
| A | 1 | No | 52.1% |
| B | 1 | Yes | 53.2% |
| C | 2 | No | 61.3% |
| D | 2 | Yes | 55.8% |

Default Savings

Default savings may be claimed using the algorithms above and the variable defaults. EDCs may also claim savings using customer specific data.

Evaluation Protocols

When possible, perform M&V to assess the energy consumption. However, where metering of IT equipment in a data center is not allowed, follow the steps outlined.

* Invoices should be checked to confirm the number and type of servers virtualized.
* If not using the default values listed in Table 3‑175, utilization rates should be confirmed by examining the data center’s server performance software.
  1. <http://mjf.ie/wp-content/uploads/white-papers/IDC-White-Paper_the-cost-of-retaining-aging-IT-infrastructure.pdf>

IDC (2010). “Strategies for Server Refresh.” Sponsored by Dell. Online. <http://i.dell.com/sites/content/business/smb/sb360/en/Documents/server-refresh-strategies.pdf>

1. An ENERGY STAR qualified server has an “Idle Power Typical or Single Configuration (W)” listed in the qualified product list for servers. The EDC should use the server make and model number to obtain the variable used in the algorithms. The ENERGY STAR qualified server list is located at here: <http://www.energystar.gov/productfinder/product/certified-enterprise-servers/results>.
2. Utilization of a server can be derived from a data center’s server performance software. This data should be used, instead of the default values listed in Table 3‑175, when possible.
3. The estimated utilization of the ENERGY STAR server for servers with one processor was based on the average of two sources, as follows.

Glanz, James. Power Pollution and The Internet, The New York Times, September 22, 2012.

1. processors was based on the average of two sources, as follows.
   1. Using Virtualization to Improve Data Center Efficiency, Green Grid White Paper, Editor: Richard Talaber, VMWare, 2009. A target of 50% server utilization is recommended when setting up a virtual host.
   2. Stakeholders interviewed during the development of the ENERGY STAR server specification reported that the average utilization rate for servers with two processors is approximately 30%.
2. In December 2013, ENERGY STAR stopped including full load power data as a field in the ENERGY STAR certified product list. In order to full load power required in the Uniform Methods Project algorithm for energy efficient servers, a ratio of idle power to full load power was estimated. The idle to full load power ratios were estimated based on the ENERGY STAR qualified product list from November 18th, 2013. The ratios listed in Table 3‑176 are based on the average idle to full load ratios for all ENERGY STAR qualified servers in each server category.

## 

### 

|  |  |  |  |
| --- | --- | --- | --- |
| **Target Sector** | | Commercial and Industrial Establishments | |
| **Measure Unit** | | Cycling Refrigerated Thermal Mass Dryer | |
| **Measure Life** | | 10 years Source 1 | |
| **Measure Vintage** | | Early Replacement | |

When air is compressed, water vapor in the air condenses and collects in liquid form. Some of this condensate collects in the air distribution system and can contaminate downstream components such as air tools with rust, oil, and pipe debris. Refrigerated air dryers remove the water vapor by cooling the air to its dew point and separating the condensate. Changes in production and seasonal variations in ambient air temperature lead to partial loading conditions on the dryer. Standard refrigerated thermal mass air dryers use a hot gas bypass system that is inefficient at partial loads. A Cycling Refrigerated Thermal Mass Dryer uses a thermal storage medium to store cooling capacity when the system is operated at partial loads allowing the dryer refrigerant compressor to cycle.

Eligibility

This measure is targeted to non-residential customers whose equipment is a non-cycling refrigerated air dryer with a capacity of 600 cfm or below.

Acceptable baseline conditions are a non-cycling (e.g., continuous) air dryer with a capacity of 600 cfm or below. The replacement of desiccant, deliquescent, heat-of-compression, membrane, or other types of dryers does not qualify under this measure.

Efficient conditions are a cycling thermal mass dryer with a capacity of 600 cfm or below.

Algorithms

|  |  |
| --- | --- |
|  |  |
|  |  |

Definition of Terms

Table ‑: Terms, Values, and References for Cycling Refrigerated Thermal Mass Dryers

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Compressor output per HP |  | EDC Data Gathering  Default: 4 | EDC Data Gathering  2 |
| , Nominal HP rating of the air compressor motor | *HP* | Nameplate data | EDC Data Gathering |
| , Ratio of dryer kW to compressor CFM |  | EDC Data Gathering  Default: 0.0087 | EDC Data Gathering  3 |
| , Chilled coil response time derate | *Hours* | EDC Data Gathering  Default: 0.925 | EDC Data Gathering  3 |
| , Average compressor operating capacity | *None* | EDC Data Gathering Default: 65% | EDC Data Gathering  4 |
| , Annual hours of compressor operation |  | EDC Data Gathering  Default: Table 3‑178 | EDC Data Gathering  5 |
| , Coincidence factor | *Decimal* | EDC Data Gathering  Default: Table 3‑178 | EDC Data Gathering  5 |



Table ‑: Default Hours

and Coincidence Factors by Shift Type

|  |  |  |  |
| --- | --- | --- | --- |
| Shift Type | Hours Per Year | CF | Description |
| Single Shift (8/5) | 1,976 | 0.24\* | 7 AM – 3 PM, weekdays, minus some holidays and scheduled downtime |
| 2-shift (16/5) | 3,952 | 0.95 | 7 AM – 11 PM, weekdays, minus some holidays and scheduled downtime |
| 3-shift (24/5) | 5,928 | 0.95 | 24 hours per day, weekdays, minus some holidays and scheduled downtime |
| 4-shift (24/7) | 8,320 | 0.95 | 24 hours per day, 7 days a week minus some holidays and scheduled downtime |
| \* Note: This value is derived by adjusting the coincidence factor to account for assumed compressor operation (7 a.m. to 3 p.m.) during only one of the four hours of peak period (2 p.m. to 6 p.m.). 0.95 \* (1/4) = 0.2375. | | | |



Default Savings

Default savings per compressor motor HP for four shift types are shown below. EDCs may also claim savings using customer specific data.

Table 3‑179: Default Savings per HP for Cycling Refrigerated Thermal Mass Dryers

|  |  |  |
| --- | --- | --- |
| **Shift Type** | **Annual Energy Savings (** | **Peak Demand Savings ()** |
| Single Shift (8/5) | 22.3 | 0.003 |
| 2-shift (16/5) | 44.5 | 0.011 |
| 3-shift (24/5) | 66.8 | 0.011 |
| 4-shift (24/7) | 93.7 | 0.011 |

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. Measure Life Study prepared for the Massachusetts Joint Utilities. Energy and Resource Solutions, 2005. <https://www.focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf>. Accessed on June 2018.
2. Manufacturer’s data suggests that CFM output per compressor HP ranges from 4 to 5.
3. Conversion factor based on a linear regression analysis of the relationship between air compressor full load capacity and non-cycling dryer full load kW assuming that the dryer is sized to accommodate the maximum compressor capacity. Efficiency Vermont, Technical Reference Manual 2014-87. http://puc.vermont.gov/sites/psbnew/files/doc\_library/ev-technical-reference-manual.pdf
4. Based on an analysis of load profiles from 50 facilities using air compressors 40 HP and below. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc\_library/ev-technical-reference-manual.pdf
5. Hours account for holidays and scheduled downtime.The CF is drawn from the summer period, which is when the PA peak kW peak is calculated. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc\_library/ev-technical-reference-manual.pdf

### Air-Entraining Air Nozzle

|  |  |  |  |
| --- | --- | --- | --- |
| **Target Sector** | | Commercial and Industrial Establishments | |
| **Measure Unit** | | Air-entraining Air Nozzle | |
| **Measure Life** | | 15 years Source 1 | |
| **Measure Vintage** | | Early Replacement | |

Air entraining air nozzles use compressed air to entrain and amplify atmospheric air into a stream, increasing pressure with minimal compressed air use. This decreases the compressor work necessary to provide the nozzles with compressed air. Air entraining nozzles can also reduce noise in systems with air at pressures greater than 30 psig.

Eligibility

This measure is targeted to non-residential customers whose compressed air equipment uses stationary air nozzles in a production application with an open copper tube of 1/8” or 1/4” orifice diameter.

Energy efficient conditions require replacement of an inefficient, non-air entraining air nozzle with an energy efficient air-entraining air nozzle that use less than 15 CFM at 100 psi for industrial applications.

Algorithms

|  |  |
| --- | --- |
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|  |  |

Definition of Terms

Table ‑: Terms, Values, and References for Air-entraining Air Nozzles

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Baseline nozzle air flow | *CFM* | EDC Data Gathering  Default: Table 3‑181 | 2 |
| , Energy efficient nozzle air flow | *CFM* | EDC Data Gathering  Default: Table 3‑182 | 3 |
| , Ratio of compressor kW to CFM |  | EDC Data Gathering  Default: Table 3‑183 | 4 |
| , Annual hours of compressor operation |  | EDC Data Gathering  Default: Table 3‑184 | 6 |
| , Percent of hours when nozzle is in use | *None* | EDC Data Gathering  Default: 5% | 5 |
| , Coincidence Factor | *Decimal* | EDC Data Gathering  Default: Table 3‑184 | 6 |

Table ‑: Baseline Nozzle Flow

|  |  |
| --- | --- |
| **Nozzle Diameter** | **Air Mass Flow (CFM) @ 80 psi** |
| 1/8” | 21 |
| 1/4" | 58 |

Table ‑: Air Entraining Nozzle Flow

|  |  |
| --- | --- |
| **Nozzle Diameter** | **Air Mass Flow (CFM) @ 80 psi** |
| 1/8” | 6 |
| 1/4" | 11 |

Table ‑: Average Compressor kW / CFM (COMP)

|  |  |
| --- | --- |
| **Compressor Control Type** | **Average Compressor kW/CFM (COMP)** |
| Modulating w/ Blowdown | 0.32 |
| Load/No Load w/ 1 gal/CFM Storage | 0.32 |
| Load/No Load w/ 3 gal/CFM Storage | 0.30 |
| Load/No Load w/ 5 gal/CFM Storage | 0.28 |
| Variable Speed w/ Unloading | 0.23 |

|  |  |  |  |
| --- | --- | --- | --- |
| Unknown | | 0.27 | |

Table ‑: Default Hours and Coincidence Factors by Shift Type

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Shift Type** | **Hours Per Year** | **CF** | **Description** | |
| Single Shift (8/5) | 1,976 | 0.24\* | 7 AM – 3 PM, weekdays, minus some holidays and scheduled downtime | |
| 2-shift (16/5) | 3,952 | 0.95 | 7 AM – 11 PM, weekdays, minus some holidays and scheduled downtime | |
| 3-shift (24/5) | 5,928 | 0.95 | 24 hours per day, weekdays, minus some holidays and scheduled downtime | |
| 4-shift (24/7) | 8,320 | 0.95 | 24 hours per day, 7 days a week minus some holidays and scheduled downtime | |
| \* Note: This value is derived by adjusting the coincidence factor to account for assumed compressor operation (7 a.m. to 3 p.m.) during only one of the four hours of peak period (2 p.m. to 6 p.m.). 0.95 \* (1/4) = 0.2375. | | |

Default Savings

Default savings may be claimed using the algorithms above and the variable defaults. EDCs may also claim savings using customer specific data.

Sources

1. PA Consulting Group (2009). Business Programs: Measure Life Study. Prepared for State of Wisconsin Public Service Commission. <https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf>
2. Machinery's Handbook, 25th Ed. Ed by Erik Oberg (Et Al). Industrial Press, Inc. ISBN-10: 0831125756 Survey of Engineered Nozzle Suppliers.
3. Survey of Engineered Nozzle Suppliers.
4. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. The average compressor kW/CFM values were calculated using DOE part load curves and load profile data from 50 facilities employing compressors less than or equal to 40 hp. http://puc.vermont.gov/sites/psbnew/files/doc\_library/ev-technical-reference-manual.pdf
5. Assumes 50% handheld air guns and 50% stationary air nozzles. Manual air guns tend to be used less than stationary air nozzles, and a conservative estimate of 1 second of blow-off per minute of compressor run time is assumed. Stationary air nozzles are commonly more wasteful as they are often mounted on machine tools and can be manually operated resulting in the possibility of a long term open blow situation. An assumption of 5 seconds of blow-off per minute of compressor run time is used.
6. Hours account for holidays and scheduled downtime.The CF is drawn from the summer period, which is when the PA peak kW peak is calculated. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc\_library/ev-technical-reference-manual.pdf

### No-Loss Condensate Drains

|  |  |  |  |
| --- | --- | --- | --- |
| **Target Sector** | | Commercial and Industrial Establishments | |
| **Measure Unit** | | No-loss Condensate Drain | |
| **Measure Life** | | 5 years Source 1 | |
| **Measure Vintage** | | Early Replacement | |

When air is compressed, water vapor in the air condenses and collects in the system. The water must be drained to prevent corrosion to the storage tank and piping system, and to prevent interference with other components of the compressed air system such as air dryers and filters. Many drains are controlled by a timer and are opened for a fixed amount of time on regular intervals regardless of the amount of condensate. When the drains are opened compressed air is allowed to escape without doing any purposeful work. No-loss Condensate Drains are controlled by a sensor that monitors the level of condensate and only open when there is a need to drain condensate. They close before compressed air is allowed to escape.

Eligibility

This measure is targeted to non-residential customers whose equipment is a timed drain that operates on a pre-set schedule.

Acceptable baseline conditions are compressed air systems with standard condensate drains operated by a solenoid and timer.

Energy efficient conditions are systems retrofitted with new No-loss Condensate Drains properly sized for the compressed air system.

Algorithms

The following algorithms apply for No-loss Condensate Drains.

|  |  |
| --- | --- |
|  |  |
|  |  |

Definition of Terms

Table ‑: Terms, Values, and References for No-loss Condensate Drains

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Air Loss Rate; an hourly average rate for the timed drain dependent on drain orifice diameter and system pressure. | *CFM* | EDC Data Gathering  Default: Table 3‑186 | EDC Data Gathering  2 |
| , Compressor kW / CFM; the amount of electrical demand in KW required to generate one cubic foot of air at 100 PSI. |  | EDC Data Gathering  Default: Table 3‑187 | EDC Data Gathering  3 |
| , Hours per year drain is open |  | EDC Data Gathering  Default: 146 | EDC Data Gathering  4 |
| , Adjustment Factor; accounts for periods when compressor is not running and the system depressurizes due to leaks and operation of time drains. | *None* | EDC Data Gathering  Default: Table 3‑188 | EDC Data Gathering  5 |
| , Percent Not Condensate; accounts for air loss through the drain after the condensate has been cleared and the drain remains open. | *None* | EDC Data Gathering  Default: 0.75 | EDC Data Gathering  5 |
| , Annual hours of compressor operation |  | EDC Data Gathering  Default: Table 3‑189 | EDC Data Gathering  6 |
| , Coincidence factor |  | EDC Data Gathering  Default: Table 3‑189 | EDC Data Gathering  6 |

Table ‑: Average Air Loss Rates (ALR)

| **Pressure (psig)** | **Orifice Diameter (inches)** | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| **1/64** | **1/32** | **1/16** | **1/8** | **1/4** | **3/8** |
| 70 | 0.29 | 1.16 | 4.66 | 18.62 | 74.4 | 167.8 |
| 80 | 0.32 | 1.26 | 5.24 | 20.76 | 83.1 | 187.2 |
| 90 | 0.36 | 1.46 | 5.72 | 23.1 | 92 | 206.6 |
| 95 | 0.38 | 1.51 | 6.02 | 24.16 | 96.5 | 216.8 |
| 100 | 0.4 | 1.55 | 6.31 | 25.22 | 100.9 | 227 |
| 105 | 0.42 | 1.63 | 6.58 | 26.31 | 105.2 | 236.7 |
| 110 | 0.43 | 1.71 | 6.85 | 27.39 | 109.4 | 246.4 |
| 115 | 0.45 | 1.78 | 7.12 | 28.48 | 113.7 | 256.1 |
| 120 | 0.46 | 1.86 | 7.39 | 29.56 | 117.9 | 265.8 |
| 125 | 0.48 | 1.94 | 7.66 | 30.65 | 122.2 | 275.5 |
| For well-rounded orifices, values should be multiplied by 0.97. For sharp orifices, values should be multiplied by 0.61. When the baseline value is unknown, use 100.9 CFM[[50]](#footnote-265). | | | | | | |

Table ‑: Average Compressor kW/CFM (COMP)

|  |  |
| --- | --- |
| **Compressor Control Type** | **Average Compressor kW/CFM (COMP)** |
| Modulating w/ Blowdown | 0.32 |
| Load/No Load w/ 1 gal/CFM Storage | 0.32 |
| Load/No Load w/ 3 gal/CFM Storage | 0.30 |
| Load/No Load w/ 5 gal/CFM Storage | 0.28 |
| Variable Speed w/ Unloading | 0.23 |
| Unknown | 0.27 |

Table ‑: Adjustment Factor (AF)

|  |  |
| --- | --- |
| **Compressor Operating Hours** | **AF** |
| Single Shift (8/5) | 0.62 |
| 2-Shift (16/5) | 0.74 |
| 3-Shift (24/5) | 0.86 |
| 4-Shift (24/7) | 0.97 |

Table ‑: Default Hours and Coincidence Factors by Shift Type

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Shift Type** | **Hours Per Year** | **CF** | **Description** | |
| Single Shift (8/5) | 1,976 | 0.24\* | 7 AM – 3 PM, weekdays, minus some holidays and scheduled downtime | |
| 2-shift (16/5) | 3,952 | 0.95 | 7 AM – 11 PM, weekdays, minus some holidays and scheduled downtime | |
| 3-shift (24/5) | 5,928 | 0.95 | 24 hours per day, weekdays, minus some holidays and scheduled downtime | |
| 4-shift (24/7) | 8,320 | 0.95 | 24 hours per day, 7 days a week minus some holidays and scheduled downtime | |
| \* Note: This value is derived by adjusting the coincidence factor to account for assumed compressor operation (7 a.m. to 3 p.m.) during only one of the four hours of peak period (2 p.m. to 6 p.m.). 0.95 \* (1/4) = 0.2375. | | |



Default Savings

Default savings may be claimed using the algorithms above and the variable defaults. EDCs may also claim savings using customer specific data.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc\_library/ev-technical-reference-manual.pdf
2. US DOE Compressed Air Tip Sheet #3, August 2004, from Fundamentals for Compressed Air Systems Training offered by the Compressed Air Challenge. https://www.energy.gov/sites/prod/files/2014/05/f16/compressed\_air3.pdf
3. The average compressor kW/CFM values were calculated using DOE part load curves and load profile data from 50 facilities employing compressors less than or equal to 40 hp. Efficiency Vermont, Technical Reference Manual 2014-87. http://puc.vermont.gov/sites/psbnew/files/doc\_library/ev-technical-reference-manual.pdf
4. Assumes 10 seconds per 10-minute interval. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc\_library/ev-technical-reference-manual.pdf
5. Based on observed data. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc\_library/ev-technical-reference-manual.pdf
6. Accounts for holidays and scheduled downtime. Efficiency Vermont, Technical Reference Manual 2014-87. The CF is drawn from the summer period, which is when the PA peak kW peak is calculated. http://puc.vermont.gov/sites/psbnew/files/doc\_library/ev-technical-reference-manual.pdf

### Air Tanks for Load/No Load Compressors

|  |  |  |  |
| --- | --- | --- | --- |
| **Target Sector** | | Commercial and Industrial Establishments | |
| **Measure Unit** | | Receiver Tank Addition | |
| **Measure Life** | | 15 years Source 1 | |
| **Measure Vintage** | | Early Replacement | |

This measure protocol applies to the installation of air receivers with pressure/flow controls to load/no load compressors. Load/no load compressors unload when there is low demand. The process of unloading is done over a period of time to avoid foaming of the lubrication oil. Using a storage tank with pressure/flow control will buffer the air demands on the compressor. Reducing the number of cycles in turn reduces the number of transition times from load to no load and saves energy. The baseline equipment is a load/no load compressor with a 1 gal/cfm storage ratio or a modulating compressor with blowdown.

Eligibility

This measure protocol applies to the installation of new air receivers with pressure/flow controls to load/no load compressors. The high efficiency equipment is a load/no load compressor with a minimum storage ratio of 4 gallons of storage per cfm.

Algorithms

|  |  |
| --- | --- |
|  |  |
|  |  |

Definition of Terms

Table ‑: Terms, Values, and References for Air Tanks for Load/No Load Compressors

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Horsepower of compressor motor | HP | Nameplate | EDC Data Gathering |
| *0.746*, Conversion factor |  | 0.746 | Conversion factor |
| , Annual hours of compressor operation | hr | Based on logging, panel data or modeling  Default: Table 3‑191 | EDC Data Gathering  2 |
| , Load factor, average load on compressor motor | Fraction | Default = 0.92 | 3 |
| , Load reduction | Fraction | Default = 0.10 | 5 |
| , Efficiency of compressor motor | Fraction | Default = 0.91 | 4 |
| , Coincidence factor | Fraction | Based on logging, panel data or site contact interview  Default: Table 3‑191 | EDC Data Gathering  2 |



Table ‑: Default Hours and Coincidence Factors by Shift Type



|  |  |  |  |
| --- | --- | --- | --- |
| **Shift Type** | **Hours Per Year** | **CF** | **Description** |
| Single Shift (8/5) | 1,976 | 0.24\* | 7 AM – 3 PM, weekdays, minus some holidays and scheduled downtime |
| 2-shift (16/5) | 3,952 | 0.95 | 7 AM – 11 PM, weekdays, minus some holidays and scheduled downtime |
| 3-shift (24/5) | 5,928 | 0.95 | 24 hours per day, weekdays, minus some holidays and scheduled downtime |
| 4-shift (24/7) | 8,320 | 0.95 | 24 hours per day, 7 days a week minus some holidays and scheduled downtime |
| \* Note: This value is derived by adjusting the coincidence factor to account for assumed compressor operation (7 a.m. to 3 p.m.) during only one of the four hours of peak period (2 p.m. to 6 p.m.). 0.95 \* (1/4) = 0.2375. | | | |

Default savings per compressor motor HP for four shift types are shown below. EDCs may also claim savings using customer specific data.

Table 3‑192: Default Savings per HP for Air Tanks for Load/No Load Compressors

|  |  |  |
| --- | --- | --- |
| **Shift Type** | **Annual Energy Savings (** | **Peak Demand Savings ()** |
| Single Shift (8/5) | 149.0 | 0.018 |
| 2-shift (16/5) | 298.1 | 0.072 |
| 3-shift (24/5) | 447.1 | 0.072 |
| 4-shift (24/7) | 627.5 | 0.072 |

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. PA Consulting Group (2009). Business Programs: Measure Life Study. Prepared for State of Wisconsin Public Service Commission. <https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf>
2. The CF is drawn from the summer period, which is when the PA peak kW peak is calculated. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc\_library/ev-technical-reference-manual.pdf
3. Cascade Energy, Prepared for Regional Technical Forum. *Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors*. November 2012. Load factor for air compressors and average motor efficiency. https://rtf.nwcouncil.org/meeting/rtf-meeting-november-14-2012
4. Average efficiency for 1800 RPM ODP motors with 75% and 100% load factors. Cascade Energy, Prepared for Regional Technical Forum. *Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors*. November 2012. Load factor for air compressors and average motor efficiency. https://rtf.nwcouncil.org/meeting/rtf-meeting-november-14-2012
5. United States Department of Energy, Advanced Manufacturing Office. *Improving Compressed Air System Performance, a Sourcebook for Industry, Third Edition*. March 2016. Compressed air storage. https://www.energy.gov/sites/prod/files/2016/03/f30/Improving%20Compressed%20Air%20Sourcebook%20version%203.pdf

### Variable-Speed Drive Air Compressor

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Compressor Motor |
| **Measure Life** | 13 years Source 1 |
| **Measure Vintage** | Replace on Burnout, Early Replacement, Retrofit, New Construction |

Variable-Speed Drive (VSD) Air Compressors use a variable speed drive on the motor to match motor output to the load, resulting in greater efficiency than fixed-speed air compressors. Baseline compressors choke off inlet air to modulate the compressor output, resulting in increased energy consumption and peak demand.

Eligibility

To qualify for this measure, a participating commercial or industrial establishment must install or retrofit a ≤ 40 HP compressor with variable speed control. Projects involving compressors larger than 40 HP should be treated as custom projects.

Algorithms

Savings are calculated using representative baseline and efficient demand numbers for compressor capacities according to the facility’s load shape and runtime. Demand curves are derived from DOE data for a variable speed compressor versus a modulating compressor. The following formulas are used to quantify the annual energy and coincident peak demand savings.

|  |  |
| --- | --- |
|  |  |
|  |  |

Definition of Terms

Table 3‑193: Terms, Values, and References for Variable-Speed Drive Air Compressors

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , compressor total hours of operation below depending on shift | Hours/yr | EDC Data Gathering  Default: Table 3‑194 | 2 |
| , compressor motor nominal HP | HP | Nameplate | EDC Data Gathering |
| , baseline compressor factor | None | EDC Data Gathering  Default = 0.890 | 3 |
| , efficient compressor factor | None | EDC Data Gathering  Default = 0.705 | 3 |
| , Coincidence factor | None | Default: Table 3‑194 | 2 |
| *0.9,* Compressor motor nominal HP to full load kW conversion factor. | kW/HP | Default = 0.9 | 4 |

Table 3‑194: Default Hours and Coincidence Factors by Shift Type

|  |  |  |  |
| --- | --- | --- | --- |
| **Shift Type** | **Hours Per Year** | **CF** | **Description** |
| Single Shift (8/5) | 1,976 | 0.24\* | 7 AM – 3 PM, weekdays, minus some holidays and scheduled downtime |
| 2-shift (16/5) | 3,952 | 0.95 | 7 AM – 11 PM, weekdays, minus some holidays and scheduled downtime |
| 3-shift (24/5) | 5,928 | 0.95 | 24 hours per day, weekdays, minus some holidays and scheduled downtime |
| 4-shift (24/7) | 8,320 | 0.95 | 24 hours per day, 7 days a week minus some holidays and scheduled downtime |
| \* Note: This value is derived by adjusting the coincidence factor to account for assumed compressor operation (7 a.m. to 3 p.m.) during only one of the four hours of peak period (2 p.m. to 6 p.m.). 0.95 \* (1/4) = 0.2375. | | | |

Default Savings

Default savings per compressor motor HP for four shift types are shown below. EDCs may also claim savings using customer specific data.

Table 3‑195: Default Savings per HP for Variable-Speed Drive Air Compressors

|  |  |  |
| --- | --- | --- |
| **Shift Type** | **Annual Energy Savings (** | **Peak Demand Savings ()** |
| Single Shift (8/5) | 329.0 | 0.040 |
| 2-shift (16/5) | 658.0 | 0.158 |
| 3-shift (24/5) | 987.0 | 0.158 |
| 4-shift (24/7) | 1,385.3 | 0.158 |

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. Illinois Statewide Technical Reference Manual v7.0, Section 4.7.1, p. 542, <http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf>
2. Accounts for holidays and scheduled downtime. The CF is drawn from the summer period, which is when the PA peak kW peak is calculated. Efficiency Vermont, Technical Reference Manual 2014-87. http://puc.vermont.gov/sites/psbnew/files/doc\_library/ev-technical-reference-manual.pdf
3. Compressor factors were developed using DOE part load data for different compressor control types as well as load profiles from 50 facilities employing air compressors less than or equal to 40 hp. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. <http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf>
4. Conversion factor based on a linear regression analysis of the relationship between air compressor motor nominal horsepower and full load kW from power measurements of 72 compressors at 50 facilities. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc\_library/ev-technical-reference-manual.pdf

### Compressed Air Controller

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Per Compressed Air System |
| **Measure Life** | 15 years Source 1 |
| **Measure Vintage** | New Construction or Retrofit |

Eligibility

The following protocol for the measurement of energy and demand savings applies to the installation of a compressed air pressure or flow controller for compressed air systems in commercial or industrial facilities.

A pressure/flow controller can greatly increase the control of an air storage system. These units, also called demand valves, precision flow controllers, or pilot‐operated regulators, are precision pressure regulators that allow the airflow to fluctuate while maintaining a constant pressure to the facility’s air distribution piping network. Installing a pressure/flow controller on the downstream side of an air storage receiver creates a pressure differential entering and leaving the vessel. This pressure differential stores energy in the form of readily available compressed air, which can be used to supply the peak air demand for short duration events, in place of using more compressor horsepower to feed this peak demand. The benefits of having a pressure/flow controller include:

* Reducing the kilowatts of peak demand, especially with multiple compressor configurations.
* Saving kilowatt‐hours by allowing the compressor to run at most efficient loads, then turn itself off in low demand and no demand periods.
* Saving kilowatt‐hours by reducing plant air pressure to the minimum allowable. This leads to reduced loads on the electric motors and greater system efficiency. For every 2 psi reduced in the system, 1% of energy is saved.
* Maintaining a reduced, constant pressure in the facility wastes less air due to leakage, and less volume is required by the compressor.
* Ensuring quality control of the process by the constant pressure: machines can produce an enhanced product quality when the pressure is allowed to fluctuate.

The baseline condition is having no existing pressure/flow controller and an existing compressed air system with a total compressor motor capacity ≥ 40 hp. This measure requires a minimum storage of 3gal/cfm. This protocol is not applicable for compressed air systems with total motor nameplate capacity < 40 hp. This measure is not replacing drop‐line regulators or filter‐regulator lubricators.

Algorithms

|  |  |
| --- | --- |
|  |  |
|  |  |

Definition of Terms

Table 3‑196: Terms, Values, and References for Compressed Air Controllers

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , total air compressor motor nameplate horsepower | *HP* | Nameplate | EDC Data Gathering |
| , conversion factor from kW to HP | *kW/HP* | Constant | Constant |
| average annual run hours of compressed air system |  | Based on logging, panel data or modeling  Default: Table 3‑197 | EDC Data Gathering  1 |
| load factor; ratio between the actual load on the compressor motor and the rated load | *%* | Based on spot metering and nameplate  Default: 0.92 | EDC Data Gathering  2 |
| , compressor motor efficiency at the full-rated load | *%* | Nameplate  Default: 0.91 | EDC Data Gathering  3 |
| , percentage decrease in power input | *%* | Default: 5% | 4 |
| Coincidence factor | *Decimal* | EDC Data Gathering  Default: Table 3‑197 | EDC Data Gathering  1 |

Table 3‑197: Default Hours and Coincidence Factors by Shift Type

|  |  |  |  |
| --- | --- | --- | --- |
| **Shift Type** | **Hours Per Year** | **CF** | **Description** |
| Single Shift (8/5) | 1,976 | 0.24\* | 7 AM – 3 PM, weekdays, minus some holidays and scheduled downtime |
| 2-shift (16/5) | 3,952 | 0.95 | 7 AM – 11 PM, weekdays, minus some holidays and scheduled downtime |
| 3-shift (24/5) | 5,928 | 0.95 | 24 hours per day, weekdays, minus some holidays and scheduled downtime |
| 4-shift (24/7) | 8,320 | 0.95 | 24 hours per day, 7 days a week minus some holidays and scheduled downtime |
| \* Note: This value is derived by adjusting the coincidence factor to account for assumed compressor operation (7 a.m. to 3 p.m.) during only one of the four hours of peak period (2 p.m. to 6 p.m.). 0.95 \* (1/4) = 0.2375. | | | |

Default Savings

Default savings per compressor motor HP for four shift types are shown below. EDCs may also claim savings using customer specific data.

Table 3‑198: Default Savings per HP for Compressed Air Controllers

|  |  |  |
| --- | --- | --- |
| **Shift Type** | **Annual Energy Savings (** | **Peak Demand Savings ()** |
| Single Shift (8/5) | 74.5 | 0.009 |
| 2-shift (16/5) | 149.0 | 0.036 |
| 3-shift (24/5) | 223.5 | 0.036 |
| 4-shift (24/7) | 313.7 | 0.036 |

Evaluation Protocol

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. Accounts for holidays and scheduled downtime. The CF is drawn from the summer period, which is when the PA peak kW peak is calculated. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc\_library/ev-technical-reference-manual.pdf
2. Cascade Energy, Prepared for Regional Technical Forum. *Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors*. November 2012. Load factor for air compressors and average motor efficiency. https://rtf.nwcouncil.org/meeting/rtf-meeting-november-14-2012
3. Average efficiency for 1800 RPM ODP motors with 75% and 100% load factors. Cascade Energy, Prepared for Regional Technical Forum. *Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors*. November 2012 https://rtf.nwcouncil.org/meeting/rtf-meeting-november-14-2012
4. United States Department of Energy. *Improving Compressed Air System Performance: A Sourcebook for Industry.* p. 20. November 2003.

### Compressed Air Low Pressure Drop Filters

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Per Compressed Air System |
| **Measure Life** | 10 years Source 1 |
| **Measure Vintage** | New Construction or Retrofit |

Eligibility

The following protocol for the measurement of energy and demand savings applies to the installation of low pressure drop air filters for compressed air systems in commercial and industrial facilities. Low pressure drop filters remove solids and aerosols from compressed air systems with a longer life and lower pressure drop than standard coalescing filters, resulting in better efficiencies.

The baseline condition is a standard coalescing filter with a pressure drop of 3 psi when new and 5 psi or more at element change. The efficient condition is a low pressure drop filter with pressure drop not exceeding 1 psi when new and 3 psi at element change.

Algorithms

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| --- | --- |
|  |  |
|  |  |

Definition of Terms

Table 3‑199: Terms, Values, and References for Compressed Air Low Pressure Drop Filters

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , total air compressor motor nameplate horsepower | *HP* | Nameplate | EDC Data Gathering |
| *0.746*, conversion factor |  | 0.746 | Conversion factor |
| reduced filter pressure loss | *psi* | Default: 2.0 | 3 |
| load factor; ratio between the actual load on the compressor motor and the rated load | *%* | Default: 0.92 | 4 |
| , savings factor | *%/psi* | Default: 0.005 | 5 |
| , compressed air system total annual hours of operation |  | Default: Table 3‑200 | 6 |
| Based on logging and panel data | EDC Data Gathering |
| Coincidence factor | *Decimal* | EDC Data Gathering | EDC Data Gathering |
| Default: Table 3‑200 | 6 |

Table 3‑200: Default Hours and Coincidence Factors by Shift Type

|  |  |  |  |
| --- | --- | --- | --- |
| **Shift Type** | **Hours Per Year** | **CF** | **Description** |
| Single Shift (8/5) | 1,976 | 0.24\* | 7 AM – 3 PM, weekdays, minus some holidays and scheduled downtime |
| 2-shift (16/5) | 3,952 | 0.95 | 7 AM – 11 PM, weekdays, minus some holidays and scheduled downtime |
| 3-shift (24/5) | 5,928 | 0.95 | 24 hours per day, weekdays, minus some holidays and scheduled downtime |
| 4-shift (24/7) | 8,320 | 0.95 | 24 hours per day, 7 days a week minus some holidays and scheduled downtime |
| \* Note: This value is derived by adjusting the coincidence factor to account for assumed compressor operation (7 a.m. to 3 p.m.) during only one of the four hours of peak period (2 p.m. to 6 p.m.). 0.95 \* (1/4) = 0.2375. | | | |

Default Savings

Default savings per compressor motor HP for four shift types are shown below. EDCs may also claim savings using customer specific data.

Table 3‑201: Default Savings per HP for Compressed Air Low Pressure Drop Filters

|  |  |  |
| --- | --- | --- |
| **Shift Type** | **Annual Energy Savings (** | **Peak Demand Savings ()** |
| Single Shift (8/5) | 14.7 | 0.002 |
| 2-shift (16/5) | 29.5 | 0.007 |
| 3-shift (24/5) | 44.2 | 0.007 |
| 4-shift (24/7) | 62.1 | 0.007 |

Evaluation Protocol

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. Based on survey of manufacturer claims (Zeks, Van Air, Quincy), as recommended in Navigant ‘ComEd Effective Useful Life Research Report’, May 2018. Illinois Technical Reference Manual v.7.0 Volume 2. September 2018. Page 545.
2. Illinois Statewide Technical Reference Manual v.7.0 Volume 2. September 2018. Page 546. <http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf>
3. Assumed pressure will be reduced from a roughly 3 psi pressure drop through a filter to less than 1 psi, for a 2 psi savings.
4. Cascade Energy, Prepared for Regional Technical Forum. *Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors*. November 2012. Load factor for air compressors and average motor efficiency. https://rtf.nwcouncil.org/meeting/rtf-meeting-november-14-2012
5. “Optimizing Pneumatic Systems for Extra Savings,” Compressed Air Best Practices, DOE Compressed Air Challenge, 2010. (1% reduction in power per 2 psi reduction in system pressure is equal to 0.5% reduction per 1 psi, or a savings factor of 0.005)
6. Accounts for holidays and scheduled downtime. The CF is drawn from the summer period, which is when the PA peak kW peak is calculated. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc\_library/ev-technical-reference-manual.pdf

### Compressed Air Mist Eliminators

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Per Air Mist Eliminator |
| **Measure Life** | 5 years Source 1 |
| **Measure Vintage** | New Construction or Retrofit |

Eligibility

The following protocol for the measurement of energy and demand savings applies to the installation of mist eliminator air filters for compressed air systems in commercial and industrial facilities.

Large compressed air systems require air filtration for proper operation. These filters remove oil mist from the supply air of lubricated compressors, protecting the distribution system and end‐use devices. While these filters are important to the operation of the system, they do have a pressure drop across them, and thus require a slightly higher operating pressure. Typical coalescing oil filters will operate with a 2 psig to 10 psig pressure drop. Mist eliminator air filters operate at a 0.5 psig pressure drop that increases to 3 psig over time before replacement is recommended.

This reduction in pressure drop allows the compressed air system to operate at a reduced pressure and, in turn, reduces the energy consumption of the system. In general, the energy consumption will decrease by 1% for every 2 psig the operating pressure is reduced.[[51]](#footnote-268) Lowering the operating pressure has the secondary benefit of decreasing the demand of all unregulated usage, such as leaks and open blowing. The equipment is mist eliminator air filters. The compressed air system must be greater than 50 HP to qualify, and the mist eliminator must have less than a 1 psig pressure drop and replace a coalescing filter.

The baseline condition is a standard coalescing filter. The efficient condition is a mist eliminator air filter that replaces a standard coalescing filter. This protocol is not applicable for compressed air systems with total air compressor nameplate horsepower < 40 HP or mist eliminators with ≥ 1 psig pressure drop.

Algorithms

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|  |  |

Definition of Terms

Table 3‑202: Terms, Values, and References for Compressed Air Mist Eliminators

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , Rated horsepower of the air compressor motor | *HP* | Nameplate | EDC Data Gathering |
| , conversion factor from horsepower to kW | *kW/HP* | Constant | Constant |
| , compressor motor efficiency at the full-rated load | *%* | Nameplate  Default: 0.91 | EDC Data Gathering  2 |
| load factor; ratio between the actual load on the compressor motor and the rated load | *%* | Based on spot metering and nameplate  Default: 0.92 | EDC Data Gathering  3 |
| average annual run hours of the compressed air system |  | Based on logging, panel data or modeling  Default: Table 3‑203 | EDC Data Gathering  4 |
| , percentage of energy saved | *%* | Default: 2% | 5 |
| total pressure reduction from replacing filter |  | Default: 4 psig | 5 |
| , percentage of energy saved for each psig reduced | *%/psig* | Default: 0.5% | 6 |
| Coincidence factor | *Decimal* | EDC Data Gathering  Default: Table 3‑203 | EDC Data Gathering  4 |

Table 3‑203: Default Hours and Coincidence Factors by Shift Type

|  |  |  |  |
| --- | --- | --- | --- |
| **Shift Type** | **Hours Per Year** | **CF** | **Description** |
| Single Shift (8/5) | 1,976 | 0.24\* | 7 AM – 3 PM, weekdays, minus some holidays and scheduled downtime |
| 2-shift (16/5) | 3,952 | 0.95 | 7 AM – 11 PM, weekdays, minus some holidays and scheduled downtime |
| 3-shift (24/5) | 5,928 | 0.95 | 24 hours per day, weekdays, minus some holidays and scheduled downtime |
| 4-shift (24/7) | 8,320 | 0.95 | 24 hours per day, 7 days a week minus some holidays and scheduled downtime |
| \* Note: This value is derived by adjusting the coincidence factor to account for assumed compressor operation (7 a.m. to 3 p.m.) during only one of the four hours of peak period (2 p.m. to 6 p.m.). 0.95 \* (1/4) = 0.2375. | | | |

Default Savings

Default savings per compressor motor HP for four shift types are shown below. EDCs may also claim savings using customer specific data.

Table 3‑204: Default Savings per HP for Compressed Air Mist Eliminators

|  |  |  |
| --- | --- | --- |
| **Shift Type** | **Annual Energy Savings (** | **Peak Demand Savings ()** |
| Single Shift (8/5) | 29.8 | 0.004 |
| 2-shift (16/5) | 59.6 | 0.014 |
| 3-shift (24/5) | 89.4 | 0.014 |
| 4-shift (24/7) | 125.5 | 0.014 |

Evaluation Protocol

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. Based on product warranty period Sullair Corporation. *Compressed Air Filtration and Mist Eliminators Datasheet*. <http://www.amcompair.com/products/brochures/sullair_brochures/_Sullair%20filtration.pdf>
2. Average efficiency for 1800 RPM ODP motors with 75% and 100% load factors. Cascade Energy, Prepared for Regional Technical Forum. *Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors*. November 2012. https://rtf.nwcouncil.org/meeting/rtf-meeting-november-14-2012
3. Cascade Energy, Prepared for Regional Technical Forum. *Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors*. November 2012. Load factor for air compressors and average motor efficiency. <https://rtf.nwcouncil.org/meeting/rtf-meeting-november-14-2012>
4. Accounts for holidays and scheduled downtime. The CF is drawn from the summer period, which is when the PA peak kW peak is calculated. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc\_library/ev-technical-reference-manual.pdf
5. Sullair Corporation. *Compressed Air Filtration and Mist Eliminators Datasheet*. <http://www.amcompair.com/products/brochures/sullair_brochures/_Sullair%20filtration.pdf>
6. United States Department of Energy. *Improving Compressed Air System Performance: A**Sourcebook for Industry*. p. 20. November 2003.

## Miscellaneous

### High Efficiency Transformer

|  |  |  |  |
| --- | --- | --- | --- |
| **Target Sector** | | Commercial, Industrial, and Agricultural Establishments | |
| **Measure Unit** | | Transformer | |
| **Measure Life** | | 15 years Source 1 | |
| **Measure Vintage** | | Retrofit, New Construction | |

Eligibility

Distribution transformers are used in some multi-family, commercial and industrial applications to step down power from distribution voltage to be used in HVAC or process loads (208V or 480V) or to serve plug loads (120V).

Distribution transformers that are more efficient than the required minimum federal standard efficiency qualify for this measure. If there is no specific standard efficiency requirement, the transformer does not qualify (because the baseline cannot be defined). For example, although the federal standards increased the minimum required efficiency in 2016, most transformers with a NEMA premium or CEE Tier 2 rating will still achieve energy conservation. Standards are defined for low-voltage dry-type distribution transformers (up to 333kVA single-phase and 1000kVA 3-phase.

The baseline equipment is a transformer that meets the minimum federal efficiency requirement. Standards are developed by the DOE and published in Federal Register 10CFR 431. Transformers more efficient than the federal minimum standard are eligible. This includes CEE Tier II (single or three phase) and most NEMA premium efficiency rated products. Projects with liquid-immersed distribution transformers and medium voltage dry type transformer energy savings should be treated as custom projects.

Algorithms

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Definition of Terms

Table ‑: Terms, Values, and References for High Efficiency Transformers

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , kVA rating of the transformer | *kVA* | EDC Data Gathering | EDC Data Gathering |
| , Baseline total efficiency rating of federal minimum standard transformer | *Percent* | Default: Table 3‑206 | 2 |
| , Installed total efficiency rating of the transformer | *Percent* | EDC Data Gathering | EDC Data Gathering  3 |
| , Load factor for the transformer | *Percent* | EDC Data Gathering  Default: 35% | EDC Data Gathering  3 |
| , Power factor for the load served by the transformer | *Decimal* | EDC Data Gathering[[52]](#footnote-271) | EDC Data Gathering |
| Default: 1.0 | 4 |



Table ‑: Baseline Efficiencies for Low-Voltage Dry-Type Distribution Transformers

|  |  |  |  |
| --- | --- | --- | --- |
| **Single-phase** | | **Three-phase** | |
| **kVA** | **Efficiency (%)** | **kVA** | **Efficiency (%)** |
| 15 | 97.70 | 15 | 97.89 |
| 25 | 98.00 | 30 | 98.23 |
| 37.5 | 98.20 | 45 | 98.40 |
| 50 | 98.30 | 75 | 98.60 |
| 75 | 98.50 | 112.5 | 98.74 |
| 100 | 98.60 | 150 | 98.83 |
| 167 | 98.70 | 225 | 98.94 |
| 250 | 98.80 | 300 | 99.02 |
| 333 | 98.90 | 500 | 99.14 |
| --- | --- | 750 | 99.23 |
| --- | --- | 1,000 | 99.28 |

Default Savings

There are no default savings for this measure.

Evaluation Protocol

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

1. US DOE lists the lifetime at 32 years. The maximum measure life allowed by the PA TRM is 15 years. US Department of Energy, “Energy Conservation Program: Energy Conservation Standards for Distribution Transformers; Final Rule”, 10 CFR Part 431, Published April 18, 2013, Effective as of January 1, 2016.
2. US Department of Energy, “Energy Conservation Program: Energy Conservation Standards for Distribution Transformers; Final Rule”, 10 CFR Part 431, Published April 18, 2013, Compliance effective as of January 1, 2016.
3. Use the efficiency rating calculated by the appropriate DOE test method, generally at 35% load factor. Energy Conservation Program: Test Procedures for Distribution Transformers; Final Rule. Effective May 30, 2006.
4. Unity power factor for used as default value, as used in the test procedures provided by US DOE. Energy Conservation Program: Test Procedures for Distribution Transformers; Final Rule. Effective May 30, 2006.

### Engine Block Heat Timer

|  |  |
| --- | --- |
| **Target Sector** | Commercial, Industrial, and Agricultural Establishments |
| **Measure Unit** | Engine Block Heater Timer |
| **Measure Life** | 15 years Source 1 |
| **Measure Vintage** | Retrofit |

Eligibility

This protocol documents the energy savings attributed to installation of engine block heater timers in commercial, industrial, and agricultural establishments. The baseline for this measure is an engine block heater in use without a timer.

Algorithms

Engine block heater timers save energy by reducing the time that engine block heaters operate. Typically, block heaters are plugged in throughout the night. Using timers allows the heater to come on at a preset time during the night, rather than being on throughout the night. Because this measure does not affect peak period usage, there are no peak demand savings associated with the measure.

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| --- | --- |
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Definition of Terms



Table ‑

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|  |  |  |  |

207: Terms, Values, and References for Engine Block Heater Timer

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Average power consumption of engine block heater | kW | EDC Data Gathering | EDC Data Gathering |
| Default = 1.3 | 2 |
| , Reduction in number of hours block heater is used per night | Hours/day | EDC Data Gathering | EDC Data Gathering |
| Default = 9 | 2 |
| , Number of operating days per year | Days/year | EDC Data Gathering | EDC Data Gathering |
| Default = 65 | 2 |
| , Usage factor | None | EDC Data Gathering | EDC Data Gathering |
| Default = 0.97 | 2 |

Default Savings

Default savings for this measure are shown in the table below.

Table 3‑208: Default Savings for Engine Block Heater Timer

|  |  |
| --- | --- |
| **Energy Savings (kWh)** | **Peak Demand Reduction (kW)** |
| 737.7 | 0 |

Evaluation Protocol

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. Gutierrez, Alfredo. Circulating Block Heater. Prepared for the California Technical Forum. <http://static1.squarespace.com/static/53c96e16e4b003bdba4f4fee/t/556f7c9ee4b0b65c3515c80c/1433369758093/Circulating+Block+Heater+Presentation_ver+2.pdf>
2. Wisconsin Focus on Energy 2018 Technical Reference Manual. Public Service Commission of Wisconsin. The Cadmus Group, Inc. 2018. Pg. 590. <https://www.focusonenergy.com/sites/default/files/TRM%202018%20Final%20Version%20Dec%202017_1.pdf>

### High Frequency Battery Chargers

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | Charger |
| **Measure Life** | 15 years Source 1 |
| **Measure Vintage** | New Construction, Replace on Burnout |

Eligibility

This measure applies to industrial high frequency battery chargers, used for industrial equipment such as fork lifts, replacing existing SCR (silicon controlled rectifier) or ferroresonant charging technology. They have a greater efficiency than silicon controlled rectifier (SCR) or ferroresonant chargers.

The baseline equipment is a SCR or ferroresonant battery charger system with minimum 8-hour shift operation five days per week. The energy efficient equipment is a high frequency battery charger system with a minimum power conversion efficiency of 90% and 8-hour shift operation five days per week.

Algorithms

Algorithms for annual energy savings and peak demand savings are shown below.

|  |  |
| --- | --- |
|  |  |
|  |  |

Definition of Terms

Table 3‑209: Terms, Values, and References for High Frequency Battery Chargers

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Capacity of battery | *kWh* | EDC Data Gathering | EDC Data Gathering |
| Default: 35 | 2 |
| , Depth of discharge | *Percent* | Default: 80% | 3 |
| , Number of charges per year | *N* | EDC Data Gathering | EDC Data Gathering |
| Default: Table 3‑210 | 4 |
| , Baseline charge return factor | *Decimal* | Default: 1.2485 | 3, 5 |
| , Baseline power conversion efficiency | *Decimal* | Default: 0.84 | 3 |
| , Efficient charge return factor | *Decimal* | Default: 1.107 | 3 |
| , Efficient power conversion efficiency | *Decimal* | Default: 0.89 | 3 |
| , Power factor of baseline charger | *Decimal* | Default: 0.9095 | 3 |
| , Power factor of high frequency charger | *Decimal* | Default: 0.9370 | 3 |
| , DC rated voltage of charger | *V* | EDC Data Gathering | EDC Data Gathering |
| Default: 48 | 6 |
| , DC rated amerage of charger | *A* | EDC Data Gathering | EDC Data Gathering |
| Default: 81 | 6 |
| 1,000, Conversion factor |  | 1,000 | Conversion Factor |
| , Coincidence factor | *Decimal* | Default for single shift or 2-shift: 0.25  Default for 3-shift or 4-shift: 1 | 7 |

Table 3‑210: Default Values for Number of Charges Per Year

|  |  |
| --- | --- |
| **Operation Facility Schedule**  **(hours per day / days per week)** | **Number of Charges Per Year** |
| Single Shift (8/5) | 260 |
| 2-Shift (16/5) | 520 |
| 3-Shift (24/5) | 780 |
| 4-Shift (24/7) | 1,092 |

Default Savings

Default savings for this measure are shown in the table below.

Table 3‑211: Default Savings for High Frequency Battery Charging

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Value** | **Operation Facility Schedule**  **(hours per day / days per week)** | | | |
| **Single Shift (8/5) or Unknown** | **2-Shift**  **(16/5)** | **3-Shift**  **(24/5)** | **4-Shift**  **(24/7)** |
| Annual Energy Savings (kWh) | 1,765.3 | 3,530.6 | 5,296.0 | 7,414.4 |
| Peak Demand Savings (kW) | 0.029 | 0.029 | 0.116 | 0.116 |

Evaluation Protocol

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. Ecos Consulting. Analysis of Standards Options for Battery Charger Systems. Prepared for the California IOUs. October 2010. Page 45.
2. Jacob V. Renquist, Brian Dickman, and Thomas H. Bradley, “Economic Comparison of fuel cell powered forklifts to battery powered forklifts”, International Journal of Hydrogen Energy Volume 37, Issue 17, (2012): 2
3. Ryan Matley, “Measuring Energy Efficiency Improvements in Industrial Battery Chargers”, (ESL-IE-09-05-32, Energy Technology Conference, New Orleans, LA, May 12-15, 2009), 4.
4. Values are based on an estimated one charge per 8-hour workday.
5. Average of SCR and ferroresonant.
6. Pacific Gas & Electric, “Emerging Technologies Program Application Assessment Report #0808”, Industrial Battery Charger Energy Savings Opportunities. May 29, 2009. Page 8, Table 3. Voltage and ampere rating based on the assumption of 35kWh battery with a normalized average amp-hour capacity of 760 Ah charged over a 7.5-hour charge cycle. <https://www.kannahconsulting.com/wp-content/uploads/2016/08/etcc_report_industrial_battery_chargers_final_v5.pdf>
7. Pacific Gas & Electric, “Emerging Technologies Program Application Assessment Report #0808”, Industrial Battery Charger Energy Savings Opportunities. May 29, 2009. See discussion below Table 7. For single shifts and 2-shifts, the average charge cycle will begin at 5:00 PM. This equates to 1 hour during the PJM peak period (2 PM – 6 PM). For 3-shift and 4-shift, it is expected that the charger will be charging during the full peak period. <https://www.kannahconsulting.com/wp-content/uploads/2016/08/etcc_report_industrial_battery_chargers_final_v5.pdf>

## Demand Response

### Load Curtailment for Commercial and Industrial Programs

|  |  |
| --- | --- |
| **Target Sector** | Commercial and Industrial Establishments |
| **Measure Unit** | N/A |
| **Measure Life** | 1 year |
| **Measure Vintage** | Demand Response |

In a C&I Load Curtailment (LC) program, end-use customers are provided a financial incentive to reduce the amount of electricity they take from the EDC during Demand Response events. This temporary reduction in electricity consumption can be achieved in a number of ways. The specific load curtailment actions taken by program participants are outside of the scope of this protocol. Load curtailment is a dispatchable, event-based resource because the load impacts are only expected to occur on days when DR events are called. This is fundamentally different from non-dispatchable DR options such as dynamic pricing or permanent load shifting. This protocol only applies to dispatchable resources.

Peak demand reductions associated with DR resources are defined as the difference between a customer’s actual (measured) electricity demand and the amount of electricity the customer would have demanded in the absence of the DR program incentive. The latter is inherently counterfactual because it never occurred and therefore cannot be measured and must be estimated. This estimate of how much electricity would have been consumed absent the DR program is analogous to the baseline condition for an energy efficiency measure. In this protocol, this estimate is referred to as the reference load.

The reference load used to determine impacts from a LC program participant during a DR event shall be estimated using one of the following methods.[[53]](#footnote-274) The methods are in hierarchical order of preference based on expected accuracy. The EDCs are strongly encouraged to utilize the first three methodologies to verify achievement of demand reductions targets for the phase. In scenarios where an EDC determines a Customer Baseline (CBL) approach is more appropriate, the EDC should provide sound reasoning for the choice of the CBL approach as opposed to the first three methodologies.

1. A comparison group analysis where the loads of a group of non-participating customers that are similar to participating customers with respect to observable characteristics (e.g. non-event weekday consumption) are used to estimate the reference load. A variety of matching techniques are available and the EDC evaluation contractor can choose the technique used to select the comparison group based on their professional judgment. The primary objective of statistical matching is to eliminate bias in the reference load during the most relevant load hours. The most relevant hours are those during the event, but hours immediately prior to and immediately following the event period are also important. As such, matching methods should focus on finding customers with loads during these critical hours that are as close as possible to the loads of participating customers for days that have weather and perhaps other conditions very similar to event days. If events are most likely to be called on hot days, hot non-event days should be used for statistical matching (and very cool days should be excluded). If need be, difference-in-differences techniques can be utilized to eliminate any pre-existing differences in consumption between the treatment and matched control group during estimation.
2. A ‘within-subjects’ regression analysis where the loads of participating customers on non-event days are used to estimate the reference load. The regression equation should include temperature and other variables that influence usage as explanatory variables. This method is superior to the baseline methods discussed in (4).
3. A hybrid Regression-Matching method where matching is used for most customers and regression methods are used to predict reference loads for any large customers who are too unique to have a good matching candidate. This approach allows for matching methods to be used when good matches are available without dropping unique customers who do not have valid matches from the analysis. The hybrid approach is also superior to the baseline methods discussed in (4).
4. A CBL approach (1) with a weather adjustment to account for the more extreme conditions in place on event days or (2) without a weather adjustment in cases where loads are associated with non-weather-sensitive end-uses. In this approach, the reference load is estimated by calculating the average usage in the corresponding hours for selected days leading up to or following an event day. Multiplicative or additive same-day adjustments for the CBL are prohibited because of the day-ahead event notification. A variety of CBL methods are available to be used and the EDC contractor should provide justification for the specific method that is selected. Reference loads should generally be calculated separately for each participant, but aggregation of accounts or meters is permissible at the discretion of the EDC evaluation contractor. CBL methods are the least preferred of the four approaches, but may produce valid results in situations where customer loads are fairly constant and are not highly sensitive or insensitive to weather conditions.

The weather conditions in place at the time of the event are always used to claim savings. Weather-normalized or extrapolation of impacts to other weather conditions is not permitted.

Other curtailment event days – either Act 129 or PJM – should be removed when estimating the reference load for an Act 129 event day. Additionally, weekends, holidays, and shut down days may be removed when estimating reference loads.

Where feasible, matching-based methods are capable of effectively removing selection bias and providing accurate impact estimates that are comparable to results from a randomized experiment and are generally superior to within-subjects approaches.[[54]](#footnote-275) Because of this, in situations where large and representative control pools are available, it is suggested that the comparison group approach be used.

**Eligibility**

In order to be eligible for an EDC Load Curtailment program, a customer must have an hourly or sub-hourly revenue meter. Interval demand readings are necessary to calculate the reference load and estimate load impacts from DR events. Sub-metered loads may be used for accounts which do not have interval meters at the discretion of the SWE.

**Algorithms**

Annual peak demand savings must be estimated using individual customer data (e.g. account, meter, or site as defined by program rules) regardless of which evaluation method is used. Program savings are the sum of the load impacts across all participants. The equations below provide mathematical definitions of the average peak period load impact estimate that would be calculated using an approved method.

|  |  |
| --- | --- |
|  |  |
|  | *=* |

**Definition of Terms**

Table 3‑212: Terms, Values, and References for C&I Load Curtailment

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| *n*, Number of DR hours during a program year for the EDC | Hours | EDC Data Gathering | EDC Data Gathering |
| *,* Estimated load impact achieved by an LC participant in hour i. This term can be positive (a load reduction) or negative (a load increase). | kW | EDC Data Gathering | EDC Data Gathering |
| , Estimated customer load absent DR during hour i | kW | EDC Data Gathering | EDC Data Gathering |
| , Measured customer load during hour i | kW | EDC Data Gathering | EDC Data Gathering |

**Default Savings**

There are no default savings for this measure.

**Evaluation Protocols**

The evaluation protocols for the Load Curtailment measure follow the calculation methodologies described in this document. Evaluation of the measure should rely on a census of program participants unless a sampling approach (either of days or participants) is approved by the SWE. Detailed protocols for implementing the methodologies described above and the outputs that must be produced are provided in the Evaluation Framework.

# Agricultural Measures

## Agricultural

### Automatic Milker Takeoffs

|  |  |  |  |
| --- | --- | --- | --- |
| **Target Sector** | | Agriculture | |
| **Measure Unit** | | Milker Takeoff System | |
| **Measure Life** | | 10 years Source 1 | |
| **Measure Vintage** | | Retrofit | |

Eligibility

The following protocol for the calculation of energy and demand savings applies to the installation of automatic milker takeoffs on dairy milking vacuum pump systems. Automatic milker takeoffs shut off the suction on teats once a minimum flow rate is achieved. This reduces the load on the vacuum pump.

This measure requires the installation of automatic milker takeoffs to replace pre-existing manual takeoffs on dairy milking vacuum pump systems. Equipment with existing automatic milker takeoffs is not eligible. In addition, the vacuum pump system serving the impacted milking units must be equipped with a variable speed drive (VSD) to qualify for incentives. Without a VSD, little or no savings will be realized.

Algorithms

The annual energy savings are obtained through the following formulas:

|  |  |
| --- | --- |
|  |  |
|  |  |

Definition of Terms

Table ‑: Terms, Values, and References for Automatic Milker Takeoffs

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Term** | | **Unit** | **Values** | **Source** | |
| , Number of cows milked per day (not the number of individual milkings; each cow is assumed to be milked twice per day) | | *Cows* | Based on customer application | EDC Data Gathering | |
| , Annual Energy Savings per cow | |  | 34 | 2, 3, 4, 5, 6 | |
| , Energy to Demand factor | |  | 0.00017 | 7 | |

Default Savings

There are no default savings for this protocol.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. Idaho Power Demand Side Management Potential Study – Volume II Appendices, Nexant, 2009.
2. The ESC was calculated based on the following assumptions:
   1. Average herd size is 102 cows in PA (Source 3)
   2. The typical dairy vacuum pump size for the average herd size is 10 horsepower (Source 4)
   3. Based on the herd size, average pump operating hours are estimated at 10 hours per day (or 0.10 hours per cow per day) (Source 5)
   4. A 12.5% annual energy saving factor (Source 6)
3. Chuck Nicholson, Mark Stephenson, Andrew Novakovic: “Study to Support Growth and Competitiveness of the Pennsylvania Dairy Industry”, 2017. <https://dairymarkets.org/Growth_and_Competitiveness_Study_DRAFT_Final_Report_June_2018.pdf>
4. Average dairy vacuum pump size was estimated based on the Minnesota Dairy Project literature.
5. Mark Mayer, David Kammel: “Dairy Modernization Works for Family Farms”, 2008. <https://joe.org/joe/2010october/rb7.php>. The paper asserts an average of 22.7 cows milked per hour prior to modernization. This TRM adopts a conservative estimate of 20 cows milked per hour. Annual pump operating hours are based on the assumption that 20 cows are milked per hour and two milkings occur per day.
6. Savings are based on the assumption that automatic milker take-offs eliminate open vacuum pump time associated with milker take-offs separating from the cow or falling off during the milking process. The following conservative assumptions were made to determine energy savings associated with the automatic milker take-offs:
7. There is 30 seconds of open vacuum pump time for every 8 cows milked.
8. The vacuum pump has the ability to turn down during these open-vacuum pump times from a 90% VFD speed to a 40% VFD speed.
9. Additionally, several case studies from the Minnesota Dairy Project include dairy pump VFD and automatic milker take-off energy savings that are estimated at 50-70% pump savings. It is assumed that the pump VFD savings are 46%, therefore the average remaining savings can be attributed to automatic milker take-offs.
10. Agricultural: Variable Frequency Drives-Dairy, FY2012, V1.2. <https://rtf.nwcouncil.org/measure/dairy-milking-machines-vacuum-pump>

### Dairy Scroll Compressors

|  |  |  |  |
| --- | --- | --- | --- |
| **Target Sector** | | Agriculture | |
| **Measure Unit** | | Compressor | |
| **Measure Life** | | 15 years Source 1 | |
| **Measure Vintage** | | Replace on Burnout or New Construction | |

Eligibility

The following protocol for the calculation of energy and demand savings applies to the installation of a scroll compressor to replace an existing reciprocating compressor or the installation of a scroll compressor in a new construction application. The compressor is used to cool milk for preservation and packaging. The energy and demand savings per cow will depend on the installed scroll compressor energy efficiency ratio (EER), operating days per year, and the presence of a precooler in the refrigeration system.

This measure requires the installation of a scroll compressor to replace an existing reciprocating compressor or to be installed in a new construction application. Existing farms replacing existing scroll compressors are not eligible.

Algorithms

The energy and peak demand savings are dependent on the presence of a precooler in the system, and are obtained through the following formulas:

|  |  |
| --- | --- |
|  |  |
|  |  |

Definition of Terms

Table ‑: Terms, Values, and References for Dairy Scroll Compressors

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Term** | **Unit** | | **Values** | | | **Source** |
| , Baseline compressor efficiency |  | | Baseline compressor manufacturers data based upon customer application | | | EDC Data Gathering |
| Default: 5.85 | | | 2 |
| , Installed compressor efficiency |  | | From nameplate | | | EDC Data Gathering |
| Heat load of milk per cow per day for a given refrigeration system |  | | System without precooler: 2,864  System with precooler: 922 | | | 3, 4 |
| , Milking days per year | *Days* | | Based on customer application | | | EDC Data Gathering |
|  |  | | Default: 365 days/year | | | 4, 5 |
| , Average number of cows milked per day (not the number of individual milkings; each cow is assumed to be milked twice per day) | *Cows* | | Based on customer application | | | EDC Data Gathering |
| , Energy to Demand factor |  | | 0.00017 | | | 6 |

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. PA Consulting Group for the State of Wisconsin Public Service Commission, Focus on Energy Evaluation. Business Programs: Measure Life Study. August 25, 2009. Appendix B <https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf>
2. Based on the average EER data for a variety of reciprocating compressors from Emerson Climate Technologies. https://climate.emerson.com/en-us/products
3. Based on a specific heat value of 0.93 and density of 8.7 lb/gallon for whole milk. American Society of Heating Refrigeration and Air-conditioning Engineers Refrigeration Handbook, 2010, Ch.19.5.
4. Based on delta T (temperature difference between the milk leaving the cow and the cooled milk in tank storage) of 59 °F for a system with no pre-cooler and 19 °F for a system with a pre-cooler. It was also assumed that an average cow produces 6 gallons of milk per day. KEMA 2009 Evaluation of IPL Energy Efficiency Programs, Appendix F, pg. 347. <http://alliantenergy.com/wcm/groups/wcm_internet/@int/documents/document/mdaw/mdey/~edisp/012895.pdf>
5. Based on typical dairy parlor operating hours referenced for agriculture measures in California. California Public Utility Commission. Database for Energy Efficiency Resources (DEER) 2005. The DEER database assumes 20 hours of operation per day but is based on much larger dairy farms (e.g. herd sizes > 300 cows). Therefore, the DEER default value was lowered to 8 hours per day.
6. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Agricultural: Variable Frequency Drives-Dairy, FY2012, V1.2. <https://rtf.nwcouncil.org/measure/dairy-milking-machines-vacuum-pump>

### High Efficiency Ventilation Fans with and without Thermostats

|  |  |  |  |
| --- | --- | --- | --- |
| **Target Sector** | | Agriculture | |
| **Measure Unit** | | Fan | |
| **Measure Life** | | 15 years Source 1 | |
| **Measure Vintage** | | Replace on Burnout or New Construction | |

Eligibility

The following protocol for the calculation of energy and demand savings applies to the installation of high efficiency ventilation fans to replace standard efficiency ventilation fans or the installation of a high efficiency ventilation fans in a new construction application. The high efficiency fans move more cubic feet of air per watt compared to standard efficiency ventilation fans. Adding a thermostat control will reduce the number of hours that the ventilation fans operate. This protocol does not apply to circulation fans.

This protocol applies to: (1) the installation of high efficiency ventilation fans in either new construction or retrofit applications where standard efficiency ventilation fans are replaced, and/or (2) the installation of a thermostat controlling either new efficient fans or existing fans. Default values are provided for dairy and swine applications. Other facility types are eligible; however, data must be collected for all default values. Note that savings are calculated per fan.

Algorithms

The annual energy savings are obtained through the following formulas:



|  |  |
| --- | --- |
|  |  |
|  |  |

Definition of Terms

Table ‑: Terms, Values, and References for Ventilation Fans

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | | | **Source** |
| , Efficiency of the standard efficiency fan at a static pressure of 0.1 inches water |  | Based on customer application | | | EDC Data Gathering |
| Default: Table 4‑4 | | | 2 |
| , Efficiency of the high efficiency fan at a static pressure of 0.1 inches water |  | Based on customer application. | | | EDC Data Gathering |
| Default: Table 4‑4 | | | 2, 3, 4 |
| , operating hours per year of the fan | *Hours* | Based on customer application | | | EDC Data Gathering |
| Default without thermostat: Table 4‑5  Default with thermostat: Table 4‑6 | | | 2, 5 |
| , cubic feet per minute of air movement |  | Based on customer application. This can vary for pre- and post-installation if the information is known for the pre-installation case. | | | EDC Data Gathering |
|  | Default: Table 4‑4 | | | 2 |
| 1,000, watts per kilowatt |  | 1,000 | | | Conversion Factor |
| , Energy to Demand factor |  | 0.000197 | | | Engineering calculations |

Table 4‑4: Default values for standard and high efficiency ventilation fans for dairy and swine facilities

|  |  |  |  |
| --- | --- | --- | --- |
| **Fan Size (inches)** | **High Efficiency Fan**  **(cfm/W at 0.1 inches water)** | **Standard Efficiency Fan**  **(cfm/W at 0.1 inches water)** | **CFM** |
| 14 - 23 | 12.4 | 9.2 | 3,600 |
| 24 - 35 | 15.3 | 11.2 | 6,274 |
| 36 - 47 | 19.2 | 15.0 | 10,837 |
| 48 - 61 | 22.7 | 17.8 | 22,626 |

Table ‑: Default Hours for Ventilation Fans by Facility Type by Location (No Thermostat)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Facility Type** | **Allentown** | **Binghamton** | **Bradford** | **Erie** | **Harrisburg** | **Philadelphia** | **Pittsburgh** | **Scranton** | **Williamsport** |
| Dairy - Stall Barn | 5,071 | 4,596 | 4,336 | 4,807 | 5,163 | 5,390 | 5,010 | 4,843 | 5,020 |
| Dairy – Free-Stall or Cross-Ventilated Barn | 3,299 | 2,665 | 2,365 | 2,984 | 3,436 | 3,732 | 3,231 | 2,985 | 3,241 |
| Hog Nursery or Sow House | 5,864 | | | | | | | | |
| Hog Finishing House | 4,729 | | | | | | | | |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Unknown | 3,299 | 2,665 | | 2,365 | | 2,984 | | 3,436 | 3,732 | 3,231 | 2,985 | 3,241 | |

Table 4‑6: Default Hours for Ventilation Fans by Facility Type by Location (With Thermostat)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Facility Type** | **Allentown** | **Binghamton** | **Bradford** | **Erie** | **Harrisburg** | **Philadelphia** | **Pittsburgh** | **Scranton** | **Williamsport** |
| Dairy - Stall Barn | 3,457 | 3,562 | 3,526 | 3,458 | 3,367 | 3,285 | 3,441 | 3,594 | 3,448 |
| Dairy – Free-Stall or Cross-Ventilated Barn | 1,685 | 1,663 | 1,574 | 1,635 | 1,640 | 1,627 | 1,662 | 1,736 | 1,669 |
| Hog Nursery or Sow House | 3,235 | 2,581 | 2,139 | 2,879 | 3,541 | 3,685 | 3,132 | 2,979 | 3,198 |
| Hog Finishing House\* | 4,729 | 4,729 | 4,729 | 4,729 | 4,729 | 4,729 | 4,729 | 4,729 | 4,729 |
| Unknown | 1,685 | 1,663 | 1,574 | 1,635 | 1,640 | 1,627 | 1,662 | 1,736 | 1,669 |
| \* Hog finishing house ventilation needs are based on humidity; therefore a thermostat will not reduce the number of hours the fans operate. | | | | | | | | | |

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. KEMA. 2009 Evaluation of IPL Energy Efficiency Programs, Appendix F, 2008. See Table H-5. <http://alliantenergy.com/wcm/groups/wcm_internet/@int/documents/document/mdaw/mdey/~edisp/012895.pdf>
3. Pennsylvania State University. Tunnel Ventilation for Tie Stall Dairy Barns. 2004. Downloaded from <https://extension.psu.edu/tunnel-ventilation-for-tie-stall-dairy-barns>. Static pressure reference point for dairy barns comes from page 3. The recommended static pressure is 0.125 to 0.1-inch water gauge.
4. Iowa State University. Mechanical Ventilation Design Worksheet for Swine Housing. 1999. Downloaded from <http://www.extension.iastate.edu/Publications/PM1780.pdf>. Static pressure reference point for swine housing comes from page 2. The recommended static pressure is 0.125 to 0.1 inches water for winter fans and 0.05 to 0.08 inches water for summer fans. A static pressure of 0.1 inches water was assumed for dairy barns and swine houses as it is a midpoint for the recommended values.
5. Based on the methodology in KEMA’s evaluation of the Alliant Energy Agriculture Program (Source 1). Updated the hours for dairies and thermostats using TMY3 temperature data for PA, as fan run time is dependent on ambient dry-bulb temperature. For a stall barn, it was assumed 33% of fans are on 8,760 hours per year, 67% of fans are on when the temperature is above 50 degrees Fahrenheit, and 100% of the fans are on when the temperature is above 70 degrees Fahrenheit. For a cross-ventilated or free-stall barn, it was assumed 10% of fans are on 8,760 hours per year, 40% of fans are on when the temperature is above 50 degrees Fahrenheit, and 100% of the fans are on when the temperature is above 70 degrees Fahrenheit. The hours for hog facilities are based on humidity. These hours were not updated as the methodology and temperatures for determining these hours was not described in KEMA’s evaluation report and could not be found elsewhere. However, Pennsylvania and Iowa are in the same ASHRAE climate zone (5A) and so the Iowa hours provide a good estimate for hog facilities in Pennsylvania.

### Heat Reclaimers

|  |  |  |  |
| --- | --- | --- | --- |
| **Target Sector** | | Agriculture | |
| **Measure Unit** | | Heat Reclaimer | |
| **Measure Life** | | 15 years Source 1 | |
| **Measure Vintage** | | Replace on Burnout or New Construction | |

Eligibility

The following protocol for the calculation of energy and demand savings applies to the installation of heat recovery equipment on dairy parlor milk refrigeration systems. The heat reclaimers recover heat from the refrigeration system and use it to pre-heat water used for sanitation, sterilization and cow washing.

This measure requires the installation of heat recovery equipment on dairy parlor milk refrigeration systems to heat hot water. This measure only applies to dairy parlors with electric water heating equipment.

Algorithms

The annual

energy and peak demand savings are dependent on the presence of a precooler in the refrigeration system, and are obtained through the following formulas:

|  |  |
| --- | --- |
|  |  |
|  |  |

Definition of Terms

Table ‑: Terms, Values, and References for Heat Reclaimers

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Term** | **Unit** | | **Values** | | | **Source** |
| *ES*, Energy savings for specified system |  | | System with precooler = 0.29  System without precooler = 0.38 | | | 2, 3 |
| , Milking days per year |  | | Based on customer application | | | EDC Data Gathering |
| Default: 365 | | | 3 |
| , Average number of cows milked per day (not the number of individual milkings; each cow is assumed to be milked twice per day) | *Cows* | | Based on customer application | | | EDC Data Gathering |
| , Heating element factor | *None* | | Heat reclaimers with no back-up heat = 1.0  Heat reclaimers with back-up heating elements = 0.50 | | | 4 |
| , Electric water heater efficiency | *None* | | Electric tank water heater = 0.90  Heat pump water heater = 2.0 | | | 5 |
| , Energy to Demand factor |  | | 0.00017 | | | 6 |

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. State of Wisconsin. Focus on Energy Evaluation, Business Program: Measure Life Study Final Report: August 25, 2009. Appendix B. <https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf>
2. Based on a specific heat value of 0.93 Btu/lb deg F and density of 8.7 lb/gallon for whole milk. American Society of Heating Refrigeration and Air-conditioning Engineers Refrigeration Handbook, 2010, Ch.19.5.
3. Based on a delta T (temperature difference between the milk leaving the cow and the cooled milk in tank storage) of 59°F for a system without a pre-cooler and 19°F for a system with a pre-cooler. It was also assumed that a cow produces 6 gallons of milk per day (based on two milkings per day), requires 2.2 gallons of hot water per day, and the water heater delta T (between ground water and hot water) is 70°F. Evaluation of Alliant Energy Agriculture Program, Appendix F, 2008.
4. Some smaller dairy farms may not have enough space for an additional water storage tank and will opt to install a heat reclaimer with a back-up electric resistance element. The HEF used in the savings algorithm is a conservative savings de-ration factor to account for the presence of back-up electric resistance heat. The HEF is based on the assumption that the electric resistance element in a heat reclaimer will increase the incoming ground water temperature by 40-50 °F before the water is heated by the heat reclaim coil.
5. Pennsylvania Act 129 2018 Non-Residential Baseline Study, <http://www.puc.pa.gov/Electric/pdf/Act129/SWE-Phase3_NonRes_Baseline_Study_Rpt021219.pdf>
6. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Agricultural: Variable Frequency Drives-Dairy, FY2012, V1.2. <https://rtf.nwcouncil.org/measure/dairy-milking-machines-vacuum-pump>

### High Volume Low Speed Fans

|  |  |  |  |
| --- | --- | --- | --- |
| **Target Sector** | | Agriculture | |
| **Measure Unit** | | Fan | |
| **Measure Life** | | 15 years Source 1 | |
| **Measure Vintage** | | Replace on Burnout or New Construction | |

Eligibility

The following protocol for the calculation of energy and demand savings applies to the installation of High Volume Low Speed (HVLS) fans to replace conventional circulating fans. HVLS fans are a minimum of 16 feet long in diameter and move more cubic feet of air per watt than conventional circulating fans. Default values are provided for dairy, poultry, and swine applications. Other facility types are eligible, however, the operating hours assumptions should be reviewed and modified as appropriate.

Algorithms

The annual energy and peak demand savings are obtained through the following formulas:

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |

Definition of Terms

Table ‑: Terms, Values, and References for HVLS Fans

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Wattage of the removed conventional fans | *W* | Based on customer application | EDC Data Gathering |
| Default: Table 4‑9 | 2 |
| , Wattage of the installed HVLS fan | *W* | Based on customer application | EDC Data Gathering |
| Default: Table 4‑9 | 2 |
| , annual hours of operation of the fans | *Hours* | Based on customer application | EDC Data Gathering |
| Default: Table 4‑10 | 3 |
| , watts per kilowatt |  | 1,000 | Conversion factor |
| , Coincidence factor | *Decimal* | 1.0 | 3 |

Table 4‑9: Default Values for Conventional and HVLS Fan Wattages

|  |  |  |
| --- | --- | --- |
| **Fan Size (ft)** |  |  |
| ≥ 16 and < 18 | 761 | 4,497 |
| ≥ 18 and < 20 | 850 | 5,026 |
| ≥ 20 and < 24 | 940 | 5,555 |
| ≥ 24 | 1,119 | 6,613 |

Table 4‑10: Default Hours by Location for Dairy/Poultry/Swine Applications

|  |  |
| --- | --- |
| **Location** |  |
| Allentown | 2,459 |
| Binghamton |  | |
| Bradford | 1,340 | |
| Erie | 2,124 |
| Harrisburg | 2,718 |
| Philadelphia | 2,914 |
| Pittsburgh | 2,296 |
| Scranton | 2,154 |
| Williamsport | 2,371 |

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. State of Wisconsin. Focus on Energy Evaluation, Business Program: Measure Life Study Final Report: August 25, 2009. Appendix B. <https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf>
2. KEMA. 2009 Evaluation of IPL Energy Efficiency Programs, Appendix F Group I Programs Volume 2. See Table H-17.
3. Number of hours above 65 degrees Fahrenheit. Based on TMY3 data. The coincidence factor has been set at 1.0 as the SWE believes all hours during the peak window will be above 65 degrees Fahrenheit.

### Livestock Waterer

|  |  |  |  |
| --- | --- | --- | --- |
| **Target Sector** | | Agriculture | |
| **Measure Unit** | | Livestock Waterer System | |
| **Measure Life** | | 10 years Source 1 | |
| **Measure Vintage** | | Replace on Burnout or New Construction | |

Eligibility

The following protocol for the calculation of energy and demand savings applies to the installation of energy-efficient livestock waterers. In freezing climates no or low energy livestock waterers are used to prevent livestock water from freezing. These waterers are closed watering containers that typically use super insulation, relatively warmer ground water temperatures, and the livestock’s use of the waterer to keep water from freezing.

This measure requires the installation of an energy efficient livestock watering system that is thermostatically controlled and has factory-installed insulation with a minimum thickness of two inches. Savings algorithms are for one unit.

Algorithms



No demand savings are expected for this measure, as the energy savings occur during the winter months. The annual energy savings are obtained through the following formula:

|  |  |
| --- | --- |
|  |  |

Definition of Terms

Table ‑: Terms, Values, and References for Livestock Waterers

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Annual operating hours | *Hours* | Allentown = 1,498  Binghamton = 2,083  Bradford = 2,510  Erie = 1,778  Harrisburg = 1,309  Philadelphia = 1,090  Pittsburgh = 1,360  Scranton = 1,718  Williamsport = 1,575 | 2 |
| , Change in connected load (deemed) |  | 0.50 | 3, 4, 5 |
| , % heater run time | *None* | 80% | 6 |

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. State of Wisconsin. Focus on Energy Evaluation, Business Program: Measure Life Study Final Report: August 25, 2009. Appendix B. <https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf>
2. Based on TMY3 data for various climate zones in Pennsylvania. The annual operating hours represent the annual hours when the outdoor air dry-bulb temperature is less than 32 °F, and it is assumed that the livestock waterer electric resistance heaters are required below this temperature to prevent water freezing.
3. Field Study of Electrically Heated and Energy Free Automated Livestock Water Fountains - Prairie Agricultural Machinery Institute, Alberta and Manitoba, 1994.
4. Facts Automatic Livestock Waterers Fact Sheet, December 2008. <http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex5421/$file/716c52.pdf>
5. Connecticut Farm Energy Program: Energy Best Management Practices Guide, 2010. <http://www.ctfarmenergy.org/Pdfs/CT_Energy_BMPGuide.pdf>
6. The Regional Technical Forum (RTF) analyzed metered data from three baseline livestock waterers and found the average run time of electric resistance heaters in the waterers to be approximately 80% for average monthly temperatures similar to Pennsylvania climate zones. This run time factor accounts for warmer make-up water being introduced to the tank as livestock drinking occurs. <https://rtf.nwcouncil.org/measure/dairy-milking-machines-vacuum-pump>

### Variable Speed Drive (VSD) Controller on Dairy Vacuum Pumps

|  |  |  |  |
| --- | --- | --- | --- |
| **Target Sector** | | Agriculture | |
| **Measure Unit** | | Dairy Vacuum Pump VSD | |
| **Measure Life** | | 15 years Source 1 | |
| **Measure Vintage** | | Retrofit or New Construction | |

Eligibility

The following protocol for the calculation of energy and demand savings applies to the installation of a variable speed drive (VSD) and controls on a dairy vacuum pump. The vacuum pump operates during the milk harvest and equipment washing on a dairy farm. The vacuum pump creates negative air pressure that draws milk from the cow and assists in the milk flow from the milk receiver to either the bulk tank or the receiver bowl.

Dairy vacuum pumps are more efficient with VSDs since they enable the motor to speed up or slow down depending on the pressure demand. The energy savings for this measure is based on pump capacity and hours of use of the pump.

This measure requires the installation of a VSD and controls on dairy vacuum pumps, or the purchase of dairy vacuum pumps with variable speed capability. Pre-existing pumps with VSD’s are not eligible for this measure.

Algorithms

The annual energy savings are obtained through the following formulae:

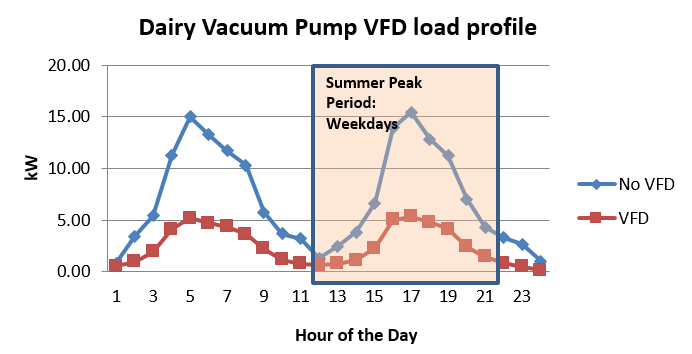
|  |  |
| --- | --- |
|  |  |
|  |  |

Energy to Demand Factor

An average of pre and post kW vacuum pump power meter data from five dairy farms in the Pacific Northwestare used to create the vacuum pump demand load profile in Figure 4‑1.Source 2 Because dairy vacuum pump operation does not vary based on geographical location, the average peak demand reduction obtained from these five sites can be applied to Pennsylvania. There are no seasonal variations in cow milking times, as dairy farms milk cows year round, so the load profile below applies to 365 days of operation. The average percent demand reduction for these five sites during the coincident peak demand period of June through September between noon and 8 pm is 46%, which is consistent with the energy savings factors and demand savings estimated for the sources cited in this protocol.

Based on this data, the energy to demand factor is estimated by dividing the average peak coincident demand kW reduction by savings for a 1 horsepower motor. The result is an energy to demand factor equal to 0.00014. Note that this value has been adapted from a definition of peak period that differs from the definition in Pennsylvania.

Figure ‑: Typical Dairy Vacuum Pump Coincident Peak Demand Reduction



Definition of Terms

Table ‑: Terms, Values, and References for VSD Controller on Dairy Vacuum Pump

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Term** | **Unit** | | **Values** | | **Source** |
| , Rated horsepower of the motor | *HP* | | Nameplate | | EDC Data Gathering |
| 0.746, conversion factor from horsepower to kW |  | | 0.746 | | Conversion Factor |
| , Load Factor. Ratio between the actual load and the rated load. The default value is 0.90 | *None* | | Based on spot metering and nameplate | | EDC Data Gathering |
| Default: 90%[[55]](#footnote-284) | | 3 |
| , Motor efficiency at the full-rated load. For VFD installations, this can be either an energy efficient motor or standard efficiency motor. | *None* | | Nameplate | | EDC Data Gathering |
| , Energy Savings Factor. Percent of baseline energy consumption saved by installing VFD. | *None* | | 46% | | 4, 5 |
| , Daily run hours of the motor | *Hours/Day* | | Based on customer application | | EDC Data Gathering |
| Default: 8 | | 4, 5 |
| , Annual operating days | *Days* | | Based on customer application | | EDC Data Gathering |
| Default: 365 | | 4, 5 |
| , Energy to Demand factor |  | | 0.00014 | | 5 |

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Pre and post power meter data for five sites were used to establish RTF energy savings for this measure, and raw data used to generate the load profile referenced in this protocol can be found in the zip file on the “BPA Case Studies” tab.
3. Southern California Edison, Dairy Farm Energy Management Guide: California, p. 11, 2004.
4. California Public Utility Commission. *Database for Energy Efficiency Resources (DEER)* 2005. The DEER database assumes 20 hours of operation per day, but is based on much larger dairy farms (e.g. herd sizes > 300 cows). Therefore, the DEER default value was lowered to 8 hours per day, as the average heard size is significantly less in Pennsylvania. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Agricultural: Variable Frequency Drives-Dairy, FY2012, V1.2. Accessed from RTF website <http://rtf.nwcouncil.org/measures/Default.asp> on February 27, 2013.
5. Agricultural: Frequency Drives-Dairy, FY2012, V1.2. <https://rtf.nwcouncil.org/measure/dairy-milking-machines-vacuum-pump>

### Low Pressure Irrigation System

|  |  |  |  |
| --- | --- | --- | --- |
| **Target Sector** | | Agriculture and Golf Courses | |
| **Measure Unit** | | Irrigation System | |
| **Measure Life** | | 5 years Source 1 | |
| **Measure Vintage** | | Replace on Burnout or New Construction | |

Eligibility

The following protocol for the measurements of energy and demand savings applies to the installation of a low-pressure irrigation system, which reduces the amount of energy required to apply the same amount of water as a baseline system.

The amount of energy saved per acre will depend on the actual operating pressure decrease, the pumping plant efficiency, the amount of water applied, and the number of nozzle, sprinkler or micro irrigation system conversions made to the system.

This measure requires a minimum of 50% reduction in irrigation pumping pressure through the installation of a low-pressure irrigation system in agriculture or golf course applications. The pressure reduction can be achieved in several ways, such as nozzle or valve replacement, sprinkler head replacement, alterations or retrofits to the pumping plant, or drip irrigation system installation, and is left up to the discretion of the owner. Pre and post retrofit pump pressure measurements are required.

Algorithms

The annual energy savings are obtained through the following formulas:

**Agriculture applications:**

|  |  |
| --- | --- |
|  |  |
|  |  |

**Golf Course applications:**

|  |  |
| --- | --- |
|  |  |

No peak demand savings may be claimed for golf course applications as watering typically occurs during non-peak demand hours.

Definition of Terms

Table ‑: Terms, Values, and References for Low Pressure Irrigation Systems

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , Number of acres irrigated | *Acres* | Based on customer application | EDC Data Gathering |
| , Baseline pump pressure, must be measured and recorded prior to installing low-pressure irrigation equipment. | *Pounds per square inch (psi)* | Based on pre retrofit pressure measurements taken by the installer | EDC Data Gathering |
| , Installed pump pressure, must be measured and recorded after the installation of low-pressure irrigation equipment by the installer. | *Pounds per square inch (psi)* | Based on post retrofit pressure measurements taken by the installer | EDC Data Gathering |
| , Pump flow rate per acre for agriculture applications. | *Gallons per minute (gpm) per acre* | Based on pre retrofit flow measurements taken by the installer | EDC Data Gathering |
| , Pump flow rate for pumping system for golf courses. | *Gallons per minute (gpm)* | Based on pre retrofit flow measurements taken by the installer | EDC Data Gathering |
| , Constant used to calculate hydraulic horsepower for conversion between horsepower and pressure and flow |  |  | Conversion Factor |
| , Average irrigation hours per growing season for agriculture | *Hours* | Based on customer application | EDC Data Gathering |
| , Hours of watering per day for golf courses | *Hours/Day* | Based on customer application | EDC Data Gathering |
| , Annual operating days of irrigation for golf courses | *Days* | Based on customer application | EDC Data Gathering |
| , Pump motor efficiency | *None* | Based on customer application | EDC Data Gathering |
| Look up pump motor efficiency based on the pump nameplate horsepower (HP) from customer application and nominal efficiencies defined in Table 3‑66 and Table 3‑67 | 2 |
| , Energy to demand factor |  | 0.0026 | 3, 4 |

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Table 3‑66 and Table 3‑67 contain federal motor efficiency values by motor size and type. If existing motor nameplate data is not available, these tables will be used to establish motor efficiencies. The CF was only estimated for agricultural applications, and was determined by using the following formula .
3. Pennsylvania census data was used to estimate an average ∆kW savings/acre and ∆kWh/yr/savings/acre value. Pamela Kanagy. Farm and Ranch Irrigation. Pennsylvania Agricultural Statistics 2009-2010. <http://www.nass.usda.gov/Statistics_by_State/Pennsylvania/Publications/Annual_Statistical_Bulletin/2009_2010/fris.pdf>
4. Irrigation Water Withdrawals, 2015 by the U.S. Geological Society. Table 7. <https://pubs.usgs.gov/circ/1441/circ1441.pdf>

1. Permanent fixture and lamp removal savings do not include replacements. Customers are responsible for determining whether permanent fixture and/or lamp removal will maintain or exceed minimum lighting requirements. Recommended light levels are provided by the Illuminating Engineering Society of North America (IESNA). [↑](#footnote-ref-3)
2. By definition, general service lamps are limited to lamps with initial lumen output of greater than or equal to 310 lumens and less than or equal to 3,300 lumens, so very low and high output lamps are unaffected by this baseline shift. [↑](#footnote-ref-5)
3. Subject to verification by EDC Evaluation or SWE. [↑](#footnote-ref-6)
4. Street Lighting” is generally municipally owned, operates from dusk to dawn, and is not connected to a specific facility. “Exterior Lighting” is connected to a specific facility and does not always operate from dusk to dawn. If an exterior lighting project cannot demonstrate that the lighting operates from dusk to dawn, the “Exterior Lighting” HOU should be used. However, if the exterior lighting operates from dusk to dawn, the “Street Lighting” HOU are the appropriate HOU. [↑](#footnote-ref-7)
5. Ibid. [↑](#footnote-ref-8)
6. The Commission allows the EDCs to use alternative methods for obtaining customer-specific data where customer processes do not support metering. The EDCs are required to provide supporting documentation to the SWE for review if there are any such exceptions. [↑](#footnote-ref-11)
7. It is noted that if site-specific data is used to determine HOU, then the same data must be used to determine the site-specific CF. Similarly, if the default TRM HOU is used, then the default TRM CF must also be used in the savings calculations. [↑](#footnote-ref-16)
8. Ibid. [↑](#footnote-ref-17)
9. Lighting Zone 1 includes developed areas of national parks, state parks, forest land, and rural areas. Zone 2 includes areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited nighttime use and residential mixed-use areas. Zone 3 includes all other areas not classified as lighting zone 1, 2, or 4. Zone 4 includes high-activity commercial districts in major metropolitan areas as designated by the local land use planning authority. [↑](#footnote-ref-23)
10. Various lighting control strategies are required by IECC 2015 for multiple new construction space types. The percentage of connected load found in covered space types varies by commercial building type. The default values for SVGbase for new construction are estimated by building type and were determined by scaling the savings factor of 24% associated with occupancy sensors from Table 3 by the percentage of connected load found in covered space types. The percentage of connected load is based on Source 3. For example, education facilities have 69% of the load within the space types requiring occupancy sensors. As such, the baseline SVGbase becomes 0.69 \* 0.24, or 0.17. [↑](#footnote-ref-24)
11. The Commission allows the EDCs to use alternative methods for obtaining customer-specific data where customer processes do not support metering. The EDCs are required to provide supporting documentation to the SWE for review if there are any such exceptions. [↑](#footnote-ref-27)
12. It is noted that if site-specific data is used to determine HOU, then the same data must be used to determine the site-specific CF. Similarly, if the default TRM HOU is used, then the default TRM CF must also be used in the savings calculations. [↑](#footnote-ref-30)
13. Ibid. [↑](#footnote-ref-31)
14. The peak demand reduction is zero, as the exterior lighting applications are assumed to be in operation during off-peak hours and have a peak coincidence factor of 0.0. [↑](#footnote-ref-41)
15. Assumption of T12 retrofit baselines are limited to refrigeration display case lighting due to the specialized high CRI application. [↑](#footnote-ref-43)
16. See Lighting Improvements measure. [↑](#footnote-ref-44)
17. Use one of the following approaches to determine the incandescent equivalent for PAR, MR and MRX bulbs: (1) If the ENERGY STAR Qualified Products List (QPL) (https://data.energystar.gov/Active-Specifications/ENERGY-STAR-Certified-Light-Bulbs/v33x-ybr3) provides a value for “Wattage Equivalency (watts),” use that value. (2) If the product does not have the aforementioned value, enter the bulb’s beam angle, center beam candle power, and diameter into the ENERGY STAR Center Beam Candle Power tool (http://energystar.supportportal.com/link/portal/23002/23018/Article/32655/). [↑](#footnote-ref-45)
18. Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit). [↑](#footnote-ref-56)
19. Chillers must satisfy efficiency requirements for both full load and IPLV efficiencies for either Path A or Path B. The table shows the efficiency ratings to be used for the baseline chiller efficiency in the savings estimation algorithm, which must be consistent with the expected operating conditions of the efficient chiller. For example, if the efficient chiller satisfies Path A and generally performs at part load, the appropriate baseline chiller efficiency is the IPLV value under Path A for energy savings. If the efficient chiller satisfies Path B and generally performs at full load, the appropriate baseline chiller efficiency is the full load value under Path B for energy savings. Generally, chillers operating above 70 percent load for a majority (50% or more) of operating hours should use Path A and chillers below 70% load for a majority of operating hours should use Path B. The “full load” efficiency from the appropriate Path A or B should be used to calculate the Peak Demand Savings as it is expected that the chillers would be under full load during the peak demand periods. [↑](#footnote-ref-57)
20. The cooling efficiency ratings of the baseline and efficient units should be used not including pumps where appropriate. [↑](#footnote-ref-59)
21. 11.3/13 = Conversion factor from SEER to EER, based on average EER of a SEER 13 unit. [↑](#footnote-ref-60)
22. 11.3/13 = Conversion factor from SEER to EER, based on average EER of a SEER 13 unit. [↑](#footnote-ref-61)
23. Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit). [↑](#footnote-ref-62)
24. Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit). [↑](#footnote-ref-64)
25. represents the addition of cooling and heating annual equivalent full load hours for commercial HVAC for different occupancies, respectively. [↑](#footnote-ref-65)
26. Based on program requirements submitted during protocol review. [↑](#footnote-ref-68)
27. Cap represents the rated cooling capacity of the product in Btu/h. If the unit’s capacity is less than 7,000 Btu/h, 7,000 Btu/h is used in the calculation. If the unit’s capacity is greater than 15,000 Btu/h, 15,000 Btu/h is used in the Calculation. Use HSPF = COP x 3.412. [↑](#footnote-ref-72)
28. Cap represents the rated cooling capacity of the product in Btu/h. If the unit’s capacity is less than 7,000 Btu/h, 7,000 Btu/h is used in the calculation. If the unit’s capacity is greater than 15,000 Btu/h, 15,000 Btu/h is used in the Calculation. Use SEER = EER x (13/11.3). [↑](#footnote-ref-74)
29. Pump motors are typically 1/25 HP. With 1,000 hours of runtime and 80% assumed efficiency, this translates to 37 kWh. [↑](#footnote-ref-79)
30. Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit). [↑](#footnote-ref-81)
31. Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit). [↑](#footnote-ref-85)
32. Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit). [↑](#footnote-ref-88)
33. Modeling is an acceptable substitute to metering and panel data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit). [↑](#footnote-ref-100)
34. Operating hours subject to adjustment with data provided by EDCs and accepted by SWE. [↑](#footnote-ref-103)
35. Operating hours subject to adjustment with data provided by EDCs and accepted by SWE. [↑](#footnote-ref-104)
36. Operating hours subject to adjustment with data provided by EDCs and accepted by SWE. [↑](#footnote-ref-105)
37. Operating hours subject to adjustment with data provided by EDCs and accepted by SWE. [↑](#footnote-ref-106)
38. Operating hours subject to adjustment with data provided by EDCs and accepted by SWE. [↑](#footnote-ref-107)
39. The Commission allows the EDCs to use alternative methods for obtaining customer-specific data where customer processes do not support metering. The EDCs are required to provide supporting documentation to the SWE for review if there are any such exceptions. [↑](#footnote-ref-108)
40. Default value can be used by EDC but is subject to metering and adjustment by evaluators or SWE. [↑](#footnote-ref-110)
41. The Commission allows the EDCs to use alternative methods for obtaining customer-specific data where customer processes do not support metering. The EDCs are required to provide supporting documentation to the SWE for review if there are any such exceptions. [↑](#footnote-ref-115)
42. Modeling is an acceptable substitute to metering and panel data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit). [↑](#footnote-ref-121)
43. Also called a flood back control. [↑](#footnote-ref-167)
44. We define *curtain efficacy* as the fraction of the potential airflow that is blocked by an infiltration barrier. For example, a brick wall would have an efficacy of 1.0, while the lack of any infiltration barrier corresponds to an efficacy of 0. [↑](#footnote-ref-176)
45. The solid green profile is derived from a normalized load shape based on metering of residential in-unit dryers. The dashed black profile is a smoothed version of the green profile and represents the utilization factors for common laundry facilities in multifamily establishments. [↑](#footnote-ref-216)
46. ENERGY STAR-qualified commercial clothes washers are only front-loading units as there are no top-loading commercial clothes washers which as meet the standards. While there are top loading commercial machines on the market, because this is a replace-on-burnout measure the front loading washer federal minimum standard will be used as a comparison point. [↑](#footnote-ref-221)
47. Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit). [↑](#footnote-ref-252)
48. Site-specific design values should be used in the calculation wherever possible, to avoid overestimating the savings using the default minimally compliant EERs. [↑](#footnote-ref-253)
49. Managed Server: A computer server that is designed for a high level of availability in a highly managed environment. For purposes of this specification, a managed server must meet all of the following criteria (from ENERGY STAR server specification 2.0): (A) is designed to be configured with redundant power supplies; and (B) contains an installed dedicated management controller (e.g., service processor). [↑](#footnote-ref-261)
50. Based on market activity as reported by several compressed air equipment vendors. [↑](#footnote-ref-265)
51. Cascade Energy. Proposed Standard Savings Estimation Protocol for Ultra‐Premium Efficiency Motors. November 5, 2012. [↑](#footnote-ref-268)
52. Use the actual power factor for the network segment served. [↑](#footnote-ref-271)
53. Detailed technical guidance for matching techniques is provided in the Evaluation Framework. [↑](#footnote-ref-274)
54. See the Evaluation Framework for a discussion of the advantages of matching over within-subjects methods. [↑](#footnote-ref-275)
55. Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE. [↑](#footnote-ref-284)