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# Technical Reference User Manual (TRM)

## Measure Savings Algorithms and Cost Assumptions

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# Introduction

This reference manual provides methods, formulas and default assumptions for estimating energy and peak impacts from measures and projects promoted by Efficiency Vermont's energy efficiency programs.

The reference manual is organized by program (or program component), end use and measure. Each section provides mathematical equations for determining savings (algorithms), as well as default assumptions for all equation parameters that are not based on site-specific information. In addition, any descriptions of calculation methods or baselines are provided, as appropriate. The parameters for calculating savings are listed in the same order for each measure. In order to maintain a similar appearance for all of the measure assumption pages, large tables are located at the end of the measure assumptions under the Reference Tables category. Algorithms are provided for estimating annual energy and demand impacts. Data assumptions are based on Vermont data, where available. Where Vermont data was not available, data from neighboring regions is used, including New York, New Jersey and New England, where available. In some cases, engineering judgment is used.

# Gross-to-Net Savings Calculation

The algorithms shown with each measure calculate gross customer electric savings without counting the effects of line losses from the generator to the customer, freeridership, or spillover. The algorithms also do not distribute the savings among the different costing periods. The formulae for converting gross customer-level savings to net generation-level savings (counting freeridership and spillover) for the different costing periods is as follows:

$$netkWh_i = \Delta kWh \times (1+LLF_i) \times (FR + SPL - 1) \times RPF_i$$

$$netkW_j = \Delta kW \times (1+LLF_j) \times (FR + SPL - 1) \times CF_j$$

Where:

$netkWh_i$ = kWh energy savings at generation-level, net of free riders and persistence, and including spillover, for period $i$

$i$ = subscript used to denote variable energy rating periods (Winter Peak, Winter Off-Peak, Summer Peak, Summer Off-Peak).

$\Delta kWh$ = gross customer annual kWh savings for the measure

$LLF_i$ = line loss factor for period $i$

FR = Freeridership factor, as presented in the measure characterizations. The Freeridership factor is equal to 1 minus the percent freeridership. For example, if it is assumed that 10% of measure installations are freeriders, FR will be equal to 0.9.

SPL =Spillover factor, as presented in the measure characterizations. The Spillover factor is equal to 1 plus the percent spillover. For example, if it is assumed that a measure has 5% spillover, SPL will be equal to 1.05.

$RPF_i$ = rating period factor for period $i$

$netkW_j$ = kW demand savings, net of free riders and persistence, and including spillover, for season $j$

$j$ = subscript used to denote variable seasonal peaks (Summer, Winter and Spring/Fall).

$\Delta kW$ = gross customer connected load kW savings for the measure

$LLF_j$ = line loss factor for seasonal peak $j$

$CF_j$ = the percent of kW savings that is concurrent with Vermont's seasonal peak, for season $j$

All of the parameters except line loss factors (LLF) for the above equations may be found in the specific section for the measure. The line loss factors do not vary by measure, but by costing period, and are in the following table:

**Line Loss Factors**

| Energy ($LLF_i$) | | | | Peak ($LLF_j$) | | |
|---|---|---|---|---|---|---|
| Winter Peak Period | Winter Off-Peak Period | Summer Peak Period | Summer Off-Peak Period | Winter Peak | Summer Peak | Spring/Fall Peak |
| 13.466% | 12.151% | 13.697% | 10.682% | 9.97% | 10.51% | |

The free ridership and spillover factors are related to but slightly different from the freeridership and spillover rates used in the gross-to-net equation. Free ridership and spillover factors are defined as follows:

Free ridership factor = 1 – FR

Spillover factor = 1 + SPL

## Interactive Effects

The TRM provides specific savings algorithms for many prescriptive measures. When a customer installs a prescriptive measure, the savings are determined according to these algorithms. In some cases these algorithms include the effects of interactions with other measures or end uses (e.g., cooling and heating effects from interior lighting waste heat). For "custom" measures, EVT performs site-specific customized calculations. In this case, EVT takes into account interactions between measures (e.g., individual savings from installation of window film and replacement of a chiller are not additive because the first measure reduces the cooling load met by the second measure). EVT will calculate total savings for the package of custom measures being installed, considering interactive effects, either as a single package or in rank order of measures as described below. If a "custom" project includes both prescriptive and custom measures, the prescriptive measures will be calculated in the normal manner. However, the prescriptive measures will be assumed to be installed prior to determining the impacts for the custom measures. Custom interior lighting measures will use the standard prescriptive algorithm to estimating waste heat impacts.

In most cases of multiple custom measures EVT models a single custom package including all measures the customer will install. This modeling effectively accounts for all interactions between measures, and the "package" is tracked in FastTrack as a single "measure." In instances where modeling is not completed on a package of measures, and where individual measures are separately listed in FastTrack with measure-specific savings EVT will use the following protocol (typically lighting only projects). To determine custom measure savings EVT will calculate measure impacts in descending order of measure life (i.e., starting with the longest lived measure). The procedure is to calculate savings for the longest lived measure first, then consider that measure's impact on the next longest lived measure, and so on. This is because a short-lived measure can reduce savings from a long-lived measure, but only for part of its life. Since tracking system limitations require that annual measure savings remain constant for all years, this is the only way to ensure proper lifetime savings and total resource benefits are captured. For example, fixing compressed air leaks can reduce savings from installing a new compressor. However, leak repair only lasts 1 year. If the leak repair savings were calculated first the calculated lifetime savings and benefits from the compressor would be unreasonably low because compressor savings would go back up starting in year 2.

## Persistence

Persistence factors may be used to reduce lifetime measure savings in recognition that initial engineering estimates of annual savings may not persist long term. This might be because a measure is removed or breaks prior to the end of its normal engineering lifetime, because it is not properly maintained over its lifetime, because it is overridden or goes out of calibration (controls only), or some other reason. Each measure algorithm contains an entry for persistence factor. The default value if none is indicated is 1.00 (100%). A value lower than 1.00 will result in a downward adjustment of lifetime savings and total resource benefits. For any measure with a persistence value less than 1.00, the normal measure life

(“Engineering Measure Life”) will be reduced to arrive at an “Adjusted Measure Life” for purposes of measure screening, savings and TRB claims, and tracking. The “Adjusted Measure Life” used will be equal to the product of the Engineering Measure Life and the persistence factor. Both the Engineering Measure Life and the Adjusted Measure Life will be shown in each measure algorithm. All data in FastTrack and CAT indicating “measure life” shall be equal to “Adjusted Measure Life.”

## Glossary

The following glossary provides definitions for necessary assumptions needed to calculate measure savings.

Baseline Efficiency ($\eta_{base}$): The assumed standard efficiency of equipment, absent an Efficiency Vermont program.

Coincidence Factor (CF): Coincidence factors represent the fraction of connected load expected to be coincident with a particular system peak period, on a diversified basis. Coincidence factors are provided for summer, winter and spring/fall peak periods.

Connected Load: The maximum wattage of the equipment, under normal operating conditions.

Freeridership (FR): The fraction of gross program savings that would have occurred despite the program.

Full Load Hours (FLH): The equivalent hours that equipment would need to operate at its peak capacity in order to consume its estimated annual kWh consumption (annual kWh/connected kW).

High Efficiency ($\eta_{effic}$): The efficiency of the energy-saving equipment installed as a result of an efficiency program.

Lifetimes: The number of years (or hours) that the new high efficiency equipment is expected to function. These are generally based on engineering lives, but sometimes adjusted based on expectations about frequency of remodeling or demolition.

Line Loss Factor (LLF): The marginal electricity losses from the generator to the customer – expressed as a percent of meter-level savings. The Energy Line Loss Factors vary by period. The Peak Line Loss Factors reflect losses at the time of system peak, and are shown for three seasons of the year. Line loss factors are the same for all measures. See the Gross-to-Net Calculation section for specific values.

Load Factor (LF): The fraction of full load (wattage) for which the equipment is typically run.

Operating Hours (HOURS): The annual hours that equipment is expected to operate.

Persistence (PF): The fraction of gross measure savings obtained over the measure life.

Rating Period Factor (RPF): Percentages for defined times of the year that describe when energy savings will be realized for a specific measure.

Spillover (SPL): Savings attributable to the program, but generated by customers not directly participating in the program. Expressed as a fraction of gross savings. All values can be changed as new information becomes available.

## Loadshapes

The following table includes a listing of measure end-uses and associated loadshapes. In some cases, the loadshapes have been developed through negotiations between Efficiency Vermont and the Vermont Department of Public Service. In other cases, these loadshapes are based on engineering judgment.

**Loadshape Table of Contents**

| EndUse | # | Winter-on kWh | Winter-off kWh | Summer-on kWh | Summer-off kWh | Winter kW | Summer kW |
|---|---|---|---|---|---|---|---|
| Residential Indoor Lighting | 1 | 36.9% | 35.0% | 13.0% | 15.1% | 29.8% | 8.2% |
| Residential Outdoor Lighting | 2 | 20.5% | 50.6% | 6.1% | 22.8% | 34.6% | 1.8% |
| Residential Outdoor HID | 3 | 20.5% | 50.6% | 6.1% | 22.8% | 61.4% | 3.2% |
| Residential Refrigerator | 4 | 30.8% | 33.0% | 17.1% | 19.1% | 79.6% | 100% |
| Residential Space heat | 5 | 45.5% | 53.0% | 0.6% | 0.9% | 45.4% | 0.0% |
| Residential DHW fuel switch | 6 | 40.2% | 32.0% | 15.1% | 12.7% | 40.1% | 20.3% |
| Residential DHW insulation | 7 | 31.7% | 34.9% | 15.9% | 17.5% | 100.0% | 100.0% |
| Residential DHW conserve | 8 | 48.7% | 29.1% | 14.3% | 7.9% | 40.1% | 20.3% |
| Residential Clothes Washer | 9 | 42.0% | 28.8% | 16.9% | 12.3% | 4.4% | 3.3% |
| Residential Ventilation | 10 | 31.7% | 34.9% | 15.9% | 17.5% | 32.2% | 32.2% |
| Residential A/C | 11 | 0.7% | 2.8% | 53.3% | 43.2% | 0.0% | 82.9% |
| Commercial Indoor Lighting | 12 | 48.8% | 19.5% | 22.2% | 9.5% | 46.9% | 67.9% |
| Commercial Outdoor Lighting | 13 | 20.5% | 50.6% | 6.1% | 22.8% | 70.2% | 3.7% |
| Commercial Refrigeration | 14 | 33.0% | 32.6% | 17.0% | 17.4% | 69.0% | 77.2% |
| Commercial A/C | 15 | 18.0% | 10.0% | 46.0% | 26.0% | 0.0% | 34.20% |
| Commercial Ventilation motor | 16 | 34.4% | 36.6% | 14.9% | 14.1% | 59.9% | 55.5% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Commercial Space heat | 17 | 38.7% | 61.2% | 0.0% | 0.1% | 57.0% | 0.3% |
| Industrial Indoor Lighting | 18 | 57.8% | 8.8% | 29.0% | 4.4% | 49.7% | 75.9% |
| Industrial Outdoor Lighting | 19 | 20.5% | 50.6% | 6.1% | 22.8% | 70.2% | 3.7% |
| Industrial A/C | 20 | 18.0% | 10.0% | 46.0% | 26.0% | 0.0% | 34.20% |
| Industrial Motor | 21 | 62.4% | 4.2% | 31.3% | 2.1% | 95.0% | 95.0% |
| Industrial Space heat | 22 | 38.7% | 61.2% | 0.0% | 0.1% | 57.0% | 0.3% |
| Industrial Process | 23 | 62.4% | 4.2% | 31.3% | 2.1% | 95.0% | 95.0% |
| Dairy Farm Combined End Uses | 24 | 43.6% | 23.2% | 21.7% | 11.5% | 91.5% | 34.1% |
| Flat (8760 hours) | 25 | 31.7% | 34.9% | 15.9% | 17.5% | 100.0% | 100.0% |
| HVAC Pump (heating) | 26 | 47.6% | 52.4% | 0.0% | 0.0% | 100.0% | 0.0% |
| HVAC Pump (cooling) | 27 | 9.6% | 10.6% | 38.0% | 41.8% | 0.0% | 100.0% |
| HVAC Pump (unknown use) | 28 | 28.6% | 31.5% | 19.0% | 20.9% | 50.0% | 50.0% |
| Traffic Signal - Red Balls, always changing or flashing | 29 | 31.7% | 34.9% | 15.9% | 17.5% | 55.0% | 55.0% |
| Traffic Signal - Red Balls, changing day, off night | 30 | 47.6% | 19.0% | 23.9% | 9.5% | 55.0% | 55.0% |
| Traffic Signal - Green Balls, always changing | 31 | 31.7% | 34.9% | 15.9% | 17.5% | 42.0% | 42.0% |
| Traffic Signal - Green Balls, changing day, off night | 32 | 47.6% | 19.0% | 23.9% | 9.5% | 42.0% | 42.0% |
| Traffic Signal - Red Arrows | 33 | 31.7% | 34.9% | 15.9% | 17.5% | 90.0% | 90.0% |
| Traffic Signal - Green Arrows | 34 | 31.7% | 34.9% | 15.9% | 17.5% | 10.0% | 10.0% |
| Traffic Signal - Flashing Yellows | 35 | 31.7% | 34.9% | 15.9% | 17.5% | 50.0% | 50.0% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Traffic Signal - “Hand” Don’t Walk Signal | 36 | 31.7% | 34.9% | 15.9% | 17.5% | 75.0% | 75.0% |
| Traffic Signal - “Man” Walk Signal | 37 | 31.7% | 34.9% | 15.9% | 17.5% | 21.0% | 21.0% |
| Commercial HP 0-65 kBTUh | 38 | 32.2% | 43.8% | 18.5% | 5.5% | 58.6% | 75.4% |
| Commercial HP 65-375 kBTUh | 39 | 31.4% | 41.6% | 20.8% | 6.2% | 58.7% | 81.1% |
| Commercial PTHP | 40 | 31.3% | 41.5% | 21.0% | 6.2% | 58.7% | 81.1% |
| Commercial Water-Source Heat Pump | 41 | 28.1% | 33.0% | 30.0% | 8.9% | 58.7% | 81.1% |
| Transformer | 42 | 56.2% | 9.5% | 29.2% | 5.1% | 100.0% | 100.0% |
| Vending Miser | 43 | 9.5% | 57.1% | 4.8% | 28.6% | 0.0% | 0.0% |
| Compressed Air - 1-shift (8/5) | 44 | 66.6% | 0.0% | 33.4% | 0.0% | 0.0% | 59.4% |
| Compressed Air - 2-shift (16/5) | 45 | 62.4% | 4.2% | 31.3% | 2.1% | 95.0% | 95.0% |
| Compressed Air - 3-shift (24/5) | 46 | 44.4% | 22.2% | 22.3% | 11.1% | 95.0% | 95.0% |
| Compressed Air - 4-shift (24/7) | 47 | 31.7% | 34.9% | 15.9% | 17.5% | 95.0% | 95.0% |
| Storage ESH (Statewide) | 48 | 29.6% | 68.7% | 0.5% | 1.2% | 0.0% | 0.0% |
| Controlled ESH (Statewide) | 49 | 29.6% | 68.7% | 0.5% | 1.2% | 0.0% | 0.0% |
| Storage ESH (GMP) | 50 | 58.0% | 40.3% | 1.0% | 0.7% | 3.7% | 0.3% |
| Controlled ESH (GMP) | 51 | 76.7% | 21.5% | 1.4% | 0.4% | 2.8% | 0.2% |
| Controlled DHW Fuel Switch | 52 | 40.2% | 32.0% | 15.1% | 12.7% | 20.5% | 12.1% |
| Controlled DHW Insulation | 53 | 31.7% | 34.9% | 15.9% | 17.5% | 51.0% | 59.4% |
| Controlled DHW Conservation | 54 | 48.7% | 29.1% | 14.3% | 7.9% | 20.5% | 12.1% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| VFD Supply fans <10 HP | 55 | 39.0% | 30.5% | 21.6% | 8.9% | 19.8% | 50.8% |
| VFD Return fans <10 HP | 56 | 39.0% | 30.8% | 21.4% | 8.8% | 28.5% | 71.2% |
| VFD Exhaust fans <10 HP | 57 | 44.4% | 22.2% | 16.0% | 17.4% | 100.0% | 37.0% |
| VFD Boiler feedwater pumps <10 HP | 58 | 53.6% | 46.3% | 0.0% | 0.1% | 100.0% | 67.0% |
| VFD Chilled water pumps <10 HP | 59 | 30.9% | 18.1% | 35.9% | 15.1% | 0.0% | 90.2% |
| Economizer | 60 | 24.5% | 23.7% | 22.6% | 29.2% | 0.0% | 0.0% |
| VFD Milk Vacuum Pump | 61 | 36.9% | 30.1% | 18.2% | 14.8% | 63.4% | 28.7% |
| Computer Office | 62 | 28.9% | 37.7% | 14.5% | 18.9% | 57.9% | 30.3% |
| Commercial Indoor Lighting with cooling bonus | 63 | 46.5% | 16.8% | 26.8% | 9.9% | 35.8% | 69.4% |
| Industrial Indoor Lighting with cooling bonus | 64 | 53.6% | 8.2% | 32.5% | 5.8% | 47.3% | 93.3% |
| Continuous C&I Indoor Lighting with cooling bonus | 65 | 30.1% | 31.6% | 20.7% | 17.6% | 74.6% | 100.0% |
| Refrigeration Economizer | 66 | 44.3% | 55.5% | 0.0% | 0.2% | 100.0% | 0.0% |
| Strip Curtain | 67 | 33.0% | 32.6% | 17.0% | 17.4% | 100.0% | 100.0% |
| Evaporator Fan Control | 68 | 29.1% | 39.5% | 13.7% | 17.7% | 45.9% | 43.0% |
| Door Heater Control | 69 | 47.6% | 52.4% | 0.0% | 0.0% | 100.0% | 0.0% |
| Floating Head Pressure Control | 70 | 33.3% | 37.1% | 12.8% | 16.8% | 100.0% | 0.0% |
| Furnace Fan Heating and Cooling | 71 | 31.7% | 37.5% | 16.9% | 13.9% | 45.4% | 82.9% |
| Traffic Signal - Bi-Modal Walk/Don’t Walk | 72 | 31.7% | 34.9% | 15.9% | 17.5% | 100% | 100% |
| Residential - Dehumidifier | 73 | 15.9% | 17.5% | 31.7% | 34.9% | 0% | 35.3% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Internal Power Supply, Commercial Desktop | 74 | 39.2% | 27.5% | 19.6% | 13.7% | 50.0% | 80.0% |
| Internal Power Supply, Residential Desktop | 75 | 33.8% | 32.9% | 16.9% | 16.4% | 52.2% | 40.5% |
| VFD Boiler circulation pumps <10 HP | 76 | 45.9% | 47.1% | 4.6% | 2.4% | 49.5% | 2.1% |
| Refrigeration Night Covers | 77 | 5.9% | 60.6% | 3.0% | 30.4% | 0.0% | 0.0% |
| ECM Fan Motor Commercial Heating | 78 | 34.4% | 56.1% | 4.5% | 5.0% | 50.2% | 19.0% |
| ECM Fan Motor Commercial Cooling | 79 | 18.3% | 0.4% | 67.4% | 13.9% | 0.0% | 80.1% |
| ECM Fan Motor Commercial Heating & Cooling | 80 | 30.9% | 42.2% | 19.1% | 7.8% | 50.2% | 52.4% |
| Core Performance – Office w/ Pkg VAV and Chiller | 81 | 32.2% | 21.3% | 30.7% | 15.8% | 13.2% | 56.1% |
| Core Performance – Office w/ Pkg RTU and HW baseboard | 82 | 41.8% | 14.6% | 31.0% | 12.7% | 18.7% | 63.5% |
| Core Performance – Office w/ Pkg RTU and Furnace | 83 | 38.0% | 15.2% | 32.4% | 14.4% | 14.6% | 57.5% |
| Core Performance – Office w/ Water Source HP | 84 | 34.5% | 21.7% | 27.9% | 15.9% | 22.3% | 74.0% |
| Core Performance – School w/ Unit Vent. and Pkg units | 85 | 73.9% | 8.2% | 14.7% | 3.2% | 27.7% | 8.8% |
| Core Performance – Retail w/ Pkg RTU and Furnace | 86 | 35.7% | 17.7% | 31.1% | 15.5% | 16.0% | 39.5% |
| Grocery/Conv. Store Indoor Lighting | 87 | 39.7% | 26.7% | 19.7% | 13.9% | 84.7% | 90.8% |
| Hospital Indoor Lighting | 88 | 36.4% | 30.2% | 17.9% | 15.5% | 50.5% | 70.1% |
| Office Indoor Lighting | 89 | 54.7% | 12.1% | 27.0% | 6.2% | 42.7% | 71.2% |
| Restaurant Indoor Lighting | 90 | 40.7% | 25.7% | 20.2% | 13.4% | 63.0% | 77.0% |
| Retail Indoor Lighting | 91 | 45.5% | 21.0% | 22.6% | 10.9% | 51.7% | 79.9% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Warehouse Indoor Lighting | 92 | 50.9% | 15.7% | 25.3% | 8.1% | 44.9% | 70.1% |
| K-12 School Indoor Lighting | 93 | 59.1% | 19.6% | 14.6% | 6.7% | 28.7% | 50.9% |
| Efficient Television | 94 | 48.0% | 19.0% | 24.0% | 9.0% | 22.0% | 17.0% |
| Standby Losses - Entertainment Center | 96 | 32.0% | 35.0% | 16.0% | 17.0% | 72.5% | 90.0% |
| Standby Losses - Home Office | 97 | 28.0% | 38.0% | 14.0% | 19.0% | 25.0% | 76.3% |
| Standby Losses - Commercial Office | 98 | 7.0% | 60.0% | 3.0% | 30.0% | 8.0% | 1.0% |
| Room Air Conditioning | 99 | 0.7% | 2.8% | 53.3% | 43.2% | 0.0% | 27.6% |
| Pool Pump | 100 | 0.0% | 0.0% | 65.0% | 35.0% | 0.0% | 83.1% |
| Commercial EP Lighting | 101 | 48.8% | 19.5% | 22.2% | 9.5% | 37.2% | 68.1% |
| VFD Boiler draft fans <10 HP | 102 | 45.8% | 53.1% | 0.7% | 0.4% | 40.0% | 0.0% |
| VFD Cooling Tower Fans <10 HP | 103 | 10.1% | 5.0% | 58.6% | 26.3% | 0.0% | 61.6% |
| Engine Block Heater Timer | 104 | 30.39% | 69.61% | 0.00% | 0.00% | 37.50% | 0.00% |
| Lodging Indoor Lighting | 105 | 36.1% | 30.5% | 17.7% | 15.7% | 54.6% | 56.0% |
| Public Assembly Indoor Lighting | 106 | 40.7% | 25.8% | 20.1% | 13.4% | 46.0% | 60.3% |
| Public Safety Indoor Lighting | 107 | 40.7% | 25.8% | 20.1% | 13.4% | 35.5% | 50.4% |
| Religious Indoor Lighting | 108 | 33.2% | 33.6% | 15.8% | 17.4% | 51.4% | 34.6% |
| Service Indoor Lighting | 109 | 47.9% | 18.7% | 23.7% | 9.7% | 32.1% | 79.2% |
| C&I Unitary AC | 110 | 18.0% | 10.0% | 46.0% | 26.0% | 0.0% | 34.2% |
| Farm Plate Cooler / Heat Recovery Unit | 111 | 28.97% | 16.38% | 31.60% | 23.05% | 26.97% | 16.08% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Maple Sap VFD | 112 | 51.2% | 48.8% | 0.00% | 0.00% | 0.00% | 0.00% |
| Commercial Small Exhaust-only Vent Fan | 113 | 48.80% | 19.50% | 22.20% | 9.50% | 50.80% | 72.40% |
| PTHP, Hotel | 114 | 39.97% | 48.93% | 5.36% | 5.74% | 34.15% | 41.61% |
| Streetlighting | 115 | 20.5% | 50.6% | 6.1% | 22.8% | 98.0% | 0% |
| Prescriptive cold climate variable speed heat pump, heat pump baseline | 116 | 41.8% | 48.8% | 5.0% | 4.4% | 100% | 4.9% |

Notes: See Excel spreadsheet <Lighting loadshape with cooling bonus-102103.xls> for derivation of loadshapes 63, 64, and 65. Heavier weighting is given to the summer periods and less to the other periods to account for the cooling bonus that is included in the kWh and kW savings.

All loadshape numbers referenced in the measure characterizations correspond to the most recent generation of the loadshape as detailed in the loadshape table of contents. The coincident peak factors in the standard load profiles above are based on the listed assumptions for full load hours. To account for the effect on peak savings from a change in full load hours, use of full load hours different than the standard will result in an automatic adjustment of the coincident peak factors (% of connected load kW) used in screening and reported in the database, unless custom coincident peak factors are also entered. The coincidence factors are multiplied by the ratio of [custom full load hours]/[standard full load hours], with a maximum value of 100% for each factor. As a result, coincidence factors for particular measures may be higher or lower than the standard factors listed above even when a standard load profile is used.

As of January 1, 2012 Efficiency Vermont is using new avoided costs with different costing period definitions. The new energy periods are based on the 2011 Avoided Energy Supply Costs in New England report prepared for the Avoided-Energy-Supply-Component (AESC) Study Group by Synapse Energy Economics, Inc. The new coincident peak periods are based on ISO New England performance hours for the forward capacity market. The new costing period definitions required new loadshapes consistent with the new period definitions. The loadshapes in this TRM reflect the change in costing period definitions.

EVT Current Avoided Cost Definitions:
Winter Peak Energy: 7AM - 11PM, weekdays, October to May;
Winter Off-Peak Energy: 11PM - 7AM, weekdays, all weekend hours, October to May;
Summer Peak Energy: 7AM - 11PM, weekdays, June to September;
Summer Off-Peak Energy: 11PM - 7AM weekdays, all weekend hours, June to September.

Summer Gen. Capacity: 1PM-5PM, weekday, non-holiday, June-August
Winter Gen. Capacity: 5PM-7PM, weekday, non-holiday, December-January

# Business Energy Services

## Motors End Use

# Variable Frequency Drives (VFD)

Measure Number: I-A-2-c (Business Energy Services, Motors End Use)

**Version Date & Revision History**
Draft date: Portfolio No. 72
Effective date: 1/1/2012
End Date: TBD

**Referenced Documents:**
1) VFD Incremental Cost Analysis.xls
2) VFD EQuest Analysis.xlsx

**Description**
Below are two sets of equations. The first are standardized savings algorithms and assumptions for all VFDs applied to motors of 10 HP or less for the following HVAC applications: supply fans, return fans, boiler draft fans, cooling tower fans, chilled water pumps, and hot water pumps ("Standardized Approach"). All other VFDs are treated as custom measures.

**Algorithms**
For VFDs <= 10 HP on HVAC supply fans, return fans, boiler draft fans, cooling tower fans, chilled water pumps and hot water pumps.

**Energy Savings**
$\Delta kWh = ESVG \times HP \times OTF$

**Demand Savings**
$\Delta kW = DSVG \times HP \times OTF$

Where:

| | |
|---|---|
| $\Delta kWh$ | = gross customer annual kWh savings for the measure |
| $\Delta kW$ | = gross customer kW savings for the measure at either the summer or winter peak (whichever is greater) |
| HP | = horsepower of motor VFD is applied to (site specific, from customer application) |
| ESVG | = energy savings factor, see Table below (kWh/HP) |
| DSVG | = demand savings factor, see Table below (kW/HP) |
| OTF | = operational testing factor for standard approach applications. OTF = 1.00 when the project undergoes operational testing or commissioning services, OTF = 0.9 otherwise. |

**Energy Savings**
$\Delta kWh$ = kWh savings calculated on a site-specific basis × OTF

**Demand Savings**
$\Delta kW$ = kW reduction calculated on a site-specific basis × OTF

Where:

| | |
|---|---|
| $\Delta kWh$ | = gross customer annual kWh savings for the measure |
| $\Delta kW$ | = gross customer kW savings claimed for the measure |

OTF = Operational Testing Factor. OTF = 1.0 when the project undergoes operational testing or commissioning services, 0.90 otherwise.

**Baseline Efficiencies – New or Replacement**

For hot water and chilled water pumps, the baseline reflects variable flow water loops with pumps without a VFD. For boiler draft fans, the baseline is a draft fan with no VFD. For cooling towers, the baseline reflects a tower fan with damper controls, and for supply and return fans, the baseline is a mixture of discharge damper controls (75%), and inlet guide vanes (25%).[1]

**High Efficiency**

The high efficiency case is installation and use of a VFD.

**Operating Hours**

N/A for VFDs < 10 HP on HVAC supply, and return fans, cooling tower fans, boiler draft fans, chilled water pumps and hot water pumps. Site-specific otherwise.

**Loadshapes**

Loadshape #55 VFD Supply Fans < 10 HP
Loadshape #56 VFD Return Fans < 10 HP
Loadshape #59 VFD Chilled Water Pumps < 10 HP
Loadshape #76 VFD Boiler Distribution Pumps < 10 HP
Loadshape #102 VFD Boiler Draft Fans < 10 HP
Loadshape #103 VFD Cooling Tower Fans < 10 HP

**Freeridership/Spillover Factors**

| Measure Category | | Motor Controls | |
|---|---|---|---|
| Measure Code | | MTCSTVFD | |
| Product Description | | Variable frequency drive, standardized HVAC | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | 0.89 | 1.00 |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | 0.94 | 1.00 |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | 0.95 | 1.00 |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | 0.95 | 1.00 |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | 1.00 | 1.00 |
| LIMF Retrofit | 6017RETR | 1.00 | 1.00 |
| LIMF NC | 6018LINC | 1.00 | 1.00 |
| LIMF Rehab | 6018LIRH | 1.00 | 1.00 |
| MF Mkt NC | 6019MFNC | 1.00 | 1.00 |
| MF Mkt Retro | 6020MFMR | 0.90 | 1.00 |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |

[1] Based on EVT project experience

| | | | |
|---|---|---|---|
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.[2]

**Lifetimes**
15 years for non-process VFDs. 10 years for process. Analysis period is the same as the lifetime.

**Measure Cost**
See the table named "VFD Cost Estimates" in the reference tables section. Incremental costs for other VFDs are determined on a site-specific custom basis and screened based on actual costs.

**O&M Cost Adjustments**
There are no standard operation and maintenance cost adjustments used for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

**VFD Energy and Demand Savings Factors (ESVG and DSVG)**

| Application | ESVG (kWh/HP) | DSVG (kW/HP)[1] |
|---|---|---|
| Supply Fans | 871 | 0.34 |
| Return Fans | 869 | 0.24 |
| Chilled Water Pumps | 635 | 0.25 |
| Boiler Distribution Pumps | 830 | 0.27 |
| Boiler Draft Fans | 500 | 0.27 |
| Cooling Tower Fans | 239 | 0.28 |
| Source: EQuest analysis based on models developed for Efficiency Vermont's Core Performance (cf TRM entry I-N-1 "New Construction Core Performance Package"). See 'VFD EQuest Analysis.xlsx' for details.<br>1. The DSVG factors represent *the maximum* kW reduction throughout the year. Must be multiplied by the coincidence factors above to find the coincident savings. | | |

**VFD Cost Estimates**[3]

[2] National Grid evaluated persistence in 1999 of VFDs installed in 1995 and estimated a factor of 97%. Given that the discounted value of a 3% degradation in 5 years is minimal, no persistence reduction has been applied.
[3] Based on a review of VFD pricing from Grainger Catalogue No. 401 and RSMeans Mechanical Cost Data 2010. Average of 220V and 480V. See referenced document "VFD Incremental Cost Analysis.xls".

| Horse Power | Installation cost estimate |
|---|---|
| 3 | $1,512 |
| 5 | $1,668 |
| 7.5 | $2,000 |
| 10 | $2,293 |

# Efficient Milk Pumping Systems for Dairy Farms

Measure Number: I-A-5-c (Business Energy Services, Motors End Use)

**Version Date & Revision History**
Draft date: Portfolio No. 77
Effective date: 1/1/2012
End date: TBD

Referenced Documents: Dairy_VFD_Analysis.xls

**Description**
A variable speed milk transfer (VSMT) pump is a VFD regulated pump that allows operators to to increase the efficiency of a plate heat exchanger by making the flow of milk slower and more consistent to maximize heat transfer within the heat exchanger. Electrical savings occurs “downstream” by reducing the load on the chiller in the milk storage tank and is adjusted for the increased load due to adding the pump itself to the system. A VSMT is typically an add-on to an existing system or replaces old equipment when it reaches the end of its useful life.

A milk vacuum pump is used to move milk between the milking area and bulk storage. A VFD equipped milk vacuum pump is used to reduce pump speed, and energy consumption, when pumping needs fall below peak levels. Electricity is saved relative to a system that pumps at a constant rate. A VFD milk vacuum pump typically replaces old equipment when it reaches the end of its useful life.

**Algorithms**

**Variable Speed Milk Transfer Pump**[4]

**Demand Savings**
$\Delta$kW = 2.73 kW

**Energy Savings**
$\Delta$kWh = 7,687 kWh

**Milk Vacuum Pump VFD**[5]

**Demand Savings**
$\Delta$kW = 3.01 kW

**Energy Savings**
$\Delta$kWh = 7,769 kWh

Where:

| | |
|---|---|
| $\Delta$kW | = gross customer connected load kW savings for the measure |
| $\Delta$kWh | = gross customer average annual kWh savings for the measure |

**Baseline Efficiencies – Retrofit or Replacement**[6]

[4] Savings estimates are the average savings claimed for EVT custom projects from 2003 through 2011, see Dairy_VFD_Analysis.xls
[5] Savings estimates are the average savings claimed for EVT custom projects from 2003 through 2011, see Dairy_VFD_Analysis.xls
[6] While these technologies would be baseline for new construction, farmers typically re-use old equipment when extensively renovating old facilities. New construction due to construction of new facilities is rare and EVT staff has only heard of one case (between 2006 and 2012) where a new construction project resulted in purchase of new equipment.

*VSMT:* the baseline state is no regulation of milk flow rate to the plate cooler.

*Milk vacuum pump VFD:* the baseline state is a non-VFD equipped pump.

**High Efficiency**
A variable speed milk transfer pump regulates flow to optimize the performance of a plate cooler
A VFD equipped milk vacuum pump reduces pump speed when pumping needs fall below peak levels

**Operating Hours**
N/A

**Loadshapes**[7]
VSMT = Loadshape #122, Farm Plate Cooler / Heat Recovery Unit
Milk Vacuum Pump = Loadshape #61, VFD Milk Vacuum Pump

**Freeridership/Spillover Factors**

| **Measure Category** | | **Motor Controls** | | | |
|---|---|---|---|---|---|
| **Measure Code** | | MTCMTVFD | | MTCDFVFD | |
| **Product Description** | | Variable Speed Milk Transfer Pump | | Milk Vacuum Pump VFD | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** | **Freerider** | **Spillover** |
| C&I Retrofit | 6012CNIR | n/a | n/a | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a | n/a | n/a |
| Farm Equip Rpl | 6013FARM | 1.00 | 1.00 | 1.00 | 1.00 |
| Farm Rx | 6013FRMP | 1.00 | 1.00 | 1.00 | 1.00 |
| Pres Equip Rpl | 6013PRES | n/a | n/a | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.[8]

**Lifetimes**
10 years.

**Measure Cost**[9]
Variable speed milk transfer pump: $3,004
Milk vacuum pump VFD: $4,014

**O&M Cost Adjustments**
There are no standard operation and maintenance cost adjustments used for this measure.

[7] Load shapes were developed based on actual data for EVT custom projects installed through the EVT dairy farm program from 2008 through 2011, see Dairy_VFD_Analysis.xls The variable speed milk transfer pump load profile is the same as the "Dairy Plate Cooler / Heat Recovery Unit," which is based on 112 plate cooler and heat recovery unit projects. The milk vacuum pump load profile is based on 94 projects.
[8] National Grid evaluated persistence in 1999 of VFDs installed in 1995 and estimated a factor of 97%. Given that the discounted value of a 3% degradation in 5 years is minimal, no persistence reduction has been applied.
[9] Values derived from Efficiency Vermont custom data 2003-2012, see Dairy_VFD_Analysis.xls

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**
None

# Commercial Brushless Permanent Magnet (BLPM) Fan Motor

Measure Number: I-A-6-b (Business Energy Services, Motors End Use)

**Version Date & Revision History**
Draft date: Portfolio 66
Effective date: 1/1/2011
End date: TBD

Referenced Documents: 1) WisconsinFieldStudy2003.pdf; 2) SachsSmithEfficientFurnaceFans.pdf; 3) Canadian Gas Increase Study.pdf; 4) Commercial Furnace Fan Motor Savings.xls; 5) Wisconsin ECM Impact Evaluation (emcfurnaceimpactassessment_evaluationreport.pdf).

**Description**
This measure will provide incentives for installing an ultra high efficiency programmable brushless permanent magnet fan motor called Brushless Permanent Magnet Motor (BLPM, sometimes referred to as ECM, ICM, or brushless DC motor), hereafter referred to as "BLPM fan motor." The incentive offer and savings estimation relate only to the efficiency gains associated with an upgrade to a BLPM fan motor, rather than for improvements in the efficiency of the heating and cooling equipment. That is, increases in AFUE or EER/SEER are NOT covered by this measure. The installation of a BLPM fan motor for businesses can apply to: just the heating system (heating only), just the central A/C system (cooling only), or for an air handler servings both heating and cooling systems (heating and cooling).

**Algorithms**

**Energy Savings**[10]

$\Delta$kWh = 783 for BLPM Fan Motor Commercial Heating Only
$\Delta$kWh = 179 for BLPM Fan Motor Commercial Cooling Only[11]
$\Delta$kWh = 947 for BLPM Fan Motor Commercial Heating and Cooling

Where:
$\Delta$kWh = gross customer annual kWh savings for the measure. See reference tables for explanation

**Demand Savings**[12]

$\Delta$kW = 0.39 for BLPM Fan Motor Commercial Heating Only
$\Delta$kW = 0.22 for BLPM Fan Motor Commercial Cooling Only
$\Delta$kW = 0.39 for BLPM Fan Motor Commercial Heating and Cooling

Where:
$\Delta$kW = maximum kW savings for the measure for either the winter or summer period, whichever is higher.
See reference tables.

[10] Calculated in "Commercial Furnace Fan Motor Savings.xls" based on data from: Pigg, S. Electricity Use by New Furnaces: A Wisconsin Field Study, October 2003 (Focus On Energy Technical Report 230-1), and State of Wisoconsin ECM Furnace Impact Assessment Report, January, 2009. Adapted for Vermont climate. Commercial savings calculated by adjusting residential savings upward to reflect greater hours of operation in small commercial buildings based on the ratio of commercial and residential equivalent full load hours. Assumes a weighted average of continuous and non-continuous usage, based on Wisconsin Impact Evaluation. For commercial cooling 800 FLH are assumed, consistent with TRM for high efficiency AC.
[11] Cooling savings based on auto-mode only
[12] Demand savings (kW) are based on a weighted average of continuous mode and auto-mode use. Heating Only applications are still assumed to have some summer demand reduction, due to the percentage of applications that use the fan year round for ventilation.

**Baseline Efficiencies – New or Replacement**
A low-efficiency permanent split capacitor (PSC) fan motor on a hot air furnace, split system air conditioner, or a combined air handling system serving both heating and cooling.

**High Efficiency**
A brushless permanent magnet motor (BLPM, also called ECM, ICM, and other terms) on a hot air furnace, split system air conditioner, or a combined air handling system serving both heating and cooling.

**Operating Hours**

Cooling: 800 equivalent full load hours/year.[13]

**Loadshape[14]**
Loadshape #78, BLPM Fan Motor Commercial Heating
Loadshape #79, BLPM Fan Motor Commercial Cooling
Loadshape #80, BLPM Fan Motor Commercial Heating and Cooling

**Freeridership/Spillover Factors**

| Measure Category | | Space Heat Efficiency | |
|---|---|---|---|
| Measure Code | | SHEFNMTR | |
| Product Description | | Efficient Furnace Fan Motor | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | 1 × 0.95 = 0.95 * | 1.0 |
| Cust Equip Rpl | 6013CUST | 1.0 | 1.0 |
| Farm Retro | 6012FARM | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | 1.0 | 1.0 |
| Pres Equip Rpl | 6013PRES | 1.0 | 1.0 |
| C&I Upstream | 6013UPST | n/a | n/a |
| C&I Retro | 6012CNIR | 1.0 | 1.0 |
| MF Mkt Retro | 6012MFMR | 0.9 | 1.0 |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | 1.0 | 1.0 |
| LIMF NC | 6018LINC | 1.0 | 1.0 |
| LIMF Rehab | 6018LIRH | 1.0 | 1.0 |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | 1.0 | 1.0 |

* Freeridership of 0% per agreement between DPS and EVT.  All Act 250 measures will also have a 5% Adjustment Factor applied, which will be implemented through the Freeridership factor

**Persistence**
The persistence factor is assumed to be one.

[13] Based on TRM characterization for Commercial Electric HVAC.
[14] See derivation of the savings profiles in "Commercial Furnace Fan Motor Savings.xls".

**Lifetimes**
18 years.[15]
Analysis period is the same as the lifetime.

**Measure Cost**
\$200[16] for Market Opportunity

**Incentive Level**
\$150 Total (\$100 to customer, \$50 to contractor)

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There is an increase in fossil fuel use associated with this measure, due the decrease in waste heat produced by the BLPM motor during the heating season.

$\Delta$MMBtu = 2.5[17] For Heating Only and Heating and Cooling
$\Delta$MMBtu = 0.0 For Cooling Only

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

**Table 1. Average Savings for BLPM Commercial HVAC Fan Motors**

| Application | kWh savings | kW reduction |
|---|---|---|
| Heating Only | 783 | .39 |
| Cooling Only | 179 | .22 |
| Heating and Cooling | 947 | .39 |

[15] Sachs and Smith, “Saving Energy with Efficient Residential Furnace Air Handlers: A Status Report and Program Recommendations,” 2003 (ACEEE report A033).
[16] Estimated incremental cost for efficient motor only. Sachs and Smith, 2003, Page 12.
[17] See calculation in “Commercial Furnace Fan Motor Savings.xls,” based on Gusdorf, J. et al. “The Impact of ECM furnace motors on natural gas use and overall energy use during the heating season of CCHT research facility.” Canadian Centre for Housing Technology. 2002 (Canadian Gas Increase Study.pdf).

# Brushless Permanent Magnet (BLPM) Circulator Pump

Measure Number: I-A-7-a (Business Energy Services, Motors End Use)

**Version Date & Revision History**
Draft: Portfolio 68
Effective date: 1/1/2011
End date: TBD

**Referenced Documents:** BLPM Pump Motor Analysis.xls, BLPM Pump Operating Hours Analysis.xlsx,

**Description**
This measure is for installing fractional horsepower circulator pumps with brushless permanent magnet pump (BLPM) motors. Typical applications include baseboard and radiant floor heating systems that utilize a primary/secondary loop system in multifamily residences and small commercial buildings. This measure is restricted to systems that use high mass boilers (>300,000 Btu/h) where the primary loop circulator runs constantly during the heating season. Circulator pumps that use BLPMs are more efficient because they lack brushes that add friction to the motor, as well as the ability to modulate their speed to match the load. This is possible because the drive senses the difference between the magnetic field of the rotating rotor and the rotating magnetic field of the windings in the motor stator. As the system flow demand changes (zones open or close), the drive senses the torque difference at the impeller via the change in the magnetic field difference and adjusts its speed by altering the frequency to the motor. BLPMs are especially efficient in no-load/low-load applications.

**Demand Savings**
$\Delta kW = \Delta kWh/HOURS$

**Energy Savings**
$\Delta kWh$ = value from a savings table in the Reference Tables section

Where:

$\Delta kW$ = gross customer connected load kW savings for the measure (kW)
$\Delta kWh$ = gross customer annual kWh savings for the measure (kWh)
HOURS = 4684

**Baseline Efficiencies – New or Replacement**
The baseline equipment is a circulator pump using a low-efficiency shaded pole motor. It is assumed that this pump is installed on the primary loop of a multi-loop system, and is running constantly when outside temperatures are 55°F or lower during the winter heating season (October – April).

**High Efficiency**
The efficient equipment is a circulator pump with brushless permanent magnet motor.

**Operating Hours**
The annual operating hours are assumed to be 4684[18]

**Loadshape**
Loadshape #17: Commercial Space Heat

**Freeridership/Spillover Factors**

| | |
|---|---|
| Measure Category | Space Heat Efficiency |
| Measure Code | SHECPMTR |

[18] This value is calculated as the total hours between the months of October 1st and April 30th where the outside air dry-bulb temperature is below 55°. See “BLPM pump operating hours analysis.xlsx” for further detail.

| Product Description | | Efficient Circulator Pump Motor | |
|---|---|---|---|
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | $1 \times 0.95 = 0.95$ * | 1.0 |
| Cust Equip Rpl | 6013CUST | 0.95 | 1.0 |
| Farm Retro | 6012FARM | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | 1.0 | 1.0 |
| Pres Equip Rpl | 6013PRES | 0.95 | 1.0 |
| C&I Upstream | 6013UPST | n/a | n/a |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6012MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | 1.0 | 1.0 |
| LIMF Rehab | 6018LIRH | 1.0 | 1.0 |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | 1.0 | 1.0 |
| CC | 6015 CC | n/a | n/a |
| C&I Lplus | 6021 LPLU | n/a | n/a |
| LIMF Lplus | 6052 LPLU | n/a | n/a |
| MFMR Lplus | 6053 LPLU | n/a | n/a |
| EP GMP Blueline | 6042 EPEP | n/a | n/a |
| GMP Furnace | 6044 RETR | n/a | n/a |
| GMP HP | 6046 RETR | n/a | n/a |
| VEEP GMP | 6048 VEEP | n/a | n/a |

**Persistence**
The persistence factor is assumed to be 1.

**Lifetimes**
20 years – typical circulator pumps using shaded pole motors are expected to last around 15 years; circulator pump motors with ECMs typically operate at lower RPMs, thus producing less heat and extending the life of the motor.

**Measure Cost**
The estimated incremental cost for this measure varies based on the size of the motor. See the savings table in the reference section for the appropriate value.

**Incentive Level**
The recommended incentive level is $125 for circulator pumps ≤1.25 max rated amps, $375 for circulator pumps with max rated amps between 1.25 and 5, and $500 for circulator pumps with max rated amps greater than 5. This is equivalent to roughly 50% of the estimated incremental cost.

**O&M Cost Adjustments**
None.

**Fossil Fuel Descriptions**
None.

**Water Descriptions**
None.

**Reference Tablessss**

**Savings and Incremental Cost for BLPM circulator pumps**
Where $A_{MAX}$ = Maximum rated amperage of circulator pump (nameplate information)

| Maximum Rated Amps | Annual ΔkWh[19] | Incremental Cost |
|---|---|---|
| $A_{MAX} \leq 1.25$ | 411 | $368 |
| $1.25 < A_{MAX} \leq 5$ | 775 | $758 |
| $A_{MAX} > 5$ | 2494 | $1,018 |

[19] Average kWh savings calculated from a survey of available BLPM and their equivalent shaded pole circulator pumps. See "BLPM Pump Motor Analysis.xslx" for further detail.

# Engine Block Timer for Agricultural Equipment

Measure Number: I-A-8-a (Business Energy Services, Motors End Use)

**Version Date & Revision History**
Draft date: Portfolio 73
Effective date: 1/1/2011
End date: TBD

**Referenced documents**

1)AgTimer_Calculations.xlsx

**Description**
The measure is a plug-in timer to control an engine block heater in agricultural equipment. Engine block heaters are typically used during cold weather to pre-warm an engine prior to start, for convenience heaters are typically plugged in considerably longer than necessary to improve startup performance. A timer allows a user to preset the heater to come on for only the amount of time necessary to pre-warm the engine block, reducing unnecessary run time.

**Algorithms**
**Energy Savings**

$\Delta$kWh = ISR * Use Season * %Days * HrSave/Day * $kW_{heater}$ - ParaLd
= 78.39% * 87 days * 84.23% * 7.765 Hr/Day * 1.5 kW - 5.46 kWh
= 664 kWh

**Demand Savings**

$\Delta$kW = $p_{(Dec/Jan)}$ * ISR * ($kW_{heater}$ – Parasitic Load)
= 0.90 * 78.39% * 1.5 kW

Where:

| | |
|---|---|
| $\Delta$kW | = connected load kW savings per plugin timer |
| ISR | = "In Service Rate"= 78.39%[20] |
| Use Season | = 87 days[21] |
| %Days | = proportion of days timer is used within Use Season= 84.23%[22] |
| HrSave/Day | = hours of savings per day when timer is used= 7.765 Hr/day[23] |
| Parasitic Load | = parasitic load = 5.46 kWh[24] |
| kW(heater) | = 1.5 kW[25] |
| AnnHr | = annual hours = Use Season * 24 = 1,759 hr |
| $p_{(Dec/Jan)}$ | = proportion of Jan/Dec temperature <25 deg F = 56/62 = 0.90[26] |

**Baseline Efficiencies – New or Replacement**
The baseline scenario is an engine block heater that is manually plugged in by the farmer to facilitate equipment startup at a later time.

[20] Based on a combination of survey data from Vermont and Minnesota, see AgTimer_Calculations.xlsx.
[21] Estimate is based on period between the first and last days of winter season with average temperature below 25 deg F. The 25 deg F threshold was derived through examination of Minnesota temperature data in view of the 90 use season reported by Minnesota farmers, see AgTimer_Calculations.xlsx.
[22] Estimate is derived from reported use of 5.90 days per week in VT farmer survey, see AgTimer_Calculations.xlsx.
[23] Estimate is derived from use patterns reported by VT farmer survey: baseline = 10.66 h/day, with timer = 2.90 h/day, see AgTimer_Calculations.xlsx.
[24] Estimate is based on data collected from 15 Amp Intermatic pool/spa timer, see AgTimer_Calculations.xlsx.
[25] Standard size reported by EnSave as well as EVT staff, see AgTimer_Calculations.xlsx.
[26] Based on December 7th through January 31st, see AgTimer_Calculations.xlsx.

**High Efficiency**
The efficient measure is an engine block heater operated by an outdoor plug-in timer (15 amp or greater) that turns on the heater only when it is required.

**Operating Hours**
927[27]

**Loadshape**
Engine Block Heater Timer, #104

**Freeridership/Spillover Factors**

| Measure Category | | Agricultural | |
|---|---|---|---|
| Measure Code | | ZZZBHTIM | |
| Product Description | | Engine Block Timer for Agricultural Equipment | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | 0.95 | 1.1 |
| Farm Rx | 6013FRMP | 0.95 | 1.1 |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | 0.95 | 1.1 |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetime**
3 years[28]

[27] Baseline Use * Use Season = 10.66 h/day * 87 days/yr

(Analysis period is the same as the lifetime.)

**Incremental Cost per Unit**
Incremental cost per installed plug-in timer is $10.19[29].

**Reference Tables**
None

[28] Equipment life is expected to be longer, but measure life is more conservative to account for possible attrition in use over time.
[29] Based on bulk pricing reported by EnSave, which administers the program

# Maple Sap Vacuum Pump VFD

Measure Number: I-A-10-a (Business Energy Services, Motors End Use)

**Version Date & Revision History**
Draft date: Portfolio 77
Effective date: 1/1/2012
End date: TBD

Referenced Documents: Maple Sap VFD_Analysis.xls

**Description**
The measure is a VFD attached to the vacuum pump in a maple sap extraction system that allows operators to manage system pressure by reducing pump speed rather than by using an inefficient method such as a differential pressure relief valve.

**Algorithms**

**VFD Savings**[30]

**Demand Savings**
$\Delta$kW = 1.38 kW

**Energy Savings**
$\Delta$kWh = 1,807 kWh

Where:

| | |
|---|---|
| $\Delta$kW | = gross customer connected load kW savings for the measure |
| $\Delta$kWh | = gross customer average annual kWh savings for the measure |

**Baseline Efficiencies – Retrofit or Replacement**
The baseline reflects a maple sap extraction system without a VFD equipped vacuum pump.

**High Efficiency**
The high efficiency case is installation and use of a VFD equipped vacuum pump.

**Operating Hours**
N/A.

**Loadshapes**
Loadshape #113: Maple Sap VFD

[30] Savings estimates are the average savings claimed for EVT custom projects in 2010 and 2011, see Maple Sap VFD_Analysis.xls

**Freeridership/Spillover Factors**

| Measure Category | | Motor Controls | |
|---|---|---|---|
| **Measure Code** | | MTCSAPVP | |
| **Product Description** | | Maple Sap Vacum Pump VFD | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | 1.00 | 1.00 |
| Farm Rx | 6013FRMP | 1.00 | 1.00 |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetime**
15 years.

**Measure Cost**[31]
$1,692

**O&M Cost Adjustments**
There are no standard operation and maintenance cost adjustments used for this measure.

**Fossil Fuel Descriptions**
There are no fossil-fuel algorithms or default savings for this measure.

**Water Descriptions**

[31] Values derived from Efficiency Vermont custom data 2010-2011, see Maple Sap VFD_Analysis.xls

There are no water algorithms or default values for this measure.

**Reference Tables**
None

## HVAC End Use

# Electric HVAC

Measure Number: I-B-1-l (Business Energy Services, HVAC End Use)

**Version Date & Revision History**
Draft date: Portfolio 79
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**
1) Minisplits_Pricing.xls;
2) NEEP_HVAC_Load_Shape_Report_Final_August2.pdf
3) Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.
4) 2005 Vermont Guidelines for Energy Efficient Commercial Construction
5) 2011 Vermont Commercial Building Energy Standards

**Description**
For existing buildings and New Construction, electric HVAC equipment exceeding baseline efficiencies as defined in the reference tables below.

**Algorithms**

The savings calculation equations vary by HVAC equipment type and are grouped below accordingly: Efficiency for the majority of HVAC equipment is described according to efficiency factors of the BTU/W form. Savings calculations for this equipment follows this general format:

**Energy Savings**
$\Delta kWh_{ccol} = kBTU/hr_{cool} \times (1/EF_{base} - 1/EF_{ee}) \times FLH_{cool}$
$\Delta kWh_{heat} = kBTU/hr_{heat} \times (1/EF_{base} - 1/EF_{ee}) \times FLH_{heat}$

**Demand Savings**
$\Delta kW_{cool} = kBTU/hr_{cool} \times (1/EF_{base} - 1/EF_{ee})$
$\Delta kW_{heat} = kBTU/hr_{heat} \times (1/EF_{base} - 1/EF_{ee})$

Where:

| | | |
|---|---|---|
| $\Delta kWh_{cool}$ | = | gross customer annual kWh cooling energy savings for the measure |
| $\Delta kWh_{heat}$ | = | gross customer annual kWh heating energy savings for the measure |
| $\Delta kW_{cool}$ | = | gross customer connected load kW cooling demand savings for the measure |
| $\Delta kW_{heat}$ | = | gross customer connected load kW heating demand savings for the measure |
| $kBTU/hr_{cool}$ | = | the nominal cooling capacity of equipment in thousands of BTU per hour (1 Ton = 12 kBTU/hr) |
| $kBTU/hr_{heat}$ | = | the nominal heating capacity of equipment in thousands of BTU per hour (1 Ton = 12 kBTU/hr) |
| $EF_{base}$ or $EF_{ee}$ | = | "efficiency factor" (for baseline or efficient equipment) with units BTU/W, specific calculation method varies depending on the type of equipment and heating vs. cooling mode, see table below for detail |
| $FLH_{cool}$ or $FLH_{heat}$ | = | "full load hours" per year (cooling or heating) |

**Table of efficiency factors, by technology**

| Technologies | Efficiency Factor (EF) | | | |
|---|---|---|---|---|
| | Cooling | | Heating | |
| | Energy Savings | Demand Savings | Energy Savings | Demand Savings |
| • Split and single package A/Cs (< 65K BTUh)<br>• Heat pumps<br>• Ductless mini-splits | SEER | EER | HSPF | HSPF |
| • Split and single package A/Cs (>65K BTUh) | IEER[32] | EER | IEER | EER |
| • PTACs<br>• PTHPs<br>• Room A/Cs<br>• Water source heat pumps<br>• Ground source heat pumps | EER | EER | EER | EER |

Where:

**SEER** = "seasonal energy efficiency ratio" of cooling equipment (BTU/W)

**HSPF** = "heating seasonal performance factor" of heat pump equipment (BTU/W)

**EER** = "energy efficiency ratio" of heating or cooling equipment (BTU/W)

**IEER** = "integrated energy efficiency ratio" of heating or cooling equipment (BTU/W)

Where the desired baseline efficiency factors are unavailable, EER, SEER, KW/ton, HSPF or COP can be converted according to the following relationships:

- EER = SEER /1.1.
- EER or IEER = 12 / (kW/ton)
- EER or IEER = 3.413 × COP
- HSPF = 0.65 × SEER

The savings for chillers should be calculated using cooling kW/ton efficiencies and the following algorithms:

**Energy Savings**

$\Delta kWh_{cool} = tons \times [(IPLV_{base} - IPLV_{ee})] \times FLH_s$

**Demand Savings**

$\Delta kW_{cool} = tons \times [(PE_{base} - PE_{ee})]$

Where:

$IPLV_{base}$ = Integrated part load value efficiency of the baseline chiller (kW/ton)
$IPLV_{ee}$ = Integrated part load value efficiency of the energy efficient chiller (kW/ton)
$PE_{base}$ = Peak efficiency of the baseline chiller (kW/ton)
$PE_{ee}$ = Peak efficiency of the energy efficient chiller (kW/ton)
tons = the nominal cooling capacity of equipment in tons (1 Ton = 12 kBTU/hr)

[32] Older units may use either EER or IPLV, "integrated part load value" (KW/ton).

Savings for HVAC controls and distribution systems are calculated on a custom basis with baseline technologies established in the Electric HVAC Baseline table. If EVT convinces a customer to switch technologies, savings would be calculated using the technology the customer was planning to use as the baseline. For example, if a customer was intending to install an air-cooled heat pump and EVT convinced them to install a water source heat pump instead, savings would be based on going from a baseline air cooled heat pump to the actual water source unit installed.

**Baseline Efficiencies – New or Replacement**

For all business new construction projects commencing construction prior to January 3rd, 2012 OR initiated with Efficiency Vermont prior to January 3rd, 2012, but completed on or after January 3rd, 2012, savings shall be calculated using “2005 Vermont Guidelines for Energy Efficient Commercial Construction” as baseline. Refer to that document for tables of appropriate baseline efficiency values.

For all business new construction projects commencing construction after January 3rd, 2012 and iniated with Efficiency Vermont on or after January 3rd, 2012, regardless of when they are completed, savings shall be calculated using “2011 Vermont Commercial Building Energy Standards” as baseline. Refer to Reference Tables section for appropriate baseline efficiency values for most common technologies. Refer to 2011 Vermont Commercial Building Energy Standards for baseline efficiencies for other technologies.

**High Efficiency**

Measure efficiencies should be obtained from customer data. If the efficiencies are missing, but the manufacturer and model # are available, then refer to the ARI directories. The minimum qualifying efficiencies for unitary equipment are shown in Table 1 “High-Efficiency Unitary AC and Heat Pumps” in the reference tables section.

**Operating Hours**

<u>Split system and Single Package (rooftop units):</u> 755 cooling full load hours[33], 2200 heating full load hours for heat pumps less than 65,000 BTUh and using HSPF, 1600 heating full load hours for heat pumps greater than or equal to 65,000 BTUh and using EER (electric resistance heating may be on for an additional 600 hours, but those hours should not be included in the algorithms when calculated savings are based on EER).

<u>Ductless mini-splits:</u> 829 cooling full load hours[34]

<u>PTAC:</u> 830 cooling full load hours, 1640 heat pump heating full load hours (electric resistance heating would be on for an additional 600 hours, but those hours should not be included in the algorithms when based on EER)

<u>Water Source Heat Pumps:</u> 2088 cooling full load hours, 2248 heat pump heating full load hours

<u>Room AC:</u> 800 cooling full load hours, 1600 heat pump heating full load hours

<u>Chillers:</u> Site-specific based on engineering estimates.

**Loadshapes**

Loadshape #15, Commercial A/C
Loadshape #20, Industrial A/C
Loadshape #17, Commercial Space heat
Loadshape #22, Industrial Space heat

[33] Average EFLH for large and small rooftop units from NEEP_HVAC_Load_Shape_Report_Final_August2.pdf
[34] EFLH small (<11.25 tons) rooftop units from NEEP_HVAC_Load_Shape_Report_Final_August2.pdf

**Freeridership/Spillover Factors**

| **Measure Category** | | **HVAC** | | | |
|---|---|---|---|---|---|
| Measure Codes | | ACEACUNI, ACEHPAIR, ACEHPWAT, ACECHILL, ACEACPTL, ACEHPPTL, ACEHPUMP ACEACDMS | | ACECA206, ACECA213, ACECA237, ACECP206, ACECP237, ACECW237 | |
| **Product Description** | | Efficient HVAC equipment | | CEE Tier 2 Air Conditioning and Heat Pump equipment | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** | **Freerider** | **Spillover** |
| Cust Equip Rpl | 6013CUST | 0.94 | 1.0 | 0.94 | 1.05 |
| Pres Equip Rpl | 6013PRES | 1.0 | 1.0 | 0.95 | 1.05 |
| C&I Upstream | 6013UPST | 0.95 | 1.05 | 0.95 | 1.05 |
| Act250 NC | 6014A250 | 0.95 | 1.05 | 0.95 | 1.05 |
| Non Act 250 NC | 6014NANC | 0.95 | 1.05 | 0.95 | 1.05 |

* Freeridership of 0% per agreement between DPS and EVT. All Act 250 measures will also have a 5% Adjustment Factor applied, which will be implemented through the Freeridership factor.

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
Unitary and ductless mini-splits – 15 years.[35]
Chillers – 25 years
Room Air Conditioner – 10 years
Analysis period is the same as the lifetime.

**Measure Cost**
See Table 1 “High-Efficiency Unitary AC and Heat Pumps” in the reference tables section. Incremental costs for other HVAC equipment are determined on a site-specific basis.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil-fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**
Reference Tables located on following pages

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

## Table 1: High-Efficiency Unitary AC and Heat Pumps

| Equip-ment Type | Size Category | Sub-Category | CEE Tier I Minimum Efficiency[1] | Incremental Cost Baseline[2] to Tier I | CEE Tier II Minimum Efficiency[1] | Incremental Cost Baseline to Tier II |
|---|---|---|---|---|---|---|
| Air Cooled UnitaryAC | <65 kBtu/h (<5.42 tons) | Split System | n/a | n/a | 15.0 SEER 12.5 EER | $150 per ton |
| | | Single Package | n/a | n/a | 15.0 SEER 12.0 EER | $150 per ton |
| | ≥65 kBtu/h and<135 kBtu/h (5.42 to 11.25 tons) | Split System and Single Package | 11.5 EER 12.8 IEER | $100 per ton | 12.0 EER 13.8 IEER | $130 per ton |
| | ≥135 kBtu/h to <240 kBtu/h (11.25 to 20 tons) | Split System and Single Package | 11.5 EER 12.3 IEER | $100 per ton | 12.0 EER 13.2 IEER | $130 per ton |
| | ≥240 kBtu/h to ≤760 kBtu/h (20 to 63.33 tons) | Split System and Single Package | 10.3 EER 11.1 IEER | $100 per ton | 10.6 EER 12.1 IEER | $140 per ton |
| | ≥760 kBtu/h (63.33 tons) | Split System and Single Package | 9.7 EER 10.9 IEER | $100 per ton | 10.2 EER 11.4 IEER | $140 per ton |
| Water Source Heat Pumps | <135 kBTU/h (<11.25 tons) | | 14 EER 4.6 COP | $100 per ton | n/a | n/a |

## Baseline Table A: Package Terminal Air Conditioners and Heat Pumps [a]

| Equipment Type | Purchase Type | Baseline[b] EER / C.O.P. (New Unit) | |
|---|---|---|---|
| | | Before 10/08/2012 | After 10/08/2012 |
| PTAC (Cooling Mode) | New Const. | 12.5 - (0.213 x Cap / 1,000) EER | 13.8 – (0.300 x Cap/1,000) EER |
| PTHP (Cooling Mode) | New Const. | 12.3 - (0.213 x Cap / 1,000) EER | 14.0 – (0.300 x Cap/1,000) EER1,2,3 |
| PTHP (Heating Mode) | New Const. | 3.2 - (0.026 x Cap / 1,000) COP | No Change 1,2,3 |

Notes:

a. Applies to projects initiated with EVT on or after 1/3/2013. See 2011 CBES code for complete details on referenced standards. See table 803.2.2(3) in 2005 Vermont Guidelines for Energy Efficient Commercial Construction for baseline efficiencies for projects initiated prior to 1/3/2012.

b. "Cap" means the rated cooling capacity of the producted BTU/h. If the unit's capacity is less than 7,000 BTU/h, use 7,000 BTU/h in the calculation. If the unit's capacity is greater than 15,000 BTU/h, use 15,000 BTU/h in the calculation.

c. Replacement units must be labeled as follows: "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY: NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS." Replacement efficiencies apply only to units with existing sleeves less than 16 inches (406 mm) high and less than 42 inches (1067 mm) wide.

## Baseline Table B: Unitary Air Conditioners and Condensing Units [a]

| Type | Size | Baseline Efficiency | | |
|---|---|---|---|---|
| | | EER | SEER / IEER | C.O.P./ HSPF |
| Through-the-wall (air cooled) | <30 kBTU/h | 10.9 | 12.00 SEER | |
| Small-duct high-velocity (air cooled) | <65 kBTU/h | 9.1 | 10.0 SEER | |
| Air Cooled - Split System and Single Package | < 65 kBTU/h (5.42 tons) | 11.8 | 13.0 SEER | - |
| Air Cooled | ≥ 65 and < 135 kBTU/h (5.42 to 11.25 tons) | 11.0 | 11.2 IEER | - |
| Air Cooled | ≥ 135 and < 240 kBTU/h (11.25 to 20 tons) | 10.8 | 11.0 IEER | - |
| Air Cooled | ≥ 240 and < 760 kBTU/h (20 to 63.33 tons) | 9.8 | 9.9 IEER | - |
| Air Cooled | ≥ 760 kBTU/h (63.33 tons) | 9.5 | 9.6 IEER | - |
| Ductless Mini Splits [b] | < 65 kBTU/h (5.42 tons) | 12.0 | 14.0 SEER | - |
| Evaporatively Cooled | < 65 kBTU/h (5.42 tons) | 12.1 | 12.3 IEER | - |
| Evaporatively Cooled | ≥ 65 and < 135 kBTU/h (5.42 to 11.25 tons) | 11.9 | 12.1 IEER | - |
| Evaporatively Cooled | ≥ 135 and < 240 kBTU/h (11.25 to 20 tons) | 11.8 | 12.0 IEER | - |
| Evaporatively Cooled | ≥ 240 kBTU/h and <760 kBTU/h (20 to 63.33 tons) | 11.7 | 11.9 IEER | - |
| Evaporatively Cooled | ≥ 760 kBTU/h (63.33 tons) | 11.5 | 11.7 IEER | - |
| Water Cooled | < 65 kBTU/h (5.42 tons) | 12.1 | 12.3IEER | - |
| Water Cooled | ≥ 65 and < 135 kBTU/h (5.42 to 11.25 tons) | 11.9 | 12.1 IEER | - |
| Water Cooled | ≥ 135 and < 240 kBTU/h (11.25 to 20 tons) | 12.3 | 12.5 IEER | - |
| Water Cooled | ≥ 240 kBTU/h (20 tons) and <760 kBTU/h (20 to 63.33 tons) | 12.2 | 12.4 IEER | - |
| Water Cooled | ≥ 760 kBTU/h (63.33 tons) | 12.0 | 12.2 IEER | - |
| Cond. Units - Air Cooled | ≥ 135 kBTU/h (11.25 tons) | 10.5 | 11.8 IEER | - |
| Cond. Units - Water or Evap. Cooled | ≥ 135 kBTU/h (11.25 tons) | 13.5 | 14.0 IEER | - |

Notes:

a. Applies to projects initiated with EVT on or after 1/3/2013. See 2011 CBES code for complete details on referenced standards. See table 803.2.2(3) in 2005 Vermont Guidelines for Energy Efficient Commercial Construction for baseline efficiencies for projects initiated prior to 1/3/2012.

b. The baseline for Mini Splits is set at the Unitary qualifying level (14 SEER 12 EER) due to information provided by distributors indicating that most mini split units being sold are in excess of the federal minimum. In the absence of any evaluation, this higher baseline efficiency level is chosen to account for this.

## Baseline Table C: Unitary and Applied Heat Pumps (Heating and Cooling) [a]

| Type | Size | Baseline Efficiency | | |
|---|---|---|---|---|
| | | Cooling EER | Cooling SEER / IEER | Heating C.O.P./ HSPF |
| Through-the-wall, air cooled (cooling mode) | < 30 kBTU/h (2.5 tons) | 10.9 | 12.0 SEER | 7.7 HSPF |
| Small-duct high-velocity air cooled (cooling mode) | < 65 kBTU/h (5.42 tons) | 9.1 | 10.0 SEER | 6.8 HSPF |
| Air Cooled - Split system and single package | < 65 kBTU/h (5.42 tons) | 11.8 | 13.0 SEER | 7.7 HSPF |
| Water Source | < 17 kBTU/h (1.42 tons) | 11.2 [b] | - | 4.2 COP [c] |
| Water Source [b] | ≥ 17 and < 135 kBTU/h (1.42 to 5.42 tons) | 12.0 [b] | - | 4.2 COP [c] |

Notes:

a. Applies to projects initiated with EVT on or after 1/3/2013. See 2011 CBES code for complete details on referenced standards. See table 803.2.2(3) in 2005 Vermont Guidelines for Energy Efficient Commercial Construction for baseline efficiencies for projects initiated prior to 1/3/2012.
b. Water source heat pump EER based on 86 degree F entering water temperature in cooling mode
c. Water source heat pump COP based on 68 degree F entering water temperature in heating mode.

## Baseline Table E: Room AC [a]

| Type | Size | Baseline Efficiency | | |
|---|---|---|---|---|
| | | SEER / EER | IPLV | C.O.P. / HSPF |
| Room Air Conditioners, with louvered sides | < 6,000 Btu/hr | 9.7 | - | - |
| Room Air Conditioners, with louvered sides | ≥ 6,000 Btu/hr and < 8,000 Btu/hr | 9.7 | - | - |
| Room Air Conditioners, with louvered sides | ≥ 8,000 Btu/hr and < 14,000 Btu/hr | 9.8 | - | - |
| Room Air Conditioners, with louvered sides | ≥ 14,000 Btu/hr and < 20,000 Btu/hr | 9.7 | - | - |
| Room Air Conditioners, with louvered sides | ≥ 20,000 Btu/hr | 8.5 | - | - |
| Room Air Conditioners, without louvered sides | < 8,000 Btu/hr | 9.0 | - | - |
| Room Air Conditioners, without louvered sides | ≥ 6,000 Btu/hr and < 20,000 Btu/hr | 8.5 | - | - |
| Room Air Conditioners, without louvered sides | ≥ 20,000 Btu/hr | 8.5 | - | - |
| Room Air Conditioner Heat Pumps, with louvered sides | < 20,000 Btu/hr | 9.0 | - | - |
| Room Air Conditioner Heat Pumps, with louvered sides | ≥ 20,000 Btu/hr | 8.5 | | |
| Room Air Conditioner Heat Pumps, without louvered sides. | < 14,000 Btu/hr | 8.5 | - | - |
| Room Air Conditioner Heat Pumps, without louvered sides. | ≥ 14,000 Btu/hr | 8.0 | | |
| Room air conditioner casement only | All capacities | 8.7 | | |
| Room air conditioner casement-slider | All capacities | 9.5 | | |

Notes:

a. Applies to projects initiated with EVT on or after 1/3/2013. See 2011 CBES code for complete details on referenced standards. See table 803.2.2(3) in 2005 Vermont Guidelines for Energy Efficient Commercial Construction for baseline efficiencies for projects initiated prior to 1/3/2012.

# Dual Enthalpy Economizer

Measure Number: I-B-2-d (Business Energy Services, HVAC End Use)

**Version Date & Revision History**
Draft date: Portfolio 79
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:** Economizer_013002.xls

**Description**
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.

This is a prescriptive measure included on the regional Cool Choice application form. Customers are eligible for a Cool Choice incentive only with the purchase of an efficient HVAC unit that also qualifies for an incentive. Custom incentives are available for other cost-effective dual enthalpy economizers for both retrofit and replacement/new construction units.

**Algorithms**

**Energy Savings**
$\Delta kWh = SF \times Tons \times OTF / EER$

**Demand Savings**

$\Delta kW = \Delta kWh / 4{,}438$

Where:

| | |
|---|---|
| $\Delta$kWh | = gross customer annual kWh savings for the measure |
| SF | = Savings Factor: annual kWh savings per ton of cooling equipment at an EER of 1.0. Based on simulation modeling for Burlington, VT. For units less than 4.5 tons: SF = 4,576 (assumes fixed damper baseline). For units 4.5 tons or more: SF = 3,318 (assumes dry bulb economizer baseline). |
| Tons | = tonnage of cooling equipment from application form or customer information. |
| OTF | = Operational Testing Factor. OTF = 1.0 when the project undergoes Operational Testing or commissioning services, 0.80 otherwise. |
| EER | = cooling energy efficiency ratio of the equipment (BTUh/W), from application form or customer information. (EER may be estimated as SEER/1.1). |
| $\Delta$kW | = gross customer diversified connected load kW savings for the measure |
| 4,438 | = typical annual hours of economizer operation (Based on appropriate temperature range bin hours at Burlington, VT) |

Baseline Efficiencies – New or Replacement
For units less than 4.5 tons: fixed damper (no economizer).
For units 4.5 tons or more: dry bulb economizer.

**High Efficiency**
Dual enthalpy economizer.

**Operating Hours**

4,438 typical annual hours of savings from dual enthalpy economizer (Based on appropriate temperature range bin hours at Burlington, VT)

**Loadshape**
Loadshape #60, Economizer

**Freeridership/Spillover Factors**

| **Measure Category** | | **Air Conditioning Efficiency** | |
|---|---|---|---|
| Measure Codes | | ACEMIZER | |
| **Product Description** | | HVAC Economizer | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | 0.94 | 1.0 |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | 0.95 | 1.0 |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | 0.95 | 1.05 |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | 0.95 | 1.05 |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be 70% as agreed to between DPS and EVT.

**Lifetime**
Engineering Measure Life is 14 years.
Adjusted Measure Life used for savings and screening will be 0.7 * 14 years = 9.8 years, to adjust for persistence.
Analysis period is the same as the Adjusted Measure Life..

**Measure Cost**
The incremental cost for this measure is:
$400 from dry bulb economizer baseline (units 4.5 tons or more),
$800 from fixed damper baseline (units less than 4.5 tons)[36]

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**
None

[36] $800 measure cost based on EVT project experience and conversations with suppliers.

# Commercial Room Air Conditioner, Early Replacement

Measure Number: I-B-4-a (GT Peak Reduction Program, Room Air Conditioner Early Replacement)

**Version Date & Revision History**
Draft date: Portfolio No. 59
Effective date: 10/1/2009
End date: TBD

**Referenced Documents:**
NYSERDA Keep Cool 2000-2003 Report; Rosenquist et al (2004) Life-cycle Cost and Payback Period Analysis for Commercial Unitary Air Conditioners, Lawerence Berkeley Laboratories; AHAM Market Survey Data; www.energystar.gov; www.ari.org

Calculation worksheets: RAC_Screening_Summary.xls; EnergyStar_RAC_Stats.xls; LBL document

**Description**
This is an early retrofit measure to remove inefficient air conditioners from service in commercial settings, ensure proper disposal, and replace them with new units that meet or exceed current minimum ENERGY STAR efficiency standards. There will be four separate measures corresponding with typical size classes of equipment.

**Algorithms**

**Annual Energy Savings (per unit)**

| **Product Class (BTU/h)** | **Representative capacity (BTU/h)** | **kWh Savings, years 1-4** | **kWh Savings, years 5-14** |
|---|---|---|---|
| **<8,000** | 6,000 | 207 | 28 |
| **8,000-13,999** | 12,000 | 413 | 56 |
| **14,000-20,000** | 18,000 | 625 | 85 |
| **>20,000** | 24,000 | 940 | 128 |

Example calculations:
Annual Energy Savings for remaining life of existing 12,000 BTU unit (initial 4 years):

$$\Delta kWh_{1\text{-}4} = kBTU/hr \times [1/EER_{exist} * 1/Degrade_{(14\ years)} - 1/EER_{eff} * 1/Degrade_{(2\ years)}] \times FLH$$
$$= 12 \times [(1/9.05 * 1/0.86 - 1/10.85 * 1/0.98)] \times 1{,}000 = 413$$

Annual Energy Savings for remaining life of measure (10 years):

$$\Delta kWh_{1\text{-}4} = kBTU/hr \times [1/EER_{base} * 1/Degrade_{(5\ years)} - 1/EER_{eff} * Degrade_{(9\ years)}] \times FLH$$
$$= 12 \times [1/9.93 * 1/0.95 - 1/10.85 * 1/0.91] \times 1{,}000 = 56$$

**Demand Savings (per unit)**

| Product Class (BTU/h) | **Representative size (Btu/h)** | **kW Reduction, years 1-4** | **kW Reduction, years 5-14** |
|---|---|---|---|
| **<8,000** | 6,000 | 0.207 | 0.028 |
| **8,000-13,999** | 12,000 | 0.413 | 0.056 |
| **14,000-20,000** | 18,000 | 0.625 | 0.085 |
| **>20,000** | 24,000 | 0.940 | 0.128 |

Example calculations:

Annual demand savings for remaining life of existing 8,000-13,999 BTU unit (years 1-4):

$$\Delta kW_{1\text{-}4} = kBTU/hr \times [(1/EER_{exist} * 1/Degrade_{(14\ years)}) - (1/EER_{eff} * 1/Degrade_{(2\ years)})]$$
$$= 12 \times [(1/9.05 * 1/0.86) - (1/10.85 * 1/0.98)] = 0.413$$

Annual demand savings for remaining life of measure (years 5-10):

$$\Delta kW_{5\text{-}14} = kBTU/hr \times [1/EER_{new} * Degrade_{(5\ years)} - 1/EER_{eef} * 1/ Degrade_{(9\ years)}]$$
$$= 12 \times [((1/9.93 - 1/10.85)] = 0.056$$

Where:

*k*BTU = 6, 12, 18, or 24, corresponding to <8,000; 8,000-13,999; 14,000-20,000; or >20,000 product classes, respectively
$EER_{exist}$ = Energy Efficiency Ratio of existing unit (see Efficiency Ratings table, below)
$EER_{new\_}$ = Energy Efficiency Ratio of new baseline unit (see Efficiency Ratings table, below)
$EER_{eff}$ = Energy Efficiency Ratio of efficient unit (see Efficiency Ratings table, below)
Degrade = [1 – (0.01 * unit's median age)], for a given period of years
FLH = 1,000[37] (annual full load hours)
$\Delta kW_{1\text{-}4}$ = gross customer connected load kW savings for remaining four (4) years of life of existing unit
$\Delta kW_{5\text{-}14}$ = gross customer connected load kW savings for remaining ten (10) years the measure life
$\Delta kWh_{1\text{-}4}$ = gross customer kWh savings for remaining four (4) years of life of existing unit
$\Delta kWh_{5\text{-}14}$= gross customer kWh savings for remaining ten (10) years the measure life

**Baseline Efficiencies – New or Replacement**
Baseline efficiency for existing units is based on the market average efficiencies of air conditioners sold from 1994 to 1999 (i.e. 10-15 years before present) adjusted by a degradation factor (see efficiency ratings section, below for details). Baseline efficiency for replacement units is based on the market average efficiency for air conditioners sold in 2008.[38] see Reference Table for specifications.

**High Efficiency**
The high efficiency level is room AC meeting or exceeding ENERGY STAR specifications for efficiency established January 1st, 2003, see Reference Table.

**Loadshape**
Loadshape #15 (Commercial A/C)

**Operating Hours**
1000 full load hours yearly for commercial customers.

**Freerider / Spillover Table**

| Measure Category | | Air Conditioning Efficiency | |
|---|---|---|---|
| Measure Code | | ACEESAER | |
| Product Description | | Energy Star room AC, early replacement | |
| Track Name | Track No. | Freerider | Spillover |

[37] FLH for commercial room air conditioner applications, consistent with Loadshape #15 from the Vermont Screening Tool
[38] "Room Air Conditioners: Energy Efficiency and Consumption Trends", provided electronically by Association of Home Appliance Manufacturers, sent 06/30/09

| | | | |
|---|---|---|---|
| Act250 NC | 6014A250 | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Retro | 6012CNIR | 0.89 | 1.0 |
| MF Mkt Retro | 6012MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes and remaining life calculations**

This program will actively target units over 10 years old for replacement. We assume that the average unit replaced will be 12 years old and would have remained in service for an additional 4 years if not replaced by this program.[39] The lifespan of the new unit is 14 years.

**Equipment Costs[40]**

| Product Class (Btu/h) | Efficient | New Baseline |
|---|---|---|
| **<8,000** | $256 | $212 |
| **8,000-13,999** | $337 | $293 |
| **14,000-20,000** | $491 | $447 |
| **>20,000** | $611 | $567 |

**Incentive Level**

| Product Class (Btu/h) | Incentive |
|---|---|
| **<8,000** | $150 |
| **8,000-13,999** | $250 |
| **14,000-20,000** | $400 |
| **>20,000** | $400 |

[39] Based on Lawerence Berkeley Laboratories study on air conditioner survival rates. (See http://www.osti.gov/bridge/servlets/purl/829989-lK2zOw/native/829989.pdf page 26, as well as spreadsheet for detailed calculations)
[40] Costs were surveyed on the Lowes, Home Depot and Sears websites, cost for each product size class is based on the average cost per BTU of units of similar sizes and weighted average calculated assuming 10% of units will be more expensive CEE Tier 1 compliant.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure

**Fossil Fuel Descriptions**
There are no fossil fuel algorithm or default values for this measure

**Water Descriptions**
There are no water algorithms or default values for this measure

**Reference Information**

**Efficiency Ratings**

| Product Class (Btu/h) | Existing unit Baseline[41] (1994-99 average) | New Base (2008)[42] | Efficient Std[43] |
|---|---|---|---|
| **<8,000** | 7.57 | 9.89 | 10.80 |
| **8,000-13,999** | 7.60 | 9.93 | 10.85 |
| **14,000-20,000** | 7.53 | 9.84 | 10.74 |
| **>20,000** | 6.68 | 8.72 | 9.52 |

Degradation factors were applied to all EER's assuming a linear degradation rate of 1% per year[44]. E.g. the EER of an efficient 12,000 BTU/hr unit during years 5-14 of its lifespan = 10.85 * (1 – 0.01 * 9) = 9.87

[41] Association of Home Appliance Manufacturers provided information for the 8,000-13,999 size class, EER's for other size classes were calculated assuming the same ratios between size classes as for efficient equipment
[42] See comment above
[43] Averages of E-Star published EER's for A/C equipment.. (See http://www.energystar.gov/index.cfm?fuseaction=roomac.display_products_html , data downloaded 08/07/2009)
[44] Personal communications with Harvey Sachs (ACEEE) and Michael Pilat (NYSERDA/Lockheed Martin), both dated 10/09/09. Also, the "NYSERDA Keep Cool Report 2000-2003" (Aspen Systems Corporation, 2003) page A-2 describes testing of old AC units which found EER degradation of 16% in units averaging 15 years of age.

# Commercial Ventilation Fan

Measure Number: I-B-5-a

**Version Date & Revision History**
Draft date: Portfolio 82
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**

1. EVT Custom Commercial Exhaust Fan Data.xlsx
2. GDS Associates Measure Life Report "Residential and C&I Lighting and HVAC measures"

**Description**
An ENERGY STAR qualified efficient fan configured to meet ASHRAE 62.1 requirements for bathroom ventilation. This market opportunity is defined by the need for continuous mechanical ventilation in bathrooms and mechanical closets of small commercial and industrial buildings during operating hours. This measure assumes an efficient fan will be run during business hours to provide 10-500 CFM under static pressure conditions ranging from 0.1 to 0.25 inches of water.

**Algorithms**
**Annual Demand Savings**
$\Delta kW = CFM * (1/Fan_{Efficiency,\ Baseline} - 1/Fan_{Efficiency,\ Efficient}) / 1000$

Where:
CFM = Nominal Capacity of the exhaust fan. Savings calculatation use a common rating within the range, as shown in the "Assumed CFM" column.
$Fan_{Efficiency,\ Baseline}$ = Efficacy for baseline fan[45]
= 1.7 CFM/Watt
$Fan_{Efficiency,\ Efficient}$ = Efficacy for efficient fan[46]
= 4.7 CFM/Watt

ΔkW =

| CFM code | Nominal CFM Range | Assumed CFM | ΔkW |
|---|---|---|---|
| CFM1 | 10-89 | 70 | 0.027 |
| CFM2 | 90-150 | 110 | 0.042 |
| CFM3 | 151-250 | 175 | 0.066 |
| CFM4 | 251-500 | 350 | 0.133 |

* Averge CFM for the capacity range

**Annual Energy Savings**
$\Delta kWh = Hours * \Delta kW$

Where:
ΔkW = connected load kW savings per qualified ventilation fan and controls.
Hours = assumed annual run hours
= 2870[47]

ΔkWh =

| CFM code | Nominal CFM Range | Assumed CFM | ΔkWh |
|---|---|---|---|

[45] Weighted average of 20 best-selling ceiling exhaust fans at Grainger on 8/8/2013 using assumed sales distribution, EVT Custom Commercial Exhaust Fan Data.xlsx
[46] Median of fans installed through EVT custom projects 2008-2011, EVT Custom Commercial Exhaust Fan Data.xlsx
[47] Median of run hours of fans installed through EVT custom projects 2008-2011, EVT Custom Commercial Exhaust Fan Data.xlsx

| | | | |
|---|---|---|---|
| CFM1 | 10-89 | 70 | 76 |
| CFM2 | 90-150 | 110 | 120 |
| CFM3 | 151-250 | 175 | 190 |
| CFM4 | 251-500 | 350 | 381 |

**Baseline Efficiencies – New or Replacement**
New standard efficiency (average CFM/Watt of 1) exhaust-only ventilation fan operating in accordance with recommended ventilation rate indicated by ASHRAE 62.1 for commercial bathrooms during business hours.

**High Efficiency**
New efficient (average CFM/watt of 5) exhaust-only ventilation fan, operating in accordance with recommended ventilation rate indicated by ASHRAE 62.1 for commercial bathrooms during business hours.

**Annual Operating Hours**
2870[48]

**Loadshape**
Loadshape #113: Commercial Small Exhaust-only Vent Fan

**Freeridership/Spillover Factors**

| Measure Category | | Ventilation | |
|---|---|---|---|
| Measure Code | | VNTXCEIL | |
| Product Description | | Exhaust fan, variable speed | |
| Track Name | Track No. | Freerider | Spillover |
| C&I NC Cust | 6014CUST | 0.95 | 1.05 |
| Cust Equip Rpl | 6013CUST | 0.94 | 1.0 |
| C&I NC Pres | 6014PRES | 0.95 | 1.05 |
| Pres Equip Rpl | 6013PRES | 1.0 | 1.0 |
| C&I Retro | 6012CNIR | 0.89 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetime**
15 years.[49] Analysis period is the same as the lifetime.

**Incremental Cost per Unit**
Incremental cost per installed fan is $95 for quiet, efficient fans.[50]

**Reference Tables**
None

[48] Ibid.
[49] Estimate based upon GDS Associates Measure Life Report "Residential and C&I Lighting and HVAC measures" 25 years for residential whole-house fans, 19 for residential thermostatically-controlled attic fans, and 15 years for several commercial measures.
[50] Based on February, 2013 review of generally available prices for baseline and eligible products, controls. ($150 efficient fan + $35 programmable controls vs. $65 for comparable base fan + $25 for on/off cycle controller)

# Package Terminal Heat Pump (Hotel Room)

Measure Number: I-B-5-a (Business Energy Services, HVAC End Use)

**Version Date & Revision History**
Draft date: Portfolio 83
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**

1. PTHP_Analysis.xlsx;
2. State Screening Tool for PTHP;
3. Massachusetts Electric PAs Cross-Cutting C&I Free-ridership and Spillover Field Study (April 18, 2011)
4. 2011 Commercial and Industrial Electric and Natural Gas Programs Free-ridership and Spillover Study, Connecticut Energy Fund (September 25, 2012)

**Description**
A 9,000 BTU/hour package terminal heat pump (PTHP) is purchased instead of a package terminal air conditioner (PTAC) with electric resistance heat and installed in a hotel room, as an end of life replacement of an existing unit.

This program will be targeted exclusively to hotels and motels likely to have existing PTAC units with electric resistance heat. While there may be application for PTHP equipment in the context of new construction, the baseline is difficult to generalize. Therefore new construction applications will be handled through a custom process.

**Algorithms**

**PTHP Savings**[51]

**Demand Savings**
$\Delta kW = 0.697\ kW$

**Energy Savings**
$\Delta kWh = 1{,}443\ kWh$

Where:

| | |
|---|---|
| ΔkW | = gross customer connected load kW savings for the measure |
| ΔkWh | = gross customer average annual kWh savings for the measure |

**Baseline Efficiency –End of Life Replacement**[52]
The baseline reflects a code compliant PTAC with resistance heat.

**High Efficiency**
The high efficiency case matches standards specified in the 2011 Energy Star scoping report.[53]

**Equivalent Full Load Hours**[54]

[51] Savings estimate is based on 9,000 BTU/hr unit, see calculation tool in reference documents.
[52] 2011 Vermont Commercial Building Energy Standards, see Table 503.2.3(3)
[53] Energy Star Market and Industry Scoping Report, Dec 2011 (table 6, *http://www.energystar.gov/ia/products/downloads/ESTAR_PTAC_and_PTHP_Scoping_Report_Final_Dec_2011.pdf*)

[54] Assumes balance point of 55 degrees and that equipment is oversized by 25% on average.

765, cooling
1,305, heating

**Loadshapes**
PTHP, Hotel.

**Freeridership/Spillover Factors**

| **Measure Category** | | **ACE** | |
|---|---|---|---|
| **Measure Code** | | ACEHPPTL | |
| **Product Description** | | Package terminal heat hump | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** |
| C&I Retrofit | 6012CNIR | 0.93 | 1.00 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetime**
15 years.

**Measure Cost**[55]
$130

**O&M Cost Adjustments**
There are no standard operation and maintenance cost adjustments used for this measure.

**Fossil Fuel Descriptions**
There are no fossil-fuel algorithms or default savings for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**
None

[55] Values derived from review of catalogues commonly used by hotel managers.

## Lighting End Use

# CFL Fixture

Measure Number: I-C-2-h (Business Energy Services, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 76
Effective date: 1/1/2012
End date: 12/31/2014

**Referenced Documents:**
1) "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993.
2) Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)
3) 2012 EISA Adjustment Calculations.xls
4) NEEP CI Lighting LS FINAL Report_ver 5_7-19-11.pdf

**Description**
Compact fluorescent (CFL) hardwired fixture.

**Algorithms**
**Demand Savings**
$\Delta kW = ((Watts_{BASE} - Watts_{EE}) / 1000) \times ISR \times WHF_d$

**Energy Savings**
$\Delta kWh = ((Watts_{BASE} - Watts_{EE}) / 1000) \times HOURS \times ISR \times WHF_e$

Where:

$\Delta kWh$ = gross customer annual kWh savings for the measure (includes the reduced cooling load from the more efficient lighting)
$kW_{save}$ = lighting connected load kW saved, baseline kW minus efficient kW
HOURS = annual lighting hours of use per year; collected from prescriptive application form
ISR = In service rate, or the percentage of units rebated that actually get used. For prescriptive measures, this is assumed to be 98%.[56]
$WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting. For prescriptive lighting in existing buildings, the default value is 1.082 (calculated as 1 + (0.47*0.67*.808) / 3.1))[57]. For prescriptive lighting in new buildings, the value is 1.084 (calculated as 1 + (0.47*0.67*.808) / 3.4))[58]. The cooling savings are only added to the summer peak savings.
$WHF_e$ = Waste heat factor for energy to account for cooling savings from efficient lighting. For prescriptive lighting in existing buildings, the default value is 1.033 (calculated as 1 +

[56] 2005 TAG agreement.
[57] Based on the following assumptions: 3.1 COP typical cooling system efficiency for existing buildings; average 47% of spaces have mechanical cooling; 33% average outside air; and 80.8% coincidence of cooling with the summer peak period. See WasteHeatAdjustment.doc for additional discussion.
[58] Based on the same assumptions used for existing buildings, except 3.4 COP typical cooling system efficiency for new buildings. See WasteHeatAdjustment.doc for additional discussion.

((0.47*0.29*.75) / 3.1)) [59]. For prescriptive lighting in new buildings, the value is 1.030 (calculated as 1 + ((0.47*0.29*.75) / 3.4))[60].

$\Delta$kW = gross customer connected load kW savings for the measure. This number represents the maximum summer kW savings – including the reduced cooling load from the more efficient lighting.

**Waste Heat Adjustment**

Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF). See above.

**Heating Increased Usage**

$\Delta MMBTU_{WH}$ = $(\Delta kWh / WHF_e) \times 0.003413 \times (1 - OA) \times AR \times HF \times DFH / HEff$

Where:

| | |
|---|---|
| $\Delta MMBTU_{WH}$ | = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat. |
| 0.003413 | = Conversion from kWh to MMBTU |
| OA | = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[61]. |
| AR | = Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of commercial buildings within 15 feet of exterior wall. |
| HF | = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont[62] |
| DFH | = Percent of lighting in heated spaces. For prescriptive lighting, assumed to be 95% |
| HEff | = Average heating system efficiency, For prescriptive lighting, assumed to be 79% in existing buildings and 83 % in new Construction[63]. |

Oil heating is assumed typical for commercial buildings.

**Baseline Efficiencies – New or Replacement**

Refer to the table titled CFL Fixture Saved Wattage for lighting baseline efficiencies and savings.

**Baseline Adjustment**

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescent will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become EISA qualified incandescent or Halogen bulbs.

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012, 2013 or 2014 depending on the assumed baseline wattage (note if a mix of bulbs is assumed, the adjustment always occurs in 2012).
The appropriate adjustments are provided below (see 2012 EISA Adjustment Calculations.xls for details):

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[59] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 25% average outside air; and 29% of annual lighting energy contributes to cooling load. See "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993 and WasteHeatAdjustment.doc for additional discussion.

[60] Based on the same assumptions used for existing buildings, except 3.4 COP typical cooling system efficiency for new buildings. See WasteHeatAdjustment.doc for additional discussion.

[61] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

[62] From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993.

[63] See WasteHeatAdjustment.doc.

| Measure | Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|---|
| CFL fixture -- 1 lamp < 20 W total | 2012 | 0.66 | 2 |
| | 2013 | 0.72 | 1 |
| | 2014 | 0.85 | 1 |
| CFL fixture -- 1 lamp >= 20 W total | 2012 | 0.73 | 1 |
| | 2013 | 0.86 | 1 |
| | 2014 | 0.91 | 1 |
| CFL fixture – 2 lamp >= 20 W total | 2012 | 0.64 | 2 |
| | 2013 | 0.71 | 1 |
| | 2014 | 0.84 | 1 |

**High Efficiency**
Refer to the table titled CFL Fixture Saved Wattage for efficient lighting wattage and savings.

**Operating Hours**
The lighting operating hours are collected from the prescriptive application form. If not available, then assume hours per year from the table titled Lighting Operating Hours by Building Type.

**Loadshape**
Loadshape # 12 (Commercial Indoor Lighting-Blended) for demand and lighting energy savings and #15 (Commercial A/C) for cooling energy savings.

**Freeridership/Spillover Factors**

| **Measure Category** | | **Lighting Hardwired Fixture** | | | | | |
|---|---|---|---|---|---|---|---|
| **Measure Code** | | LFHCNFIX | | | | | |
| **Product Description** | | **Compact Fluorescent Interior Fixture** | | | | | |
| | | **2012** | | **2013** | | **2014** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** | **Freerider** | **Spillover** | **Freerider** | **Spillover** |
| C&I Retrofit | 6012CNIR | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |
| Farm Retrofit | 6012FARM | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |
| Cust Equip Rpl | 6013CUST | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |
| Farm Equip Rpl | 6013FARM | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |
| Farm Rx | 6013FRMP | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |
| Pres Equip Rpl | 6013PRES | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |
| C&I Upstream | 6013UPST | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |
| Act250 NC | 6014A250 | 0.95 | 1.05 | 0.95 | 1.05 | 0.95 | 1.05 |
| Farm NC | 6014FARM | 1.00 | 1.05 | 1.00 | 1.05 | 1.00 | 1.05 |
| Non Act 250 NC | 6014NANC | 0.95 | 1.05 | 0.95 | 1.05 | 0.95 | 1.05 |
| C&I Lplus | 6021LPLU | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |
| LIMF Lplus | 6052LPLU | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |
| MFMR Lplus | 6053LPLU | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |

Note: FR/SP values for 6014 are subject to 2011 TAG CBES discussion.

**Lifetime**
CFL fixture lifetime is 15 years.
Note: a provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore the analysis period (i.e. the life of the savings) is reduced to the number of years remaining to 2020. So for installations in 2012, the measure life is 8 years, for 2013 7 years.

**Incremental Cost**
1-lamp CFL fixture -- $35
2-lamp CFL fixture -- $40
Dimming CFL fixture -- $55

**Operation and Maintenance Savings**
Because compact fluorescent lamps last much longer than incandescent bulbs, CFLs offer significant operation and maintenance (O&M) savings over the life of the fixture for avoided incandescent lamps and the labor to install them. The following assumptions are used to calculate the O&M savings:
Incandescent bulb cost: $0.50 per bulb
Life of incandescent bulb: 1000 hours
Labor cost to replace any kind of lamp: $2.67 per lamp (8 minutes at $20/hour)
EISA qualified bulb cost: $1.50 per bulb
Life of EISA qualified bulb: 1000 hours
CFL lamp cost: $2.5 per lamp
Life of CFL lamp: 12,000 hours
CFL ballast replacement cost: $19 ($14 ballast, $5 labor)
Life of CFL ballast: 40,000 hours

The O&M calculation results in a levelized annual baseline replacement cost as presented below (see 2012 EISA Adjustment Calculations.xls for details)[64]:

| Measure | Year Installed | Hour assumption | Annual baseline replacement cost | Annual efficient replacement cost |
|---|---|---|---|---|
| CFL fixture -- 1 lamp < 20 W total | 2012 | 1095 | $4.69 | $0.82 |
| | | 3285 | $14.03 | $2.41 |
| | | 5475 | $23.61 | $5.93 |
| | | 8760 | $37.99 | $11.21 |
| | 2013 | 1095 | $4.98 | $0.92 |
| | | 3285 | $14.74 | $2.72 |
| | | 5475 | $24.81 | $6.68 |
| | | 8760 | $39.93 | $12.63 |
| | 2014 | 1095 | $5.16 | $1.06 |
| | | 3285 | $15.48 | $3.13 |
| | | 5475 | $26.21 | $7.68 |
| | | 8760 | $42.31 | $14.53 |
| CFL fixture -- 1 lamp >= 20 W total | 2012 | 1095 | $4.88 | $0.82 |
| | | 3285 | $14.87 | $2.41 |
| | | 5475 | $25.11 | $5.93 |
| | | 8760 | $40.47 | $11.21 |
| | 2013 | 1095 | $5.00 | $0.92 |
| | | 3285 | $15.13 | $2.72 |
| | | 5475 | $25.58 | $6.68 |
| | | 8760 | $41.26 | $12.63 |
| | 2014 | 1095 | $5.16 | $1.06 |

[64] Note: As described above, the measure life is reduced to the number of years remaining until 2020 when the EISA legislation makes the CFL the baseline. The O&M calculation takes the entire stream of replacements for both the baseline and efficient cases over the actual expected lifetime (15 years) and converts to a levelized annual cost over the reduced measure 'savings' lifetime.

| | | | | |
|---|---|---|---|---|
| | | 3285 | $15.48 | $3.13 |
| | | 5475 | $26.21 | $7.68 |
| | | 8760 | $42.31 | $14.53 |
| CFL fixture – 2 lamp >= 20 W total | 2012 | 1095 | $9.38 | $0.79 |
| | | 3285 | $14.17 | $2.35 |
| | | 5475 | $24.08 | $5.81 |
| | | 8760 | $38.94 | $11.01 |
| | 2013 | 1095 | $9.96 | $0.89 |
| | | 3285 | $13.35 | $2.65 |
| | | 5475 | $22.76 | $6.55 |
| | | 8760 | $36.87 | $12.41 |
| | 2014 | 1095 | $10.33 | $1.03 |
| | | 3285 | $12.91 | $3.04 |
| | | 5475 | $21.65 | $7.53 |
| | | 8760 | $34.76 | $14.27 |

This adjustment will be recalculated for subsequent years

**Reference Tables**

**CFL Fixture Saved Wattage ($kW_{saved}$)**

| Lighting Technology | Year | Efficient Wattage | Baseline Wattage | Saved Wattage $kW_{save}$ |
|---|---|---|---|---|
| | | | | |
| **Compact Fluorescent Fixtures** | | | | |
| CFL fixture -- 1 lamp < 20 W total | 2012 | 15 | 58 | 43 |
| | 2013 | 15 | 55 | 40 |
| | 2014 | 15 | 48 | 33 |
| CFL fixture -- 1 lamp >= 20 W total | 2012 | 29 | 90 | 61 |
| | 2013 | 29 | 80 | 51 |
| | 2014 | 29 | 76 | 47 |
| CFL fixture -- 2 lamp >= 20 W total | 2012 | 34 | 116 | 82 |
| | 2013 | 34 | 110 | 76 |
| | 2014 | 34 | 96 | 62 |
| Dimming CFL fixture < 20 W lamp | | 20 | 75 | 55 |
| Dimming CFL fixture >= 20 W lamp | | 25 | 100 | 75 |

Typical efficient wattages for each category based on review of most common wattage fixtures rebated in Efficiency Vermont programs to date, baselines provided by NEEP RLS Study,2011 and assumptions used by NGrid for dimming CFL fixtures.

**Interior Lighting Operating Hours by Building Type**

| Building Type | Annual Hours |
|---|---|
| Grocery/Convenience Store | 6,019 |
| Hospital | 4,007 |
| K-12 Schools | 2,456 |
| Lodging/Hospitality | 4,808 |
| Manufacturing | 4,781 |

| | |
|---|---|
| Office | 3,642 |
| Public Assembly | 3,035 |
| Public Safety | 3,116 |
| Religious | 2,648 |
| Restaurant | 4,089 |
| Retail | 4,103 |
| Service | 3,521 |
| University/College | 3,416 |
| Warehouse | 4,009 |
| From C&I Lighting Load Shape Project FINAL Report, July 19, 2011, prepared by KEMA for NEEP. See document NEEP CI Lighting LS FINAL Report_ver 5_7-19-11.pdf | |

# Lighting Controls

Measure Number: I-C-5-k (Business Energy Services)

**Version Date & Revision History**
Draft date: Portfolio 86
Effective date: 1/1/2014
End date: TBD

**Referenced Documents:**

1) Lighting Controls TRM Reference 2014 rev2.xlsx
2) LBNL Lighting Controls in Commercial Buildings 2012.pdf
3) KEMA Lighting Controls Summary of Findings.pdf
4) WasteHeatAdjustment.doc
5) "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993.
6) NEEP CI Lighting LS FINAL Report_ver 5_7-19-11.pdf

**Description**
Controls for interior & exterior lighting, including occupancy sensors and daylight sensors.

**Algorithms**
**Energy Savings**
$\Delta kWh = kW_{connected} \times HOURS \times SVG \times OTF \times ISR \times WHF_e$

**Demand Savings**
$\Delta kW = kW_{connected} \times SVG \times OTF \times ISR \times WHF_d$

Where:

$\Delta kWh$ = gross customer annual kWh savings for the measure (includes the reduced cooling load from the more efficient lighting)

HOURS = annual lighting hours of use per year; refer to table by building type

$WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting. For prescriptive lighting in existing buildings, the default value is 1.082 (calculated as 1 + (0.47*0.67*.808) / 3.1))[65]. For prescriptive lighting in new buildings, the value is 1.084 (calculated as 1 + (0.47*0.67*.808) / 3.4))[66]. The cooling savings are only added to the summer peak savings. For refrigerated case lighting, the value is 1.29 (calculated as (1 + (1.0 / 3.5))). Based on the assumption that all lighting in refrigerated cases is mechanically cooled, with a typical 3.5[67] COP refrigeration system efficiency, and assuming 100% of lighting heat needs to be mechanically cooled at time of summer peak. For freezer case lighting, the value is 1.50 (calculated as (1 + (1.0 / 2.0))). Based on the assumption that all lighting in freezer cases is mechanically cooled, with a typical 2.0 COP[68] freezer system efficiency, and assuming 100% of lighting needs to be mechanically cooled at time of summer peak.

$WHF_e$ = Waste heat factor for energy to account for cooling savings from efficient lighting. For prescriptive lighting in existing buildings, the default value is 1.033

[65] Based on the following assumptions: 3.1 COP typical cooling system efficiency for existing buildings; average 47% of spaces have mechanical cooling; 33% average outside air; and 80.8% coincidence of cooling with the summer peak period. See WasteHeatAdjustment.doc for additional discussion.
[66] Based on the same assumptions used for existing buildings, except 3.4 COP typical cooling system efficiency for new buildings. See WasteHeatAdjustment.doc for additional discussion.
[67] Assumes 3.5 COP for medium temp cases based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of 20°F and a condensing temperature of 90°F.
[68] Assumes 2.0 COP for low temp cases based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of -20°F and a condensing temperature of 90°F.

(calculated as 1 + ((0.47*0.29*.75) / 3.1)) [69]. For prescriptive lighting in new buildings, the value is 1.030 (calculated as 1 + ((0.47*0.29*.75) / 3.4))[70]. For refrigerated case lighting, the value is 1.29 (calculated as (1 + (1.0 / 3.5))). Based on the assumption that all lighting in refrigerated cases is mechanically cooled, with a typical 3.5[132] COP refrigeration system efficiency, and assuming 100% of lighting heat needs to be mechanically cooled at time of summer peak. For freezer case lighting, the value is 1.50 (calculated as (1 + (1.0 / 2.0))). Based on the assumption that all lighting in freezer cases is mechanically cooled, with a typical 2.0 COP[133] freezer system efficiency, and assuming 100% of lighting needs to be mechanically cooled at time of summer peak.

SVG = % of annual lighting energy saved by lighting control; determined on a site-specific basis or refer to table by control type

OTF = Operational Testing Factor. OTF = 1.0 for all occupancy sensors and for daylight dimming controls when the project undergoes Operational Testing or commissioning services, 0.80 for daylight dimming controls otherwise.

ISR = In service rate, or the percentage of units rebated that actually get used. For prescriptive measures, this is assumed to be 98%.[71]

$kW_{connected}$ = kW lighting load connected to control. For multi-level and perimeter switching in the Comprehensive Track the savings is applied to all interior lighting kW load.

$\Delta kW$ = gross customer connected load kW savings for the measure. This number represents the maximum summer kW savings – including the reduced cooling load from the more efficient lighting.

**Waste Heat Adjustment**

Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF). See above.

**Heating Increased Usage**

$$\Delta MMBTU_{WH} = (\Delta kWh / WHF_e) \times 0.003413 \times (1 - OA) \times AR \times HF \times DFH / HEff$$

Where:

$\Delta MMBTU_{WH}$ = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.

0.003413 = Conversion from kWh to MMBTU

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[72].

AR = Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of commercial buildings within 15 feet of exterior wall.

HF = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont[73]

DFH = Percent of lighting in heated spaces. For prescriptive lighting, assumed to be 95%

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[69] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 25% average outside air; and 29% of annual lighting energy contributes to cooling load. See “Calculating lighting and HVAC interactions”, Table 1, ASHRAE Journal November 1993 and WasteHeatAdjustment.doc for additional discussion.

[70] Based on the same assumptions used for existing buildings, except 3.4 COP typical cooling system efficiency for new buildings. See WasteHeatAdjustment.doc for additional discussion.

[71] 2005 TAG agreement.

[72] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

[73] From “Calculating lighting and HVAC interactions”, Table 1, ASHRAE Journal November 1993.

HEff = Average heating system efficiency. For prescriptive lighting assumed to be 79% in existing buildings and 83 % in new Construction[74].

Oil heating is assumed typical for commercial buildings.

**Baseline Efficiencies – New or Replacement**
This TRM applies only to Prescriptive Projects, or those projects less than 10,000 Square Feet and less than 250 rebate-eligible items, by agreement with DPS. Analysis of Occupancy Sensors and Daylight Dimming on custom projects will be calculated on a custom basis using the actual site conditions.

**High Efficiency**
Controlled lighting such as occupancy sensors and daylight dimming.

**Operating Hours**
The lighting operating hours are collected from the prescriptive application form. If not available, then assume hours per year from the table titled Lighting Operating Hours by Building Type.

**Loadshape**
Loadshape # 12 (Commercial Indoor Lighting-Blended) for demand and lighting energy savings and #15 (Commercial A/C) for cooling energy savings.

**Freeridership/Spillover Factors**

| Measure Category | | Lighting Efficiency/Controls | | Lighting Efficiency/Controls | |
|---|---|---|---|---|---|
| Measure Code | | LECOCCUP<br>LECOCCEX<br>LECOCCRE<br>LECOCCFR<br>LECOCCDL | | LECDAYLT | |
| Product Description | | Interior Occupancy Sensors, Exterior Occupancy Sensors, Refrigerator/Freezer Case Controls, Dual Occupancy & Daylight | | Daylighting | |
| Track Name | Track No. | Free-rider | Spill-over | Free-rider | Spill-over |
| C&I Retrofit | 6012CNIR | 0.89 | 1 | 0.89 | 1 |
| Cust Equip Rpl | 6013CUST | 0.97 | 1 | 0.97 | 1 |
| Pres Equip Rpl | 6013PRES | 0.98 | 1 | 0.98 | 1 |
| Act250 NC | 6014A250 | 0.95 | 1.05 | .095 | 1.05 |
| Non Act 250 NC | 6014NANC | 0.95 | 1.05 | 0.95 | 1.05 |

**Incremental Cost**

| Lighting Control Type | Location | Incremental Cost |
|---|---|---|
| Wall Switch Occupancy Sensor | Interior | $55 |
| Fixture-Mounted Occupancy Sensor | Interior | $67 |
| Remote-Mounted Occupancy Sensor | Interior | $125 |
| Fixture-Mounted Daylight Sensor | Interior | $50 |
| Remote-Mounted Daylight Sensor | Interior | $65 |
| Fixture-Mounted Dual Occupancy & Daylight Sensor | Interior | $100 |

[74] See WasteHeatAdjustment.doc.

| | | |
|---|---|---|
| Refrigerator Case Occupancy Sensor | Interior | $60 |
| Freezer Case Occupancy Sensor | Interior | $60 |
| Exterior Occupancy Sensor | Exterior | $82 |

See Lighting Controls TRM Reference 2014 rev2.xlsx for more information.

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
Controls – 10 years. Analysis period is the same as the lifetime.

**Reference Tables**

| Lighting Control Type | Measure Code | Location | % Savings (SVG) |
|---|---|---|---|
| Wall Switch Occupancy Sensor | LECOCCUP | Interior | 24% |
| Fixture-Mounted Occupancy Sensor | LECOCCUP | Interior | 24% |
| Remote-Mounted Occupancy Sensor | LECOCCUP | Interior | 24% |
| Fixture-Mounted Daylight Sensor | LECDAYLT | Interior | 28% |
| Remote-Mounted Daylight Sensor | LECDAYLT | Interior | 28% |
| Fixture-Mounted Dual Occupancy & Daylight Sensor | LECOCCDL | Interior | 38% |
| Refrigerator Case Occupancy Sensor | LECOCCRE | Interior | 40% |
| Freezer Case Occupancy Sensor | LECOCCFR | Interior | 40% |
| Exterior Occupancy Sensor | LECOCCEX | Exterior | 41% |

See Lighting Controls TRM Reference 2014 rev2.xlsx for more information.

| Lighting Control Type | Default Controlled Wattage | Wattage Unit |
|---|---|---|
| Wall Switch Occupancy Sensor | 305 | per control |
| Fixture-Mounted Occupancy Sensor | 180 | per fixture |
| Remote-Mounted Occupancy Sensor | 517 | per control |
| Fixture-Mounted Daylight Sensor | 94 | per fixture |
| Remote-Mounted Daylight Sensor | 269 | per control |
| Fixture-Mounted Dual Occupancy & Daylight Sensor | 168 | per control |
| Refrigerator Case Occupancy Sensor | 184 | per control |
| Freezer Case Occupancy Sensor | 184 | per control |
| Exterior Occupancy Sensor | 76 | per fixture |

See Lighting Controls TRM Reference 2014 rev2.xlsx for more information.

**Lighting Operating Hours by Building Type**

| Building Type | Annual Hours |
|---|---|
| Grocery/Convenience Store | 6,019 |

| | |
|---|---|
| Hospital | 4,007 |
| K-12 Schools | 2,456 |
| Lodging/Hospitality | 4,808 |
| Manufacturing | 4,781 |
| Office | 3,642 |
| Public Assembly | 3,035 |
| Public Safety | 3,116 |
| Religious | 2,648 |
| Restaurant | 4,089 |
| Retail | 4,103 |
| Service | 3,521 |
| University/College | 3,416 |
| Warehouse | 4,009 |
| Exterior | 3,338 |
| From C&I Lighting Load Shape Project FINAL Report, July 19, 2011, prepared by KEMA for NEEP. See document NEEP CI Lighting LS FINAL Report_ver 5_7-19-11.pdf. Exterior Lighting hours based on estimated mix of photocell-controlled lighting (12 hpd) and switch-controlled lighting. | |

# CFL Screw-in

Measure Number: I-C-8-f (Business Energy Services, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 76
Effective date: 1/1/2012
End date: 12/31/2014

**Referenced Documents:**

1) "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993.
2) Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)
3) 2012 EISA Adjustment Calculations.xls
4) NEEP CI Lighting LS FINAL Report_ver 5_7-19-11.pdf

**Description**
An existing incandescent light bulb is replaced with a lower wattage compact fluorescent lamp. This is a retrofit measure.

**Algorithms**
**Demand Savings**

$\Delta kW = ((\Delta Watts) / 1000) \times ISR \times WHF_d$

| Year | Algorithm | ΔkW |
|---|---|---|
| 2012 | (49.0 / 1000) * 0.9 * 1.082 | 0.0477 |
| 2013 | (43.6 / 1000) * 0.9 * 1.082 | 0.0425 |
| 2014 | (37.0 / 1000) * 0.9 * 1.082 | 0.0360 |

**Energy Savings**

$\Delta kWh = ((\Delta Watts) / 1000) \times HOURS \times ISR \times WHF_e$

Where:

$\Delta kWh$ = gross customer annual kWh savings for the measure
$\Delta kW$ = average kilowattage reduction
$\Delta Watts$ = $Watts_{BASE} - Watts_{EE}$[75]
HOURS = average hours of use per year (see table below)
ISR = In service rate, or the percentage of units rebated that actually get used. For prescriptive measures, this is assumed to be 90%.[76]
$WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting. For prescriptive lighting in existing buildings, the default value is 1.082 (calculated as 1 + (0.47*0.67*.808) / 3.1))[77]. For prescriptive lighting in new buildings, the value is 1.084 (calculated as 1 + (0.47*0.67*.808) / 3.4))[78]. The cooling savings are only added to the summer peak savings.
$WHF_e$ = Waste heat factor for energy to account for cooling savings from efficient lighting. For prescriptive lighting in existing buildings, the default value is 1.033 (calculated as 1 + ((0.47*0.29*.75) / 3.1)) [79]. For prescriptive lighting in new buildings, the value is 1.030 (calculated as 1 + ((0.47*0.29*.75) / 3.4))[80].

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75 Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011
76 2005 TAG agreement.
77 Based on the following assumptions: 3.1 COP typical cooling system efficiency for existing buildings; average 47% of spaces have mechanical cooling; 33% average outside air; and 80.8% coincidence of cooling with the summer peak period. See WasteHeatAdjustment.doc for additional discussion.
78 Based on the same assumptions used for existing buildings, except 3.4 COP typical cooling system efficiency for new buildings. See WasteHeatAdjustment.doc for additional discussion.
79 Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 25% average outside air; and 29% of annual lighting energy contributes to cooling load. See

**Waste Heat Adjustment**
Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF). See above.

**Heating Increased Usage**

$\Delta MMBTU_{WH}$ = $(\Delta kWh / WHF_e) \times 0.003413 \times (1 - OA) \times AR \times HF \times DFH / HEff$

Where:

| | |
|---|---|
| $\Delta MMBTU_{WH}$ | = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat. |
| 0.003413 | = Conversion from kWh to MMBTU |
| OA | = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[81]. |
| AR | = Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of commercial buildings within 15 feet of exterior wall. |
| HF | = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont[82] |
| DFH | = Percent of lighting in heated spaces. For prescriptive lighting, assumed to be 95% |
| HEff | = Average heating system efficiency, For prescriptive lighting, assumed to be 79% in existing buildings and 83 % in new Construction[83]. |

Oil heating is assumed typical for commercial buildings.

**Operating Hours**
Operating hours will be collected from the prescriptive application form or from the table of hours by building type located in the reference tables section of this document.

**Baseline Efficiencies – New or Replacement**
The baseline condition is an incandescent light bulb.

**Baseline Adjustment**
In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become EISA qualified incandescent or Halogen bulbs. To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012, 2013 or 2014 depending on the assumed baseline wattage (note if a mix of bulbs is assumed, the adjustment always occurs in 2012).The appropriate adjustments are provided below (see 2012 EISA Adjustment Calculations.xls for details):

"Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993 and WasteHeatAdjustment.doc for additional discussion.
[80] Based on the same assumptions used for existing buildings, except 3.4 COP typical cooling system efficiency for new buildings. See WasteHeatAdjustment.doc for additional discussion.
[81] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."
[82] From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993.
[83] See WasteHeatAdjustment.doc.

| Measure | Year Installed | Hours assumption | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|---|---|
| CFL Screw In, C&I | 2012 | 1095 | $4.01 | 2 |
| | | 3285 | $12.48 | 1 |
| | | 5475 | $19.52 | 1 |
| | | 8760 | $45.65 | 1 |
| | 2013 | 1095 | $4.09 | 1 |
| | | 3285 | $13.06 | 1 |
| | | 5475 | $21.20 | 1 |
| | | 8760 | $50.04 | 1 |
| | 2014 | 1095 | $4.34 | 1 |
| | | 3285 | $13.30 | 1 |
| | | 5475 | $21.96 | 1 |
| | | 8760 | $52.13 | 1 |

**High Efficiency**
High efficiency is a compact fluorescent lamp.

**Loadshape**
Loadshape # 12 (Commercial Indoor Lighting-Blended) for demand and lighting energy savings and #15 (Commercial A/C) for cooling energy savings.

**Freeridership/Spillover Factors**

| **Measure Category** | | **Light Bulbs/Lamps** | | | | | |
|---|---|---|---|---|---|---|---|
| **Measure Code** | | **LBLCFBLB** | | | | | |
| **Product Description** | | **Compact Fluorescent screw-base bulbs - Commercial** | | | | | |
| | | **2012** | | **2013** | | **2014** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** | **Freerider** | **Spillover** | **Freerider** | **Spillover** |
| C&I Retrofit | 6012CNIR | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |
| Farm Retrofit | 6012FARM | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |
| Cust Equip Rpl | 6013CUST | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |
| Farm Equip Rpl | 6013FARM | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |
| Farm Rx | 6013FRMP | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |
| Pres Equip Rpl | 6013PRES | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |
| C&I Upstream | 6013UPST | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |
| Act250 NC | 6014A250 | 0.95 | 1.05 | 0.95 | 1.05 | 0.95 | 1.05 |
| Farm NC | 6014FARM | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |
| Non Act 250 NC | 6014NANC | 0.95 | 1.05 | 0.95 | 1.05 | 0.95 | 1.05 |
| C&I Lplus | 6021LPLU | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Cost**
The incremental cost for this measure is as follows

| Year | Measure Cost |
|---|---|
| 2012 | $1.90 |
| 2013 | $1.80 |
| 2014 | $1.50 |

**Lifetimes**
Lifetime is a function of the average hours of use for the lamp. Most CFLs have a *rated* lifetime of 10,000 hours. However, units that are turned on and off more frequently have shorter lives and those that stay on for longer periods of time have longer lives. The table below lists the lifetime based on number of annual hours of operation. Also note: a provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore the analysis period (i.e. the life of the savings) for any measure that lasts beyond 2020 will be reduced to the number of years remaining to 2020. Measures lives for the 4 prescriptive groups are therefore as follows:

| Hour Assumption | Rated life assumption | Savings Life for 2012 measures | Savings Life for 2013 measures | Savings Life for 2014 measures |
|---|---|---|---|---|
| 1095 | 7000 | 6.4 | 6.4 | 6 |
| 3285 | 12000 | 3.7 | 3.7 | 3.7 |
| 5475 | 12000 | 2.2 | 2.2 | 2.2 |
| 8760 | 12000 | 1.4 | 1.4 | 1.4 |

**Annual Operations and Maintenance Savings**
Because compact fluorescent lamps last much longer than incandescent bulbs, CFLs offer significant operation and maintenance (O&M) savings over the life of the fixture for avoided incandescent lamps and the labor to install them. The following assumptions are used to calculate the O&M savings:
Incandescent bulb cost: $0.50 per bulb
Life of incandescent bulb: 1000 hours
Labor cost to replace any kind of lamp: $2.67 per lamp (8 minutes at $20/hour)
EISA qualified bulb cost: $1.50 per bulb
Life of EISA qualified bulb: 1000 hours
CFL lamp cost: $2.5 per lamp
Life of CFL lamp: 12,000 hours

The O&M calculation results in a levelized annual baseline replacement cost as presented below (see EISA Adjustment Calculations.xls for details):

| Measure | Year Installed | Hour Assumption | Annual baseline replacement cost |
|---|---|---|---|
| CFL Screw In, C&I | 2012 | 1095 | $4.15 |
| | | 3285 | $12.90 |
| | | 5475 | $20.16 |
| | | 8760 | $46.81 |
| | 2013 | 1095 | $4.24 |
| | | 3285 | $13.55 |
| | | 5475 | $21.99 |
| | | 8760 | $51.52 |
| | 2014 | 1095 | $4.48 |
| | | 3285 | $13.82 |
| | | 5475 | $22.83 |
| | | 8760 | $53.80 |

This adjustment will be recalculated for subsequent years

| Low range hours/yr | High range hours/yr | Lamp Lifetime Hours |
|---|---|---|
| 0.0 | 729.9 | 3000 |
| 730.0 | 912.4 | 5000 |
| 912.5 | 1,094.9 | 6000 |

| | | |
|---|---|---|
| 1,095.0 | 1,277.4 | 7000 |
| 1,277.5 | 1,459.9 | 8000 |
| 1,460.0 | 1,824.9 | 9000 |
| 1,825.0 | 2,189.9 | 9500 |
| 2,190.0 | 2,919.9 | 10000 |
| 2,920.0 | 8,760.0 | 12000 |

**Interior Lighting Operating Hours by Building Type**

| **Building Type** | **Annual Hours** |
|---|---|
| Grocery/Convenience Store | 6,019 |
| Hospital | 4,007 |
| K-12 Schools | 2,456 |
| Lodging/Hospitality | 4,808 |
| Manufacturing | 4,781 |
| Office | 3,642 |
| Public Assembly | 3,035 |
| Public Safety | 3,116 |
| Religious | 2,648 |
| Restaurant | 4,089 |
| Retail | 4,103 |
| Service | 3,521 |
| University/College | 3,416 |
| Warehouse | 4,009 |
| Exterior | 3,338 |
| From C&I Lighting Load Shape Project FINAL Report, July 19, 2011, prepared by KEMA for NEEP. See document NEEP CI Lighting LS FINAL Report_ver 5_7-19-11.pdf. Exterior Lighting hours based on estimated mix of photocell-controlled lighting (12 hpd) and switch-controlled lighting. | |

# Dairy Farm Hard-Wired Vapor-Proof CFL Fixture with Electronic Ballast

Measure Number: I-C-9-e (Business Energy Services, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 69
Effective date: 1/1/2010
End date: TBD

**Referenced Documents**: DF_SavingsCalcs_4_1_02.xls

**Description**
Hard wired vapor-proof CFL fixtures with electronic ballasts. These are intended for existing construction only. However, it is recognized that some prescriptive measures may be installed in new buildings without EVT's knowledge.

**Algorithms**

**Energy Savings**
$\Delta kWh = 169.4$

**Demand Savings**
$\Delta kW = 0.0632$

Where:

| | |
|---|---|
| $\Delta kWh$ | = gross customer average annual kWh savings for the measure |
| 169.4[84] | = $\Delta kWh$ |
| $\Delta kW$ | = gross customer connected load kW savings for the measure |
| 0.0632[85] | = $\Delta kW$ |

**Waste Heat Adjustment**
Assumed to be 0% as most dairy farm lighting applications are in unconditioned space.

**Baseline Efficiencies**
Incandescent fixtures of various wattages.

**Baseline Adjustment**
In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become EISA qualified incandescent or Halogen bulbs.

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012, 2013 or 2014 depending on the assumed baseline wattage (note if a mix of bulbs is assumed, the adjustment always occurs in 2012).
The appropriate adjustments are provided below (see EISA Adjustment Calculations.xls for details):

| Measure | Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|---|

[84] Energy savings based on actual Efficiency Vermont Dairy Farm program data March 2000 – December 19, 2001 (see referenced document: DF_SavingsCalcs_4_1_02.xls). Program data used to determine average energy savings per measure.
[85] $\Delta kW$ determined by $\Delta kWh$ / Operating Hours

| | | | |
|---|---|---|---|
| Dairy Farm Hard-Wired Vapor-Proof | 2010 | 0.62 | 2 |
| CFL Fixture with Electronic Ballast | 2011 | 0.65 | 1 |

**High Efficiency**
Hard wired vapor-proof CFL fixtures with electronic ballasts.

**Operating Hours**
2679[86] hours / year

**Loadshape**
Loadshape #24, Dairy Farm Combined End Uses

**Freeridership/Spillover Factors**

| Measure Category | | Lighting Hardwired Fixture | |
|---|---|---|---|
| Measure Code | | LFHCFFIX | |
| Product Description | | Compact Fluorescent farm fixture | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | 0.95 | 1.00 |
| Cust Equip Rpl | 6013CUST | 0.89 | 1.05 |
| Farm Equip Rpl | 6013FARM | 1 | 1.00 |
| Pres Equip Rpl | 6013PRES | 0.90 | 1.05 |
| C&I Retro | 6012CNIR | 0.89 | 1.05 |

**Persistence**
Persistence is assumed to be 67% based on agreement between DPS and EVT.

**Lifetimes**
Engineering measure life: Hard wired CFL Fixtures – 15 years.
Measure life, adjusted for persistence: 10 years.
Note: a provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore the analysis period (i.e. the life of the savings) is reduced to the number of years remaining to 2020. So for installations in 2010, the measure life is 10 years, for 2011 9 years.

**Measure Cost**
The incremental cost for this measure is $70.

**Annual Operations and Maintenance Savings**
Because compact fluorescent lamps last much longer than incandescent bulbs, CFLs offer significant operation and maintenance (O&M) savings over the life of the fixture for avoided incandescent lamps and the labor to install them. The following assumptions are used to calculate the O&M savings:
Incandescent bulb cost: $0.50 per bulb
Life of incandescent bulb: 1000 hours

[86] Operating hours consistent with Dairy Farm Combined End-Use loadshape from Vermont State Screening Tool (Loadshape #24).

Labor cost to replace any kind of lamp: $2.67 per lamp (8 minutes at $20/hour)
EISA qualified bulb cost: $2.00 per bulb
Life of EISA qualified bulb: 3000 hours
CFL lamp cost: $3 per lamp
Life of CFL lamp: 12,000 hours
CFL ballast replacement cost: $19 ($14 ballast, $5 labor)
Life of CFL ballast: 40,000 hours

The O&M calculation results in a levelized annual baseline replacement cost as presented below (see EISA Adjustment Calculations.xls for details) [87]:

| Measure | Year Installed | Annual baseline replacement cost | Annual efficient replacement cost |
|---|---|---|---|
| Dairy Farm Hard-Wired Vapor-Proof | 2010 | $6.14 | $0.81 |
| CFL Fixture with Electronic Ballast | 2011 | $5.86 | $0.89 |

This adjustment will be recalculated for subsequent years

**Fossil Fuel Descriptions**
There are no fossil-fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

[87] Note: As described above, the measure life is reduced to the number of years remaining until 2020 when the EISA legislation makes the CFL the baseline. The O&M calculation takes the entire stream of replacements for both the baseline and efficient cases over the actual expected lifetime (10 years) and converts to a levelized annual cost over the reduced measure 'savings' lifetime.

# Agricultural Vapor Proof HPT8/T5HO Fixtures

Measure Number: I-C-10-f (Business Energy Services, Lighting End Use)

**Version Date & Revision History:**
Draft date: Portfolio 75
Effective date: 01/01/2011
End Date: TBD

**Referenced Documents:** AgLighting_Calculations.xlsx

**Description**
Vapor-proof T8/T5HO fixtures meeting National Electric Code Article 547-6 rating for agricultural buildings. These fixtures are typically installed in both free-stall and tie-stall barns in place of incandescent, T8 or metal-halide fixtures.

**Algorithms**

**Demand Savings**
$\Delta kW = (Watts_{BASE} - Watts_{EE}) / 1000)$

**Energy Savings**
$\Delta kWh = \Delta kW \text{ x hours}$

Where:

| | |
|---|---|
| $\Delta kW$ | = Instantaneous demand savings |
| $\Delta kWh$ | = Gross customer average annual kWh savings for the measure |
| $Watts_{BASE}$ | = Wattage of baseline equipment |
| $Watts_{EE}$ | = Wattage of efficient equipment |
| hours | = Annual hours of operation as reported by customer. If not reported, assumed to be 3,847 hours/year for dairy farm operations (see “Operating Hours” section, below). |

**Waste Heat Adjustment**
Assumed to be 0% as most lighting applications are in unconditioned space

**Baseline Efficiencies**
Baseline represents a blend of T8, EISA qualified and EISA compliant incandescent,or pulse start metal-halide fixtures. See reference table below.

**High Efficiency**
Vapor-proof T8/T5 fixtures meeting National Electric Code Article 547-6 rating for agricultural buildings.

**Operating Hours**
3,847[88] hours / year

**Rating Period & Coincidence Factors**
Loadshape #24, Dairy Farm Combined End Uses

**Freeridership/Spillover Factors[89]**

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[88] Operating hours derived from daily hour reports provided on EVT prescriptive rebate forms in 2011, see AgLightingCalculations.xlsx

| Measure Category | | Lighting Hardwired Fixture | |
|---|---|---|---|
| **Measure Code** | | LFHST8VP<br>LFHST5VP | |
| **Product Description** | | Vapor-proof Fluorescent HPT8/T5 fixture | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | 1.00 | 1.00 |
| Farm Rx | 6013FRMP | 1.00 | 1.00 |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | 1.00 | 1.00 |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
Persistence is assumed to be one.

**Lifetimes**
HPT8/T5 fixtures – 15 years.
Analysis period is the same as the lifetime.

**Measure Cost**
See reference table below.

**O&M Cost Adjustments**
See reference table below.

[89] Freeridership from TRM for dairy farm retrofit measures, as agreed to between the DPS and EVT.

**Fossil Fuel Descriptions**
There are no fossil-fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

High Efficiency Agricultural Vapor Proof High-Performance T8 and T5 Fixtures Reference Table:

| Efficient Technology | Watts | Baseline Technology[90] | Watts[91] | Watts Saved | Blended Measure Cost[92] |
|---|---|---|---|---|---|
| 1 Lamp High-Performance T8 Vapor-Proof | 25 | 25% 73 Watt EISA Inc, 75% 1L T8 | 42 | 17 | $96.00 |
| 2 Lamp High-Performance T8 Vapor-Proof | 48 | 25% 146 Watt EISA Inc, 75% 2L T8 | 81 | 33 | $102.31 |
| 3 Lamp High-Performance T8 Vapor-Proof | 72 | 25% 217 Watt EISA Inc, 75% 3L T8 | 121 | 49 | $108.35 |
| 4 Lamp High-Performance T8 Vapor-Proof | 94 | 25% 292 Watt EISA Inc, 75% 4L T8 | 159 | 65 | $165.66 |
| 6-Lamp High-Performance T8 Vapor Proof with High-BF Ballast | 206 | 320 Watt Pulse-Start Metal Halide | 365 | 159 | $212.97 |
| 1 Lamp T5 HO Vapor-Proof | 60 | 25% 146 Watt EISA Inc, 75% 2L T8 | 81 | 21 | $107.50 |
| 2 Lamp T5 HO Vapor-Proof | 110 | 25% 292 EISA Watt Inc, 75% 4L T8 | 159 | 49 | $127.15 |
| 3-Lamp T5 HO Vapor Proof | 180 | 200 Watt Pulse-Start Metal Halide | 232 | 52 | $157.00 |
| 4-Lamp T5 HO Vapor Proof | 240 | 320 Watt Pulse-Start Metal Halide | 365 | 125 | $193.12 |
| 6-Lamp T5 HO Vapor Proof | 360 | In proportion to 320 Watt Pulse-Start Metal Halide | 548 | 188 | $208.98 |

**Component Costs and Lifetimes for Computing O&M Savings**

| **Efficient Technologies** | **Lamp Replacement Cost:** | **Life:** | **Ballast Replacement Cost** | **Life** |
|---|---|---|---|---|
| 1-Lamp High-Performance T8 Vapor-Proof | $5.37 | 6.24 | $35.00 | 18.20 |

[90] The assumption for baseline technology is based on estimated distribution of retrofit vs. equipment replacement vs. new construction agricultural lighting projects. It is estimated that 50% of dairy farm lighting projects are retrofits, 40% are equipment replacement, and 10% are new construction. Retrofit projects are assumed to carry a baseline of 50% EISA incandescent and 50% T8. Equipment replacement and new construction carry a baseline of 100% T8. Blending these estimates results in a final baseline assumption of 25% EISA incandescent, 75% T8. Note that higher wattage fixtures typically used in free-stall barns with high-ceilings use a 100% metal-halide baseline as opposed to a mix of EISA incandescent/T8.
[91] Baseline Watts determined assuming average of 25% EISA incandescent and 75% T8.
[92] Measure costs assume blend of 50% retrofit and 50% market opportunity, see AgLighting_Calculations.xlsx

| | | | | |
|---|---|---|---|---|
| 2-Lamp High-Performance T8 Vapor-Proof | $10.74 | 6.24 | $35.00 | 18.20 |
| 3-Lamp High-Performance T8 Vapor-Proof | $16.11 | 6.24 | $35.00 | 18.20 |
| 4-Lamp High-Performance T8 Vapor-Proof | $21.48 | 6.24 | $35.00 | 18.20 |
| 6-Lamp High-Performance T8 Vapor-Proof with High-BF Ballast | $32.22 | 6.24 | $70.00 | 18.20 |
| 1-Lamp T5HO Vapor-Proof | $10.74 | 6.24 | $67.00 | 18.20 |
| 2-Lamp T5HO Vapor-Proof | $21.48 | 6.24 | $67.00 | 18.20 |
| 3-Lamp T5HO Vapor-Proof | $35.92 | 6.24 | $67.00 | 18.20 |
| 4-Lamp T5HO Vapor-Proof | $79.92 | 6.24 | $67.00 | 18.20 |
| 6-Lamp T5HO Vapor-Proof | $119.88 | 6.24 | $134.00 | 18.20 |

| **Baseline Technologies**[93] | **Lamp Replacement Cost**[94] | **Life** | **Ballast Replacement Cost** | **Life** |
|---|---|---|---|---|
| 73 W EISA Incandescent | $4.67 | 0.78 | N/A | N/A |
| 146 W EISA Incandescent | $9.34 | 0.78 | N/A | N/A |
| 219 W EISA Incandescent | $14.01 | 0.78 | N/A | N/A |
| 292 W EISA Incandescent | $18.68 | 0.78 | N/A | N/A |
| 1-Lamp T8 | $5.37 | 5.20 | $35.00 | 18.20 |
| 2-Lamp T8 | $10.74 | 5.20 | $35.00 | 18.20 |
| 3-Lamp T8 | $16.11 | 5.20 | $35.00 | 18.20 |
| 4-Lamp T8 | $21.48 | 5.20 | $35.00 | 18.20 |
| 200 Watt Pulse Start Metal-Halide | $35.92 | 3.12 | $80.50 | 10.40 |
| 320 Watt Pulse Start Metal-Halide | $79.92 | 5.20 | $134.15 | 10.40 |

[93] To account for mix of baselines, EISA Incandescent and T8 baseline replacement costs are be weighted by 25% and 75% respectively, in calculations (see AgLighting_Calculations.xlsx)
[94] All lamp and ballast replacement cost and life data derived from TRM. For summary see AgLighting_Calcluations.xlsx

# High Performance T8 or "HPT8" Fixtures and Lamp/Ballast Systems

Measure Number: I-C-12-i (Business Energy Services, Lighting End Use)

**Version Date & Revision History**
Draft Portfolio: Portfolio 86
Effective date: 1/1/2014
End date: TBD

**Referenced Documents**

1. HPT8-T5 TRM Reference Tables Oct 2014.xlsx
2. WasteHeatAdjustment.doc
3. EVT 2011 TAG T12 Baseline Summary DPS 10-25.doc
4. NEEP CI Lighting LS FINAL Report_ver 5_7-19-11.pdf

**Description**
"High-Performance" T8 or "HPT8" lamp/ballast systems have higher lumens per watt than standard T8 systems. This results in lamp/ballast systems that produce equal or greater light than standard T8 systems, while using fewer watts. When used in a high-bay application, high-performance T8 fixtures can provide equal light to HID High-Bay fixtures, while using fewer watts. Eligible fixtures include new, replacement, or retrofit.

**Algorithms**

**Demand Savings**
$\Delta kW = ((Watts_{BASE} - Watts_{EE}) / 1000) \times ISR \times WHF_d \times BDB$

**Energy Savings**
$\Delta kWh = ((Watts_{BASE} - Watts_{EE}) / 1000) \times HOURS \times ISR \times WHF_e \times BDB$

Where:

$\Delta kW$ = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW from table located in Reference Tables section.
$Watts_{EE}$ = Energy efficient connected kW from table located in Reference Tables section.
ISR = In service rate, or the percentage of units rebated that actually get used. For prescriptive measures, this is assumed to be 98%.[95]
$WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting. For prescriptive lighting in existing buildings, the default value is 1.082 (calculated as 1 + (0.47*0.67*.808) / 3.1))[96]. For prescriptive lighting in new buildings, the value is 1.084 (calculated as 1 + (0.47*0.67*.808) / 3.4))[97]. The cooling savings are only added to the summer peak savings.
$WHF_e$ = Waste heat factor for energy to account for cooling savings from efficient lighting. For prescriptive lighting in existing buildings, the default value is 1.033 (calculated as 1 + ((0.47*0.29*.75) / 3.1)) [98]. For prescriptive lighting

[95] 2005 TAG agreement.
[96] Based on the following assumptions: 3.1 COP typical cooling system efficiency for existing buildings; average 47% of spaces have mechanical cooling; 33% average outside air; and 80.8% coincidence of cooling with the summer peak period. See WasteHeatAdjustment.doc for additional discussion.
[97] Based on the same assumptions used for existing buildings, except 3.4 COP typical cooling system efficiency for new buildings. See WasteHeatAdjustment.doc for additional discussion.
[98] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 25% average outside air; and 29% of annual lighting energy contributes to cooling load. See

in new buildings, the value is 1.030 (calculated as 1 + ((0.47*0.29*.75) / 3.4))[99].

ΔkWh = gross customer annual kWh savings for the measure

HOURS = annual lighting hours of use per year; collected from prescriptive application form. If operating hours are not available, then the value will be selected from the table 'Operating Hours by Building Type' in the reference tables section of this document.

BDB = Bonus Savings from Bi-Level or Dimming Controls. Without controls, the value is one. With controls, the factor is calculated as (1 + ((percent savings) * (percent of time) * ($Watts_{EE}$ ) / ($Watts_{BASE}$ – $Watts_{EE}$ ). The values for each measure are in the table 'T8 New and Baseline Assumptions'.

**Savings Baseline Adjustment**

Due to new federal standards for linear fluorescent lamps, manufacturers of T12 lamps will not be permitted to manufacture most varieties of T12 lamps for sale in the United States after July 2012. All remaining stock and previously manufactured product may be sold after the July 2012 effective date. To account for this new standard, the savings for High-Performance T8 measures incorporating the T12 lamp baseline will be reduced to account for the higher baseline starting in 2014[100]. For measures installed in 2012, the full savings (as calculated above in the Algorithm section) will be claimed for the first two years, and the adjusted savings will be claimed for the remainder of the measure life. The adjustment to be applied for each measure is listed in the reference table 'Savings Adjustment Factors.'

**Waste Heat Adjustment**

Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF).

**Heating Increased Usage**

$\Delta MMBTU_{WH}$ = $(\Delta kWh / WHF_e) \times 0.003413 \times (1 – OA) \times AR \times HF \times DFH / HEff$

Where:

$\Delta MMBTU_{WH}$ = gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.

0.003413 = conversion from kWh to MMBTU

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[101].

AR = Typical aspect ratio factor. ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of building within 15 feet of exterior wall.

HF = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont[102]

DFH = Percent of lighting in heated spaces. For prescriptive lighting, assumed to be 95%

HEff = Average heating system efficiency, For prescriptive lighting, assumed to be 79% in existing buildings and 83 % in new Construction[103].

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"Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993 and WasteHeatAdjustment.doc for additional discussion.

[99] Based on the same assumptions used for existing buildings, except 3.4 COP typical cooling system efficiency for new buildings. See WasteHeatAdjustment.doc for additional discussion.

[100] Based on the 2011 EVT/DPS TAG Agreement. See EVT 2011 TAG T12 Baseline Summary DPS 10-25.doc for additional detail.

[101] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

[102] From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993.

[103] See WasteHeatAdjustment.doc.

**Baseline Efficiencies**
Refer to reference table T8 New and Baseline Assumptions (also in 'Reference file: HPT8-T5 TRM Reference Tables Oct 2014.xlsx').

**High Efficiency**
Refer to reference table T8 New and Baseline Assumptions (also in 'Reference file: HPT8-T5 TRM Reference Tables Oct 2014.xlsx').

**Operating Hours**
Operating hours will be collected from the prescriptive application form or from the table of hours by building type located in the reference tables section of this document..

**Loadshape**
# 12 (Commercial Indoor Lighting-Blended) for demand and lighting energy savings and #15 (Commercial A/C) for cooling energy savings

**Freeridership/Spillover Factors**

| Measure Category | | Lighting Hardwired Fixture | | Lighting Hardwired Fixture | | Lighting Hardwired Fixture | |
|---|---|---|---|---|---|---|---|
| Measure Code | | LFHST8TW | | LFHST8HB | | LFH8T8RR | |
| Product Description | | New HPT8 Fixture | | New HPT8 High-Bay | | Relamp/Reballast T8 to HPT8 | |
| Track Name | Track No. | Freerider | Spillover | Freerider | Spillover | Freerider | Spillover |
| Cust Equip Rpl | 6013CUST | 0.99 | 1.15 | 0.95 | 1.05 | 0.99 | 1.15 |
| C&I NC Cust | 6014CUST | 0.95 | 1.05 | 0.95 | 1.05 | 0.95 | 1.05 |
| Pres Equip Rpl | 6013PRES | 1.0 | 1.15 | 0.95 | 1.05 | 1.0 | 1.15 |
| C&I NC Pres | 6014PRES | 0.95 | 1.05 | 0.95 | 1.05 | 0.95 | 1.05 |
| C&I Retro | 6012CNIR | 0.99 | 1.15 | 0.90 | 1.0 | 0.99 | 1.15 |

Freerider rates are shown below to account for the new federal standard for linear fluorescent lamps[104]. These rates by year apply to all measures using a T12 baseline.

| Measure Category | | Lighting Hardwired Fixture | |
|---|---|---|---|
| Measure Code | | LFHST8RR | |
| Product Description | | Relamp/Reballast T12 to HPT8 | |
| Track Name | Track No. | Freerider | Spillover |
| Cust Equip Rpl | 6013CUST | 0.70 | 1.05 |
| C&I NC Cust | 6014CUST | 0.70 | 1.05 |
| Pres Equip Rpl | 6013PRES | 0.70 | 1.05 |
| C&I NC Pres | 6014PRES | 0.70 | 1.05 |
| C&I Retro | 6012CNIR | 0.70 | 1.05 |

**Persistence**
The persistence factor is assumed to be one for all measures.

**Lifetimes**
15 years
Analysis period is the same as lifetime.

[104] Based on the 2011 EVT/DPS TAG Agreement. See EVT 2011 TAG T12 Baseline Summary DPS 10-25.doc for additional detail.

**Measure Cost**
Refer to reference table T8 New and Baseline Assumptions (also in 'Reference file: HPT8-T5 TRM Reference Tables Oct 2014.xlsx').

**Component Costs and Lifetimes Used in Computing O&M Savings**
Refer to reference table T8 Component Costs and Lifetimes (also in 'Reference file: HPT8-T5 TRM Reference Tables Oct 2014.xlsx').

**Fossil Fuel Descriptions**
See algorithm in 'Heating Increased Usage'

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

**Interior Lighting Operating Hours by Building Type**

| Building Type | Annual Hours |
|---|---|
| Grocery/Convenience Store | 6,019 |
| Hospital | 4,007 |
| K-12 Schools | 2,456 |
| Lodging/Hospitality | 4,808 |
| Manufacturing | 4,781 |
| Office | 3,642 |
| Public Assembly | 3,035 |
| Public Safety | 3,116 |
| Religious | 2,648 |
| Restaurant | 4,089 |
| Retail | 4,103 |
| Service | 3,521 |
| University/College | 3,416 |
| Warehouse | 4,009 |
| From C&I Lighting Load Shape Project FINAL Report, July 19, 2011, prepared by KEMA for NEEP. See document NEEP CI Lighting LS FINAL Report_ver 5_7-19-11.pdf | |

**Reference file:** HPT8-T5 TRM Reference Tables Oct 2014.xlsx

**New and Baseline Assumptions**

| EE Measure Description | $Watts_{EE}$ | System $Lumens_{EE}$ | Baseline Description | $Watts_{BASE}$ | System $Lumens_{EE}$ | $Watts_{SAVE}$ | Incremental Cost | Bi-Level / Dimming Savings Assumptions | Bi-Level / Dimming Bonus Factor (BDF) | Bi-Level / Dimming Cost | Measure Code |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4-Lamp HPT8 w/ High-BF Ballast High-Bay | 147 | 11,600 | 4-Lamp T8HO High-Bay | 196 | 11,600 | 49 | $75.00 | 50% Power 20% of Time | 1.30 | $40.00 | LFHST8HB |
| 6-Lamp HPT8 w/ High-BF Ballast High-Bay | 220 | 17,500 | 6-Lamp T8HO High-Bay | 294 | 17,400 | 74 | $75.00 | 50% Power 20% of Time | 1.30 | $40.00 | LFHST8HB |
| 8-Lamp HPT8 w/ High-BF Ballast High-Bay | 294 | 23,300 | 8-Lamp T8HO High-Bay | 392 | 23,300 | 98 | $75.00 | 50% Power 20% of Time | 1.30 | $40.00 | LFHST8HB |
| | | | | | | | | | | | |
| 1-Lamp Relamp/Reballast T8 to HPT8 | 25 | | 1-Lamp F32T8 w/ Elec. Ballast | 32 | | 7 | $50.00 | N/A | 1.00 | $40.00 | LFH8T8RR |
| 2-Lamp Relamp/Reballast T8 to HPT8 | 49 | | 2-Lamp F32T8 w/ Elec. Ballast | 59 | | 10 | $55.00 | 50% Power 20% of Time | 1.49 | $40.00 | LFH8T8RR |
| 3-Lamp Relamp/Reballast T8 to HPT8 | 72 | | 3-Lamp F32T8 w/ Elec. Ballast | 88 | | 16 | $60.00 | 67% Power 20% of Time | 1.30 | $40.00 | LFH8T8RR |
| 4-Lamp Relamp/Reballast T8 to HPT8 | 94 | | 4-Lamp F32T8 w/ Elec. Ballast | 114 | | 20 | $65.00 | 50% Power 20% of Time | 1.47 | $40.00 | LFH8T8RR |
| | | | | | | | | | | | |
| 1-Lamp HPT8 Fixture | 25 | | 1-Lamp F32T8 w/ Elec. Ballast | 32 | | 7 | $15.00 | N/A | 1.00 | $40.00 | LFHST8TW |
| 2-Lamp HPT8 Fixture | 49 | | 2-Lamp F32T8 w/ Elec. Ballast | 59 | | 10 | $17.50 | 50% Power 20% of Time | 1.49 | $40.00 | LFHST8TW |
| 3-Lamp HPT8 Fixture | 72 | | 3-Lamp F32T8 w/ Elec. Ballast | 88 | | 16 | $20.00 | 67% Power 20% of Time | 1.30 | $40.00 | LFHST8TW |
| 4-Lamp HPT8 Fixture | 94 | | 4-Lamp F32T8 w/ Elec. Ballast | 114 | | 20 | $22.50 | 50% Power 20% of Time | 1.47 | $40.00 | LFHST8TW |
| | | | | | | | | | | | |
| 2-lamp High-Performance HPT8 Troffer | 49 | | 3-Lamp F32T8 w/ Elec. Ballast | 88 | | 39 | $100.00 | 67% Power 20% of Time | 1.13 | $40.00 | LFHST8HP |

**Savings Adjustment Factors**

| EE Measure Description | Savings Adjustment | Savings Adjustment with Bi-Level/Dimming Bonus |
|---|---|---|
| 1-Lamp Relamp/Reballast T12 to HPT8 | 46.7% | 46.7% |
| 2-Lamp Relamp/Reballast T12 to HPT8 | 52.6% | 62.3% |
| 3-Lamp Relamp/Reballast T12 to HPT8 | 42.1% | 48.5% |
| 4-Lamp Relamp/Reballast T12 to HPT8 | 44.4% | 54.0% |

Savings adjustment factors are applied to the full savings for savings starting in 2014 and for the remainder of the measure life. The savings adjustment is equal to the ratio between savings from T8 baseline and savings from T12 baseline from the table 'T8 New and Baseline Assumptions' within 'Commercial Lighting TRM Reference Tables - 2012.xlsx'

**Reference File:** HPT8-T5 TRM Reference Tables Oct 2014.xlsx

**Component Costs and Lifetimes**

| EE Measure Description | EE Lamp Life (hrs) | Total EE Lamp Replacement Cost | EE Lamp Qty | EE Lamp Cost | EE Ballast Life (hrs) | Total EE Ballast Replacement Cost | EE Ballast Qty | EE Ballast Cost | EE Ballast Rep. Labor Cost | Baseline Description | Base Lamp Life (hrs) | Total Base Lamp Replacement Cost | Base Lamp Qty | Base Lamp Cost | Base Lamp Rep. Labor Cost | Base Ballast Life (hrs) | Total Base Ballast Replacement Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4-Lamp HPT8 w/ High-BF Ballast High-Bay | 30,000 | $46.67 | 4 | $5.00 | 70,000 | $55.00 | 1 | $32.50 | $22.50 | 4-Lamp T8HO High-Bay | 20,000 | $70.67 | 4 | $11.00 | $6.67 | 70,000 | $75.00 |
| 6-Lamp HPT8 w/ High-BF Ballast High-Bay | 30,000 | $70.00 | 6 | $5.00 | 70,000 | $110.00 | 2 | $32.50 | $22.50 | 6-Lamp T8HO High-Bay | 20,000 | $106.00 | 6 | $11.00 | $6.67 | 70,000 | $112.50 |
| 8-Lamp HPT8 w/ High-BF Ballast High-Bay | 30,000 | $93.33 | 8 | $5.00 | 70,000 | $110.00 | 2 | $32.50 | $22.50 | 8-Lamp T8HO High-Bay | 20,000 | $141.33 | 8 | $11.00 | $6.67 | 70,000 | $150.00 |
| | | | | | | | | | | | | | | | | | |
| 1-Lamp Relamp/Reballast T8 to HPT8 | 30,000 | $7.67 | 1 | $5.00 | 70,000 | $47.50 | 1 | $32.50 | $15.00 | 1-Lamp F32T8 w/ Elec. Ballast | 20,000 | $5.17 | 1 | $2.50 | $2.67 | 70,000 | $30.00 |
| 2-Lamp Relamp/Reballast T8 to HPT8 | 30,000 | $15.33 | 2 | $5.00 | 70,000 | $47.50 | 1 | $32.50 | $15.00 | 2-Lamp F32T8 w/ Elec. Ballast | 20,000 | $10.33 | 2 | $2.50 | $2.67 | 70,000 | $30.00 |
| 3-Lamp Relamp/Reballast T8 to HPT8 | 30,000 | $23.00 | 3 | $5.00 | 70,000 | $47.50 | 1 | $32.50 | $15.00 | 3-Lamp F32T8 w/ Elec. Ballast | 20,000 | $15.50 | 3 | $2.50 | $2.67 | 70,000 | $30.00 |
| 4-Lamp Relamp/Reballast T8 to HPT8 | 30,000 | $30.67 | 4 | $5.00 | 70,000 | $47.50 | 1 | $32.50 | $15.00 | 4-Lamp F32T8 w/ Elec. Ballast | 20,000 | $20.67 | 4 | $2.50 | $2.67 | 70,000 | $30.00 |
| | | | | | | | | | | | | | | | | | |
| 1-Lamp HPT8 Fixture | 30,000 | $7.67 | 1 | $5.00 | 70,000 | $47.50 | 1 | $32.50 | $15.00 | 1-Lamp F32T8 w/ Elec. Ballast | 20,000 | $5.17 | 1 | $2.50 | $2.67 | 70,000 | $30.00 |
| 2-Lamp HPT8 Fixture | 30,000 | $15.33 | 2 | $5.00 | 70,000 | $47.50 | 1 | $32.50 | $15.00 | 2-Lamp F32T8 w/ Elec. Ballast | 20,000 | $10.33 | 2 | $2.50 | $2.67 | 70,000 | $30.00 |
| 3-Lamp HPT8 Fixture | 30,000 | $23.00 | 3 | $5.00 | 70,000 | $47.50 | 1 | $32.50 | $15.00 | 3-Lamp F32T8 w/ Elec. Ballast | 20,000 | $15.50 | 3 | $2.50 | $2.67 | 70,000 | $30.00 |
| 4-Lamp HPT8 Fixture | 30,000 | $30.67 | 4 | $5.00 | 70,000 | $47.50 | 1 | $32.50 | $15.00 | 4-Lamp F32T8 w/ Elec. Ballast | 20,000 | $20.67 | 4 | $2.50 | $2.67 | 70,000 | $30.00 |
| | | | | | | | | | | | | | | | | | |
| 2-lamp High-Performance HPT8 Troffer | 30,000 | $15.33 | 2 | $5.00 | 70,000 | $47.50 | 1 | $32.50 | $15.00 | 3-Lamp F32T8 w/ Elec. Ballast | 20,000 | $15.50 | 3 | $2.50 | $2.67 | 70,000 | $30.00 |

# Lighting Power Density

Measure Number: I-C-14-d (Business Energy Services)

**Version Date & Revision History**
Draft date: Portfolio 79
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**
1. 2005 Vermont Guidelines for Energy Efficient Commercial Construction , Table 805.5.2 and 805.5.3.
2. 2011 Vermont Commercial Building Energy Standards, Tables 505.5.2(1-2); 505.6.2(1); 505.6.2(2)

**Description**
Efficient lighting with a reduced wattage compared to the baseline, other than controls. Either the Building Area Method or Space-by-Space Method can be used for calculating the Interior Lighting Power Density in accordance with the applicable version of the Vermont Commercial Building Energy Standards (CBES), although the Space-by-Space Method is preferred. This methodology is generally applied to commercial new construction and remodel or renovation of existing buildings,.

**Algorithms**

**Energy Savings**
$\Delta kWh = kW_{save} \times HOURS \times WHF_e$

**Demand Savings**
$\Delta kW = kW_{save} \times WHF_d$

$kW_{save} = (WSF_{base} - WSF_{effic}) \times SF/1000$

Where:

$\Delta kWh$ = gross customer annual kWh savings for the measure
$kW_{save}$ = lighting connected load kW saved, baseline kW minus efficient kW
HOURS = annual lighting hours of use per year; refer to table by building type if site-specific hours are not available.
$WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting. The default value is 1.160 (calculated as 1 + (0.67*.808) / 3.4)) [105]. The cooling savings are only added to the summer peak savings.
WHFe = Waste heat factor for energy to account for cooling savings from efficient lighting. The default value is 1.064 (calculated as 1 + ((0.29*.75) / 3.4)) [106].
$\Delta kW$ = gross customer connected load kW savings for the measure. This number represents the maximum summer kW savings – including the reduced cooling load from the more efficient lighting.
$WSF_{base}$ = the baseline lighting watts per square foot or linear foot. Refer to the tables listed below under Baselines/Guidelines for Energy Efficient Commercial Construction – Lighting.

[105] Based on the following assumptions: 3.4 COP typical cooling system efficiency for new construction buildings; 33% average outside air; and 80.8% coincidence of cooling with the summer peak period. See WasteHeatAdjustment.doc for additional discussion.
[106] Based on the following assumptions: 3.4 COP typical cooling system efficiency for new construction buildings; 25% average outside air; and 29% of annual lighting energy contributes to cooling load. See "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993 and WasteHeatAdjustment.doc for additional discussion.

| | |
|---|---|
| $WSF_{effic}$ | = the actual installed lighting watts per square foot or linear foot. |
| SF | = Building or space square footage, or linear feet if usage expressed as watts per linear foot. |

**Waste Heat Adjustment**
Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF). See above.

**Heating Increased Usage**

$$\Delta MMBTU_{WH} = (\Delta kWh / WHF_e) \times 0.003413 \times (1 - OA) \times AR \times HF \times DFH / HEff$$

Where:

| | |
|---|---|
| $\Delta MMBTU_{WH}$ | = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat. |
| 0.003413 | = Conversion from kWh to MMBTU |
| OA | = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[107]. |
| AR | = Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of commercial buildings within 15 feet of exterior wall. |
| HF | = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont[108] |
| DFH | = Percent of lighting in heated spaces. For prescriptive lighting, assumed to be 95% |
| HEff | = Average heating system efficiency, For prescriptive lighting, assumed to be 79% in existing buildings and 83 % in new Construction[109]. |

Oil heating is assumed typical for commercial buildings.

**Baseline Efficiencies – New or Replacement**
Refer to the tables listed below under Baselines/Guidelines for Energy Efficient Commercial Construction – Lighting.

For all business new construction projects commencing construction prior to January 3rd, 2012 OR initiated with Efficiency Vermont prior to January 3rd, 2012, but completed on or after January 3rd, 2012, savings shall be calculated using “2005 Vermont Guidelines for Energy Efficient Commercial Construction” as baseline.

For all business new construction projects commencing construction after January 3rd, 2012 and iniated with Efficiency Vermont on or after January 3rd, 2012, regardless of when they are completed, savings shall be calculated using “2011 Vermont Commercial Building Energy Standards” as baseline.

**High Efficiency**
Based on actual installed watts per square foot.

**Operating Hours**
Lighting hours of operation determined on a site-specific basis. If site-specific data is not available then use hours of use by building type for interior lighting. See the table titled Interior Lighting Operating

[107] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."
[108] From “Calculating lighting and HVAC interactions”, Table 1, ASHRAE Journal November 1993.
[109] See WasteHeatAdjustment.doc.

Hours by Building Type. If building type is not specified then use default 3,500 hours for interior lighting. For exterior lighting use default 3,338 hours of use[110].

**Loadshapes**

Indoor Lighting:
If space has cooling: Loadshape # 12 (Commercial Indoor Lighting-Blended) for demand and lighting energy savings and #15 (Commercial A/C) for cooling energy savings.
If space does not have cooling, or is refrigerated: Loadshape #12, Commercial Indoor Lighting-Blended

Outdoor Lighting: Loadshape #13, Commercial Outdoor Lighting.

**Freeridership/Spillover Factors**

| **Measure Category** | | **Lighting** | |
|---|---|---|---|
| Measure Codes | | LECACINT, LECACEXT | |
| **Product Description** | | Efficient Lighting | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | 0.95 | 1.05 |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | 0.95 | 1.05 |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | 0.90 | 1.0 |
| LIMF Rehab | 6018LIRH | 0.90 | 1.0 |
| MF Mkt NC | 6019MFNC | 1.0 | 1.0 |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

* Freeridership of 0% per agreement between DPS and EVT. All Act 250 measures will also have a 5% Adjustment Factor applied, which will be implemented through the Freeridership factor.

**Persistence**

The persistence factor is assumed to be one.

[110] Based on 5 years of metering on 235 outdoor circuits in New Jersey.

**Lifetimes**
15 years. Analysis period is the same as the lifetime.

**Measure Cost**
The incremental cost for this measure is:
Per square foot $1.25 per Watt/SF reduction.
Per linear foot $0.50 per Watt/lin ft reduction.

**O&M Cost Adjustments**
None.

**Fossil Fuel Descriptions**
See Heating Increased Usage above.

**Water Descriptions**
There are no water algorithms or default values for this measure.

## Reference Tables

**Baselines/Guidelines for Energy Efficient Commercial Construction – Lighting**

| Baselines/Guidelines for ASHRAE 2001 Categories<br>Lighting Power Density (w/ft$^2$)<br>Building Area Method | | |
|---|---|---|
| **Building Area Type** | **Initiated w/ EVT prior to 1/3/2012<br>2005 CBES<br>(w/ft$^2$)** | **Initiated w/ EVT on or after 1/3/2012<br>2011 CBES<br>(w/ft$^2$)** |
| Automotive Facility | 0.9 | 0.9 |
| Convention Center | 1.2 | 1.2 |
| Court House | 1.2 | 1.2 |
| Dining: Bar Lounge/Leisure | 1.3 | 1.3 |
| Dining: Cafeteria | 1.4 | 1.4 |
| Dining: Family | 1.6 | 1.6 |
| Dormitory | 1.0 | 1.0 |
| Exercise Center | 1.0 | 1.0 |
| Fire Station | | 0.8 |
| Gymnasium | 1.1 | 1.1 |
| Health Care | 1.0 | 1.0 |
| Hospital | 1.2 | 1.2 |
| Hotel | 1.0 | 1.0 |
| Library | 1.3 | 1.3 |
| Manufacturing Facility | 1.3 | 1.3 |
| Motel | 1.0 | 1.0 |
| Motion Picture Theater | 1.2 | 1.2 |
| Multi-Family | 0.7 | 0.7 |
| Museum | 1.1 | 1.1 |
| Office | 1.0 | 0.9 |
| Parking Garage | 0.3 | 0.3 |
| Penitentiary | 1.0 | 1.0 |
| Performing Arts Theater | 1.6 | 1.6 |
| Police/Fire Station | 1.0 | 0.8 |
| Post Office | 1.1 | 1.1 |
| Religious Building | 1.3 | 1.3 |
| Retail | 1.5 | 1.4 |
| School/University | 1.2 | 1.2 |
| Sports Arena | 1.1 | 1.1 |

| | | |
|---|---|---|
| Town Hall | 1.1 | 1.1 |
| Transportation | 1.0 | 1.0 |
| Warehouse | 0.8 | 0.6 |
| Workshop | 1.4 | 1.4 |

**2011 Vermont Commercial Building Energy Standards Space-by-SpaceTables for projects initiated with EVT on or after 1/3/2012**

**TABLE 505.5.2(2)**
**INTERIOR LIGHTING POWER ALLOWANCES—SPACE-BY-SPACE METHOD**

| COMMON SPACE-BY-SPACE TYPES | LPD (w/ft$^2$) |
|---|---|
| Atrium – First 40 feet in height | 0.03 per ft. ht. |
| Atrium – Above 40 feet in height | 0.02 per ft. ht. |
| Audience/seating area—permanent | |
| For auditorium | 0.9 |
| For performing arts theater | 2.6 |
| For motion picture theater | 1.2 |
| Classroom/Lecture/training | 1.30 |
| Conference/meeting/multipurpose | 1.2 |
| Corridor/transition | 0.7 |
| Dining area | |
| Bar/lounge/leisure dining | 1.40 |
| Family dining area | 1.40 |
| Dressing/fitting room performing arts theater | 1.1 |
| Electrical/mechanical | 1.10 |
| Food preparation | 1.20 |
| Laboratory for classrooms | 1.3 |
| Laboratory for medical/industrial/research | 1.8 |
| Lobby | 1.10 |
| Lobby for performing arts theater | 3.3 |
| Lobby for motion picture theater | 1.0 |
| Locker room | 0.80 |
| Lounge recreation | 0.8 |
| Office—enclosed | 1.1 |
| Office—open plan | 1.0 |
| Restroom | 1.0 |
| Sales area | 1.6[a] |
| Stairway | 0.70 |
| Storage | 0.8 |
| Workshop | 1.60 |
| Courthouse/police station/penetentiary | |
| Courtroom | 1.90 |
| Confinement cells | 1.1 |
| Judge chambers | 1.30 |
| Penitentiary audience seating | 0.5 |
| Penitentiary classroom | 1.3 |
| Penitentiary dining | 1.1 |
| **BUILDING SPECIFIC SPACE-BY-SPACE TYPES** | **LPD (w/ft$^2$)** |
| Automotive – service/repair | 0.70 |
| Bank/office – banking activity area | 1.5 |
| Convention center | |
| Exhibit Space | 1.50 |
| Audience/Seating Area | 0.90 |
| Dormitory living quarters | 1.10 |
| Gymnasium/fitness center | |
| Fitness area | 0.9 |
| Gymnasium Audience/Seating | 0.40 |
| Playing Area | 1.40 |

*(continued)*

**Table 505.5.2(2)—continued**
**INTERIOR LIGHTING POWER ALLOWANCES—SPACE-BY-SPACE METHOD**

| COMMON SPACE-BY-SPACE TYPES | LPD (w/ft$^2$) |
|---|---|
| Healthcare clinic/hospital | |
| Corridors /transition | 1.00 |
| Exam/treatment | 1.70 |
| Emergency | 2.70 |
| Public & staff lounge | 0.80 |
| Medical supplies | 1.40 |
| Nursery | 0.9 |
| Nurse station | 1.00 |
| Physical therapy | 0.90 |
| Patient room | 0.70 |
| Pharmacy | 1.20 |
| Radiology/imaging | 1.3 |
| Operating room | 2.20 |
| Recovery | 1.2 |
| Lounge/recreation | 0.8 |
| Laundry—washing | 0.60 |
| Hotel | |
| Dining area | 1.30 |
| Guest rooms | 1.10 |
| Hotel lobby | 2.10 |
| Highway lodging dining | 1.20 |
| Highway lodging guest rooms | 1.10 |
| Library | |
| Stacks | 1.70 |
| Card file & cataloguing | 1.10 |
| Reading area | 1.20 |
| Manufacturing | |
| Corridors/transition | 0.40 |
| Detailed manufacturing | 1.3 |
| Equipment room | 1.0 |
| Extra high bay (> 50-foot floor-ceiling height) | 1.1 |
| High bay (25-50-foot floor-ceiling height) | 1.20 |
| Low Bay (< 25-foot floor-ceiling height) | 1.2 |
| Museum | |
| General exhibition | 1.00 |
| Restoration | 1.70 |
| Parking garage – garage areas | 0.2 |
| Fire stations | |
| Engine room | 0.80 |
| Sleeping quarters | 0.30 |
| Post office | |
| Sorting area | 0.9 |
| Religious building | |
| Fellowship hall | 0.60 |
| Audience seating | 2.40 |
| Worship pulpit/choir | 2.40 |
| Retail | |
| Dressing/Fitting Area | 0.9 |
| Mall Concourse | 1.6 |
| Sales Area | 1.6[a] |

*(continued)*

**Table 505.5.2(2)—continued**
**INTERIOR LIGHTING POWER ALLOWANCES—SPACE-BY-SPACE METHOD**

| COMMON SPACE-BY-SPACE TYPES | LPD (W/ft$^2$) |
|---|---|
| Sports arena | |
| Audience seating | 0.4 |
| Court sports area – Class 4 | 0.7 |
| Court sports area – Class 3 | 1.2 |
| Court sports area – Class 2 | 1.9 |
| Court sports area – Class 1 | 3.0 |
| Ring sports area | 2.7 |
| Transportation | |
| Air/Train/Bus Baggage Area | 1.00 |
| Airport Concourse | 0.60 |
| Terminal – Ticket Counter | 1.50 |
| Warehouse | |
| Fine Material Storage | 1.40 |
| Medium/Bulky Material | 0.60 |

**Interior Lighting Operating Hours by Building Type**

| Building Type | Annual Hours |
|---|---|
| Grocery/Convenience Store | 6,019 |
| Hospital | 4,007 |
| K-12 Schools | 2,456 |
| Lodging/Hospitality | 4,808 |
| Manufacturing | 4,781 |
| Office | 3,642 |
| Public Assembly | 3,035 |
| Public Safety | 3,116 |
| Religious | 2,648 |
| Restaurant | 4,089 |
| Retail | 4,103 |
| Service | 3,521 |
| University/College | 3,416 |
| Warehouse | 4,009 |
| From C&I Lighting Load Shape Project FINAL Report, July 19, 2011, prepared by KEMA for NEEP. See document NEEP CI Lighting LS FINAL Report_ver 5_7-19-11.pdf | |

**TABLE 505.6.2(2)**
**INDIVIDUAL LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS**

| | | Zone 1 | Zone 2 | Zone 3 | Zone 4 |
|---|---|---|---|---|---|
| Base Site Allowance (Base allowance may be used in tradable or nontradable surfaces.) | | 500 W | 600 W | 750 W | 1300 W |
| Tradable Surfaces (Lighting power densities for uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs and outdoor sales areas may be traded.) | **Uncovered Parking Areas** | | | | |
| | Parking areas and drives | 0.04 W/ft$^2$ | 0.06 W/ft$^2$ | 0.10 W/ft$^2$ | 0.13 W/ft$^2$ |
| | **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 | 0.14 W/ft$^2$ | 0.14 W/ft$^2$ | 0.16 W/ft$^2$ | 0.2 W/ft$^2$ |
| | Stairways | 0.75 W/ft$^2$ | 1.0 W/ft$^2$ | 1.0 W/ft$^2$ | 1.0 W/ft$^2$ |
| | Pedestrian tunnels | 0.15 W/ft$^2$ | 0.15 W/ft$^2$ | 0.2 W/ft$^2$ | 0.3 W/ft$^2$ |
| | **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/ft$^2$ | 0.25 W/ft$^2$ | 0.4 W/ft$^2$ | 0.4 W/ft$^2$ |
| | Sales Canopies | | | | |
| | Free-standing and attached | 0.6 W/ft$^2$ | 0.6 W/ft$^2$ | 0.8 W/ft$^2$ | 1.0 W/ft$^2$ |
| | **Outdoor Sales** | | | | |
| | Open areas (including vehicle sales lots) | 0.25 W/ft$^2$ | 0.25 W/ft$^2$ | 0.5 W/ft$^2$ | 0.7 W/ft$^2$ |
| | 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 |
| Nontradable Surfaces (Lighting power density calculations for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the "Tradable Surfaces" section of this table.) | Building facades | No allowance | 0.1 W/ft$^2$ for each illuminated wall or surface or 2.5 W/linear foot for each illuminated wall or surface length | 0.15 W/ft$^2$ for each illuminated wall or surface or 3.75 W/linear foot for each illuminated wall or surface length | 0.2 W/ft$^2$ for each illuminated wall or surface or 5.0 W/linear foot for each illuminated wall or surface length |
| | Automated teller machines 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/ft$^2$ of covered and uncovered area | 0.75 W/ft$^2$ of covered and uncovered area | 0.75 W/ft$^2$ of covered and uncovered area | 0.75 W/ft$^2$ of covered and uncovered area |
| | Loading areas for law enforcement, fire, ambulance and other emergency service vehicles | 0.5 W/ft$^2$ of covered and uncovered area | 0.5 W/ft$^2$ of covered and uncovered area | 0.5 W/ft$^2$ of covered and uncovered area | 0.5 W/ft$^2$ 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 |

For SI: 1 foot = 304.8 mm, 1 watt per square foot = W/0.0929 m$^2$.

**Exterior Lighting Zones**

| Lighting Zone | Description |
|---|---|
| 1 | Developed areas of national parks, state parks, forest land, and rural areas |
| 2 | Areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited nighttime use and residential mixed use areas |
| 3 | All other areas |
| 4 | High-activity commercial districts in major metropolitan areas as designated by the local land use planning authority |

**Baselines/Guidelines for 2005 CBESCategories**
**Lighting Power Densities (w/ft$^2$)**
**Space by Space Method - Building Specific Space Type**

| Building Type | Space Type | Initiated prior to 1/2/2012 ASHRAE 90.1-2004 |
|---|---|---|
| Athletic Facility Buildings | | |
| Gymnasium | Playing Area | 1.4 |
| | Dressing/Locker | 0.6 |
| | Exercise Area | 0.9 |
| Exercise Center | Exercise Area | 0.9 |
| | Dressing/Locker | 0.6 |
| Civil Service Buildings | | |
| Courthouse | Courtroom | 1.9 |
| | Confinement Cell | 0.9 |
| | Judges Chambers | 1.3 |
| Police Station | Police Station Laboratory | N/A |
| Fire Station | Fire Station Engine Room | 0.8 |
| | Sleeping Quarters | 0.3 |
| Post Office | Sorting Area | 1.2 |
| Convention Center Buildings | | |
| Convention Center | Exhibit Space | 1.3 |
| Educational Buildings | | |
| Library | Card File/Cataloging | 1.1 |
| | Stacks | 1.7 |
| | Reading Area | 1.2 |
| Hospital/ Healthcare Buildings | | |
| Emergency | | 2.7 |
| Recovery | | 0.8 |
| Nurse Station | | 1.0 |
| Exam/Treatment | | 1.5 |
| Pharmacy | | 1.2 |
| Patient Room | | 0.7 |
| Operating Room | | 2.2 |
| Nursery | | 0.6 |

| Building Type | Space Type | Initiated prior to 1/2/2012 ASHRAE 90.1-2004 |
|---|---|---|
| Industrial Buildings | | |
| Workshop | Workshop | 1.9 |
| Automotive Facility | Garage Service/Repair | 0.7 |
| Manufacturing | Gen'l Low Bay (<25') | 1.2 |
| | Gen'l High Bay (>25') | 1.7 |
| | Detailed | 2.1 |
| | Equipment Room | 1.2 |
| | Control Room | 0.5 |
| Lodging Buildings | | |
| Hotel | Guest Room | 1.1 |
| Motel | Guest Room | 1.1 |
| Dormitory | Living Quarters | 1.1 |
| Museum Buildings | | |
| Museum | General Exhibition | 1.0 |
| | Restoration | 1.7 |
| Office Buildings | | |
| Office | Banking Activity Area | 1.7 |
| | Laboratory | 1.4 |
| Penitentiary Buildings | | |
| Penitentiary | Confinement Cells | 0.9 |
| Religious Buildings | | |
| | Worship – Pulpit, Choir | 2.4 |
| | Fellowship Hall | 0.9 |
| Retail Buildings | | |
| Retail | General Sales Area | 1.7 |
| | Mall Concourse | 1.7 |
| Sports Arena Building | | |
| Sports Arena | Ring Sports Arena | 2.7 |
| | Court Sports Arena | 2.3 |

| | | |
|---|---|---|
| Medical Supply | | 1.4 |
| Physical Therapy | | 0.9 |
| Radiology | | 0.4 |
| Laundry - Washing | | 0.6 |
| | | |
| | | |

| | | |
|---|---|---|
| | Indoor Playing Field Area | 1.4 |
| Storage Buildings | | |
| Warehouse | Fine Material Storage | 1.4 |
| | Medium/Bulky Material Storage | 0.9 |
| Parking Garage | Parking Area – Pedestrian | 0.2 |
| | Parking Area – Attendant only | 0.2 |

**Baselines/Guidelines for 2005 CBES Categories**
**Lighting Power Densities (w/ft$^2$)**
**Space by Space Method - Building Specific Space Type (cont'd)**

| Building Type | Space Type | Initiated prior to 1/2/2012 ASHRAE 90.1-2004 |
|---|---|---|
| Transportation Buildings | | |
| Transportation | Airport Concourse | 0.6 |
| | Air/Train/Bus Baggage Area | 1.0 |
| | Terminal – Ticket Counter | 1.5 |

**Baselines/Guidelines for 2005 CBES Categories**
**Lighting Power Densities (w/ft$^2$)**
**Space by Space Method - Common Activity Areas**

| Building Type | Space Type | Initiated prior to 1/2/2012 ASHRAE 90.1-2004 (w/ft$^2$) |
|---|---|---|
| Lobby | | |
| | General | 1.3 |
| | Hotel | 1.1 |
| | Performing Arts | 3.3 |
| | Motion Picture | 1.1 |
| Atrium (multi-story) | | |
| | First 3 floors | 0.6 |
| | Each additional floor | 0.2 |
| Lounge/recreation room | | 1.2 |
| Lounge/recreation for hospital | | 0.8 |
| Dining Area | | |
| | General/Cafeteria | 0.9 |
| | Bar/lounge leisure dining | 1.4 |

| Building Type | Space Type | Initiated prior to 1/2/2012 ASHRAE 90.1-2004 (w/ft$^2$) |
|---|---|---|
| Office – enclosed plan | General | 1.1 |
| Office – open plan | General | 1.1 |
| Conference/meeting room | General | 1.3 |
| Classroom/lecture/ training | General | 1.4 |
| | Penitentiary | 1.3 |
| Audience/seating area | Athletic facility | N/A |
| | Gymnasium | 0.4 |
| | Exercise center | 0.3 |
| | Civil service building | N/A |
| | Convention center | 0.7 |
| | Penitentiary building | 0.7 |
| | Religious building | 1.7 |
| | Sports arena | 0.4 |

| | | | | | |
|---|---|---|---|---|---|
| | Family | 2.1 | | | |
| | Hotel | 1.3 | | Performing arts theatre | 2.6 |
| | Motel | 1.2 | | Motion picture theatre | 1.2 |
| Food preparation | | 1.2 | | Transportation | 0.5 |
| Restrooms | | 0.9 | | | |
| Corridor/Transition | | | | | |
| | General | 0.5 | | | |
| | Hospital/healthcare | 1.0 | | | |
| | Manufacturing | 0.5 | | | |
| Stairs-active | General | 0.6 | | | |
| Active Storage | General | 0.8 | | | |
| | Hospital/healthcare | 0.9 | | | |
| | Museum | N/A | | | |
| Inactive Storage | General | 0.3 | | | |
| | Museum | 0.8 | | | |
| Electrical/ Mechanical | General | 1.5 | | | |

| **Baselines/Guidelines for Exterior Lighting for projects initiated with EVT prior to January 3, 2012** | |
|---|---|
| **Application** | **Baseline *** |
| **Tradable Surfaces** (Lighting power densities for the following surfaces may be traded) | |
| **Uncovered Parking Areas** | |
| Parking lots and drives | 0.15 W/ft$^2$ |
| **Building Grounds** | |
| Walkways less than 10 feet wide | 1.0 W/linear ft |
| Walkways 10 feet wide or wider, plaza areas and special feature areas | 0.2 W/ft$^2$ |
| Stairways | 1.0 W/ft$^2$ |
| **Building Entrances and Exits** | |
| Main entries | 30 W/linear ft of door width |
| Other doors | 20 W/linear ft of door width |
| **Canopies and Overhangs** | |
| Canopies (free standard, attached and overhangs) | 1.25 W/ft$^2$ |
| **Outdoor Sales** | |
| Open areas (including vehicle sales lots) | 0.5 W/ft$^2$ |
| Street frontage for vehicle sales lots in addition to "open area" allowance | 20 W/linear ft |
| **Nontradable Surfaces** (Lighting power densities for the following surfaces can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the "Tradable Surfaces" section) | |
| Building Facades | 0.2 W/ft$^2$ for each illuminated wall or surface or 5W/linear ft for each illuminated wall or surface length |
| Automated Teller Machines and Night Depositories | 270 W per location plus 90 watts per additional ATM per location |
| Entrances and Gatehouse Inspection Stations at Guarded Facilities | 1.25 W/ft$^2$ of uncovered area (covered areas are included in the "Canopies and Overhangs" section) |
| Loading Areas for Law Enforcement, Fire, Ambulance and other Emergency Service Vehicles | 0.5 W/ft$^2$ of uncovered area (covered areas are included in the "Canopies and Overhangs" section) |
| Drive-up Windows at Fast Food Restaurants | 400 W per drive-through |
| Parking near 24-hour Retail Entrances | 800 W per main entry |

* Baselines from ASHRAE 90.1-2004, Table 9.4.5

# T5 Fixtures and Lamp/Ballast Systems

Measure Number: I-C-18-d (Business Energy Services, Lighting End Use)

**Version Date & Revision History**
Draft Portfolio: Portfolio86
Effective date: 1/1/2014
End date: TBD

**Referenced Documents**

1. HPT8-T5 TRM Reference Tables Oct 2014.xlsx
2. WasteHeatAdjustment.doc
3. NEEP CI Lighting LS FINAL Report_ver 5_7-19-11.pdf

**Description**
T5 lamp/ballast systems have higher lumens per watt than a typical T8 system. In addition, the smaller lamp diameter allows for better optical systems, and more precise control of light. The combination of these characteristics results in light fixtures that produce equal or greater light than T8 fixtures, while using fewer watts. When used in a high-bay application, T5 fixtures can provide equal light to HID High-Bay fixtures, while using fewer watts. Eligible fixtures include new and replacement.

**Algorithms**

**Demand Savings**
$\Delta kW = ((Watts_{BASE} - Watts_{EE}) / 1000) \times ISR \times WHF_d \times BDB$

**Energy Savings**
$\Delta kWh = ((Watts_{BASE} - Watts_{EE}) / 1000) \times HOURS \times ISR \times WHF_e \times BDB$

Where:

$\Delta kW$ = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW from table located in Reference Tables section.
$Watts_{EE}$ = Energy efficient connected kW from table located in Reference Tables section.
ISR = In service rate, or the percentage of units rebated that actually get used. For prescriptive measures, this is assumed to be 98%.[111]
$WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting. For prescriptive lighting in existing buildings, the default value is 1.082 (calculated as 1 + (0.47*0.67*.808) / 3.1))[112]. For prescriptive lighting in new buildings, the value is 1.084 (calculated as 1 + (0.47*0.67*.808) / 3.4))[113]. The cooling savings are only added to the summer peak savings.
$WHF_e$ = Waste heat factor for energy to account for cooling savings from efficient lighting. For prescriptive lighting in existing buildings, the default value is 1.033 (calculated as 1 + ((0.47*0.29*.75) / 3.1)) [114]. For prescriptive lighting

[111] 2005 TAG agreement.
[112] Based on the following assumptions: 3.1 COP typical cooling system efficiency for existing buildings; average 47% of spaces have mechanical cooling; 33% average outside air; and 80.8% coincidence of cooling with the summer peak period. See WasteHeatAdjustment.doc for additional discussion.
[113] Based on the same assumptions used for existing buildings, except 3.4 COP typical cooling system efficiency for new buildings. See WasteHeatAdjustment.doc for additional discussion.
[114] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 25% average outside air; and 29% of annual lighting energy contributes to cooling load. See "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993 and WasteHeatAdjustment.doc for additional discussion.

in new buildings, the value is 1.030 (calculated as 1 + ((0.47*0.29*.75) / 3.4))[115].

| | |
|---|---|
| $\Delta$kWh | = gross customer annual kWh savings for the measure |
| HOURS | = annual lighting hours of use per year; collected from prescriptive application form. If operating hours are not available, then the value will be selected from the table 'Operating Hours by Building Type' in the reference tables section of this document. |
| BDB | = Bonus Savings from Bi-Level or Dimming Controls. Without controls, the value is one. With controls, the factor is calculated as (1 + ((percent savings) * (percent of time) * ($Watts_{EE}$ ) / ($Watts_{BASE}$ – $Watts_{EE}$ ). The values for each measure are in the table 'T5 New and Baseline Assumptions'. |

**Waste Heat Adjustment**

Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF).

**Heating Increased Usage**

$\Delta MMBTU_{WH}$ = $(\Delta kWh / WHF_e) \times 0.003413 \times (1 - OA) \times AR \times HF \times DFH / HEff$

Where:

| | |
|---|---|
| $\Delta MMBTU_{WH}$ | = gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat. |
| 0.003413 | = conversion from kWh to MMBTU |
| OA | = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[116]. |
| AR | = Typical aspect ratio factor. ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of building within 15 feet of exterior wall. |
| HF | = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont[117] |
| DFH | = Percent of lighting in heated spaces. For prescriptive lighting, assumed to be 95% |
| HEff | = Average heating system efficiency, For prescriptive lighting, assumed to be 79% in existing buildings and 83 % in new Construction[118]. |

**Baseline Efficiencies**

Refer to reference table T5 New and Baseline Assumptions (also in 'HPT8-T5 TRM Reference Tables Oct 2014.xlsx').

**High Efficiency**

Refer to reference table T5 New and Baseline Assumptions (also in 'HPT8-T5 TRM Reference Tables Oct 2014.xlsx').

**Operating Hours**

Operating hours will be collected from the prescriptive application form or from the table of hours by building type located in the reference tables section of this document.

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115 Based on the same assumptions used for existing buildings, except 3.4 COP typical cooling system efficiency for new buildings. See WasteHeatAdjustment.doc for additional discussion.

116 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

117 From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993.

118 See WasteHeatAdjustment.doc.

**Loadshape**
# 12 (Commercial Indoor Lighting-Blended) for demand and lighting energy savings and #15 (Commercial A/C) for cooling energy savings

**Freeridership/Spillover Factors**

| Measure Category | | Lighting Hardwired Fixture | | Lighting Efficiency | |
|---|---|---|---|---|---|
| Measure Code | | LFHLFT05 | | LFHST5HB | |
| Product Description | | New T5 Fixture | | New T5 High-Bay | |
| Track Name | Track No. | Freerider | Spillover | | |
| Cust Equip Rpl | 6013CUST | 0.99 | 1.15 | 0.95 | 1.05 |
| C&I NC Cust | 6014CUST | 0.95 | 1.05 | 0.95 | 1.05 |
| Pres Equip Rpl | 6013PRES | 1.0 | 1.15 | 0.95 | 1.05 |
| C&I NC Pres | 6014PRES | 0.95 | 1.05 | 0.95 | 1.05 |
| C&I Retro | 6012CNIR | 0.99 | 1.15 | 0.90 | 1.0 |

**Persistence**
The persistence factor is assumed to be one for all measures.

**Lifetimes**
15 years
Analysis period is the same as lifetime.

**Measure Cost**
Refer to reference table 'T5 New and Baseline Assumptions' (also in HPT8-T5 TRM Reference Tables Oct 2014.xlsx).

**Component Costs and Lifetimes Used in Computing O&M Savings**
Refer to reference table 'T5 Component Costs and Lifetimes' (also in 'HPT8-T5 TRM Reference Tables Oct 2014.xlsx').

**Fossil Fuel Descriptions**
See algorithm in 'Heating Increased Usage'

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

**Interior Lighting Operating Hours by Building Type**

| **Building Type** | **Annual Hours** |
|---|---|
| Grocery/Convenience Store | 6,019 |
| Hospital | 4,007 |
| K-12 Schools | 2,456 |
| Lodging/Hospitality | 4,808 |
| Manufacturing | 4,781 |
| Office | 3,642 |
| Public Assembly | 3,035 |
| Public Safety | 3,116 |

| | |
|---|---|
| Religious | 2,648 |
| Restaurant | 4,089 |
| Retail | 4,103 |
| Service | 3,521 |
| University/College | 3,416 |
| Warehouse | 4,009 |
| From C&I Lighting Load Shape Project FINAL Report, July 19, 2011, prepared by KEMA for NEEP. See document NEEP CI Lighting LS FINAL Report_ver 5_7-19-11.pdf | |

**Reference file:** HPT8-T5 TRM Reference Tables Oct 2014.xlsx

| EE Measure Description | Watts$_{EE}$ | System Lumens$_{EE}$ | References$_{EE}$ | Baseline Description | Watts$_{BASE}$ | System Lumens$_{EE}$ | References$_{BASE}$ | Watts$_{SAVE}$ | Incremental Cost | Bi-Level / Dimming Savings Assumptions | Bi-Level / Dimming Bonus Factor (BDF) | Bi-Level / Dimming Cost | Measure Code |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3-Lamp T5HO High-Bay | 176 | 12,000 | 4 | 4-Lamp T8HO High-Bay | 196 | 11,600 | 7 | 20 | $100.00 | 50% Power, 20% of Time | 1.88 | $40.00 | LFHST5HB |
| 4-Lamp T5HO High-Bay | 235 | 16,000 | 5 | 6-Lamp T8HO High-Bay | 294 | 17,400 | 8 | 59 | $100.00 | 50% Power, 20% of Time | 1.40 | $40.00 | LFHST5HB |
| 6-Lamp T5HO High-Bay | 352 | 24,000 | 6 | 8-Lamp T8HO High-Bay | 392 | 23,300 | 9 | 40 | $100.00 | 50% Power, 20% of Time | 1.88 | $40.00 | LFHST5HB |
| | | | | | | | | | | | | | |
| 1-Lamp T5 Fixture | 32 | | | Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8 | 44 | | | 12 | $35.00 | 50% Power, 20% of Time | 1.27 | $40.00 | LFHST5TW |
| 2-Lamp T5 Fixture | 64 | | | 3-Lamp F32T8 Equivalent w/ Elec. Ballast | 88 | | | 24 | $40.00 | 50% Power, 20% of Time | 1.27 | $40.00 | LFHST5TW |
| 3-Lamp T5 Fixture | 96 | | | 4-Lamp F32T8 Equivalent w/ Elec. Ballast | 114 | | | 18 | $45.00 | 50% Power, 20% of Time | 1.53 | $40.00 | LFHST5TW |

| EE Measure Description | EE Lamp Life (hrs) | Total EE Lamp Replacement Cost | EE Lamp Qty | EE Lamp Cost | EE Ballast Life (hrs) | Total EE Ballast Replacement Cost | EE Ballast Qty | EE Ballast Cost | EE Ballast Rep. Labor Cost | Baseline Description | Base Lamp Life (hrs) | Total Base Lamp Replacement Cost | Base Lamp Qty | Base Lamp Cost | Base Lamp Replacement Rate ($/hr) | Base Ballast Life (hrs) | Total Base Ballast Replacement Cost | Base Ballast Qty | Base Ballast Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3-Lamp T5HO High-Bay | 30,000 | $56.00 | 3 | $12.00 | 70,000 | $74.50 | 1 | $52.00 | $22.50 | 4-Lamp T8HO High-Bay | 20,000 | $70.67 | 4.0 | $11.00 | $20.00 | 70,000 | $75.00 | 2.0 | $15.00 |
| 4-Lamp T5HO High-Bay | 30,000 | $74.67 | 4 | $12.00 | 70,000 | $74.50 | 1 | $52.00 | $22.50 | 6-Lamp T8HO High-Bay | 20,000 | $106.00 | 6.0 | $11.00 | $20.00 | 70,000 | $112.50 | 3.0 | $15.00 |
| 6-Lamp T5HO High-Bay | 30,000 | $112.00 | 6 | $12.00 | 70,000 | $149.00 | 2 | $52.00 | $22.50 | 8-Lamp T8HO High-Bay | 20,000 | $141.33 | 8.0 | $11.00 | $20.00 | 70,000 | $150.00 | 4.0 | $15.00 |
| | | | | | | | | | | | | | | | | | | | |
| 1-Lamp T5 Fixture | 30,000 | $14.67 | 1 | $12.00 | 70,000 | $67.00 | 1 | $52.00 | $15.00 | Proportionally adjusted according to 2-Lamp T5 | 20,000 | $7.75 | 1.5 | $2.50 | $20.00 | 70,000 | $15.00 | 0.5 | $15.00 |
| 2-Lamp T5 Fixture | 30,000 | $29.33 | 2 | $12.00 | 70,000 | $67.00 | 1 | $52.00 | $15.00 | 3-Lamp F32T8 Equivalent w/ Elec. Ballast | 20,000 | $15.50 | 3.0 | $2.50 | $20.00 | 70,000 | $30.00 | 1.0 | $15.00 |
| 3-Lamp T5 Fixture | 30,000 | $44.00 | 3 | $12.00 | 70,000 | $67.00 | 1 | $52.00 | $15.00 | 4-Lamp F32T8 Equivalent w/ Elec. Ballast | 20,000 | $20.67 | 4.0 | $2.50 | $20.00 | 70,000 | $30.00 | 1.0 | $15.00 |

# SMARTLIGHT Lighting Distributor Incentives

Measure Number: I-C-21-f (Business Energy Services, Lighting End Use)

**Version Date & Revision History**

| | |
|---|---|
| Draft Portfolio: | Portfolio 84 |
| Effective date: | 1/1/2013 |
| End Date: | TBD |

**Referenced Documents:**

1) "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993.
2) PIP #67a: Upstream Distributor Incentive Model
3) SMARTLIGHT Reference Tables Final 072013.xlsx
4) LED Standard Decorative Delta Watts Calculation.xls
5) SMARTLIGHT Hours Assumptions 2012.xlsx
6) WasteHeatAdjustment.doc
7) SMARTLIGHT QA 2012.docx
8) 2013 LED Sales Review.xlsx

**Description**

In reference to PIP #67a: Upstream Distributor Incentive Model, Efficiency Vermont will offer "upstream" incentives to Vermont Electrical Distributors for certain eligible energy-efficient commercial replacement lamps. The eligible technologies are Screw Base LED lamps, Reduced-Wattage T8 and T5 Lamps, Reduced-Wattage pin-based CFL lamps, and Reduced-Wattage Metal-Halide Lamps. Both replacements and new installations are eligible. See PIP #67a (updated 5/1/2012) for a further discussion of eligible technologies and program procedures.

**Algorithms**

**Demand Savings**

$\Delta kW = ((Watts_{BASE} - Watts_{EE}) / 1000) \times ISR \times WHF_d$

**Energy Savings**

$\Delta kWh = (Watts_{BASE} - Watts_{EE}) / 1000 \times HOURS \times ISR \times WHF_e$

Where:

| | |
|---|---|
| $\Delta kW$ | = gross customer connected load kW savings for the measure |
| $Watts_{BASE}$ | = Baseline connected Watts from table located in Reference Tables Section. |
| $Watts_{EE}$ | = Energy efficient connected Watts from table located in Reference Tables Section. |
| ISR | = In service rate, or the percentage of units rebated that actually get used (see table below). |
| $WHF_d$ | = Waste heat factor for demand to account for cooling savings from efficient lighting. For prescriptive commercial lighting in existing buildings, the default value is 1.082 (calculated as 1 + (0.47*0.67*.808) / 3.1))[119]. The cooling savings are only added to the summer peak savings. The value for Residential lighting is assumed to be 1.0. |
| $WHF_e$ | = Waste heat factor for energy to account for cooling savings from efficient lighting. For prescriptive commercial lighting in existing buildings, the |

[119] Based on the following assumptions: 3.1 COP typical cooling system efficiency for existing buildings; average 47% of spaces have mechanical cooling; 33% average outside air; and 80.8% coincidence of cooling with the summer peak period. See WasteHeatAdjustment.doc for additional discussion.

default value is 1.033 (calculated as 1 + ((0.47*0.29*.75) / 3.1))[120]. The value for Residential lighting is assumed to be 1.0.

| | |
|---|---|
| $\Delta$kWh | = gross customer annual kWh savings for the measure |
| HOURS | = annual lighting hours of use per year. See 'Operating Hours' section. |

**Waste Heat Adjustment**
Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF). See above.

**Heating Increased Usage**

$$\Delta MMBTU_{WH} = (\Delta kWh / WHF_e) \times 0.003413 \times (1 - OA) \times AR \times HF \times DFH / HEff$$

Where:

| | |
|---|---|
| $\Delta MMBTU_{WH}$ | = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat. |
| 0.003413 | = Conversion from kWh to MMBTU |
| OA | = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[121]. |
| AR | = Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of commercial buildings within 15 feet of exterior wall. |
| HF | = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont[122]. Assumed to be 0.0 for residential lighting |
| DFH | = Percent of lighting in heated spaces. For prescriptive lighting, assumed to be 95% |
| HEff | = Average heating system efficiency, For prescriptive lighting, assumed to be 79% in existing buildings and 83 % in new Construction[123]. |

Oil heating is assumed typical for commercial buildings.

**Baseline Efficiencies – New or Replacement**
Refer to the tables in the Reference Tables section for lighting baseline efficiencies and savings.

**Baseline Adjustment**
Federal legislation stemming from the Energy Independence and Security Act of 2007 requires all general-purpose light bulbs between 40 and 100W to be approximately 30% more energy efficient than current incandescent bulbs, in essence beginning the phase out of standard incandescent bulbs. From 2012, 100W incandescents could no longer be manufactured, 75W incandescents are restricted from 2013, followed by restrictions on 60W and 40W in 2014. The baseline for Standard LED Screw and Pin-based Bulbs will therefore become bulbs (improved incandescent or halogen) that meet the new standard.

To account for these new standards, the savings for this measure will be reduced to account for the higher baselines. The appropriate adjustments as a percentage of the base year savings for each Standard and Decorative Screw and Pin-based LED range are provided below[124]:

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[120] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 25% average outside air; and 29% of annual lighting energy contributes to cooling load. See "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993 and WasteHeatAdjustment.doc for additional discussion.
[121] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."
[122] From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993.
[123] See WasteHeatAdjustment.doc.
[124] See 2013 LED Sales Review.xls for details on how the baseline and efficient wattages for the LED bulbs were determined based on a year's worth of sales data from a cross section of product brands and Vermont geography. Note that the baseline for Reduced Wattage CFL is a standard CFL and therefore there is no baseline adjustment.

| | | | Baseline Bulb Wattages Assumed in Calculation | | |
|---|---|---|---|---|---|
| | **LED Wattage Range** | **LED Wattage** | **2013 Baseline** | **2014 Baseline** | **2020 Baseline** |
| **Standard** | <10W | 8.4 | 39.5 | 28.8 | 11.8 |
| | >=10W | 12.1 | 59.9 | 43.2 | 18.1 |

| | | | | Mid Measure Life Savings Adjustments | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Market** | **LED Wattage Range** | **LED Wattage** | **2013** | **After # of years** | **2014** | **After # of years** | **2015** | **After # of years** |
| **Standard** | Residential | <10W | 8.4 | 23% | 3 | 17% | 6 | 17% | 5 |
| | | >=10W | 12.1 | 21% | 3 | 19% | 6 | 19% | 5 |
| | Commercial | <10W | 8.4 | 66% | 1 | n/a | n/a | 17% | 5 |
| | | >=10W | 12.1 | 64% | 1 | 19% | 6 | 19% | 5 |

See "SMARTLIGHT LED delta watts and EISA Calculation_2013.xls" for calculation details.
Note that the 2014 Commercial <10W group does not have an EISA adjustment since the measure life is shorter than the number of years to 2020.

This adjustment should be applied to both electric and fossil fuel savings and will be recalculated for subsequent years.

**High Efficiency**
Refer to the tables in the Reference Tables section for efficient lighting wattage and savings.

**Operating Hours & In Service Rate**
Fixed annual operating hours will be used for each measure. Commercial and residential participation will be established through sales data collected and reported by participating distributors.

| Measure Group | Measure Code | Commercial Operating Hours[125] | ISR |
|---|---|---|---|
| LED - Commercial | LBLSCLED | 3500 | 0.898[126] |
| LED - Residential | LBLSRLED | 1241 | 0.870[127] |
| Reduced Wattage T8 | LBLRWLT8 | 3214 | 0.9[128] |
| Reduced Wattage T5 | LBLRWLT5 | 4162 | |
| Reduced Wattage MH | LBLRWLMH | 4243 | |
| Reduced Wattage CFL | LBLRWLCF | 2800 | |

[125] LED commercial hours in-line with the Efficient Products "ENERGY STAR Integrated Screw Based SSL (LED) Lamps" TRM. LED residential hours in-line with the Efficient Products "ENERGY STAR Integrated Screw Based SSL (LED) Lamps" TRM. CFL hours in-line with Efficient Products "Interior Fluorescent Fixture" TRM. Hours for all other measures are based on 5 years of EVT data for installed measures of similar type from 2007 through 2011. See SMARTLIGHT Hours Assumptions 2012.xlsx for more detail.
[126] See SMARTLIGHT QA 2012.docx for commercial LED in service rate
[127] *Ibid*
[128] Per 2005 TAG agreement for prescriptive measures

**Loadshape**
Commercial: Loadshape # 12 (Commercial Indoor Lighting-Blended) for demand and lighting energy savings and #15 (Commercial A/C) for cooling energy savings.
Residential: Loadshape #1: Residential Indoor Lighting

**Freeridership/Spillover Factors**

| Measure Category | | Light Bulbs/Lamps | | Light Bulbs/Lamps | |
|---|---|---|---|---|---|
| Measure Code | | LBLSRLED, LBLSCLED | | LBLRWLT8, LBLRWLT5, LBLRWLCF, LBLRWLMH | |
| Product Description | | Screw based SSL Lamps, Residential and Commercial | | Reduced Wattage T8, Reduced-Wattage T5, Reduced-Wattage CFL Reduced-Wattage MH | |
| Track Name | Track No. | Freerider | Spillover | Freerider | Spillover |
| C&I Upstream | 6013UPST | 0.95 | 1.05 | 0.9 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
Lifetime is the life of the product, at the reported operating hours (lamp life in hours divided by operating hours per year – see reference table 'LED Component Costs and Lifetimes' for lamp life assumption). The analysis period is the same as the lifetime, capped at 15 years.

**Measure Cost**
Refer to 'New and Baseline Assumptions' reference tables.

**O&M Cost Adjustments**
Refer to 'Component Costs and Lifetimes' reference tables.

Baseline shift due to EISA Legislation:
The Screw Based Standard LED measures have a baseline shift due to the EISA legislation. For these measures an annual equivalent O&M baseline cost is calculated in "SMARTLIGHT LED delta watts and EISA Calculation_2013.xls" using the following assumptions:

| | | **Incandescent** | **EISA 2012-2014 Compliant** | **EISA 2020 Compliant** |
|---|---|---|---|---|
| **Standard and Decorative** | **Baseline Lamp Costs** | $0.50 | $1.50 | $5.00 |
| | **Baseline Lamp Life (hours)** | 1000 | 1000 | 8,000 for Residential 10,000 for Commercial |

The result is presented below:

| | | | Annual baseline O&M assumption | | |
|---|---|---|---|---|---|
| | | **LED Wattage** | 2013 | 2014 | 2015 |
| **Standard and Decorative** | **Residential** | <10W | $1.16 | $1.23 | $1.16 |
| | | >=10W | $1.19 | $1.17 | $1.10 |
| | **Commercial** | <10W | $13.70 | $14.38 | $12.32 |
| | | >=10W | $14.02 | $12.72 | $11.11 |

**Fossil Fuel Descriptions**
See algorithm in 'Heating Increased Usage'

**Water Descriptions**
There are no water algorithms or default values for this measure.

## Reference Tables

**LED Screw Base New and Baseline Assumptions**

| Year | EE Measure Description | EE Cost | System WattsEE | Baseline Description | Base Cost | System Watts Base | Measure Cost | Watts SAVE | Measure Code | Default Loadshape Description | Default Space Type | Baseline Shift? | Time Period for Baseline Shift |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2013 | LED Screw and Pin-based Bulbs, Std < 10W | $12.00 | 8.4 | Baseline LED Screw and Pin-based Bulbs, Std < 10W | $0.50 | 39.4 | $11.50 | 31.0 | LBLSBLED | Commercial Indoor Lighting-Blended or Residential Indoor Lighting | Prescriptive Interior (50% cooled) | Y | 2014 and 2020 |
| | LED Screw and Pin-based Bulbs, Std >= 10W | $26.00 | 12.1 | Baseline LED Screw and Pin-based Bulbs, Std >= 10W | $0.50 | 59.9 | $25.50 | 47.8 | LBLSBLED | | | Y | 2014 and 2020 |
| 2014 | LED Screw and Pin-based Bulbs, Std < 10W | $12.00 | 8.4 | Baseline LED Screw and Pin-based Bulbs, Std < 10W | $1.50 | 28.8 | $10.50 | 20.4 | LBLSBLED | | | Y | 2020 |
| | LED Screw and Pin-based Bulbs, Std >= 10W | $26.00 | 12.1 | Baseline LED Screw and Pin-based Bulbs, Std >= 10W | $1.50 | 43.2 | $24.50 | 31.1 | LBLSBLED | | | Y | 2020 |
| All | LED Screw and Pin-based Bulbs. Decorative <10W | $21.00 | 3.6 | Baseline LED Screw and Pin-based Bulbs, Decorative < 10W | $1.00 | 21.9 | $20.00 | 18.3 | LBLSBLED | | | N | N/A |
| All | LED Screw-based Bulbs, Directional, < 15W | $41.00 | 9.7 | Baseline LED Screw and Pin-based Bulbs, Directional, < 15W | $5.00 | 44.3 | $36.00 | 34.6 | LBLSBLED | | | N | N/A |
| All | LED Screw-based Bulbs, Directional, >= 15W | $57.00 | 16.7 | Baseline LED Screw and Pin-based Bulbs, Directional, >= 15W | $5.00 | 46.3 | $52.00 | 29.6 | LBLSBLED | | | N | N/A |

**High-Performance T8 and Reduced-Wattage T8 New and Baseline Assumptions**

| EE Measure Description | EE Cost | System WattsEE | Baseline Description | Base Cost | System Watts Base | Measure Cost | WattsSAVE | Measure Code | Default Loadshape Description | Default Space Type |
|---|---|---|---|---|---|---|---|---|---|---|
| RWT8 - F28T8 Lamp | $4.50 | 25 | F32T8 Standard Lamp | $2.50 | 28 | $2.00 | 4 | LBLRWLT8 | Commercial Indoor Lighting-Blended | Prescriptive Interior (50% cooled) |
| RWT8 - F28T8 Extra Life Lamp | $4.50 | 25 | F32T8 Standard Lamp | $2.50 | 28 | $2.00 | 4 | LBLRWLT8 | | |
| RWT8 - F32/25W T8 Lamp | $4.50 | 22 | F32T8 Standard Lamp | $2.50 | 28 | $2.00 | 6 | LBLRWLT8 | | |
| RWT8 - F32/25W T8 Lamp Extra Life | $4.50 | 22 | F32T8 Standard Lamp | $2.50 | 28 | $2.00 | 6 | LBLRWLT8 | | |
| RWT8 - F17T8 Lamp - 2 Foot | $4.80 | 14 | F17T8 Standard Lamp - 2 foot | $2.80 | 16 | $2.00 | 2 | LBLRWLT8 | | |
| RWT8 - F25T8 Lamp - 3 Foot | $5.10 | 20 | F25T8 Standard Lamp - 3 foot | $3.10 | 23 | $2.00 | 3 | LBLRWLT8 | | |
| RWT8 - F30T8 Lamp - 6" Utube | $11.31 | 26 | F32T8 Standard Utube Lamp | $9.31 | 28 | $2.00 | 2 | LBLRWLT8 | | |
| RWT8 - F29T8 Lamp - Utube | $11.31 | 26 | F32T8 Standard Utube Lamp | $9.31 | 28 | $2.00 | 3 | LBLRWLT8 | | |
| RWT8 - F96T8 Lamp - 8 Foot | $9.00 | 57 | F96T8 Standard Lamp - 8 foot | $7.00 | 62 | $2.00 | 5 | LBLRWLT8 | | |

Notes: Wattage assumptions for Reduced-Wattage T8 based on Existing 0.88 Normal Ballast Factor.

**Reduced Wattage T5 New and Baseline Assumptions**

| EE Measure Description | EE Cost | System WattsEE | Baseline Description | Base Cost | System Watts Base | Measure Cost | WattsSAVE | Measure Code | Default Loadshape Description | Default Space Type |
|---|---|---|---|---|---|---|---|---|---|---|
| RWT5 - F14T5 Lamp - 2 Foot | $14.00 | 13 | F14T5 Standard Lamp | $12.00 | 14 | $2.00 | 1 | LBLRWLT5 | Commercial Indoor Lighting-Blended | Prescriptive Interior (50% cooled) |
| RWT5 - F21T5 Lamp - 3 Foot | $14.00 | 20 | F21T5 Standard Lamp | $12.00 | 21 | $2.00 | 1 | LBLRWLT5 | | |
| RWT5 - F28T5 Lamp - 4 Foot | $14.00 | 26 | F28T5 Standard Lamp | $12.00 | 28 | $2.00 | 2 | LBLRWLT5 | | |
| RWT5 - F35T5 Lamp - 5 Foot | $14.00 | 33 | F35T5 Standard Lamp | $12.00 | 35 | $2.00 | 2 | LBLRWLT5 | | |
| RWT5 - F54T5 Lamp - 4 Foot 44W | $14.00 | 44 | F54T5 Standard Lamp | $12.00 | 54 | $2.00 | 10 | LBLRWLT5 | | |
| RWT5 - F54T5 Lamp - 4 Foot 47W | $14.00 | 47 | F54T5 Standard Lamp | $12.00 | 54 | $2.00 | 7 | LBLRWLT5 | | |
| RWT5 - F54T5 Lamp - 4 Foot 49W | $14.00 | 49 | F54T5 Standard Lamp | $12.00 | 54 | $2.00 | 5 | LBLRWLT5 | | |
| RWT5 - F54T5 Lamp - 4 Foot 51W | $14.00 | 51 | F54T5 Standard Lamp | $12.00 | 54 | $2.00 | 3 | LBLRWLT5 | | |

**Reduced Wattage Metal Halide New and Baseline Assumptions**

| EE Measure Description | EE Cost | System WattsEE | Baseline Description | Base Cost | System Watts Base | Measure Cost | WattsSAVE | Measure Code | Default Loadshape Description | Default Space Type |
|---|---|---|---|---|---|---|---|---|---|---|
| RWMH - 150 Watt | $38.00 | 180 | 175 Watt MH | $28.00 | 205 | $10.00 | 25 | LBLRWMHL | Industrial Indoor Lighting | Heating Only |
| RWMH - 205 Watt | $51.00 | 250 | 250 Watt MH | $21.00 | 295 | $30.00 | 45 | LBLRWMHL | | |
| RWMH - 330 Watt | $51.00 | 385 | 400 Watt MH | $21.00 | 455 | $30.00 | 70 | LBLRWMHL | | |
| RWMH - 360 Watt | $36.00 | 415 | 400 Watt MH | $21.00 | 455 | $15.00 | 40 | LBLRWMHL | | |
| RWMH - 830 Watt | $88.00 | 905 | 1000 Watt MH | $48.00 | 1075 | $40.00 | 170 | LBLRWMHL | | |
| RWMH - 950 Watt | $68.00 | 1025 | 1000 Watt MH | $48.00 | 1075 | $20.00 | 50 | LBLRWMHL | | |

**Reduced Wattage Pin Based CFL New and Baseline Assumptions**

| EE Measure Description | EE Cost | System WattsEE | Baseline Description | Base Cost | System Watts Base | Measure Cost | WattsSAVE | Measure Code | Default Loadshape Description | Default Space Type |
|---|---|---|---|---|---|---|---|---|---|---|
| RWCFL - 4 Pin Dulux Supersaver | $14.80 | 25 | CFL - 4 Pin Dulux | $12.80 | 36 | $2.00 | 11 | LBLRWCFL | Commercial Indoor Lighting-Blended or Residential Indoor Lighting | Prescriptive Interior (50% cooled) |
| RWCFL - Pin Based 14 Watt | $10.70 | 13 | CFL - Pin Based 18 Watt | $8.70 | 16 | $2.00 | 4 | LBLRWCFL | | |
| RWCFL - Pin Based 21 Watt | $11.70 | 19 | CFL - Pin Based 26 Watt | $9.70 | 23 | $2.00 | 5 | LBLRWCFL | | |
| RWCFL - Pin Based 27 Watt | $14.80 | 24 | CFL - Pin Based 32 Watt | $12.80 | 29 | $2.00 | 5 | LBLRWCFL | | |
| RWCFL - Pin Based 33 Watt | $14.80 | 30 | CFL - Pin Based 42 Watt | $12.80 | 38 | $2.00 | 8 | LBLRWCFL | | |

**LED Screw Base Component Costs and Lifetimes**

| EE Measure Description | EE Lamp Cost | EE Lamp Life (hrs) | Baseline Description | Base Lamp Cost (1) | Base Lamp Life (hrs) (1) | Base Lamp Rep. Labor Cost (1) | Assumed Technology (1) | Base Lamp Cost (2) | Base Lamp Life (hrs) (2) | Base Lamp Rep. Labor Cost (2) | Assumed Technology (2) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LED Screw and Pin-based Bulbs, Std < 10W | $12.00 | 20000 | See annual levelized payment table in "O&M Cost Adjustments" section above | | | | | | | | |
| LED Screw and Pin-based Bulbs, Std >= 10W | $26.00 | 25000 | | | | | | | | | |
| LED Screw and Pin-based Bulbs. Decorative <10W | $21.00 | 20000 | Baseline LED Screw and Pin-based Bulbs, Decorative < 10W | $1.00 | 10000 | $2.67 | INC | N/A | | | |
| LED Screw-based Bulbs, Directional, < 15W | $41.00 | 28000 | Baseline LED Screw and Pin-based Bulbs, Directional, < 15W | $5.00 | 10000 | $2.67 | 15% CFL 15W | $10.00 | 2500 | $2.67 | 85% Halogen PAR20 |
| LED Screw-based Bulbs, Directional, >= 15W | $57.00 | 44000 | Baseline LED Screw and Pin-based Bulbs, Directional, >= 15W | $5.00 | 10000 | $2.67 | 15% CFL 25W | $10.00 | 2500 | $2.67 | 85% Halogen PAR30/38 |

**High-Performance T8 and Reduced-Wattage T8 Component Costs and Lifetimes**

| EE Measure Description | EE Lamp Cost | EE Lamp Life (hrs) | Baseline Description | Base Lamp Cost | Base Lamp Life (hrs) | Base Lamp Rep. Labor Cost |
|---|---|---|---|---|---|---|
| RWT8 - F28T8 Lamp | $4.50 | 30000 | F32T8 Standard Lamp | $2.50 | 15000 | $2.67 |
| RWT8 - F28T8 Extra Life Lamp | $4.50 | 36000 | F32T8 Standard Lamp | $2.50 | 15000 | $2.67 |
| RWT8 - F32/25W T8 Lamp | $4.50 | 30000 | F32T8 Standard Lamp | $2.50 | 15000 | $2.67 |
| RWT8 - F32/25W T8 Lamp Extra Life | $4.50 | 36000 | F32T8 Standard Lamp | $2.50 | 15000 | $2.67 |
| RWT8 - F17T8 Lamp - 2 Foot | $4.80 | 18000 | F17T8 Standard Lamp - 2 foot | $2.80 | 15000 | $2.67 |
| RWT8 - F25T8 Lamp - 3 Foot | $5.10 | 18000 | F25T8 Standard Lamp - 3 foot | $3.10 | 15000 | $2.67 |
| RWT8 - F30T8 Lamp - 6" Utube | $11.31 | 24000 | F32T8 Standard Utube Lamp | $9.31 | 15000 | $2.67 |
| RWT8 - F29T8 Lamp - Utube | $11.31 | 24000 | F32T8 Standard Utube Lamp | $9.31 | 15000 | $2.67 |
| RWT8 - F96T8 Lamp - 8 Foot | $9.00 | 24000 | F96T8 Standard Lamp - 8 foot | $7.00 | 15000 | $2.67 |

## Reduced Wattage T5 Component Costs and Lifetimes

| EE Measure Description | EE Lamp Cost | EE Lamp Life (hrs) | Baseline Description | Base Lamp Cost | Base Lamp Life (hrs) | Base Lamp Rep. Labor Cost |
|---|---|---|---|---|---|---|
| RWT5 - F14T5 Lamp - 2 Foot | $14.00 | 30000 | F14T5 Standard Lamp | $12.00 | 20000 | $2.67 |
| RWT5 - F21T5 Lamp - 3 Foot | $14.00 | 30000 | F21T5 Standard Lamp | $12.00 | 20000 | $2.67 |
| RWT5 - F28T5 Lamp - 4 Foot | $14.00 | 30000 | F28T5 Standard Lamp | $12.00 | 20000 | $2.67 |
| RWT5 - F35T5 Lamp - 5 Foot | $14.00 | 30000 | F35T5 Standard Lamp | $12.00 | 20000 | $2.67 |
| RWT5 - F54T5 Lamp - 4 Foot 44W | $14.00 | 30000 | F54T5 Standard Lamp | $12.00 | 20000 | $2.67 |
| RWT5 - F54T5 Lamp - 4 Foot 47W | $14.00 | 30000 | F54T5 Standard Lamp | $12.00 | 20000 | $2.67 |
| RWT5 - F54T5 Lamp - 4 Foot 49W | $14.00 | 30000 | F54T5 Standard Lamp | $12.00 | 20000 | $2.67 |
| RWT5 - F54T5 Lamp - 4 Foot 51W | $14.00 | 30000 | F54T5 Standard Lamp | $12.00 | 20000 | $2.67 |

## Reduced Wattage Metal Halide Component Costs and Lifetimes

| EE Measure Description | EE Lamp Cost | EE Lamp Life (hrs) | Baseline Description | Base Lamp Cost | Base Lamp Life (hrs) | Base Lamp Rep. Labor Cost |
|---|---|---|---|---|---|---|
| RWMH - 150 Watt | $38.00 | 10000 | 175 Watt MH | $28.00 | 10000 | $2.67 |
| RWMH - 205 Watt | $51.00 | 20000 | 250 Watt MH | $21.00 | 10000 | $2.67 |
| RWMH - 330 Watt | $51.00 | 20000 | 400 Watt MH | $21.00 | 20000 | $2.67 |
| RWMH - 360 Watt | $36.00 | 20000 | 400 Watt MH | $21.00 | 20000 | $2.67 |
| RWMH - 830 Watt | $88.00 | 18000 | 1000 Watt MH | $48.00 | 15000 | $2.67 |
| RWMH - 950 Watt | $68.00 | 18000 | 1000 Watt MH | $48.00 | 15000 | $2.67 |

## Reduced Wattage Pin Based CFL Component Costs and Lifetimes

| EE Measure Description | EE Lamp Cost | EE Lamp Life (hrs) | Baseline Description | Base Lamp Cost | Base Lamp Life (hrs) | Base Lamp Rep. Labor Cost |
|---|---|---|---|---|---|---|
| RWCFL - 4 Pin Dulux Supersaver | $14.80 | 20000 | CFL - 4 Pin Dulux | $12.80 | 10000 | $2.67 |
| RWCFL - Pin Based 14 Watt | $10.70 | 12000 | CFL - Pin Based 18 Watt | $8.70 | 10000 | $2.67 |
| RWCFL - Pin Based 21 Watt | $11.70 | 12000 | CFL - Pin Based 26 Watt | $9.70 | 10000 | $2.67 |
| RWCFL - Pin Based 27 Watt | $14.80 | 16000 | CFL - Pin Based 32 Watt | $12.80 | 10000 | $2.67 |
| RWCFL - Pin Based 33 Watt | $14.80 | 16000 | CFL - Pin Based 42 Watt | $12.80 | 10000 | $2.67 |

# LED Lighting Systems

Measure Number: I-C-22-i (Business Energy Services, Lighting End Use)

**Version Date & Revision History**
Draft Portfolio: Portfolio 86
Effective date: 1/1/2014
End date: TBD

**Referenced Documents:**
1) LED Lighting TRM Assumptions 2014_Final.xlsx
2) LED Refrig Lighting ERCO_Talking_Pointsv3.pdf
3) 2008-2010 LED Measure Data and Aggregation.xls
4) WasteHeatAdjustment.doc
5) LED Standard Decorative Delta Watts Calculation.xls
6) "Calculating lighting and HVAC interactions", ASHRAE Journal November 1993
7) 2009 ASHRAE Handbook Fundamentals
8) NEEP DLC QPL 2.21.2014.xls & NEEP DLC QPL 9.17.2014

**Description**
LED lighting systems have source efficacies (lumens per watt) that can match or exceed efficacies of incandescent, compact fluorescent, linear fluorescent and HID lighting. In addition, LED's inherent directionality reduces or eliminates the need for a reflector to direct light, thereby reducing or eliminating fixture efficiency losses. This inherent directionality can also be used to provide better uniformity and eliminate hot spots under fixtures, as often occurs with outdoor HID lighting. By eliminating hot spots, further reductions in energy are realized. Eligible fixtures and lamps must be ENERGY STAR labeled, listed on the DesignLights Consortium Qualified Products List, or pass the Efficiency Vermont photometric criteria on Lighting Facts. Eligible measures include new and replacement.

**Algorithms**
**Demand Savings**
$\Delta kW = ((Watts_{BASE} - Watts_{EE}) / 1000) \times ISR \times WHF_d$

**Energy Savings**
$\Delta kWh = ((Watts_{BASE} - Watts_{EE}) / 1000) \times HOURS \times ISR \times WHF_e$

Where:

$\Delta kW$ = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW from table located in Reference Tables section.
$Watts_{EE}$ = Energy efficient connected kW from table located in Reference Tables section.
ISR = In service rate, or the percentage of units rebated that actually get used. For prescriptive measures, this is assumed to be 98%.[129]
$WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting. For prescriptive lighting in existing buildings, the default value is 1.082 (calculated as 1 + (0.47*0.67*.808) / 3.1))[130]. For prescriptive lighting in new buildings, the value is 1.084 (calculated as 1 + (0.47*0.67*.808) / 3.4))[131]. The cooling savings are only added to the summer peak savings. For refrigerated case lighting, the value is 1.29 (calculated as (1 + (1.0 / 3.5))). Based on the assumption that all lighting

[129] 2005 TAG agreement.
[130] Based on the following assumptions: 3.1 COP typical cooling system efficiency for existing buildings; average 47% of spaces have mechanical cooling; 33% average outside air; and 80.8% coincidence of cooling with the summer peak period. See WasteHeatAdjustment.doc for additional discussion.
[131] Based on the same assumptions used for existing buildings, except 3.4 COP typical cooling system efficiency for new buildings. See WasteHeatAdjustment.doc for additional discussion.

in refrigerated cases is mechanically cooled, with a typical 3.5[132] COP refrigeration system efficiency, and assuming 100% of lighting heat needs to be mechanically cooled at time of summer peak. For freezer case lighting, the value is 1.50 (calculated as (1 + (1.0 / 2.0))). Based on the assumption that all lighting in freezer cases is mechanically cooled, with a typical 2.0 COP[133] freezer system efficiency, and assuming 100% of lighting needs to be mechanically cooled at time of summer peak.

$\Delta$kWh = gross customer annual kWh savings for the measure

HOURS = annual lighting hours of use per year; collected from prescriptive application form. If operating hours are not available, then the value will be selected from the table 'Operating Hours by Building Type' in the reference tables section of this document.

$WHF_e$ = Waste heat factor for energy to account for cooling savings from efficient lighting. For prescriptive lighting in existing buildings, the default value is 1.033 (calculated as 1 + ((0.47*0.29*.75) / 3.1)) [134]. For prescriptive lighting in new buildings, the value is 1.030 (calculated as 1 + ((0.47*0.29*.75) / 3.4))[135]. For refrigerated case lighting, the value is 1.29 (calculated as (1 + (1.0 / 3.5))). Based on the assumption that all lighting in refrigerated cases is mechanically cooled, with a typical 3.5[132] COP refrigeration system efficiency, and assuming 100% of lighting heat needs to be mechanically cooled at time of summer peak. For freezer case lighting, the value is 1.50 (calculated as (1 + (1.0 / 2.0))). Based on the assumption that all lighting in freezer cases is mechanically cooled, with a typical 2.0 COP[133] freezer system efficiency, and assuming 100% of lighting needs to be mechanically cooled at time of summer peak.

**Waste Heat Adjustment**

Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF).

**Heating Increased Usage**

$\Delta MMBTU_{WH}$ = $(\Delta kWh / WHF_e) \times 0.003413 \times (1 - OA) \times AR \times HF \times DFH / HEff$

Where:

$\Delta MMBTU_{WH}$ = gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.

0.003413 = conversion from kWh to MMBTU

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[136].

AR = Typical aspect ratio factor. ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of building within 15 feet of exterior wall.

HF = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont[137]

DFH = Percent of lighting in heated spaces. For prescriptive lighting, assumed to be 95%

HEff = Average heating system efficiency, For prescriptive lighting, assumed to be 79% in existing buildings and 83 % in new Construction[138].

Oil heating is assumed typical for commercial buildings.

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[132] Assumes 3.5 COP for medium temp cases based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of 20°F and a condensing temperature of 90°F.

[133] Assumes 2.0 COP for low temp cases based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of -20°F and a condensing temperature of 90°F.

[134] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 25% average outside air; and 29% of annual lighting energy contributes to cooling load. See "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993 and WasteHeatAdjustment.doc for additional discussion.

[135] Based on the same assumptions used for existing buildings, except 3.4 COP typical cooling system efficiency for new buildings. See WasteHeatAdjustment.doc for additional discussion.

[136] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

[137] From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993.

[138] See WasteHeatAdjustment.doc.

**Baseline and High Efficiencies**
Refer to reference tables listed below for baseline wattage assumptions [139]

**Operating Hours**
Operating hours will be collected from the prescriptive application form or from the table of hours by building type located in the reference tables section of this document.

**Loadshape**
For Interior lighting applications, # 12 (Commercial Indoor Lighting-Blended) for demand and lighting energy savings and #15 (Commercial A/C) for cooling energy savings.
For Exterior lighting applications, #13 (Commercial Outdoor Lighting)
For refrigerated and freezer case lighting applications, # 87 (Grocery/Conv. Store Indoor Lighting) for demand and lighting energy savings and #14 (Commercial Refrigeration) for refrigeration and freezer (cooling bonus) energy savings.

**Freeridership/Spillover Factors**

| Measure Category | | Lighting Hardwired Fixture | |
|---|---|---|---|
| Measure Code | | LFHRDLED, LFHSDLED, LFHORLED, LFHODLED, LFHOWLED, LFHPGLED, LFHOBLED, LFHOSLED, LFHOPLED, LFHWWLED, LFHDHLED, LFHPTLED, LFHUSLED, LFHRCLED, LFHFLLED, LBLSBLED, LFHFCLED, LFHDCLED, LFH22LED, LFH24LED, LFH14LED, LFHHBLED, LBL4TLED | |
| Product Description | | LED Lighting System | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | 0.95 | 1.05 |
| Cust Equip Rpl | 6013CUST | 0.95 | 1.05 |
| Pres Equip Rpl | 6013PRES | 0.95 | 1.05 |
| C&I NC Cust | 6014CUST | 0.95 | 1.05 |
| C&I NC Pres | 6014PRES | 0.95 | 1.05 |
| LIMF NC | 6018LINC | 0.95 | 1.05 |
| MF Mkt NC | 6019MFNC | 0.95 | 1.05 |

**Persistence**
The persistence factor is assumed to be one for all measures.

[139] See the file LED Lighting TRM Assumptions 2011-2012.xlsx for details. Baseline assumptions for all measures except “LED Screw and Pin-based Bulbs, Std and Decorative”, “LED 2x and 1x Recessed Light Fixtures”, and “LED High- and Low-Bay Fixtures” are based on analysis of actual EVT installations of LED lighting. See the file 2008-2010 LED Measure Data and Aggregation.xls for more details of that analysis. Baseline assumption for “LED Screw and Pin-based Bulbs, Std and Decorative” based on a blend of Decorative and Standard Screw-based lamps, using assumptions consistent with the Efficient Products characterization of these measures. See the file LED Standard Decorative Delta Watts Calculation.xls for more details. Baseline assumptions for “LED 2x and 1x Recessed Light Fixtures”, and “LED High- and Low-Bay Fixtures” based on average watts of DLC qualified products as of 11/21/11. See the file NEEP DLC QPL 11.21.11.xls for more details.

**Lifetimes**
For Fixtures: 15 years
Analysis period is the same as lifetime.

For Screw-base lamps:
Lifetime is the life of the product, at the reported operating hours (lamp life in hours divided by operating hours per year – see reference table 'LED Component Costs and Lifetimes' for LED lamp life assumption).
The analysis period is the same as the lifetime, capped at 15 years.

**Measure Cost**
Refer to reference tables listed below for measure cost data[140].

**Fossil Fuel Descriptions**
See algorithm in 'Heating Increased Usage'

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

**Interior Lighting Operating Hours by Building Type**

| Building Type | Annual Hours |
|---|---|
| Grocery/Convenience Store | 6,019 |
| Hospital | 4,007 |
| K-12 Schools | 2,456 |
| Lodging/Hospitality | 4,808 |
| Manufacturing | 4,781 |
| Office | 3,642 |
| Public Assembly | 3,035 |
| Public Safety | 3,116 |
| Religious | 2,648 |
| Restaurant | 4,089 |
| Retail | 4,103 |
| Service | 3,521 |
| University/College | 3,416 |
| Warehouse | 4,009 |
| From C&I Lighting Load Shape Project FINAL Report, July 19, 2011, prepared by KEMA for NEEP. See document NEEP CI Lighting LS FINAL Report_ver 5_7-19-11.pdf | |

[140] See reference file LED Lighting TRM Assumptions 2014_Final.xlsx for details.

**LED New and Baseline Assumptions**

| LED Measure Description | WattsEE | Basis for WattsEE | Baseline Description | WattsBASE | Basis for WattsBASE | Delta Watts | Incremental Cost | Measure Code |
|---|---|---|---|---|---|---|---|---|
| LED Recessed, Surface, Pendant Downlights | 17.6 | 2008-2010 EVT Historical Data of 947 Measures | Baseline LED Recessed, Surface, Pendant Downlights | 54.3 | 2008-2010 EVT Historical Data of 947 Measures | 36.7 | $50.00 | LFHRDLED |
| LED Track Lighting | 12.2 | 2008-2010 EVT Historical Data of 947 Measures | Baseline LED Track Lighting | 60.4 | 2008-2010 EVT Historical Data of 242 Measures | 48.2 | $100.00 | LFHDHLED |
| LED Wall-Wash Fixtures | 8.3 | 2008-2010 EVT Historical Data of 947 Measures | Baseline LED Wall-Wash Fixtures | 17.7 | 2008-2010 EVT Historical Data of 220 Measures | 9.4 | $80.00 | LFHWWLED |
| LED Portable Desk/Task Light Fixtures | 7.1 | 2008-2010 EVT Historical Data of 947 Measures | Baseline LED Portable Desk/Task Light Fixtures | 36.2 | 2008-2010 EVT Historical Data of 21 Measures | 29.1 | $50.00 | LFHPTLED |
| LED Undercabinet Shelf-Mounted Task Light Fixtures | 7.1 per ft | 2008-2010 EVT Historical Data of 947 Measures | Baseline LED Undercabinet Shelf-Mounted Task Light Fixtures | 36.2 per ft | 2008-2010 EVT Historical Data of 21 Measures | 29.1 per ft | $25.00/ft | LFHUSLED |
| LED Surface & Suspended Linear Fixture, <= 1000 lumens/ft | 7.7 per ft | DLC Qualifying meaures from QPL (#18-21) and LightingFacts lists as of 2/21/2014 | 1,2 lamp F32T8, 1,2 lamp F28T5, 1 lamp F54T5HO | 12.3 per ft | Typical operating wattage for lumen equivalent baseline. | 4.6 per ft | $25.00/ft | LFHSLLED |
| LED Surface & Suspended Linear Fixture, > 1000 lumens/ft | 15.4 per ft | DLC Qualifying meaures from QPL (#18-21) and LightingFacts lists as of 2/21/2014 | 3 lamp F32T8, 3 lamp F28T5, 2,3 lamp F54T5HO | 30.3 per ft | Typical operating wattage for lumen equivalent baseline. | 14.9 per ft | $50.00/ft | LFHSLLED |
| LED Refrigerated Case Light, Horizontal or Vertical | 7.6 per ft | PG&E Refrigerated Case Study normalized to per foot. | Baseline LED Refrigerated Case Light, Horizontal or Vertical (per foot) | 15.2 per ft | PG&E Refrigerated Case Study normalized to per foot. | 7.6 per ft | $50.00/ft | LFHRCLED |
| LED Freezer Case Light, Horizontal or Vertical | 7.7 per ft | PG&E Refrigerated Case Study normalized to per foot. | Baseline LED Freezer Case Light, Horizontal or Vertical (per foot) | 18.7 per ft | PG&E Refrigerated Case Study normalized to per foot. | 11.0 per ft | $50.00/ft | LFHFCLED |
| LED Display Case Light Fixture | 7.1 per ft | Modeled after LED Undercabinet Shelf-Mounted Task Light Fixtures (per foot) | Baseline LED Display Case Light Fixture | 36.2 per ft | Modeled after LED Undercabinet Shelf-Mounted Task Light Fixtures (per foot) | 29.1 per ft | $25.00/ft | LFHDCLED |
| LED 2x2 Recessed Light Fixture, 1500-3000 lm | 32.3 | Average wattage of DLC qualified products as of 12/12/2013 | T8 U-Tube 2L-FB32 w/ Elec - 2' | 59.0 | Typical operating wattage for lumen equivalent T8 fixture | 26.7 | $36.00 | LFH22LED |
| LED 2x2 Recessed Light Fixture, 3001-4500 lm | 38.9 | Average wattage of DLC qualified products as of 12/12/2013 | T8 U-Tube 3L-FB32 w/ Elec - 2' | 88.0 | Typical operating wattage for lumen equivalent T8 fixture | 49.1 | $105.00 | LFH22LED |
| LED 2x4 Recessed Light Fixture, 2500-4000 lm | 36.0 | Average wattage of DLC qualified products as of 12/12/2013 | T8 2L-F32 w/ Elec - 4' | 59.0 | Typical operating wattage for lumen equivalent T8 fixture | 23.0 | $86.00 | LFH24LED |
| LED 2x4 Recessed Light Fixture, 4001-5500 lm | 49.7 | Average wattage of DLC qualified products as of 12/12/2013 | T8 3L-F32 w/ Elec - 4' | 88.0 | Typical operating wattage for lumen equivalent T8 fixture | 38.3 | $155.00 | LFH24LED |
| LED 2x4 Recessed Light Fixture, 5501-7000 lm | 68.2 | Average wattage of DLC qualified products as of 12/12/2013 | T8 4L-F32 w/ Elec - 4' | 114.0 | Typical operating wattage for lumen equivalent T8 fixture | 45.8 | $224.00 | LFH24LED |
| LED 1x4 Recessed Light Fixture, 1000-2500 lm | 24.8 | Average wattage of DLC qualified products as of 12/12/2013 | T8 1L-F32 w/ Elec - 4' | 32.0 | Typical operating wattage for lumen equivalent T8 fixture | 7.2 | $16.00 | LFH14LED |
| LED 1x4 Recessed Light Fixture, 2501-4000 lm | 35.7 | Average wattage of DLC qualified products as of 12/12/2013 | T8 2L-F32 w/ Elec - 4' | 59.0 | Typical operating wattage for lumen equivalent T8 fixture | 23.3 | $86.00 | LFH14LED |
| LED 1x4 Recessed Light Fixture, 4001-5500 lm | 48.7 | Average wattage of DLC qualified products as of 12/12/2013 | T8 3L-F32 w/ Elec - 4' | 88.0 | Typical operating wattage for lumen equivalent T8 fixture | 39.3 | $155.00 | LFH14LED |
| LED 4' Linear Replacement Lamp | 19.5 | Average wattage of DLC qualified products as of 12/12/2013 | T8 F32 w/ Elec - 4' - per lamp | 29.1 | Weighted average for historic EVT distribution of T8 fixtures | 9.6 | $71.00 | LBL4TLED |
| LED High- and Low-Bay Fixtures | 148.7 | Based on weighted average watts of DLC qualified products in three size categories as of 9/17/2014 | T8HO high bay fixtures (4 to 8 lamps) | 254.8 | Weighted average of typical operating wattage for 4, 6, and 8-lamp T8HO high bay fixtures | 106.1 | $200.00 | LFHHBLED |
| LED Outdoor Pole/Arm Mounted Parking/Roadway, < 30W | 18.6 | 2008-2010 EVT Historical Data of 2,813 Measures | Baseline LED Outdoor Pole/Arm Mounted Parking/Roadway, < 30W | 124.3 | 2008-2010 EVT Historical Data of 2,813 Measures | 105.7 | $125.00 | LFHORLED |
| LED Outdoor Pole/Arm Mounted Parking/Roadway, 30W - 75W | 52.5 | 2008-2010 EVT Historical Data of 1,081 Measures | Baseline LED Outdoor Pole/Arm Mounted Parking/Roadway, 30W - 75W | 182.9 | 2008-2010 EVT Historical Data of 1,081 Measures | 130.4 | $250.00 | LFHORLED |
| LED Outdoor Pole/Arm Mounted Parking/Roadway, >= 75W | 116.8 | 2008-2010 EVT Historical Data of 806 Measures | Baseline LED Outdoor Pole/Arm Mounted Parking/Roadway, >= 75W | 361.4 | 2008-2010 EVT Historical Data of 806 Measures | 244.6 | $375.00 | LFHORLED |
| LED Outdoor Pole/Arm Mounted Decorative Parking/Roadway, < 30W | 18.6 | 2008-2010 EVT Historical Data of 2,813 Measures | Baseline LED Outdoor Pole/Arm Mounted Decorative Parking/Roadway, < 30W | 124.3 | 2008-2010 EVT Historical Data of 2,813 Measures | 105.7 | $125.00 | LFHODLED |
| LED Outdoor Pole/Arm Mounted Decorative Parking/Roadway, 30W - 75W | 52.5 | 2008-2010 EVT Historical Data of 1,081 Measures | Baseline LED Outdoor Pole/Arm Mounted Decorative Parking/Roadway, 30W - 75W | 182.9 | 2008-2010 EVT Historical Data of 1,081 Measures | 130.4 | $250.00 | LFHODLED |
| LED Outdoor Pole/Arm Mounted Decorative Parking/Roadway, >= 75W | 116.8 | 2008-2010 EVT Historical Data of 806 Measures | Baseline LED Outdoor Pole/Arm Mounted Decorative Parking/Roadway, >= 75W | 361.4 | 2008-2010 EVT Historical Data of 806 Measures | 244.6 | $375.00 | LFHODLED |
| LED Parking Garage/Canopy, < 30W | 18.6 | 2008-2010 EVT Historical Data of 2,813 Measures | Baseline LED Parking Garage/Canopy, < 30W | 124.3 | 2008-2010 EVT Historical Data of 2,813 Measures | 105.7 | $125.00 | LFHPGLED |
| LED Parking Garage/Canopy, 30W - 75W | 52.5 | 2008-2010 EVT Historical Data of 1,081 Measures | Baseline LED Parking Garage/Canopy, 30W - 75W | 182.9 | 2008-2010 EVT Historical Data of 1,081 Measures | 130.4 | $250.00 | LFHPGLED |
| LED Parking Garage/Canopy, >= 75W | 116.8 | 2008-2010 EVT Historical Data of 806 Measures | Baseline LED Parking Garage/Canopy, >= 75W | 361.4 | 2008-2010 EVT Historical Data of 806 Measures | 244.6 | $375.00 | LFHPGLED |
| LED Wall-Mounted Area Lights, < 30W | 18.6 | 2008-2010 EVT Historical Data of 2,813 Measures | Baseline LED Wall-Mounted Area Lights, < 30W | 124.3 | 2008-2010 EVT Historical Data of 2,813 Measures | 105.7 | $125.00 | LFHOWLED |
| LED Wall-Mounted Area Lights, 30W - 75W | 52.5 | 2008-2010 EVT Historical Data of 1,081 Measures | Baseline LED Wall-Mounted Area Lights, 30W - 75W | 182.9 | 2008-2010 EVT Historical Data of 1,081 Measures | 130.4 | $250.00 | LFHOWLED |
| LED Wall-Mounted Area Lights, >= 75W | 116.8 | 2008-2010 EVT Historical Data of 806 Measures | Baseline LED Wall-Mounted Area Lights, >= 75W | 361.4 | 2008-2010 EVT Historical Data of 806 Measures | 244.6 | $375.00 | LFHOWLED |
| LED Bollard, < 30W | 13.9 | 2008-2010 EVT Historical Data of 33 Measures | Baseline LED Bollard, < 30W | 54.3 | 2008-2010 EVT Historical Data of 33 Measures | 40.4 | $150.00 | LFHOBLED |
| LED Bollard, >= 30W | 41.0 | 2008-2010 EVT Historical Data of 15 Measures | Baseline LED Bollard, >= 30W | 78.0 | 2008-2010 EVT Historical Data of 15 Measures | 37.0 | $250.00 | LFHOBLED |
| LED Flood and Spot Light, < 1000 lumens | 13.0 | Average wattage of products in the Lighting Facts database (insufficient DLC data) | Baseline LED Flood Light, <= 1000 lumens | 52.5 | Typical operating wattage for lumen equivalent PAR38 EISA compliant bulb | 39.5 | $150.00 | LFHFLLED |
| LED Flood and Spot Light, 1000-4000 lumens | 32.3 | Average wattage of products in the Lighting Facts database (insufficient DLC data) | Baseline LED Flood Light, 1001-4000 lumens | 108.7 | Typical operating wattage for lumen equivalent PAR38 EISA compliant bulb | 76.4 | $245.00 | LFHFLLED |
| LED Flood and Spot Light, > 4000 lumens | 107.5 | Average wattage of products in the Lighting Facts database (insufficient DLC data) | Baseline LED Flood Light, > 4000 lumens | 205.0 | Typical operating wattage for lumen equivalent metal halide flood fixture. | 97.5 | $315.00 | LFHFLLED |

**LED Component Costs and Lifetimes**

| LED Measure Description | LED Minimum Lamp Life (hrs) | LED Lamp Cost | LED Lamp Replacement Time (min) | LED Lamp Replacement Rate ($/hr) | LED Lamp Rep. Labor Cost | LED Lamp Cost Total | LED Driver Life (hrs) | LED Driver Cost | LED Driver Replacement Time (min) | LED Driver Replacement Rate ($/hr) | LED Driver Rep. Labor Cost | LED Driver Cost Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LED Recessed, Surface, Pendant Downlights | 50,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 | 70,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 |
| LED Track Lighting | 50,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 | 70,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 |
| LED Wall-Wash Fixtures | 50,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 | 70,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 |
| LED Portable Desk/Task Light Fixtures | 50,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 | 70,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 |
| LED Undercabinet Shelf-Mounted Task Light Fixtures | 50,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 | 70,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 |
| LED Surface & Suspended Linear Fixture, <= 1000 lumens/ft | 50,000 | $14.67/ft | 7.5 per ft | $45.00 | $5.63/ft | $20.29/ft | 70,000 | $6.25/ft | 7.5 per ft | $45.00 | $5.63/ft | $11.88/ft |
| LED Surface & Suspended Linear Fixture, > 1000 lumens/ft | 50,000 | $30.88/ft | 7.5 per ft | $45.00 | $5.63/ft | $36.51/ft | 70,000 | $6.25/ft | 7.5 per ft | $45.00 | $5.63/ft | $11.88/ft |
| LED Refrigerated Case Light, Horizontal or Vertical | 50,000 | $5.00/ft | 6.0 per ft | $45.00 | $4.50/ft | $9.50/ft | 70,000 | $5.00/ft | 6.0 per ft | $45.00 | $4.50/ft | $9.50/ft |
| LED Freezer Case Light, Horizontal or Vertical | 50,000 | $5.00/ft | 5.0 per ft | $45.00 | $3.75/ft | $8.75/ft | 70,000 | $4.17/ft | 5.0 per ft | $45.00 | $3.75/ft | $7.92/ft |
| LED Display Case Light Fixture | 35,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 | 70,000 | $6.25 | 30 | $45.00 | $22.50 | $28.75 |
| LED 2x2 Recessed Light Fixture, 1500-3000 lm | 50,000 | $45.00 | 30 | $45.00 | $22.50 | $67.50 | 70,000 | $25.00 | 20 | $45.00 | $15.00 | $40.00 |
| LED 2x2 Recessed Light Fixture, 3001-4500 lm | 50,000 | $76.00 | 30 | $45.00 | $22.50 | $98.50 | 70,000 | $25.00 | 20 | $45.00 | $15.00 | $40.00 |
| LED 2x4 Recessed Light Fixture, 2500-4000 lm | 50,000 | $66.00 | 30 | $45.00 | $22.50 | $88.50 | 70,000 | $25.00 | 20 | $45.00 | $15.00 | $40.00 |
| LED 2x4 Recessed Light Fixture, 4001-5500 lm | 50,000 | $96.00 | 30 | $45.00 | $22.50 | $118.50 | 70,000 | $25.00 | 20 | $45.00 | $15.00 | $40.00 |
| LED 2x4 Recessed Light Fixture, 5501-7000 lm | 50,000 | $126.00 | 30 | $45.00 | $22.50 | $148.50 | 70,000 | $25.00 | 20 | $45.00 | $15.00 | $40.00 |
| LED 1x4 Recessed Light Fixture, 1000-2500 lm | 50,000 | $35.00 | 30 | $45.00 | $22.50 | $57.50 | 70,000 | $25.00 | 20 | $45.00 | $15.00 | $40.00 |
| LED 1x4 Recessed Light Fixture, 2501-4000 lm | 50,000 | $66.00 | 30 | $45.00 | $22.50 | $88.50 | 70,000 | $25.00 | 20 | $45.00 | $15.00 | $40.00 |
| LED 1x4 Recessed Light Fixture, 4001-5500 lm | 50,000 | $96.00 | 30 | $45.00 | $22.50 | $118.50 | 70,000 | $25.00 | 20 | $45.00 | $15.00 | $40.00 |
| LED 4' Linear Replacement Lamp | 50,000 | $20.00 | 8 | $20.00 | $2.67 | $22.67 | 70,000 | $9.90 | 20 | $45.00 | $5.17 | $15.07 |
| LED High- and Low-Bay Fixtures | 35,000 | $75.00 | 30 | $75.00 | $37.50 | $112.50 | 70,000 | $25.00 | 30 | $75.00 | $37.50 | $62.50 |
| LED Outdoor Pole/Arm Mounted Parking/Roadway, < 30W | 50,000 | $25.00 | 30 | $75.00 | $37.50 | $62.50 | 70,000 | $25.00 | 30 | $75.00 | $37.50 | $62.50 |
| LED Outdoor Pole/Arm Mounted Parking/Roadway, 30W - 75W | 50,000 | $50.00 | 30 | $75.00 | $37.50 | $87.50 | 70,000 | $25.00 | 30 | $75.00 | $37.50 | $62.50 |
| LED Outdoor Pole/Arm Mounted Parking/Roadway, >= 75W | 50,000 | $75.00 | 30 | $75.00 | $37.50 | $112.50 | 70,000 | $25.00 | 30 | $75.00 | $37.50 | $62.50 |
| LED Outdoor Pole/Arm Mounted Decorative Parking/Roadway, < 30W | 50,000 | $25.00 | 30 | $75.00 | $37.50 | $62.50 | 70,000 | $25.00 | 30 | $75.00 | $37.50 | $62.50 |
| LED Outdoor Pole/Arm Mounted Decorative Parking/Roadway, 30W - 75W | 50,000 | $50.00 | 30 | $75.00 | $37.50 | $87.50 | 70,000 | $25.00 | 30 | $75.00 | $37.50 | $62.50 |
| LED Outdoor Pole/Arm Mounted Decorative Parking/Roadway, >= 75W | 50,000 | $75.00 | 30 | $75.00 | $37.50 | $112.50 | 70,000 | $25.00 | 30 | $75.00 | $37.50 | $62.50 |
| LED Parking Garage/Canopy, < 30W | 50,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 | 70,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 |
| LED Parking Garage/Canopy, 30W - 75W | 50,000 | $50.00 | 30 | $45.00 | $22.50 | $72.50 | 70,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 |
| LED Parking Garage/Canopy, >= 75W | 50,000 | $75.00 | 30 | $45.00 | $22.50 | $97.50 | 70,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 |
| LED Wall-Mounted Area Lights, < 30W | 50,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 | 70,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 |
| LED Wall-Mounted Area Lights, 30W - 75W | 50,000 | $50.00 | 30 | $45.00 | $22.50 | $72.50 | 70,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 |
| LED Wall-Mounted Area Lights, >= 75W | 50,000 | $75.00 | 30 | $45.00 | $22.50 | $97.50 | 70,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 |
| LED Bollard, < 30W | 50,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 | 70,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 |
| LED Bollard, >= 30W | 50,000 | $50.00 | 30 | $45.00 | $22.50 | $72.50 | 70,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 |
| LED Flood and Spot Light, < 1000 lumens | 50,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 | 70,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 |
| LED Flood and Spot Light, 1000-4000 lumens | 50,000 | $50.00 | 30 | $45.00 | $22.50 | $72.50 | 70,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 |
| LED Flood and Spot Light, > 4000 lumens | 50,000 | $75.00 | 30 | $45.00 | $22.50 | $97.50 | 70,000 | $25.00 | 30 | $45.00 | $22.50 | $47.50 |

**Baseline Component Costs and Lifetimes**

| Baseline Technology (1) | Number of Lamps | Lamp (1) Life (hrs) | Lamp (1) Cost | Lamp (1) Replacement Time (min) | Lamp (1) Replacement Rate ($/hr) | Lamp (1) Rep. Labor Cost | Lamp (1) Rep. Recycle Cost | Ballast (1) Life (hrs) | Ballast (1) Cost | Ballast (1) Replacement Time (min) | Ballast (1) Replacement Rate ($/hr) | Ballast (1) Rep. Labor Cost | Ballast (1) Rep. Disposal Cost | Baeline Technology (2) | Lamp (2) Life (hrs) | Lamp (2) Cost | Lamp (2) Replacement Time (min) | Lamp (2) Replacement Rate ($/hr) | Lamp (2) Rep. Labor Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40% CFL 26W Pin Base | | 10,000 | $9.70 | 8.0 | $20.00 | $2.67 | $0.25 | 40,000 | $16.00 | 20.0 | $45.00 | $15.00 | $5.00 | 60% Halogen PAR30/38 | 2,500 | $10.00 | 8.0 | $20.00 | $2.67 |
| 10% CMH PAR38 | | 12,000 | $60.00 | 8.0 | $20.00 | $2.67 | $0.25 | 40,000 | $90.00 | 20.0 | $45.00 | $15.00 | $5.00 | 90% Halogen PAR38 | 2,500 | $10.00 | 8.0 | $20.00 | $2.67 |
| 40% CFL 42W Pin Base | | 10,000 | $12.80 | 8.0 | $20.00 | $2.67 | $0.25 | 40,000 | $47.50 | 20.0 | $45.00 | $15.00 | $5.00 | 60% Halogen PAR38 | 2,500 | $10.00 | 8.0 | $20.00 | $2.67 |
| 50% 13W CFL Pin Base | | 10,000 | $2.60 | 8.0 | $20.00 | $2.67 | $0.25 | 40,000 | $5.00 | 20.0 | $45.00 | $15.00 | $5.00 | 50% 50W Halogen | 2,500 | $10.00 | 8.0 | $20.00 | $2.67 |
| 50% 2' T5 Linear | | 7,500 | $7.00 | 8.0 | $20.00 | $2.67 | $0.25 | 40,000 | $25.00 | 20.0 | $45.00 | $15.00 | $5.00 | 50% 50W Halogen | 2,500 | $10.00 | 8.0 | $20.00 | $2.67 |
| T8 2L-F32 w/ Elec - 4' | 2 | 15,000 | $1.25/ft | 4.0 per ft | $20.00 | $1.33/ft | $0.25/ft | 40,000 | $3.75/ft | 5.0 per ft | $45.00 | $3.75/ft | $1.25/ft | N/A | N/A | N/A | N/A | N/A | N/A |
| T8 3L-F32 w/ Elec - 4' | 3 | 15,000 | $1.88/ft | 6.0 per ft | $20.00 | $2.00/ft | $0.38/ft | 40,000 | $3.75/ft | 5.0 per ft | $45.00 | $3.75/ft | $1.25/ft | N/A | N/A | N/A | N/A | N/A | N/A |
| 5' T8 | | 15,000 | $0.50/ft | 1.6 per ft | $20.00 | $0.53/ft | $0.10/ft | 40,000 | $4.00/ft | 6.0 per ft | $45.00 | $4.50/ft | $1.00/ft | N/A | N/A | N/A | N/A | N/A | N/A |
| 6' T12HO | | 12,000 | $0.42/ft | 1.3 per ft | $20.00 | $0.44/ft | $0.08/ft | 40,000 | $3.33/ft | 5.0 per ft | $45.00 | $3.75/ft | $0.83/ft | N/A | N/A | N/A | N/A | N/A | N/A |
| 50% 2' T5 Linear | | 7,500 | $7.00 | 8.0 | $20.00 | $2.67 | $0.25 | 40,000 | $25.00 | 20.0 | $45.00 | $15.00 | $5.00 | 50% 50W Halogen | 2,500 | $10.00 | 8.0 | $20.00 | $2.67 |
| T8 U-Tube 2L-FB32 w/ Elec - 2' | 2 | 15,000 | $18.62 | 16.0 | $20.00 | $5.33 | $1.00 | 40,000 | $32.00 | 20.0 | $45.00 | $15.00 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| T8 U-Tube 3L-FB32 w/ Elec - 2' | 3 | 15,000 | $27.93 | 24.0 | $20.00 | $8.00 | $1.50 | 40,000 | $15.00 | 20.0 | $45.00 | $15.00 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| T8 2L-F32 w/ Elec - 4' | 2 | 15,000 | $5.00 | 16.0 | $20.00 | $5.33 | $1.00 | 40,000 | $15.00 | 20.0 | $45.00 | $15.00 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| T8 3L-F32 w/ Elec - 4' | 3 | 15,000 | $7.50 | 24.0 | $20.00 | $8.00 | $1.50 | 40,000 | $15.00 | 20.0 | $45.00 | $15.00 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| T8 4L-F32 w/ Elec - 4' | 4 | 15,000 | $10.00 | 32.0 | $20.00 | $10.67 | $2.00 | 40,000 | $15.00 | 20.0 | $45.00 | $15.00 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| T8 1L-F32 w/ Elec - 4' | 1 | 15,000 | $2.50 | 8.0 | $20.00 | $2.67 | $0.50 | 40,000 | $15.00 | 20.0 | $45.00 | $15.00 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| T8 2L-F32 w/ Elec - 4' | 2 | 15,000 | $5.00 | 16.0 | $20.00 | $5.33 | $1.00 | 40,000 | $15.00 | 20.0 | $45.00 | $15.00 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| T8 3L-F32 w/ Elec - 4' | 3 | 15,000 | $7.50 | 24.0 | $20.00 | $8.00 | $1.50 | 40,000 | $15.00 | 20.0 | $45.00 | $15.00 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| T8 F32 w/ Elec - 4' - per lamp | 1 | 15,000 | $2.50 | 8.0 | $20.00 | $2.67 | $0.50 | 40,000 | $9.90 | 20.0 | $45.00 | $5.17 | $1.92 | N/A | N/A | N/A | N/A | N/A | N/A |
| 6-lamp T8HO | 6 | 20,000 | $66.00 | 30.0 | $75.00 | $37.00 | $3.00 | 70,000 | $45.00 | 42.0 | $75.00 | $52.50 | $15.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| 100W MH | | 10,000 | $34.00 | 16.0 | $75.00 | $20.00 | $0.25 | 40,000 | $124.20 | 30.0 | $75.00 | $37.50 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| 175W MH | | 10,000 | $28.00 | 16.0 | $75.00 | $20.00 | $0.25 | 40,000 | $67.50 | 30.0 | $75.00 | $37.50 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| 250W MH | | 10,000 | $21.00 | 16.0 | $75.00 | $20.00 | $0.25 | 40,000 | $87.75 | 30.0 | $75.00 | $37.50 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| 100W MH | | 10,000 | $34.00 | 16.0 | $75.00 | $20.00 | $0.25 | 40,000 | $124.20 | 30.0 | $75.00 | $37.50 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| 175W MH | | 10,000 | $28.00 | 16.0 | $75.00 | $20.00 | $0.25 | 40,000 | $67.50 | 30.0 | $75.00 | $37.50 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| 250W MH | | 10,000 | $21.00 | 16.0 | $75.00 | $20.00 | $0.25 | 40,000 | $87.75 | 30.0 | $75.00 | $37.50 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| 100W MH | | 10,000 | $34.00 | 8.0 | $20.00 | $2.67 | $0.25 | 40,000 | $124.20 | 30.0 | $45.00 | $22.50 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| 175W MH | | 10,000 | $28.00 | 8.0 | $20.00 | $2.67 | $0.25 | 40,000 | $67.50 | 30.0 | $45.00 | $22.50 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| 250W MH | | 10,000 | $21.00 | 8.0 | $20.00 | $2.67 | $0.25 | 40,000 | $87.75 | 30.0 | $45.00 | $22.50 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| 100W MH | | 10,000 | $34.00 | 8.0 | $20.00 | $2.67 | $0.25 | 40,000 | $124.20 | 30.0 | $45.00 | $22.50 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| 175W MH | | 10,000 | $28.00 | 8.0 | $20.00 | $2.67 | $0.25 | 40,000 | $67.50 | 30.0 | $45.00 | $22.50 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| 250W MH | | 10,000 | $21.00 | 8.0 | $20.00 | $2.67 | $0.25 | 40,000 | $87.75 | 30.0 | $45.00 | $22.50 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| 50W MH | | 10,000 | $34.00 | 8.0 | $20.00 | $2.67 | $0.25 | 40,000 | $108.00 | 30.0 | $45.00 | $22.50 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| 70W MH | | 10,000 | $34.00 | 8.0 | $20.00 | $2.67 | $0.25 | 40,000 | $115.00 | 30.0 | $45.00 | $22.50 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| Halogen PAR38 | | 2,500 | $10.00 | 8.0 | $20.00 | $2.67 | $0.25 | 0 | 0 | $0.00 | 0.0 | $0.00 | $0.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| Halogen PAR38 | | 2,500 | $10.00 | 8.0 | $20.00 | $2.67 | $0.25 | 0 | 0 | $0.00 | 0.0 | $0.00 | $0.00 | N/A | N/A | N/A | N/A | N/A | N/A |
| 175W MH | | 10,000 | $28.00 | 8.0 | $20.00 | $2.67 | $0.25 | 40,000 | $67.50 | 30.0 | $45.00 | $22.50 | $5.00 | N/A | N/A | N/A | N/A | N/A | N/A |

# Commercial Direct Install CFL

Measure Number: I-C-24-a (Business Energy Services, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 75
Effective date: 1/1/2011
End date: TBD

**Referenced Documents:**
1) WasteHeatAdjustment.doc
2) C&I DI CFL baseline savings shift.xls
3) "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993

**Description**
An existing incandescent screw-in bulb is replaced with a lower wattage ENERGY STAR qualified compact fluorescent screw-in bulb through Direct Install in a commercial location.

**Algorithms**
**Demand Savings**
$\Delta kW = ((\Delta Watts) / 1000) \times ISR \times WHF_d$

| Year | Algorithm | ΔkW |
|---|---|---|
| 2011 and 2012 | (49.0 / 1000) * 0.8 * 1.082 | 0.0424 |
| 2013 | (43.6 / 1000) * 0.8 * 1.082 | 0.0377 |
| 2014 | (37.0 / 1000) * 0.8 * 1.082 | 0.0320 |

**Energy Savings**
$\Delta kWh = \Delta kW \times HOURS \times WHF_e / WHF_d$

| Year | Algorithm | ΔkWh |
|---|---|---|
| 2011 and 2012 | 0.0424 * 2800 * 1.033/1.082 | 113.3 |
| 2013 | 0.0377 * 2800 * 1.033/1.082 | 100.8 |
| 2014 | 0.0320 * 2800 * 1.033/1.082 | 85.5 |

Where:
ΔWatts = $Watts_{BASE} - Watts_{EE}$[141]
ΔkW = gross customer connected load kW savings for the measure
ΔkWh = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units rebated that actually get used = 0.8[142]
$WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting. For prescriptive commercial lighting, the value is 1.082 (calculated as 1 + (0.47*0.67*.808) / 3.1))[143]. The cooling savings are only added to the summer peak savings.

[141] Assumed difference in wattage between installed CFL and the incandescent bulb it replaces. Based on EVT and DPS agreement in TAG 2011 to use values proposed in the NEEP Residential Lighting Survey, 2011. Values decrease to account for shifting baseline due to EISA.
[142] TAG 2009 agreement for Residential applications, assumed here for C&I
[143] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 33% average outside air; and 80.8% coincidence of cooling with the summer peak period. See WasteHeatAdjustment.doc for additional discussion.

| | | |
|---|---|---|
| $WHF_e$ | = Waste heat factor for energy to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.033 (calculated as 1 + ((0.47*0.29*.75) / 2.5))[144]. |
| HOURS | = average hours of use per year<br>= 2800 hours[145] |

**Waste Heat Adjustment**
Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF). See above.

**Heating Increased Usage**

$\Delta MMBTU_{WH}$ = $(\Delta kWh / WHF_e) \times 0.003413 \times (1 - OA) \times AR \times HF \times DFH / HEff$

$\Delta MMBTU_{WH}$ (Commercial) = $(119 / 1.033) \times 0.003413 \times (1- 0.25) \times 0.70 \times 0.39 \times 0.95 / 0.79 = 0.0967$

| Year | Algorithm | ΔMMBtu |
|---|---|---|
| 2011 and 2012 | $(113.3 / 1.033) \times 0.003413 \times (1- 0.25) \times 0.70 \times 0.39 \times 0.95 / 0.79$ | 0.0922 |
| 2013 | $(100.8 / 1.033) \times 0.003413 \times (1- 0.25) \times 0.70 \times 0.39 \times 0.95 / 0.79$ | 0.0820 |
| 2014 | $(85.5 / 1.033) \times 0.003413 \times (1- 0.25) \times 0.70 \times 0.39 \times 0.95 / 0.79$ | 0.0696 |

Where:

| | |
|---|---|
| $\Delta MMBTU_{WH}$ | = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat. |
| 0.003413 | = Conversion from kWh to MMBTU |
| OA | = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[146]. |
| AR | = Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of commercial buildings within 15 feet of exterior wall. |
| HF | = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont for commercial lighting[147] |
| DFH | = Percent of lighting in heated spaces, assumed to be 95% |
| HEff | = Average heating system efficiency, assumed to be 79%[148] |

Oil heating is assumed typical for commercial buildings.

**Baseline Efficiencies – New or Replacement**
The baseline condition is an incandescent light bulb.

**Baseline Adjustment**

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[144] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 25% average outside air; and 29% of annual lighting energy contributes to cooling load. See "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993 and WasteHeatAdjustment.doc for additional discussion.
[145] Based on EVT and DPS agreement made during Savings Verification 2009.
[146] Based on 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air." See WasteHeatAdjustment.doc.
[147] From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993.
[148] Based on average efficiency for furnaces and boilers of varied sizes in ASHRAE 90.1.1999, assumed to represent typical commercial building stock in Vermont. See WasteHeatAdjustment.doc.

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become EISA qualified incandescent or Halogen bulbs (see percentages in O&M table below).

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012. For measures installed in 2011, the full savings (as calculated above in the Algorithm section) will be claimed for the first year, and the adjusted savings will be claimed for the remainder of the measure life.

The appropriate adjustments are provided below (see C&I DI CFL baseline savings shift.xls for details on how adjustment is calculated):

| Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|
| 2011 | 0.82 | 2 |
| 2012 | 0.65 | 2 |
| 2013 | 0.78 | 1 |
| 2014 | 0.88 | 1 |

**High Efficiency**
High efficiency is an ENERGY STAR qualified compact fluorescent lamp.

**Operating Hours**
2800 hours / year[149]

**Loadshape**
Loadshape # 12 (Commercial Indoor Lighting-Blended) for demand and lighting energy savings and #15 (Commercial A/C) for cooling energy savings

**Freeridership/Spillover Factors**

| **Measure Category** | | **Light Bulbs/Lamps** | |
|---|---|---|---|
| **Measure Code** | | **LBLCFDIC** | |
| **Product Description** | | **Compact Fluorescent screw-base bulbs Direct Install - Commercial** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** |
| C&I Retrofit | 6012CNIR | 0.89 | 1.05 |
| Farm Retrofit | 6012FARM | 0.89 | 1.05 |
| Cust Equip Rpl | 6013CUST | 0.89 | 1.05 |
| Farm Equip Rpl | 6013FARM | 1.0 | 1.05 |
| Farm Rx | 6013FRMP | 1.0 | 1.05 |
| Pres Equip Rpl | 6013PRES | 0.9 | 1.05 |
| Act250 NC | 6014A250 | 0.95 | 1.0 |
| Farm NC | 6014FARM | 1.0 | 1.05 |
| Non Act 250 NC | 6014NANC | 1.0 | 1.0 |

**Persistence**
The persistence factor is assumed to be 90% as agreed to by EVT and the DPS (TAG 2007).

[149] Based on agreement made during Savings Verification 2009. Many Direct Install bulbs will be installed by Building Performance contractors. To simplify and streamline implementation EVT will assume an average hours of use consistent with the Efficient Product assumption, rather than burden the contractors with requiring site location specific values.

**Lifetimes**
Lifetime is a function of the average hours of use for the lamp. For C&I installations the rated lifetime is assumed to be 10,000 hours. That translates to 3.57 years for this measure. Including the 90% persistence value gives 3.2 years. Analysis period is the same as the lifetime.

**Measure Cost**
The average installed cost is assumed to be $6.09 ($2.50 for the bulb and $3.59 for labor) [150].

**O&M Cost Adjustments**
O& M cost adjustments are based on component costs provided in the reference table below.

**Fossil Fuel Descriptions**
See Heating Increased Usage above.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

**Methodology for Computing O&M Savings**

In order to account for the shift in baseline due to the Federal Legislation, the levelized baseline replacement cost over the lifetime of the CFL was calculated (see C&I DI CFL baseline savings shift.xls). The key assumptions used in this calculation are documented below:

| | Incandescent | Halogen |
|---|---|---|
| Replacement Cost | $0.50 | $1.50 |
| Component Life (hours) | 1000 | 1000 |
| Baseline % in 2009-2011 | 100% | 0% |
| Baseline % in 2012 | 67% | 33% |
| Baseline % in 2013 | 33% | 67% |
| Baseline % in 2014 onward | 0% | 100% |

The calculation results in a levelized assumption of $9.19 baseline replacement cost every 1 year for CFL installations in 2011, $9.09 every year for installations in 2012, $9.58 for installations in 2013 and $9.77 for installations in 2014. This adjustment will be recalculated for subsequent years.

[150] $2.50 for CFL is based on TAG 2011 agreement to use recommendation from NEEP Residential Lighting Survey, 2011. Labor rate consistent with other measures.

# Agriculture Program:  Lighting Products Initiative

Measure Number: I-C-25-a (Business Energy Services, Lighting End Use)

**Version Date & Revision History**
Draft Portfolio: Portfolio 82
Effective date: 1/1/2013
End Date: TBD

**Referenced Documents:**
**1.** Ag Mail Order CFL Lighting.xlsx
**2.** *FINAL REPORT: TIER 1 WORKSHOP MODEL 2007-2008, Prepared for the Governor's Energy Office by Energy Outreach Colorado, July 3, 2008*

**Description**
This characterization provides information related in person distribution during a site visit of free CFLs to a customer in the agricultural sector starting in the calendar year 2013. The CFLs are for use in tie stall barns, farm buildings, farm houses and farm labor housing. The program rebate form indicates that the CFLs must be installed within 30 days. For the bulbs installed in housing, this characterization references the **Interior CFL Direct Install** (Residential Emerging Markets) which should be used to see details of the characterization. The assumptions and savings algorithms are identical except for ISR and cost assumptions. For the bulbs installed in the barns, the assumptions and algorithms are included in the text of this measure characterization.

**Customers will be sent any combination of the following products:**

| **For Housing:** | **For Barns:** |
|---|---|
| 14W CFL | 18W CFL |
| 19W CFL | 23W CFL |
| 23W CFL | 32W CFL |

**Algorithms**
**Demand Savings**

**Housing Bulb:**

| **Measure** | **TRM Reference** (Market) | **Difference from Reference TRM** | **Demand Savings ($\Delta$kW)** |
|---|---|---|---|
| Standard CFL installed in a home or worker housing | **Interior CFL Direct Install** (Residential Emerging Markets) | ISR = 0.75 | 0.0368 (2012)<br>0.0327 (2013)<br>0.0278 (2014) |

**Farm Bulb:**

$\Delta$kW = (($\Delta$Watts) /1000) × ISR

| Bulb | Algorithm | $\Delta$kW |
|---|---|---|
| 18W CFL | (35 / 1000) * 0.75 | 0.0263 |
| 23W CFL | (49 / 1000) * 0.75 | 0.0368 |
| 32W CFL | (40 / 1000) * 0.75 | 0.0300 |

Where:

$\Delta$kW = average kilowattage reduction

$\Delta$Watts = Difference in wattage between baseline and efficient bulb ($Watts_{BASE}$ – $Watts_{EE}$)

| Bulb | Baseline Bulb Watts | Delta Watts ($\Delta$Watts) | $\Delta$kW |
|---|---|---|---|
| 18W Pro CFL | 53W | 35W | 0.0263 |
| 23W Pro CFL | 72W | 49W | 0.0368 |
| 32W Pro CFL | 72W[151] | 40W | 0.0300 |

$Watts_{BASE}$ = Watts of baseline bulb
$Watts_{EE}$ = Watts of energy efficient bulb
ISR = In service rate, or the percentage of units mailed that actually get used. This is assumed to be 75%.[152]

**Energy Savings[153]**

For bulbs installed in housing

| **Measure** | **TRM Reference** | **Difference from Reference TRM** | **Energy Savings (Annual kWh)** |
|---|---|---|---|
| Standard CFL | Interior CFL Direct Install | ISR = 0.75 | 25.50 (2012)<br>22.69 (2013)<br>19.26 (2014) |

For bulbs installed in barns

$\Delta$kWh = (($\Delta$Watts) /1000) × ISR x Hours

Where:

$\Delta$kWh = gross customer annual kWh savings for the measure

HOURS = for barns, hours are 2679[154] hours

**Operating Hours**
For bulbs installed in housing, refer to the **Interior CFL Direct Install** (Residential Emerging Markets)

For bulbs installed in barns, operating hours are 2679[155] hours / year

**Baseline Efficiencies – New or Replacement**
For the baseline condition for bulbs installed in housing, refer to the **Interior CFL Direct Install** (Residential Emerging Markets)

For the baseline condition for bulbs installed in barns, refer to the table below . Note the baseline for 18W, 23W and 32 W are the post EISA qualified incandescent/halogen wattage wattages.

| Bulb | Baseline Bulb Watts |
|---|---|
| 18W Pro CFL | 53W |
| 23W Pro CFL | 72W |
| 32W Pro CFL | 72W |

151 The 32W CFL is a replacement a 100W (EISA compliant 72W).
152 An In Service Rate of 0.75 is chosen for this measure, consistent with the assumption for the Mail Order Efficiency Kit use in the Residential program.
153 Commercial lighting measures usually include a waste heat factor and heating penalty. These algorithms were not included in this TRM because the CFLs in this measure will be installed in either unconditioned barns (no heating or cooling) or in residential buildings. Residential CFLs do not account for a waste heat factor or a heating penalty
154 Operating hours assume 7.3 hours a day, see AgLightingCalculationsv3.xlsx
155 Operating hours assume 7.3 hours a day, see AgLightingCalculationsv3.xlsx

**High Efficiency**
High efficiency is an ENERGY STAR qualified compact fluorescent lamp specified above.

**Loadshape**
Loadshape #24, Dairy Farm Combined End Uses
Loadshape #1 - Residential Indoor Lighting

**Freeridership/Spillover Factors**

| **Measure Category** | | **Light Bulbs/Lamps** | | | | | |
|---|---|---|---|---|---|---|---|
| **Measure Code** | | **LBLCFBLB** | | | | | |
| **Product Description** | | **Compact Fluorescent screw-base bulbs - Commercial** | | | | | |
| | | **2012** | | **2013** | | **2014** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** | **Freerider** | **Spillover** | **Freerider** | **Spillover** |
| C&I Retrofit | 6012CNIR | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |
| Cust Equip Rpl | 6013CUST | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |
| Pres Equip Rpl | 6013PRES | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |

**Persistence**
For bulbs installed in housing, refer to the **Interior CFL Direct Install** (Residential Emerging Markets)

For bulbs installed in barns, the persistence factor is assumed to be 0.9.

**Measure Cost**
The full cost for this measure is as follows[156]

| Bulb | Bulb cost |
|---|---|
| Housing CFL | $1.87 |
| 18W Pro CFL | $3.91 |
| 23W Pro CFL | $4.49 |
| 32W Pro CFL | $7.65 |

**Lifetimes**
Lifetime is a function of the average hours of use for the lamp. Most CFLs have a *rated* lifetime of 10,000 hours. However, units that are turned on and off more frequently have shorter lives and those that stay on for longer periods of time have longer lives.

For bulbs installed in housing, refer to the **Interior CFL Direct Install** (Residential Emerging Markets)

For bulbs installed in barns, bulb useful life is assumed to be 12,000 hours, based on agreement between EVT and the DPS (TAG 2009). The measure life, including the 90% persistence factor is therefore assumed to be 12,000/2697 * 0.9 = 4.0 years.

Analysis period is the same as the lifetime.

**Annual Operations and Maintenance Savings**

Because compact fluorescent lamps last much longer than incandescent bulbs, CFLs offer significant operation and maintenance (O&M) savings over the life of the fixture for avoided incandescent lamps and the labor to install them.

[156] Bulb costs from EFI estimate

For bulbs installed in housing, refer to the **Interior CFL Direct Install** (Residential Emerging Markets) For bulbs installed in barns, the following assumptions are used to calculate the O&M savings:Baseline bulb cost: $1.50 per bulb.Life of baseline bulb: 1000 hours /2697. Bulb lasts 0.37 years.

## Refrigeration End Use

# Refrigerated Case Covers

Measure Number: I-E-2-b (Business Energy Services, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 37
Effective date: 01/01/06
End date: TBD

**Description**
By covering refrigerated cases the heat gain due to the spilling of refrigerated air and convective mixing with room air is reduced at the case opening. Strip curtains can be deployed continuously and allow the customer to reach through the curtain to select the product. Continuous curtains can be pulled down overnight while the store is closed. Strip curtains are not used for low temperature, multi-deck applications. Glass door retrofits are a better choice for these applications.

**Algorithms**

**Demand Savings**
$\Delta$kW = ( HG × EF × CL × DF) / (EER × 1000)

**Energy Savings**
$\Delta$kWh = $\Delta$kW × Usage × 365

Where:

- $\Delta$kW = gross customer connected load kW savings for the measure (kW)
- HG = Loss of cold air or heat gain for refrigerated cases with no cover (Btu/hr-ft opening).. The heat gain for multi-deck applications is 760 for medium temperature applications (case temperature 10°F to 40°F) and 610 for high temperature applications (case temperature 45°F to 65°F).[157]
- EF = Efficiency Factor: Fraction of heat gain prevented by case cover. The Efficiency Factor for strip curtains is 0.65. [158] The Efficiency Factor for continuous covers is 0.80.
- CL = Refrigerated case length in feet (ft). Case length is the open length of the refrigerated box. If the unit is two sided use the open length of both sides. Collected from prescriptive form.
- DF = Disabling Factor to account for the portion of the time that the strip curtain is intentionally disabled, as well as time to access the product. The Disabling factor is assumed to be 80%. [159]
- EER = Compressor efficiency (Btu/hr-watt). The average compressor efficiency (EER) is 11.95 for medium temperature applications (case temperature 10°F to 40°F) and 18.5 for high temperature applications (case temperature 45°F to 65°F). [160]
- 1000 = Conversion from watts to kW (W/kW).
- $\Delta$kWh = gross customer annual kWh savings for the measure (kWh)

[157] Source: Analysis for PG&E by ENCON Mechanical & Nuclear Engineering, 8/24/92.
[158] Source: Analysis for PG&E by ENCON Mechanical & Nuclear Engineering, 8/24/92.
[159] TAG agreement January 2006.
[160] Average EER values were calculated as the average of standard reciprocating and discus compressor efficiencies, using a typical condensing temperature of 90°F and saturated suction temperatures (SST) of 20°F for medium temperature applications and 45°F for high temperature applications.

Usage = Average hours per day that case cover is in place (hrs/day). Assume 24 hrs/day for strip curtains. Assume 8 hours per day for continuous covers.
365 = (days/yr)

**Baseline Efficiencies – New or Replacement**
The baseline condition is a refrigerated case without a cover.

**High Efficiency**
High efficiency is a refrigerated case with a strip curtain.

**Operating Hours**
Assume that case covers are in place 24 hrs/day for strip. Assume that continuous covers are in place an average of 8 hours per day.

**Loadshapes**
Strip Curtain #67
Refrigeration Night Covers #73

Source: Strip curtain uses the same energy distribution as the previously-developed commercial refrigeration loadshape in Vermont State Cost-Effectiveness Screening Tool. Coincident factors for strip curtains are set at 100% since the calculated kW savings is an average for every hour. The night case covers loadshape is based on the savings occurring from 11 PM to 7 AM.

**Freeridership / Spillover Factors**

| Measure Category | | Refrigeration End-Use | |
|---|---|---|---|
| Measure Code | | RFRCOVER | |
| Product Description | | Refrigeration Case Covers for Merchandising Cooler and Freezer Cases | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | 0.95 | 1.00 |
| Cust Equip Rpl | 6013CUST | 0.94 | 1.00 |
| Farm NC | 6014FARM | 1.00 | 1.00 |
| Farm Equip Rpl | 6013FARM | 1.00 | 1.00 |
| Non Act 250 NC | 6014NANC | 1.00 | 1.00 |
| Pres Equip Rpl | 6013PRES | 0.95 | 1.00 |
| C&I Retro | 6012CNIR | 0.94 | 1.00 |
| MF Mkt Retro | 6012MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
Strip curtains: 4 years
Continuous covers: 5 years

**Measure Cost**
Typically installation costs are approximately $15/ft of case.

**Incentive Level**
40% of installation costs or $6/ft of case.

**O&M Cost Adjustments**
Strip curtains require regular cleaning -- $2.60/yr/ft (1 minute/foot every two weeks at $6/hr).

Continuous curtains require that they are pulled down nightly – $1.52/yr/ft (5 sec. per 4-foot section, twice per day, at $6/hr)

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

# Refrigeration Economizer

Measure Number:  I-E-6-b (Business Energy Services, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 37
Effective date: 1/1/06
End date: TBD

Referenced Documents: <RefrigLoadshapes.xls>, <Economizer Calc.xls>,
**Description**
Economizers save energy in walk-in coolers by bringing in outside air when it is sufficiently cool, rather than operating the compressor.

**Algorithms**

**Demand Savings**
$\Delta kW = \Delta kWh / Hours$

**Energy Savings**
<u>With Fan Control Installed</u>

$$\Delta kWh = [HP \times kWh_{Cond}] + [((kW_{Evap} \times n_{Fans}) - kW_{Circ}) \times Hours \times DC_{Comp} \times BF] - [kW_{Econ} \times DC_{Econ} \times Hours]$$

<u>Without Fan Control Installed</u>

$$\Delta kWh = [HP \times kWh_{Cond}] - [kW_{Econ} \times DC_{Econ} \times Hours]$$

Where:

| | |
|---|---|
| $\Delta kW$ | = gross customer connected load kW savings for the measure (kW) |
| $\Delta kWh$ | = gross customer annual kWh savings for the measure (kWh) |
| HP | = Horsepower of Compressor |
| $kWh_{Cond}$ | = Condensing unit savings, per hp. (value from savings table in Reference Tables section of this measure write-up) |
| Hours | = Number of annual hours that economizer operates. 2,996 hrs based on 38° F cooler setpoint, Burlington VT weather data, and 5 degree economizer deadband. |
| $DC_{Comp}$ | = Duty cycle of the compressor (Assume 50%)[161] |
| $kW_{Evap}$ | = Connected load kW of each evaporator fan (Average 0.123 kW)[162] |
| $kW_{Circ}$ | = Connected load kW of the circulating fan (0.035 kW)[163]. |
| $n_{Fans}$ | = Number of evaporator fans |
| $DC_{Econ}$ | = Duty cycle of the economizer fan on days that are cool enough for the economizer to be working (Assume 63%)[164]. |
| BF | = Bonus factor for reduced cooling load from running the evaporator fan less or (1.3)[165]. |
| $kW_{Econ}$ | = Connected load kW of the economizer fan (Average 0.227 kW)[166]. |

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[161] 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.

[162] Based on an a weighted average of 80% shaded pole motors at 132 watts and 20% PSC motors at 88 watts.

[163] 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.

[164] Average of two manufacturer estimates of 50% and 75%.

[165] Bonus factor (1+ 1/3.5) assumes COP of 3.5, based on the average of standard reciprocating and discus compressor efficiencies with a Saturated Suction Temperature of 20°F and a condensing temperature of 90°F.

**Baseline Efficiencies – New or Replacement**
The baseline condition is a walk-in refrigeration system without an economizer.

**High Efficiency**
High efficiency is a walk-in refrigeration system with an outside air economizer.

**Operating Hours**
The economizer is expected to operate for 2,996 hours per year, based on 38° F Cooler Setpoint, Burlington VT weather data[167], and a 5 degree economizer deadband.

**Loadshape**
Refrigeration Economizer #66.
Source: The energy distribution and Fall/Spring coincident factor is derived from Burlington, Vermont temperature bin data. See file <RefrigLoadshapes.xls>. Assume summer coincidence is 0%, since the summer peak occurs during the hottest time of the year. Assume winter coincidence is 100%, because the winter peak is driven by the coldest weather.

[166] 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).
[167] Burlington weather data is used because it is the most complete data readily available for Vermont, and because its climate is a reasonable weighted average climate for the state.

**Freeridership/Spillover Factors**

| Measure Category | | Refrigeration End-Use | |
|---|---|---|---|
| Measure Code | | RFRMIZER | |
| Product Description | | Refrigeration Economizer for Walk-in Coolers | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | 0.95 | 1.00 |
| Cust Equip Rpl | 6013CUST | 0.94 | 1.00 |
| Farm NC | 6014FARM | 1.00 | 1.00 |
| Farm Equip Rpl | 6013FARM | 1.00 | 1.00 |
| Non Act 250 NC | 6014NANC | 1.00 | 1.00 |
| Pres Equip Rpl | 6013PRES | 0.95 | 1.00 |
| C&I Retro | 6012CNIR | 0.94 | 1.00 |
| MF Mkt Retro | 6012MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
15 years

**Measure Cost**
The installation cost for an economizer is $2,558.[168]

**Incentive Level**
50% of installation costs or $1,250 per economizer.

**O&M Cost Adjustments**
None

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

[168] Based on average of costs from Freeaire, Natural Cool, and Cooltrol economizer systems.

**Reference Tables**

## Condensing Unit kWh Savings, per HP, from Economizer

Calculated Using 'Economizer Calc.xls'

| | Hermetic/ Semi-Hermetic | Scroll | Discus |
|---|---|---|---|
| kWh / HP | 1,256 | 1,108 | 1,051 |

**Assumptions:**

1. 5 HP Compressor data used, based on average compressor size.
2. No floating head pressure controls installed.
3. Outdoor Compressor Installation

# Commercial Solid Door Reach-In Refrigerators

Measure Number: I-E-3-c (Business Energy Services, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 61
Effective date: 01/01/10
End date: TBD

Referenced Documents: *Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers*, Steven Nadel, ACEEE, December 2002.
CEE_Refrig_Specs.pdf,
ArthurDLittle_Report.pdf,
Nadal_ACEEE_2002.pdf,
<Reach in Savings Calcs_2010.xls>

**Description**
The measure described here is a high-efficiency packaged commercial reach-in refrigerator with solid doors, typically used by foodservice establishments. This includes one, two and three solid door reach-in, roll-in/through and pass-through commercial refrigerators. Beverage merchandisers – a special type of reach-in refrigerator with glass doors – are not included in this characterization.

**Algorithms**

**Demand Savings**
$\Delta kW = \Delta kWh / FLH$

**Energy Savings**
$\Delta kWh$ = value from savings table in Reference Tables section of this measure write-up (varies by size and efficiency tier)

Where:
$\Delta kW$ = gross customer connected load kW savings for the measure (kW)
$\Delta kWh$ = gross customer annual kWh savings for the measure (kWh)
FLH = Full load hours from DPS commercial refrigeration loadshape (5858 hours).

**Baseline Efficiencies – New or Replacement**
The baseline is a reach-in refrigerator less efficient than ENERGY STAR. See the average baseline energy use in the savings table in the Reference Tables section.

**High Efficiency**
A high efficiency reach-in refrigerator can fall into one of two tiers: Tier 1 – those meeting the ENERGY STAR specifications, or Tier 2 – those meeting ENERGY STAR plus 40% more efficient. Refer to the specification table in the Reference Tables section for the precise specification.

**Operating Hours**
The refrigerator is assumed to always be plugged in but because of compressor and fan cycling the full load hours are 5858 hours.[169]

**Rating Period & Coincidence Factors**
Loadshape #14, Commercial Refrigeration

[169] Derived from Washington Electric Coop data by West Hill Energy Consultants

**Freeridership/Spillover Factors**

| Measure Category | | Refrigeration End-Use | |
|---|---|---|---|
| Measure Code | | RFRCOMRF | |
| Product Description | | Commercial Refrigerator | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | 0.95 | 1.00 |
| Cust Equip Rpl | 6013CUST | 0.94 | 1.00 |
| Farm NC | 6014FARM | 1.00 | 1.00 |
| Farm Prescriptive | 6013FRMP | 1.00 | 1.00 |
| Farm Equip Rpl | 6013FARM | 1.00 | 1.00 |
| Non Act 250 NC | 6014NANC | 1.00 | 1.00 |
| Pres Equip Rpl | 6013PRES | 0.95 | 1.00 |
| C&I Retro | 6012CNIR | 0.94 | 1.00 |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| Customer Credit | 6015 CC | n/a | n/a |
| EDirect | 6021 DIRI | 0.98 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
9 years[170]

**Measure Cost**
Based on examination of list prices and price studies performed by others, ACEEE (2002) reported (Nadal_ACEEE_2002.pdf) that the incremental cost for energy-efficient commercial refrigerators is relatively small[171]. An inflation factor was calculated using RS Means pricing data on current baseline technology compared with baseline costs listed in the 2002 ACEEE report. For analysis purposes, the door (30 to 95301253050 cf), and $155 for a three-door (over 50 cf). These costs are consistent with the range of incremental costs identified by ACEEE. The incremental costs for Tier 2 are estimated to be twice the incremental costs for Tier 1, or $190 for a one-door, $250 for a two-door, and $310 for a three-door.

**Incentive Level**
Incentives are equal to the incremental costs mentioned above, which is the approach suggested by ACEEE.[172] Therefore, for Tier 1, this would be $95 for a one-door (3030-50 cf), 12530-50and $155 for a

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170 The following report estimates life of a commercial reach-in refrigerator at 8-10 years: *Energy Savings Potential for Commercial Refrigeration Equipment*, Arthur D. Little, Inc., 1996. (ArthurDLittle_Report.pdf)

171 From examination of list prices by ACEEE and reported in *Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers*, Steven Nadel, ACEEE, December 2002 (Nadal_ACEEE_2002.pdf)

172 From Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers, Steven Nadel, ACEEE, December 2002, p. 22. (Nadal_ACEEE_2002.pdf)

three-door (over 50 cf). Incentives for Tier 2 will be twice those for Tier 1, or $190 for a one-door, $250 for a two-door, and $310 for a three-door.

**O&M Cost Adjustments**
No differences in O&M costs are apparent between the standard and efficient refrigerators.

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

**Savings for Solid Door Reach-In Refrigerators meeting ENERGY STAR and CEE Tier 2 Specifications**

| Internal Volume (cubic feet) | Annual Energy Use of Average Base Case Model (kWh/year) | Annual kWh Savings Relative to Base Case | |
|---|---|---|---|
| | | ENERGY STAR (Tier 1) | Tier 2 |
| less than 15 cf (one door) | 1,097 | 268 | 600 |
| 15-30 cf (one door) | 1,549 | 448 | 888 |
| 30-50 cf (two door) | 2,318 | 840 | 1,431 |
| greater than 50 cf (three door) | 3,239 | 1,225 | 2,031 |

Source: See “Reach in savings calcs.xls” for savings calculations.

**Specification for Solid-Door Reach-in Refrigerators**

| Description of Specification | Maximum Energy Use (kWh/day) |
|---|---|
| BASELINE (all sizes) | 0.10V + 2.04 |
| CEE Tier 1 (i.e. Energy Star) | |
| • $0 < V < 15$ cf | 0.089V + 1.411 |
| • $15 \leq V < 30$ cf | 0.037V + 2.200 |
| • $30 \leq V < 50$ cf | 0.056V + 1.635 |
| • 50 cf $\leq V$ | 0.060V + 1.416 |
| CEE Tier 2 | [CEE Tier 1 kWh/day] – 40% |

Note: V= internal volume

# Commercial Glass Door Reach-In Refrigerators

Measure Number: I-E-14-b (Business Energy Services, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 61
Effective date: 01/01/10
End date: TBD

**Referenced Documents:**
Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers, Steven Nadel, ACEEE, December 2002., <Reach in Savings Calcs_2010.xls>, *Energy Savings Potential for Commercial Refrigeration Equipment*, Arthur D. Little, Inc., 1996, http://www.energystar.gov/ia/partners/product_specs/program_reqs/commer_refrig_glass_prog_req_Refrig_Specs.pdf, ,

**Description**
The measure described here is a high-efficiency packaged commercial reach-in glass door refrigerator, also known as beverage merchandiser, typically used by foodservice establishments.

**Algorithms**

**Demand Savings**
$\Delta$kW = $\Delta$kWh / FLH

**Energy Savings**
$\Delta$kWh = value from savings table in Reference Tables section of this measure write-up (varies by size and efficiency tier)

Where:
$\Delta$kW = gross customer connected load kW savings for the measure (kW)
$\Delta$kWh = gross customer annual kWh savings for the measure (kWh)
FLH = Full load hours from DPS commercial refrigeration loadshape (5858 hours).

**Baseline Efficiencies – New or Replacement**
The baseline is a reach-in refrigerator that does not meet CEE Tier 1 specifications. See the average baseline energy use in the savings table in the Reference Tables section.

**High Efficiency**
A high efficiency reach-in refrigerator can fall into one of two tiers: Tier 1 – the 25% of top-performing products, or Tier 2 – those meeting Tier 1 plus 28% more efficient. Refer to the specification table in the Reference Tables section for the precise specification.

**Operating Hours**
The refrigerator is assumed to always be plugged in but because of compressor and fan cycling the full load hours are 5858 hours.[173]

**Loadshape**
Loadshape #14, Commercial Refrigeration

**Freeridership/Spillover Factors**

| | | | |
|---|---|---|---|
| Measure Category | | Refrigeration End-Use | |
| Measure Code | | RFRCOMRF | |
| Product Description | | Commercial Refrigerator | |
| Track Name | Track No. | Freerider | Spillover |

[173] Derived from Washington Electric Coop data by West Hill Energy Consultants

| | | | |
|---|---|---|---|
| Act250 NC | 6014A250 | 0.95 | 1.00 |
| Cust Equip Rpl | 6013CUST | 0.94 | 1.00 |
| Farm NC | 6014FARM | 1.00 | 1.00 |
| Farm Prescriptive | 6013FRMP | 1.00 | 1.00 |
| Farm Equip Rpl | 6013FARM | 1.00 | 1.00 |
| Non Act 250 NC | 6014NANC | 1.00 | 1.00 |
| Pres Equip Rpl | 6013PRES | 0.95 | 1.00 |
| C&I Retro | 6012CNIR | 0.94 | 1.00 |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| Customer Credit | 6015 CC | n/a | n/a |
| EDirect | 6021 DIRI | 0.98 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
9 years[174]

**Measure Cost**
Based on examination of list prices, incremental costs for glass door refrigerators are assumed to be equal to solid door models. An inflation factor was calculated using RS Means pricing data on current baseline technology compared with baseline costs listed in the 2002 ACEEE report. For analysis purposes, the incremental cost for Tier 1 (EnergyStar) is assumed to be $120 for a one-door (up to 30 cf), $155 for a two-door (30 to 50 cf), and $195 for a three-door (greater than 50 cf). These costs are consistent with the range of incremental costs identified by ACEEE. The incremental costs for Tier 2 are estimated to be twice the incremental costs for Tier 1, or $240 for a one-door, $310 for a two-door, and $390 for a three-door

**Incentive Level**
Incentives are equal to the incremental cost, and are identical to the incentives suggested by ACEEE (5% of the total equipment cost).[175] For Tier 1, this would be $120 for a one-door (up to 30 cf), $155 for a two-door (30 to 50 cf), and $195 for a three-door (greater than 50 cf). Incentives for Tier 2 will be twice those for Tier 1, or $240 for a one-door, $310 for a two-door, and $390 for a three-door.

**O&M Cost Adjustments**
No differences in O&M costs are apparent between the standard and efficient refrigerators.

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

[174] The following report estimates life of a commercial reach-in refrigerator at 8-10 years: *Energy Savings Potential for Commercial Refrigeration Equipment*, Arthur D. Little, Inc., 1996. (ArthurDLittle_Report.pdf)
[175] From *Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers*, Steven Nadel, ACEEE, December 2002, p. 22. (Nadal_ACEEE_2002.pdf)

**Reference Tables**

### Savings for Glass-Door Reach-In Refrigerators meeting ENERGY STAR and CEE Tier 2 Specifications

| Internal Volume (cubic feet) | Annual Energy Use of Average Base Case Model (kWh/year) | Annual kWh Savings Relative to Base Case | |
|---|---|---|---|
| | | Tier 1 | Tier 2 |
| less than 15 cf (one door) | 1,667 | 722 | 987 |
| 15-30 cf (one door) | 2,094 | 690 | 1083 |
| 30-50 cf (two door) | 3,004 | 737 | 1372 |
| greater than 50 cf (three door) | 4,285 | 927 | 1867 |

Source: See <Reach in Savings Calcs_2010.xls> for savings calculations.

### Specification for Glass-Door Reach-in Refrigerators

| Description of Specification | Maximum Energy Use (kWh/day) |
|---|---|
| BASELINE | 0.12 V + 3.34 |
| CEE Tier 1 ( top 25% of products.) | |
| Description of Specification | Maximum Energy Use (kWh/day) |
| BASELINE | 0.12 V + 3.34 |
| CEE Tier 1 (top 25% of products.) | |
| • $0 < V < 15$ cf | 0.118V + 1.382 |
| • $15 \leq V < 30$ cf | 0.140V + 1.050 |
| • $30 \leq V < 50$ cf | 0.088V + 2.625 |
| • 50 cf $\leq V$ | 0.110V + 1.500 |
| CEE Tier 2 (28% more efficient than Tier 1) | [CEE Tier 1 kWh/day] – 28% |

Note: V= internal volume

Sources: Baseline: *Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers*, Steven Nadel, ACEEE, December 2002, p.10, Table 6. (Nadal_ACEEE_2002.pdf) , CEE_Refrig_Specs:
**http://www.energystar.gov/ia/partners/product_specs/program_reqs/commer_refrig_glass_prog_req.pdf**

# Commercial Solid Door Reach-In Freezer

Measure Number: I-E-4-c (Business Energy Services, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 77
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**
1) CEE_Refrig_Specs.pdf,
2) ArthurDLittle_Report.pdf,
3) Nadal_ACEEE_2002.pdf,
4) Reach in Savings Calcs_2012.xls
5) DOE Final Rules Commercial Refrigeration Equipment_1.1.2012.pdf

**Description**
The measure described here is a high-efficiency packaged commercial reach-in freezer with solid doors, typically used by foodservice establishments. This includes one, two and three solid door reach-in, roll-in/through and pass-through commercial freezers.

**Algorithms**

**Demand Savings**
$\Delta kW = \Delta kWh / FLH$

**Energy Savings**
$\Delta kWh$ = value from savings table in Reference Tables section of this measure write-up (varies by number of doors and efficiency tier)

Where:
$\Delta kW$ = gross customer connected load kW savings for the measure (kW)
$\Delta kWh$ = gross customer annual kWh savings for the measure (kWh)
FLH = Full load hours from DPS commercial refrigeration loadshape (5858 hours).

**Baseline Efficiencies – New or Replacement**
The baseline is a reach-in freezer less efficient than ENERGY STAR. See the average baseline energy use in the savings table in the Reference Tables section.

**High Efficiency**
A high efficiency reach-in freezer can fall into one of two tiers: Tier 1 – those meeting the ENERGY STAR specifications, or Tier 2 – those meeting ENERGY STAR plus 30% more efficient. Refer to the specification table in the Reference Tables section for the precise specification.

**Operating Hours**
The freezer is assumed to always be plugged in but because of compressor and fan cycling the full load hours are 5858 hours.[176]

**Loadshape**
Loadshape #14, Commercial Refrigeration

**Freeridership/Spillover Factors**

| Measure Category | Refrigeration End-Use |
|---|---|

[176] Derived from Washington Electric Coop data by West Hill Energy Consultants

| Measure Code | | RFRCOMFZ | |
|---|---|---|---|
| Product Description | | Commercial Refrigerator | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | 0.95 | 1.00 |
| Cust Equip Rpl | 6013CUST | 0.94 | 1.00 |
| Farm NC | 6014FARM | 1.00 | 1.00 |
| Farm Prescriptive | 6013FRMP | 1.00 | 1.00 |
| Farm Equip Rpl | 6013FARM | 1.00 | 1.00 |
| Non Act 250 NC | 6014NANC | 1.00 | 1.00 |
| Pres Equip Rpl | 6013PRES | 0.95 | 1.00 |
| C&I Retro | 6012CNIR | 0.94 | 1.00 |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| Customer Credit | 6015 CC | n/a | n/a |
| EDirect | 6021 DIRI | 0.98 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
9 years[177]

**Measure Cost**
Based on examination of list prices and price studies performed by others, ACEEE ((see Nadal_ACEEE_2002.pdf) reported that the incremental cost for energy-efficient commercial freezers is relatively small[178]. An inflation factor was calculated using RS Means pricing data on current baseline technology compared with baseline costs listed in the 2002 ACEEE report. For analysis purposes, the incremental cost for Tier 1 (EnergyStar) is assumed to be $90 for a one-door (less than 30 cf), $125 for a two-door (30 to 50 cf), and $155 for a three-door (greater than 50 cf). These costs are consistent with the range of incremental costs identified by ACEEE. The incremental costs for Tier 2 are estimated to be twice the incremental costs for Tier 1, or $180 for a one-door, $250 for a two-door, and $310 for a three-door.

**O&M Cost Adjustments**
No differences in O&M costs are apparent between the standard and efficient freezers.

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

[177] The following report estimates life of a commercial reach-in freezer at 8-10 years: *Energy Savings Potential for Commercial Refrigeration Equipment*, Arthur D. Little, Inc., 1996. (ArthurDLittle_Report.pdf)

[178] From examination of list prices by ACEEE and reported in *Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers*, Steven Nadel, ACEEE, December 2002 (Nadal_ACEEE_2002.pdf)

**Reference Tables**

**Savings for Reach-In Freezers meeting ENERGY STAR and CEE Tier 2 Specifications**

| Internal Volume (cubic feet) | Annual Energy Use of Average Base Case Model (kWh/year) | Annual kWh Savings Relative to Base Case | |
|---|---|---|---|
| | | ENERGY STAR (Tier 1) ΔkWh | Tier 2 ΔkWh |
| 0 < V < 15 cf | 1,563 | 353 | 716 |
| 15 ≤ V < 30 cf | 3,469 | 668 | 1,508 |
| 30 ≤ V < 50 cf | 6,575 | 1,903 | 3,305 |
| 50 cf ≤ V | 9,709 | 3,805 | 5,576 |

Source: See "Reach in savings calcs 2012.xls" for savings calculations.

**CEE Specification for Solid-Door Reach-in Freezers**

| Description of Specification | Maximum Energy Use (kWh/day) |
|---|---|
| Baseline (Any Size) | 0.38 V + 0.88 |
| CEE Tier 1 (ENERGY STAR) | |
| • 0 < V < 15 cf | 0.250V + 1.250 |
| • 15 ≤ V < 30 cf | 0.400V – 1.000 |
| • 30 ≤ V < 50 cf | 0.163V + 6.125 |
| • 50 cf ≤ V | 0.158V + 6.333 |
| CEE Tier 2 | [Tier 1 kWh/day] – 30% |

Note: V= internal volume
Sources: DOE Final Rules Commercial Refrigeration Equipment_1.1.2012.pdf; CEE_Refrig_Specs.pdf; Reach in Savings Calcs_2012.xls;

# Commercial Glass Door Reach-In Freezer

Measure Number: I-E-17-a (Business Energy Services, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 84
Effective date: 1/1/2014
End date: TBD

**Referenced Documents:**
1) CEE_Refrig_Specs.pdf,
2) Effective Useful Life EUL_Summary_10-1-08.xls,
3) Nadel_ACEEE_2002.pdf,
4) Focus On Energy Incremental Cost report 2009.pdf
5) Reach in Savings Calcs_2013.xlsx
6) DOE Final Rules Commercial Refrigeration Equipment_1.1.2012.pdf

**Description**
The measure described here is a high-efficiency packaged commercial reach-in freezer with glass doors, typically used by food service establishments. This includes one, two and three glass door reach-in, roll-in/through and pass-through commercial freezers. This measure relates to the installation of a new reach-in, glass door commercial freezer meeting ENERGY STAR efficiency standards. ENERGY STAR labeled commercial freezers are more energy efficient because they are designed with components such as ECM evaporator and condenser fan motors, hot gas anti-sweat heaters, or high-efficiency compressors, which significantly reduce energy consumption. This measure was developed to be applicable to Time of Sale and New Construction programs.

**Algorithms**

**Demand Savings**
$\Delta kW = \Delta kWh / FLH$

**Energy Savings**
$\Delta kWh$ = gross customer annual kWh savings for the measure, value from savings table in Reference Tables section of this measure write-up (varies by freezer volume)

Where:

| | |
|---|---|
| $\Delta kW$ | = gross customer connected load kW savings for the measure (kW) |
| $\Delta kWh$ | = gross customer annual kWh savings for the measure, value from savings table in Reference Tables section of this measure write-up (varies by freezer volume) |
| FLH | = Full load hours from DPS commercial refrigeration loadshape (5858 hours). |

**Baseline Efficiencies – New or Replacement**
The baseline is a reach-in freezer less efficient than ENERGY STAR. The baseline equipment is assumed to be an existing glass door freezer meeting the minimum federal manufacturing standards as specified by Federal Standards Effective January 10, 2010.[179]

**High Efficiency**
The High Efficiency unit is one that qualifies for ENERGY STAR V 2.0 label, equivalent to the CEE qualification. There is only one CEE Tier for high efficiency reach-in, glass door freezers. [180]

[179] DOE Final Rules Commercial Refrigeration Equipment_1.1.2012.pdf
[180] High Efficiency Specifications for Commercial Refrigerators and Freezers Effective Date 01/01/2010, CEE_Refrig_Specs.pdf,

**Operating Hours**
The freezer is assumed to always be plugged in but because of compressor and fan cycling the full load hours are 5858 hours.[181]

**Loadshape**
Loadshape #14, Commercial Refrigeration

**Freeridership/Spillover Factors**

| Measure Category | | Refrigeration End-Use | |
|---|---|---|---|
| Measure Code | | RFRCOMFZ | |
| Product Description | | Commercial Refrigerator | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | 0.95 | 1.00 |
| Cust Equip Rpl | 6013CUST | 0.94 | 1.00 |
| Farm NC | 6014FARM | 1.00 | 1.00 |
| Farm Prescriptive | 6013FRMP | 1.00 | 1.00 |
| Farm Equip Rpl | 6013FARM | 1.00 | 1.00 |
| Non Act 250 NC | 6014NANC | 1.00 | 1.00 |
| Pres Equip Rpl | 6013PRES | 0.95 | 1.00 |
| C&I Retro | 6012CNIR | 0.94 | 1.00 |
| EDirect | 6021 DIRI | 0.98 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
The expected measure life is assumed to be 12 years [182].

**Measure Cost**
The incremental capital cost for this measure is provided below[183].

| Internal volume (cubic feet) | Glass Door Freezer Incremental Cost, per unit |
|---|---|
| 0 < V < 15 | $142 |
| 15 ≤ V < 30 | $166 |
| 30 ≤ V < 50 | $166 |
| V ≥ 50 | $407 |

[181] Derived from Washington Electric Coop data by West Hill Energy Consultants
[182] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.
Effective Useful Life EUL_Summary_10-1-08.xls
[183] Estimates of the incremental cost of commercial refrigerators and freezers varies widely by source. Nadel, S., Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers, ACEEE, December 2002, indicates that incremental cost is approximately zero. ACEEE notes that incremental cost ranges from 0 to 10% of the baseline unit cost (Nadel_ACEEE_2002.pdf). For the purposes of this characterization, assume an incremental cost adder of 5% on the full unit costs presented in Goldberg et al, State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs: Incremental Cost Study, KEMA, October 28, 2009 (Focus On Energy Incremental Cost report 2009.pdf).

**O&M Cost Adjustments**
No differences in O&M costs are apparent between the standard and efficient freezers.

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

| Type | kWhbase[184] | CEE/ ENERGY STAR 2.0 Freezer $kWh_{ee}$ | Annual kWh Savings CEE/ ENERGY STAR 2.0 Freezer ΔkWh [185] |
|---|---|---|---|
| 0 < V < 15 | 0.75 * V + 4.10 | ≤ 0.607V + 0.893 | 1,562 |
| 15 ≤ V < 30 | 0.75 * V + 4.10 | ≤ 0.733V – 1.000 | 2,001 |
| 30 ≤ V < 50 | 0.75 * V + 4.10 | ≤ 0.250V + 13.500 | 3,869 |
| V ≥ 50 | 0.75 * V + 4.10 | ≤ 0.450V + 3.500 | 7,884 |
| Chest Configuration | 0.75 * V + 4.10 | ≤ 0.270V + 0.130 | 3,902 |

V = the frozen compartment volume ($ft^3$) (as defined in the Association of Home Appliance Manufacturers Standard HRF1–1979)

[184] U.S. federal standards as of January 1, 2010: DOE Final Rules Commercial Refrigeration Equipment_1.1.2012.pdf
[185] For calculations, see Reach in Savings Calcs_2013.xlsx

# ENERGY STAR Commercial Ice-makers

Measure Number: I-E-5-c (Business Energy Services, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 84
Effective date: 01/01/2014
End date: TBD

**Referenced Documents:**

1. Nadel, S., Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers, ACEEE, December 2002.
2. "A Field Study to Characterize Water and Energy Use of Commercial Ice-Cube Machines and Quantify Saving Potential", Food Service Technology Center, December 2007
3. Ice Machine Field Study: Energy and Water Savings with Ice Machine Upgrade and Load Shifting
4. 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values," California Public Utilities Commission, December 16, 2008.
5. ENERGY STAR calculator (commercial_kitchen_equipment_calculator.xls), http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/commercial_kitchen_equipment_calculator.xlsx as of October 28, 2013.

**Description**
A typical ice-maker consists of a case, insulation, refrigeration system, and a water supply system. They are used in hospitals, hotels, food service, and food preservation. Energy-savings for ice-makers can be obtained by using high-efficiency compressors and fan motors, thicker insulation, and other measures. ENERGY STAR Commercial Ice Machines are on average 15 percent more energy-efficient and 25 percent more water-efficient than standard models. The ENERGY STAR specification applies to new air-cooled, batch and continuous machines including ice-making heads, self-contained units, and remote-condensing units with ice harvest rates between 50 and 4,000 pounds of ice per day, depending on equipment type. This is a time of replacement measure.

**Algorithms**

**Demand Savings**
$\Delta$kW = $\Delta$kWh / FLH, see Reference Table 2

**Energy Savings**
$\Delta$kWh = value from savings table in Reference Table 2 (varies by type)

Where:
$\Delta$kW = gross customer connected load kW savings for the measure (kW)
$\Delta$kWh = gross customer annual kWh savings for the measure (kWh)
FLH = Full load hours

**Baseline Efficiencies – New or Replacement**
The baseline equipment is assumed to be new air-cooled, batch and continuous machines including ice-making heads, self-contained units, and remote-condensing units with ice harvest rates between 50 and 4,000 pounds of ice per day, depending on equipment type meeting federal equipment standards established January 1, 2010.

**High Efficiency**
The efficient equipment is assumed to new air-cooled, batch and continuous machines including ice-making heads, self-contained units, and remote-condensing units with ice harvest rates between 50 and 4,000 pounds of ice per day, depending on equipment type meeting the minimum ENERGY STAR efficiency level standards.

**Operating Hours**
The ice-maker is assumed to always be plugged in but the average unit operates at 57% of capacity.[186] The full load hours is therefore expected to be 57% of 8760 hrs or 4997 hours.

**Loadshape**
Loadshape #14, Commercial Refrigeration

**Freeridership/Spillover Factors**

| | | | |
|---|---|---|---|
| Measure Category | | Refrigeration End-Use | |
| Measure Code | | RFRCOMIM | |
| Product Description | | Commercial Icemaker | |
| Track Name | Track No. | Freerider | Spillover |
| Cust Equip Rpl | 6013CUST | 0.94 | 1.00 |
| Pres Equip Rpl | 6013PRES | 0.95 | 1.00 |
| C&I Retro | 6012CNIR | 0.94 | 1.00 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
10 years[187]

**Measure Cost**
There is no incremental capital cost for this measure.[188]

**O&M Cost Adjustments**
No differences in O&M costs are apparent between the standard and efficient ice-makers.

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
Continuous ice machines have zero water savings. Batch type machines have water savings given by type in Reference Table 3.

**Reference Tables**

**Reference Table #1**

**Energy Savings Algorithms**[189]

| Ice Machine Type | Baseline kWh per 100 | Efficient kWh per 100 |
|---|---|---|

[186] Duty cycle varies considerably from one installation to the next. The ENERGY STAR Commercial Ice Machine Savings Calculator assumes a value of 75%. A report prepared by ACEEE assumed a value of 40% (Nadel, S., Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers, ACEEE, December 2002). A field study of eight ice machines in California indicated an average duty cycle of 57% ("A Field Study to Characterize Water and Energy Use of Commercial Ice-Cube Machines and Quantify Saving Potential", Food Service Technology Center, December 2007). A more recent study *Ice Machine Field Study: Energy and Water Savings with Ice Machine Upgrade and Load Shifting* found a duty cycle of 64%. The value of 57% was utilized since it is from a higher quality data source.
[187] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values," California Public Utilities Commission, December 16, 2008.
[188] ENERGY STAR calculator (commercial_kitchen_equipment_calculator.xls), as of September 30, 2013.
[189] ENERGY STAR calculator (commercial_kitchen_equipment_calculator.xls), http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/commercial_kitchen_equipment_calculator.xlsx as of October 28, 2013.

| Air Cooled, batch or continuous | gallons of ice | gallons of ice |
|---|---|---|
| Ice Making Head (H < 450) | 10.26 – 0.0086×H | 9.23 – 0.0077×H |
| Ice Making Head (H ≥ 450) | 6.89 – 0.0011×H | 6.20 – 0.0010×H |
| Remote Condensing Unit(H < 1000) | 8.85 – 0.0038×H | 8.05 – 0.0035×H |
| Remote Condensing Unit (H ≥ 1000) | 5.1 | 4.64 |
| Self Contained Unit (H < 175) | 18 – 0.0469×H | 16.7 – 0.0436×H |
| Self Contained Unit (H ≥ 175) | 9.8 | 9.11 |

**Reference Table #2**

**Annual Energy Consumption/Savings per Ice Machine**[190]

| **Ice Machine Type**<br>**Air Cooled, batch or continuous** | **Assumed Ice harvest rate (H) (lbs. ice/day)** | **ΔkWh** | **ΔkW** |
|---|---|---|---|
| Ice Making Head (H < 450) | 400 | 558 | 0.112 |
| Ice Making Head (H ≥ 450) | 665 | 863 | 0.173 |
| Remote Condensing Unit(H < 1000) | 900 | 992 | 0.199 |
| Remote Condensing Unit (H ≥ 1000) | 1,160 | 1,110 | 0.222 |
| Self Contained Unit (H < 175) | 170 | 261 | 0.052 |
| Self Contained Unit (H ≥ 175) | 240 | 345 | 0.069 |

**Reference Table #3**

**Annual Water Consumption per Ice Machine for Batch Machines (gallons)** [191]

| | Batch | | |
|---|---|---|---|
| | Conventional | ENERGY STAR | Savings |
| Ice Making Head | 29,481 | 24,748 | 4,733 |
| Remote Cond./ Split System | 48,091 | 43,066 | 5,024 |
| Self Contained Unit | 10,646 | 6,897 | 3,749 |

[190] Ibid.
[191] Ibid.

# Evaporator Fan Motor Controls

Measure Number: I-E-7-b (Business Energy Services, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio No. 37a
Effective date: 1/1/06
End date: TBD

Referenced Documents: <RefrigLoadshapes.xls>.

**Description**
Walk-in cooler evaporator fans typically run all the time; 24 hrs/day, 365 days/yr. This is because they must run constantly to provide cooling when the compressor is running, and to provide air circulation when the compressor is not running. However, evaporator fans are a very inefficient method of providing air circulation. Each of these fans uses more than 100 watts. Installing an evaporator fan control system will turn off evaporator fans while the compressor is not running, and instead turn on an energy-efficient 35 watt fan to provide air circulation, resulting in significant energy savings.

**Algorithms**

**Demand Savings**
$\Delta kW = ((kW_{Evap} \times n_{Fans} \times DC_{Evap}) - kW_{Circ}) \times (1\text{-}DC_{Comp}) \times BF$

**Energy Savings**
$\Delta kWh = \Delta kW \times 8760$

Where:

| | |
|---|---|
| $\Delta kW$ | = gross customer connected load kW savings for the measure (kW) |
| $kW_{Evap}$ | = Connected load kW of each evaporator fan (Average 0.123 kW)[192] |
| $n_{Fans}$ | = Number of evaporator fans |
| $kW_{Circ}$ | = Connected load kW of the circulating fan (0.035 kW)[193]. |
| $DC_{Comp}$ | = Duty cycle of the compressor (Assume 50%)[194] |
| $DC_{Evap}$ | = Duty cycle of the evaporator fan (100% for cooler, 94% for freezer)[195] |
| BF | = Bonus factor for reduced cooling load from replacing the evaporator fan with a lower wattage circulating fan when the compressor is not running (1.5 for low temp, 1.3 for medium temp, and 1.2 for high temp)[196] |
| $\Delta kWh$ | = gross customer annual kWh savings for the measure (kWh) |
| 8760 | = (hours/year) |

**Baseline Efficiencies – New or Replacement**
The baseline condition is a refrigeration system without an evaporator fan control.

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[192] Based on a weighted average of 80% shaded pole motors at 132 watts and 20% PSC motors at 88 watts. This weighted average is based on discussions with refrigeration contractors and is considered conservative (market penetration estimated at approximately 10%).
[193] Wattage of fan used by Freeaire and Cooltrol.
[194] A 50% duty cycle is assumed based on examination of duty cycle assumptions from Richard Traverse (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.
[195] A evaporator fan in a cooler runs all the time, but a freezer only runs 8273 hours per year due to defrost cycles (4 20-min defrost cycles per day)
[196] Bonus factor (1+ 1/COP) assumes 2.0 COP for low temp, 3.5 COP for medium temp, and 5.4 COP for high temp, based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of -20°F, 20°F, and 45°F, respectively, and a condensing temperature of 90°F.
.

**High Efficiency**
High efficiency is a refrigeration system with an evaporator fan control and a smaller wattage circulating fan.

**Operating Hours**
The evaporator fan run time without a fan control is 8760 hours per year. With a fan control the evaporator fan would be replaced with a smaller wattage fan for 50% of the time, or 4380 hours per year.

**Loadshape**
Evaporator Fan Control #68
Source: Derived from the standard refrigeration loadshape, with a 50% reduction in run time. See file <RefrigLoadshapes.xls>.

**Freeridership / Spillover Factors**

| Measure Category | | Refrigeration End-Use | |
|---|---|---|---|
| Measure Code | | RFRFMCON | |
| Product Description | | Fan motor control | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | 0.95 | 1.00 |
| Cust Equip Rpl | 6013CUST | 0.94 | 1.00 |
| Farm NC | 6014FARM | 1.00 | 1.00 |
| Farm Equip Rpl | 6013FARM | 1.00 | 1.00 |
| Non Act 250 NC | 6014NANC | 1.00 | 1.00 |
| Pres Equip Rpl | 6013PRES | 0.95 | 1.00 |
| C&I Retro | 6012CNIR | 0.94 | 1.00 |
| MF Mkt Retro | 6012MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
15 years

**Measure Cost**
The installation cost for a fan control is $2,254.[197]

**Incentive Level**
25% of installation costs or $550 per fan control.

**O&M Cost Adjustments**
None

[197] Based on average of costs from Freeaire and Cooltrol fan control systems.

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**
None

# Brushless DC Motors (also known as ECM) for Walk-In Coolers, Freezers, and Refrigerated Buildings

Measure Number: I-E-8-c (Business Energy Services, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 61
Effective date: 01/01/10
End date: TBD

**Referenced Documents:**
CEE_Refrig_Specs.pdf
<Reach in Savings Calcs_2010.xls>
GE_ECM_revised.pdf

**Description**
Cooler or freezer evaporator fan boxes typically contain two to six evaporator fans that run nearly 24 hours each day, 365 days each year. Not only do these fans use electricity, but the heat that each fan generates must also be removed by the refrigeration system to keep the product cold, adding more to the annual electricity costs. If the cooler or freezer has single-phase power, the electricity usage can be reduced by choosing permanent brushless DC motors instead of conventional, shaded-pole motors. Brushless DC motors are also sometimes known by the copyrighted trade name ECM (electronically commutated motor).

**Algorithms**

**Demand Savings**
$kW_{ECM} = (kW_{SP} - kW_{BDC}) \times DC_{Evap} \times BF$

**Energy Savings**
$kWh_{ECM} = \Delta kW_{ECM} \times 8760$

Where:

$\Delta kW$ = gross customer connected load kW savings for the measure (kW)
$kW_{SP}$ = Connected load kW of a shaded pole evaporator fan (Average 0.132 kW) [198]
$kW_{BDC}$ = Connected load kW of a brushless DC evaporator fan (0.040kW)[199]
$DC_{Evap}$ = Duty cycle of the evaporator fan (100% for cooler, 94% for freezer)[200]
BF = Bonus factor for reduced cooling load from replacing a shaded-pole evaporator fan with a brushless DC fan (1.5 for low temp, 1.3 for medium temp, and 1.2 for high temp)[201]
$\Delta kWh$ = gross customer annual kWh savings for the measure (kWh)
8760 = (hours/year)

[198] Based on metered data from R.H. Travers. See also GE_ECM_revised.pdf.
[199] Based on metered data from Natural Resource Management and Efficiency Vermont See also GE_ECM_revised.pdf.
[200] A evaporator fan in a cooler runs all the time, but a freezer only runs 8273 hours per year due to defrost cycles (4 20-min defrost cycles per day)
[201] Bonus factor (1+ 1/COP) assumes 2.0 COP for low temp, 3.5 COP for medium temp, and 5.4 COP for high temp, based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of -20°F, 20°F, and 45°F, respectively, and a condensing temperature of 90°F.

**Baseline Efficiencies – New or Replacement**
The baseline condition for retrofitting of old units is shaded pole evaporator fan motor. The baseline for new units is a brushless DC motor. No incentive will be given on a new unit with an ECM motor.

**High Efficiency**
High efficiency is a brushless DC fan motor.

**Operating Hours**
A cooler evaporator fan runs all the time or 8760 hours per year. A freezer evaporator fan runs 8273 hours per year due to defrost cycles (4 20-min defrost cycles per day). The smaller number of hours for freezer fan run time is captured in the duty cycle factor in the ΔkW calculation, so that 100% coincidence factors may be applied to both applications.

**Loadshape**
Flat (8760 hours) #25

**Freeridership/Spillover Factors**

| Measure Category | | Refrigeration End-Use | |
|---|---|---|---|
| Measure Code | | RFRBLFAN | |
| Product Description | | Efficient Blower Fans | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | 0.95 | 1.00 |
| Cust Equip Rpl | 6013CUST | 0.94 | 1.00 |
| Farm NC | 6014FARM | 1.00 | 1.00 |
| Farm Equip Rpl | 6013FARM | 1.00 | 1.00 |
| Non Act 250 NC | 6014NANC | 1.00 | 1.00 |
| Pres Equip Rpl | 6013PRES | 0.95 | 1.00 |
| C&I Retro | 6012CNIR | 0.89 | 1.00 |
| MF Mkt Retro | 6012MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
15 years

**Measure Cost**
Retrofit cost for a brushless DC fan motor is $245 ($185 for the motor, $60 for installation labor including travel time).[202]

**Incentive Level**
For brushless DC motors, the incentive is $100, which is 41% of the full installed retrofit cost.

[202] Based on costs from Natural Resource Management ($250) and direct from the manufacturer GE ($120).

**O&M Cost Adjustments**
None

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**
None

# Zero-Energy Doors and Frames

Measure Number: I-E-9-c (Business Energy Services, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio No. 58
Effective date: 1/1/09
End date: TBD

Referenced Documents: < Door Heater Control Study.xls>

**Description**
Cooler reach-ins with glass doors typically have electric resistance heaters installed within the doors and frames. Refrigerator door manufacturers include these resistance heaters to prevent condensation from forming on the glass, blocking the customer's view, and to prevent frost formation on door frames. Zero-energy doors and frames may be chosen in place of standard cooler doors. These doors consist of two or three panes of glass and include a low-conductivity filler gas (e.g., Argon) and low-emissivity glass coatings. This system keeps the outer glass warm and prevents external condensation. Manufacturers can provide information on how well these systems work with "respiring" products.

**Algorithms**

**Demand Savings**
$\Delta kW = kW_{door} \times BF$

**Energy Savings**
$\Delta kWh = \Delta kW \times 8760$

Where:

| | |
|---|---|
| $\Delta kW$ | = gross customer connected load kW savings for the measure (kW) |
| $kW_{door}$ | = Connected load kW of a typical reach-in cooler door and frame with electric heaters (0.131 kW)[203] |
| BF | = Bonus factor for reduced cooling load from eliminating heat generated by the door heater from entering the cooler (1.22 for medium temp, and 1.15 for high temp)[204] |
| $\Delta kWh$ | = gross customer annual kWh savings for the measure (kWh) |
| 8760 | = (hours/year) |

**Baseline Efficiencies – New or Replacement**
The baseline condition is a cooler glass door and frame that is continuously heated to prevent condensation.

**High Efficiency**
High efficiency is a cooler glass door that prevents condensation with multiple panes of glass, inert gas, and low-e coatings instead of using electrically generated heat. The cooler high efficiency frame has a less conductive coating to minimize condensation, in place of electrically generated heat.

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[203] Based on range of wattages from manufacturers data (115 to 215 watts per door for door and frame heaters combined). See Door_heater_wattages.xls.

[204] Bonus factor ($1 + 0.65/COP_R + 0.35 \times .75 \times .29/2.5$) assumes 3.5 $COP_R$ for medium temp and 5.4 $COP_R$ for high temp, based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of 20°F and 45°F, respectively, and a condensing temperature of 90°F, and EVT assumption that 65% of heat generated by door enters the refrigerated case. It further assumes that 75% of stores have mechanical cooling, where the remaining 35% of heat that enters the store must also be cooled, with a typical 2.5 COP cooling system efficiency and 0.29 ASHRAE Lighting waste heat cooling factor for Vermont (From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993).

**Operating Hours**
8760 hours per year

**Loadshape**
Loadshape #25, Flat (8760 Hours)

**Freeridership**
5% Act 250 NC; 6% Cust Equip Replace and C&I Retro

**Spillover**
0%

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
10 years[205]

**Measure Cost**
The incremental cost of a cooler zero energy door and frame is estimated at $290,[206]

**Incentive Level**
$100 or 34% of the incremental cost for a cooler door and frame .
**O&M Cost Adjustments**
None

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**
None

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[205] The following report estimates life of a refrigerated display case at 5-15 years: *Energy Savings Potential for Commercial Refrigeration Equipment*, Arthur D. Little, Inc., 1996.
[206] Based on manufacturers cost data and EVT project experience.

# Door Heater Controls

Measure Number: I-E-10-c (Business Energy Services, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio No. 58
Effective date: 1/1/09
End date: TBD

Referenced Documents: <Door_heater_controls_loadshape_051503.xls>; < Door Heater Control Study.xls>

**Description**
Another option to zero-energy doors – that is also effective on existing reach-in cooler or freezer doors – is "on-off" control of the operation of the door heaters. Because relative humidity levels differ greatly across the United States, a door heater in Vermont needs to operate for a much shorter season than a door heater in Florida. By installing a control device to turn off door heaters when there is little or no risk of condensation, one can realize energy and cost savings.

There are two strategies for this control, based on either (1) the relative humidity of the air in the store or (2) the "conductivity" of the door (which drops when condensation appears). In the first strategy, the system activates your door heaters when the relative humidity in your store rises above a specific setpoint, and turns them off when the relative humidity falls below that setpoint. In the second strategy, the sensor activates the door heaters when the door conductivity falls below a certain setpoint, and turns them off when the conductivity rises above that setpoint.

**Algorithms**

**Demand Savings**
$\Delta kW = kW_{door} \times N_{door} \times ES \times BF$

**Energy Savings**
$\Delta kWh = \Delta kW \times 8760$

Where:

- $\Delta kW$ = gross customer connected load kW savings for the measure (kW)
- $kW_{door}$ = Connected load kW of a typical reach-in cooler or freezer door and frame with a heater (cooler 0.131 kW, freezer 0.245)[207]
- $N_{door}$ = Number of doors controlled by sensor
- BF = Bonus factor for reduced cooling load from eliminating heat generated by the door heater from entering the cooler or freezer (1.36 for low temp, 1.22 for medium temp, and 1.15 for high temp)[208]
- $\Delta kWh$ = gross customer annual kWh savings for the measure (kWh)
- 8760 = (hours/year)
- ES = Percent annual energy savings (55% for humidity-based control[209], 70% for conductivity-based control[210])

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[207] Based on data pulled from the Express Refrigeration walk-in cooler retrofit program for GT customers in 2008.. See Door Heater Control Study.xls.
[208] Bonus factor ($1 + 0.65/COP_R + 0.35 \times .75 \times .29/2.5$) assumes 2.0 $COP_R$ for low temp, 3.5 $COP_R$ for medium temp, and 5.4 $COP_R$ for high temp, based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of -20°F, 20°F, and 45°F, respectively, and a condensing temperature of 90°F, and EVT assumption that 65% of heat generated by door enters the refrigerated case. It further assumes that 75% of stores have mechanical cooling, where the remaining 35% of heat that enters the store must also be cooled, with a typical 2.5 COP cooling system efficiency and 0.29 ASHRAE Lighting waste heat cooling factor for Vermont (From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993).
[209] R.H.Travers' estimate of savings.
[210] Door Miser savings claim.

**Baseline Efficiencies – New or Replacement**
The baseline condition is a cooler or freezer glass door that is continuously heated to prevent condensation.

**High Efficiency**
High efficiency is a cooler or freezer glass door with either a humidity-based or conductivity-based door-heater control.

**Operating Hours**
Door heaters operate 8760 hours per year.

**Loadshape**
Loadshape #69, Door Heater Control

Source: Based on assumption that the door heater savings will occur when the interior humidity levels are lowest – primarily the winter months, with declining savings during the fall and spring. See <Door_heater_controls_loadshape_051503.xls>

Freeridership/Spillover Factors

| Measure Category | | Refrigeration End-Use | |
|---|---|---|---|
| Measure Code | | RFRDRCON | |
| Product Description | | Refrigeration door heater controls | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | 0.95 | 1.15 |
| Cust Equip Rpl | 6013CUST | 0.94 | 1.00 |
| Farm NC | 6014FARM | 0.94 | 1.00 |
| Farm Equip Rpl | 6013FARM | 1.00 | 1.00 |
| Non Act 250 NC | 6014NANC | 1.00 | 1.15 |
| Pres Equip Rpl | 6013PRES | 1.00 | 1.00 |
| C&I Retro | 6012CNIR | 0.94 | 1.00 |
| MF Mkt Retro | 6012MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
10 years[211]

[211] The following report estimates life of a refrigerated display case at 5-15 years: *Energy Savings Potential for Commercial Refrigeration Equipment*, Arthur D. Little, Inc., 1996.

**Measure Cost**
The cost for humidity-based control is $300 for a complete circuit, regardless of the number of doors. The cost for conductivity-based control is $200 per door.

**Incentive Level**
$15 per cooler door and $30 per freezer door for a humidity-based control and $100 per door or 50% of the cost for a conductivity-based control.

**O&M Cost Adjustments**
None

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**
None

# Efficient Refrigeration Compressors

Measure Number: I-E-11-d (Business Energy Services, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 82
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**
1) Refrigeration Compressor Pricing Analysis v1.0.xlsx
2) Compressor efficiency analysis EVT Refrigeration 2013.xlsx
3) "Performance Standards for Walk-In Refrigerator and Freezer Systems," AHRTI Report No. 09002-01, prepared by Bryan R. Becker, et al., January 2012

**Description**
This measure relates to the installation of an efficient refrigeration compressor that exceeds the energy efficiency requirements specified in this characterization. This characterization is intended to apply to lost-opportunity applications only.

This characterization was developed to be "technology-neutral." In other words, as long as an applicant compressor exceeds the EER performance requirements as specified in this characterization, the equipment should qualify for an incentive (assuming all other program requirements are met). However, some aspects of the characterization such as incremental costs, O&M costs, and measure lifetimes are closely linked to compressor technology type. Therefore, compressor technology remains an input into the characterization. For reference, typical high efficiency compressor technologies are described below.

***Reed Valve Technology***. For decades, the most common refrigeration compressors utilized reed valve technology to control the flow of refrigerant to and from the compresson chamber. The reed valves are a constrained thin strip of steel laid across the valve opening that flap open due to a differential pressure across the valve. This is a reliable technology but limited in efficiency due to leakage at the valve opening.

***Discus Technology*** (patented by Copeland) involves using effective gas and oil flow management through more advanced valving that provides the best operating efficiency in the range of the compressor load. This eliminates capillary tubes typically used for lubrication, that also offers maximum compressor protection as well as environmental integrity. Tapered disk type valves, similar to the valves used in automotive engines, improve efficiency and lower sound levels. The disks open to permit a higher refrigerant gas flow at reduced differential pressures reduces system losses and enhances efficiency.

***Scroll Technology*** involves using two identical, concentric scrolls, one inserted within the other. One scroll remains stationary as the other orbits around it. This movement draws gas into the compression chamber and moves it through successively smaller pockets formed by the scroll's rotation, until it reaches maximum pressure at the center of the chamber. At this point, the required discharge pressure has been achieved. There, it is released through a discharge port in the fixed scroll. During each orbit, several pockets are compressed simultaneously, making the operation continuous.

**Algorithms**

**Energy Savings**

$\Delta$kWh = ((Avg Cap*FLH)*((1/EERns,base)-(1/EERns efficient)))/1000

Where:

$\Delta$kWh = gross customer annual kWh savings for the measure (kWh). See Table 2 "Compressor Savings Values Based on Capacity and Temperature Application" in the Reference Table section for assumed savings values for prescriptive measures.

Avg Cap = Compressor capacity in Btu/h at non-standard rating conditions. See Table 3 "Standard and Non-Standard Rating Conditions for Compressors" in the Reference Table section for the standard and non-standard rating conditions. For prescriptive measures, the average capacity for each range of sizes from Table 2 "Compressor Savings Values Based on Capacity and Temperature Application" in the Reference Table section should be used.

EERns,base = Energy Efficiency Ratio of the baseline compressor at non-standard rating conditions. See Table 1 "Baseline and Qualifying EER Values by Capacity, and Temperature Application" in the Reference Tables section for baseline values.

$EERn_{S,Efficient}$ = Energy Efficiency Ratio of the efficient compressor at non-standard rating conditions. For prescriptive measures, the qualifying EER from Table 1"Baseline and Qualifying EER Values by Capacity, and Temperature Application" in the Reference Tables section should be used.

FLH = Full load hours (Default, 3910 hours for medium temperature and high temperature applications and 4139 hours for low temperature applications.[212]).

**Demand Savings**

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

Where:

$\Delta$kW = gross customer connected load kW savings for the measure (kW)

**Baseline Efficiencies – New or Replacement**

The baseline efficiency varies by capacity, temperature application, and type (single phase vs three-phase). See Table 1 "Baseline and Qualifying EER Values by Capacity, and Temperature Application" in the Reference Tables section for baseline values.[213]

**High Efficiency**

A high efficiency compressor is one that exceeds the qualifying EER for its capacity, temperature application, and type (single phase vs three-phase) in Table 1 "Baseline and Qualifying EER Values by Capacity, and Temperature Application" in the Reference Tables section.[214]

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[212] Based on run time estimates from "Performance Standards for Walk-In Refrigerator and Freezer Systems," AHRTI Report No. 09002-01, by Bryan R. Becker, et al., January 2012, Tables 30-33 (http://www.ahrinet.org/App_Content/ahri/files/RESEARCH/Technical%20Results/AHRTI-Rpt-09002-01.pdf%E2%80%8E.pdf). See referenced document "compressor efficiency analysis EVT Refrigeration 2013.xlsx" for details.

[213] Baseline EERs calculated as ½ standard deviation below average EER for each capacity bin of available models. See referenced document "compressor efficiency analysis EVT Refrigeration 2013.xlsx" for details.

[214] Qualifying EER calculated as ½ standard deviation above average EER for each capacity bin of available models. See referenced document compressor efficiency analysis EVT Refrigeration 2013.xlsx for details..

**Operating Hours**
The refrigeration is assumed to be in operation every day of the year, but because of compressor cycling the full load hours are 3910 hours for medium temperature and high temperature applications and 4139 hours for low temperature applications, as described above in the algorithm section.

**Loadshape**
Loadshape #14, Commercial Refrigeration

**Freeridership/Spillover**

| Measure Category | | Refrigeration | |
|---|---|---|---|
| Measure Code | | RFRCOMPR, RFRCMPDS, RFRCMPSC | |
| Product Description | | Refrigeration Compressor, Scroll Compressor, Discus Compressor | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | 0.94 | 1.00 |
| Cust Equip Rpl | 6013CUST | 0.94 | 1.00 |
| Pres Equip Rpl | 6013PRES | 0.95 | 1.00 |
| C&I NC Cust | 6014CUST | 0.95 | 1.05 |
| C&I NC Pres | 6014PRES | 0.95 | 1.05 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
Discuss and Scroll compressors have lifetimes of 13 years. A baseline compressor has a shorter lifetime of 10 years. Measure life is assumed to be 13 years.

**Measure Cost**
Varies by compressor type, horsepower and temperature application. See Table 4 “Compressor Incremental Costs” in Reference Tables section below.

**O&M Cost Adjustments**
Standard compressors are assumed to require $325/year for maintenance (2.5 hours twice per year at $65/hour), compared to $97.5/year (1.5 hours) for scroll compressors and $65/year (1 hour) for discus compressors.

The maintenance costs for standard semi-hermetic or hermetic compressors are primarily associated with cleaning the condenser and repairing leaks that are caused by the "slugging" of the liquid refrigerant in the line. The slugging hammers the refrigeration piping and joints become undone and leak.

The maintenance costs associated with Scroll compressors are due to adjustment of onboard mechanical valves and cleaning the condenser. The maintenance costs associated with Discus compressors are simply to check out the moving reed action internal to the compressor and check the refrigerant fluid for particles. There are no other moving parts in the Discus that require maintenance.

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

**Table 1: Baseline and Qualifying EER Values by Capacity, and Temperature Application**[215]

| **Low Temperature**<br>**Single-Phase compressor**<br>Baseline and Qualifying EER<br>Condensing temp 90°F, Evap Temp -25°F | | |
|---|---|---|
| **Capacity in BTU/Hr** | **Baseline EER** | **Efficient Min Qualifying EER** |
| 0-4200 | N/A | N/A |
| 4200-8399 | **4.64** | **5.05** |
| 8400-12599 | **4.89** | **5.21** |
| 12600-16799 | **5.17** | **5.48** |
| 16800-20999 | **5.33** | **5.75** |

| **Low Temperature**<br>**Three-Phase compressor**<br>Baseline and Qualifying EER<br>Condensing temp 90°F, Evap Temp -25°F | | |
|---|---|---|
| **Capacity in BTU/Hr** | **Baseline EER** | **Efficient Min Qualifying EER** |
| 0-4200 | N/A | N/A |
| 4200-8399 | **5.03** | **5.37** |
| 8400-12599 | **5.22** | **5.52** |
| 12600-16799 | **5.34** | **5.70** |
| 16800-20999 | **5.40** | **5.84** |
| 21000-25199 | **5.69** | **6.06** |
| 25200-29399 | **5.71** | **6.15** |
| 29400-33599 | **6.14** | **6.39** |
| 33600-37800 | **5.64** | **6.06** |

[215] See referenced document "compressor efficiency analysis EVT Refrigeration 2013.xlsx" for development details.

| Medium Temperature<br>Single-Phase compressor<br>Baseline and Qualifying EER<br>Condensing temp 90°F, Evap Temp 20°F | | |
|---|---|---|
| **Capacity in BTU/Hr** | **Baseline EER** | **Efficient Min Qualifying EER** |
| 0-7500 | N/A | N/A |
| 7500-14999 | **8.89** | **10.65** |
| 15000-22499 | **10.48** | **11.79** |
| 22500-29999 | **10.75** | **11.72** |
| 30000-37499 | **10.68** | **11.93** |
| 37500-44999 | **11.59** | **12.49** |
| 45000-52499 | **11.06** | **11.79** |
| 52500-59999 | **12.98** | **13.06** |

| Medium Temperature<br>Three-Phase compressor<br>Baseline and Qualifying EER<br>Condensing temp 90°F, Evap Temp 20°F | | |
|---|---|---|
| **Capacity in BTU/Hr** | **Baseline EER** | **Efficient Min Qualifying EER** |
| 0-7500 | N/A | N/A |
| 7500-14999 | **9.66** | **11.07** |
| 15000-22499 | **10.79** | **11.88** |
| 22500-29999 | **11.62** | **12.58** |
| 30000-37499 | **11.55** | **12.85** |
| 37500-44999 | **11.90** | **12.91** |
| 45000-52499 | **12.29** | **13.25** |
| 52500-59999 | **12.10** | **13.19** |
| 60000-67499 | **12.46** | **13.13** |
| 67500-75000 | **11.44** | **12.37** |

| High Temperature<br>Single-Phase compressor<br>Baseline and Qualifying EER<br>Condensing temp 90°F, Evap Temp 45°F | | |
|---|---|---|
| **Capacity in BTU/Hr** | **Baseline EER** | **Efficient Min Qualifying EER** |
| 0-12000 | N/A | N/A |
| 12000-24999 | **19.76** | **22.52** |
| 25000-49999 | **19.57** | **20.43** |
| 50000-74999 | **17.24** | **20.59** |
| | | |

| High Temperature<br>Three-Phase compressor<br>Baseline and Qualifying EER<br>Condensing temp 90°F, Evap Temp 45°F | | |
|---|---|---|
| **Capacity in BTU/Hr** | **Baseline EER** | **Efficient Min Qualifying EER** |
| 0-24999 | N/A | N/A |
| 25000-49999 | **20.61** | **23.15** |
| 50000-74999 | **19.20** | **22.36** |
| 75000-99999 | **19.48** | **21.93** |
| 100000-124999 | **19.79** | **21.65** |

**Table 2: Compressor Savings Values Based on Capacity and Temperature Application** [216]

| Low Temperature Single-Phase compressor Assumed Average Capacity and Savings Condensing temp 90°F, Evap Temp -25°F | | | |
|---|---|---|---|
| Capacity Bins BTU/Hr | Avg Cap BTU/hr | Annual KWh Savings | kW reduction |
| 0-4200 | N/A | N/A | N/A |
| 4200-8399 | **6,169** | **553** | **0.10** |
| 8400-12599 | **10,086** | **639** | **0.11** |
| 12600-16799 | **14,537** | **791** | **0.14** |
| 16800-20999 | **18,283** | **1,283** | **0.22** |

| Low Temperature Three-Phase compressor Assumed Average Capacity and Savings Condensing temp 90°F, Evap Temp -25°F | | | |
|---|---|---|---|
| Capacity Bins BTU/Hr | Avg Cap BTU/hr | Annual KWh Savings | kW reduction |
| 0-4200 | N/A | N/A | N/A |
| 4200-8399 | **6,092** | **388** | **0.07** |
| 8400-12599 | **10,162** | **527** | **0.09** |
| 12600-16799 | **14,617** | **875** | **0.15** |
| 16800-20999 | **18,986** | **1,353** | **0.23** |
| 21000-25199 | **22,609** | **1,220** | **0.21** |
| 25200-29399 | **27,060** | **1,729** | **0.30** |
| 29400-33599 | **31,860** | **1,032** | **0.18** |
| 33600-37800 | **35,964** | **2,261** | **0.39** |

| Medium Temperature Single-Phase compressor Assumed Average Capacity and Savings Condensing temp 90°F, Evap Temp 20°F | | | |
|---|---|---|---|
| Capacity Bins BTU/Hr | Avg Cap BTU/hr | Annual KWh Savings | kW reduction |
| 0-7500 | N/A | N/A | N/A |
| 7500-14999 | **11,952** | **975** | **0.17** |
| 15000-22499 | **18,898** | **879** | **0.15** |
| 22500-29999 | **26,719** | **901** | **0.16** |
| 30000-37499 | **33,067** | **1,420** | **0.25** |
| 37500-44999 | **40,393** | **1,105** | **0.19** |
| 45000-52499 | **48,467** | **1,184** | **0.20** |
| 52500-59999 | **56,250** | **103** | **0.02** |

| Medium Temperature Three-Phase compressor Assumed Average Capacity and Savings Condensing temp 90°F, Evap Temp 20°F | | | |
|---|---|---|---|
| Capacity Bins BTU/Hr | Avg Cap BTU/hr | Annual KWh Savings | kW reduction |
| 0-7500 | N/A | N/A | N/A |
| 7500-14999 | **12,030** | **704** | **0.12** |
| 15000-22499 | **18,763** | **703** | **0.12** |
| 22500-29999 | **26,714** | **782** | **0.13** |
| 30000-37499 | **33,848** | **1,314** | **0.22** |
| 37500-44999 | **40,113** | **1,170** | **0.20** |
| 45000-52499 | **48,152** | **1,250** | **0.21** |
| 52500-59999 | **57,000** | **1,730** | **0.30** |
| 60000-67499 | **64,367** | **1,182** | **0.20** |
| 67500-75000 | **70,570** | **2,049** | **0.35** |

[216] See referenced document "compressor efficiency analysis EVT Refrigeration 2013.xlsx" for development details.

| High Temperature<br>Single-Phase compressor<br>Assumed Average Capacity and Savings<br>Condensing temp 90°F, Evap Temp 45°F | | | |
|---|---|---|---|
| **Capacity Bins BTU/Hr** | **Avg Cap BTU/hr** | **Annual KWh Savings** | **kW reduction** |
| 0-12000 | N/A | N/A | N/A |
| 12000-24999 | **18,064** | **723** | **0.18** |
| 25000-49999 | **36,808** | **892** | **0.23** |
| 50000-74999 | **54,250** | **458** | **0.12** |
| | | | |

| High Temperature<br>Three-Phase compressor<br>Assumed Average Capacity and Savings<br>Condensing temp 90°F, Evap Temp 45°F | | | |
|---|---|---|---|
| **Capacity Bins BTU/Hr** | **Avg Cap BTU/hr** | **Annual KWh Savings** | **kW reduction** |
| 0-24999 | N/A | N/A | N/A |
| 25000-49999 | **36,805** | **882** | **0.15** |
| 50000-74999 | **62,553** | **2,076** | **0.36** |
| 75000-99999 | **86,864** | **2,249** | **0.39** |
| 100000-124999 | **108,909** | **2,127** | **0.37** |

**Table 3: Standard and Non-Standard Rating Conditions**

| Application | Setpoint Temperature | Evaporator Temperature | Standard Conditions Condensing Temperature | Non-Standard Conditions Condensing Temperature |
|---|---|---|---|---|
| Low | < 25° | -25°F | 105°F | 90°F |
| Medium | 24° to 40° | 20°F | 120°F | 90°F |
| High | 41° to 65° | 45°F | 130°F | 90°F |

**Table 4: Compressor Incremental Costs**[217]

**Low Temperature Application - Incremental Costs by Compressor Type**

| Capacity (Btu/h) | Semi-Hermetic | Scroll | Discus |
|---|---|---|---|
| 4200-8399 | $530 | $530 | - |
| 8400-12599 | $615 | $615 | $1,405 |
| 12600-16799 | -$273 | -$273 | $552 |
| 16800-20999 | -$652 | -$652 | $342 |
| 21000-25199 | -$120 | -$120 | -$150 |
| 25200-29399 | $294 | $294 | -$109 |
| 29400-33599 | $708 | $708 | $542 |
| 33600-37799 | $749 | $749 | $960 |

**Medium Temperature Application - Incremental Costs by Compressor Type**

| Capacity (Btu/h) | Semi-Hermetic | Scroll | Discus |
|---|---|---|---|
| 7500-14999 | $624 | $624 | - |
| 15000-22499 | $618 | $618 | - |
| 22500-29999 | $597 | $597 | - |
| 30000-37499 | $580 | $580 | $1,434 |
| 37500-44999 | -$653 | -$653 | $205 |
| 45000-52499 | -$771 | -$771 | $393 |
| 52500-59999 | -$892 | -$892 | $177 |
| 60000-67499 | -$354 | -$354 | $107 |
| 67500-75000 | $185 | $185 | -$10 |

**High Temperature Application - Incremental Costs by Compressor Type**

| Capacity (Btu/h) | Semi-Hermetic | Scroll | Discus |
|---|---|---|---|
| 12000-23999 | $563 | $563 | - |
| 24000-35999 | - | $538 | - |

[217] See referenced document "Refrigeration Compressor Pricing Analysis v1.0.xlsx" for details.

# Brushless DC Motors (also known as ECM) for Merchandising Case Coolers and Freezers

Measure Number: I-E-13-a (Business Energy Services, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 37
Effective date: 01/01/06
End date: TBD

Referenced Documents:

**Description**
Cooler and Freezer Case evaporator fans typically contain three to twelve evaporator fans that run nearly 24 hours each day, 365 days each year. Not only do these fans use electricity, but the heat that each fan generates must also be removed by the refrigeration system to keep the product cold, adding more to the annual electricity costs. If the cooler or freezer has single-phase power, the electricity usage can be reduced by choosing brushless DC motors instead of conventional, shaded-pole motors. Brushless DC motors are also sometimes known by the copyrighted trade name ECM (electronically commutated motor).

**Algorithms**

**Demand Savings**
$\Delta kW = (kW_{SP} - kW_{BDC}) \times DC_{Evap} \times BF$

**Energy Savings**
$\Delta kWh = \Delta kW \times 8760$

Where:

| | |
|---|---|
| $\Delta kW$ | = gross customer connected load kW savings for the measure (kW) |
| $kW_{SP}$ | = Connected load kW of a shaded pole evaporator fan (Average 0.0413 kW) [218] |
| $kW_{BDC}$ | = Connected load kW of a brushless DC evaporator fan (0.0113kW)[219] |
| $DC_{Evap}$ | = Duty cycle of the evaporator fan (100% for cooler, 94% for freezer)[220] |
| BF | = Bonus factor for reduced cooling load from replacing a shaded-pole evaporator fan with a lower wattage brushless DC fan (1.5 for low temp, 1.3 for medium temp, and 1.2 for high temp)[221] |
| $\Delta kWh$ | = gross customer annual kWh savings for the measure (kWh) |
| 8760 | = (hours/year) |

**Baseline Efficiencies – New or Replacement**
The baseline condition is shaded pole evaporator fan motor.

**High Efficiency**
High efficiency is a brushless DC evaporator fan motor.

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[218] Based on Technical Data Sheets from Tyler Refrigeration (48W), Hussmann Refrigeration (46W), and Hill-Phoenix Refrigeration (30W)
[219] Based on Technical Data Sheets from Tyler Refrigeration (11W), Hussmann Refrigeration (9W), and Hill-Phoenix Refrigeration (14W)
[220] A evaporator fan in a cooler runs all the time, but a freezer only runs 8273 hours per year due to defrost cycles (4 20-min defrost cycles per day)
[221] Bonus factor (1+ 1/COP) assumes 2.0 COP for low temp, 3.5 COP for medium temp, and 5.4 COP for high temp, based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of -20°F, 20°F, and 45°F, respectively, and a condensing temperature of 90°F.

**Operating Hours**
A cooler evaporator fan runs all the time or 8760 hours per year. A freezer evaporator fan runs 8273 hours per year due to defrost cycles (4  20-min defrost cycles per day). The smaller number of hours for freezer fan run time is captured in the duty cycle factor in the ΔkW calculation, so that 100% coincidence factors may be applied to both applications.

**Loadshape**
Flat (8760 hours) #25

**Freeridership / Spillover Factors**

| Measure Category | | Refrigeration End-Use | |
|---|---|---|---|
| Measure Code | | RFRBLFAN | |
| Product Description | | Efficient Blower Fans | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | 0.95 | 1.00 |
| Cust Equip Rpl | 6013CUST | 0.94 | 1.00 |
| Farm NC | 6014FARM | 1.00 | 1.00 |
| Farm Equip Rpl | 6013FARM | 1.00 | 1.00 |
| Non Act 250 NC | 6014NANC | 1.00 | 1.00 |
| Pres Equip Rpl | 6013PRES | 0.95 | 1.00 |
| C&I Retro | 6012CNIR | 0.94 | 1.00 |
| MF Mkt Retro | 6012MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
5 years

**Measure Cost**
The incremental cost of a brushless DC fan motor compared to a shaded-pole fan motor is $25.[222] Retrofit cost for a brushless DC fan motor is $120 ($60 for the motor, $60 for installation labor including travel time).

**Incentive Level**
$20 , which is 80% of the incremental cost at the time of replacement and 17% of the full installed retrofit cost..

**O&M Cost Adjustments**
None

[222] Based on actual costs from Hussmann Refrigeration.

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**
None

# Evaporator Coil Defrost Control

Measure Number: I-E-15-a (Business Energy Services, Refrigeration End Use)
**Version Date & Revision History**
Draft date: Portfolio 49
Effective date: 01/01/08
End date: TBD

Referenced Documents: *<InterLinkSDK_ETLRept_0607.pdf>, <MasterControllerMap.pdf>, <Bohn Evap 306-0D.pdf>, <LC-03A.pdf>*

**Description**
This measure applies to electric defrost control on small commercial walk-in 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 operations and requirements of the system. When the system calls for a defrost cycle, the control determines if it is necessary and skips the cycle if it is not.

**Algorithms**

**Demand Savings**
$\Delta kW$ = # fans * $kW_{DE}$ * SVG * BF

**Energy Savings**
$\Delta kWh$ = $\Delta kW$ * FLH

Where:

| | |
|---|---|
| $\Delta kW$ | = gross customer connected load kW savings for the measure (kW) |
| $\Delta kWh$ | = gross customer annual kWh savings for the measure (kWh) |
| # Fans | = number of evaporator fans |
| $kW_{DE}$ | = kW of defrost element per evaporator fan (0.9kW) [223] |
| SVG | = % of defrost cycles saved by control (average of 30%)[224] |
| BF | = Bonus factor for reduced cooling load from eliminating heat generated by the defrost element from entering the cooler or freezer (1.5 for low temp)[225] |
| FLH | = Average Full load defrost hours (487 hours). |

**Baseline Efficiencies – New or Replacement**
The baseline is a small commercial walk-in freezer refrigeration system without evaporator coil defrost control.

**High Efficiency**
High efficiency is a small commercial walk-in freezer refrigeration system with evaporator coil defrost control.

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[223] 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. See Bohn <Bohn Evap 306-0D.pdf> and Larkin <LC-03A.pdf> specifications.
[224] Smart Defrost Kits claim 30-40% savings (with 43.6% savings verified by third party testing by Intertek Testing Services. *InterLinkSDK_ETLRept_0607.pdf*. )
MasterBilt Demand Defrost claims 21% savings for the northeast. *MasterControllerMap.pdf*.
Smart Defrost Kits are more common so the assumption of 30% is a conservative estimate.
[225] Bonus factor assumes 2.0 COP for low temp, based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of -20°F, and a condensing temperature of 90°F, and 100% of heat generated by defrost element enters the refrigerated case (1+ 1 / 2.0).

**Operating Hours**
The refrigeration system is assumed to be in operation everyday of the year, while savings from the evaporator coil defrost control will only occur during set defrost cycles. This is assumed to be four, 20 minute cycles per day, or 487 hours.

**Loadshape**
Loadshape #14, Commercial Refrigeration

**Freeridership/Spillover Factors**

| Measure Category | | Refrigeration End-Use | |
|---|---|---|---|
| Measure Code | | RFRFROST | |
| Product Description | | Evaporator Coil Defrost Control | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | 0.95 | 1.00 |
| Cust Equip Rpl | 6013CUST | 0.94 | 1.00 |
| Farm NC | 6014FARM | 1.00 | 1.00 |
| Farm Prescriptive | 6013FRMP | 1.00 | 1.00 |
| Farm Equip Rpl | 6013FARM | 1.00 | 1.00 |
| Non Act 250 NC | 6014NANC | 1.00 | 1.00 |
| Pres Equip Rpl | 6013PRES | 0.95 | 1.00 |
| C&I Retro | 6012CNIR | 0.94 | 1.00 |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| Customer Credit | 6015 CC | n/a | n/a |
| EDirect | 6021 DIRI | 0.98 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
10 years[226].

**Measure Cost**
$500[227]

**Incentive Level**
$150

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[226] This is a conservative estimate based on discussion with Heatcraft. They estimate the measure life based on the components expected life. The only moving part is a relay which has a cycle life that is well over 15 years based on the frequency of the relay operation.
[227] Based on Smart Defrost Kit cost of $400 to $600 per system. *http://www.interlinkparts.com/smartdefrostkit/faqs.asp*. The MasterBilt Master Controller and Beacon II systems are more complex control and data logging systems that do more than just defrost, and are therefore more costly. This measure and so the measure cost is only for the defrost control portion of the systems.

**O&M Cost Adjustments**
None

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

# Plate Coolers for Dairy Farms

Measure Number: I-E-16-b (Business Energy Services, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 84
Effective date: 1/1/2014
End date: TBD

Referenced Documents: AG Plate Cooler Analysis_2013.xls

**Description**
A system used in dairy applications that cools milk prior to final cooling with a refrigeration system. A plate type heat exchanger is used to transfer heat from the milk stream to a stream of ambient temperature water. Electric savings are gained by reducing the downstream cooling load of the associated refrigerant based system. Generally, there is no opportunity to reclaim heat from the water used in the heat exchange process and it is therefore assumed that this energy is lost. However, Efficiency Vermont encourages farmers to use the plate cooler's warm water to feed cows. Cows prefer to drink warm water and the more water they drink the more milk output they provide. On larger dairy farms, plate coolers are generally used in conjunction with a variable speed milk transfer (VSMT) pump to manage flow rate of the milk to ensure optimal heat exchange and reduce refrigeration use even further. A VSMT is a separate TRM measure. Costs of plate coolers vary greatly based on cooler plate size therefore the rebate is a tiered rebate, with tiers based on the number of cows as proxy for the volume of milk requiring cooling:

- Tier 1: 75[228]-139 cows
- Tier 2: 140+ cows

**Algorithms**

**Plate Cooler Savings[229]**

**Demand Savings**
ΔkW Tier 1 = 4.89 kW
ΔkW Tier 2 = 8.87 kW

**Energy Savings**
ΔkWh Tier 1 = 4,496 kWh
ΔkWh Tier 2 = 19,744 kWh

Where:

ΔkW = gross customer connected load kW savings for the measure
ΔkWh = gross customer average annual kWh savings for the measure

**Baseline Efficiencies – Retrofit or Replacement**
The baseline state is a milk cooling system where milk is not pre-cooled with a plate cooler, but goes directly into a refrigerated cooling system[230].

[228] Minimum number of cows for which the measure screened
[229] Savings estimates are the average savings claimed for EVT custom projects from 2003 through 2011, see AG Plate Cooler Analysis_2013.xls
[230] While a plate cooler unit would be baseline for a new construction project, farmers typically re-use old equipment when extensively renovating old facilities. New construction, due to construction of new facilities, is rare and EVT staff has only heard of one case (between 2006 and 2012) where a new construction project resulted in purchase of new equipment.

**High Efficiency**
The high efficiency case is installation and use of a plate cooler to pre-cool milk using ambient temperature water prior to refrigerated cooling.

**Operating Hours**
N/A.

**Loadshapes**
Loadshape #122, Farm Plate Cooler / Heat Recovery Unit

**Freeridership/Spillover Factors**

| **Measure Category** | | **Refrigeration** | |
|---|---|---|---|
| **Measure Code** | | RFRPLATE | |
| **Product Description** | | Dairy Farm Heat Recovery Unit | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** |
| Farm Equip Rpl | 6013FARM | 1.00 | 1.00 |
| Farm Rx | 6013FRMP | 1.00 | 1.00 |

**Persistence**
The persistence factor is assumed to be one.[231]

**Lifetime**
10 years.

**Measure Cost[232]**

| | Average cost |
|---|---|
| Tier 1 | $2,875 |
| Tier 2 | $6,530 |

**O&M Cost Adjustments**
There are no standard operation and maintenance cost adjustments used for this measure.

**Fossil Fuel Descriptions**
There are no fossil-fuel algorithms or default savings for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

## Compressed Air End Use

[231] This equipment has no moving parts or controls and therefore rarely experiences downtime prior to failure due to corrosion at the end of service life.
[232] Value derived from Efficiency Vermont custom data 2003-2011, AG Plate Cooler Analysis_2013.xls

# Efficient Compressors 40 hp and Below

Measure Number: I-F-3-a (Business Energy Services, Compressed Air End Use)

**Version Date & Revision History**
Draft date: Portfolio 53
Effective date: 1/1/08
End date: TBD

**Referenced Documents:** "Compressed Air Analysis.xls", "BHP Weighted Compressed Air Load Profiles v3.xls", "Compiled Data Request Results.xls"

**Description**
Baseline compressors choke off the inlet air to modulate the compressor output, which is not efficient (Modulating). Efficient compressors use a variable speed drive on the motor to match output to the load. Savings are calculated using representative baseline and efficient demand numbers for compressor capacities according to the facility's load shape, and the number of hours the compressor runs at that capacity. Demand curves are as per DOE data for a Variable Speed compressor versus a Modulating compressor. This measure applies only to an individual compressor ≤ 40 hp.

**Algorithms[233]**

**Energy Savings**
$\Delta kWh = 0.9 \text{ x } hp_{compressor} \text{ x HOURS x } (CF_b - CF_e)$

**Demand Savings**
$\Delta kW = \Delta kWh / HOURS$

Where:

| | |
|---|---|
| $\Delta kWh$ | = gross customer annual kWh savings for the measure |
| $hp_{compressor}$ | = compressor motor nominal hp |
| 0.9[234] | = compressor motor nominal hp to full load kW conversion factor |
| HOURS | = compressor total hours of operation (see Operating Hours section) |
| $CF_b$ | = baseline compressor factor (see "Compressor Factors by Control Type" in Reference Tables section) |
| $CF_e$ | = efficient compressor factor (see "Compressor Factors by Control Type" in Reference Tables section) |

**Baseline Efficiencies – Retrofit or Replacement**
The baseline equipment is a modulating compressor with blow down ≤ 40 hp.

**High Efficiency**
The high efficiency equipment is a compressor ≤ 40 hp with variable speed control.

**Operating Hours**
Single shift (8/5) – 1976 hours (7 AM – 3 PM, weekdays, minus some holidays and scheduled down time)
2-shift (16/5) – 3952 hours (7AM – 11 PM, weekdays, minus some holidays and scheduled down time)
3-shift (24/5) – 5928 hours (24 hours per day, weekdays, minus some holidays and scheduled down time)
4-shift (24/7) – 8320 hours (24 hours per day, 7 days a week minus some holidays and scheduled down time)

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233 See "Compressed Air Analysis.xls" for algorithm details.
234 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 on Long Island. See "BHP Weighted Compressed Air Load Profiles v2.xls".

**Loadshape[235]**
Loadshape #44: Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape #45: Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape #46: Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape #47: Indust. 4-shift (24/7) (e.g., comp. air, lights)

**Freeridership/Spillover Factors[236]**

| Measure Category | | Compressed Air | |
|---|---|---|---|
| Measure Code | | CMPCOMPR | |
| Product Description | | Air Compressor | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | 0.75 | 1.00 |
| Cust Equip Rpl | 6013CUST | 0.75 | 1.00 |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Prescriptive | 6013FRMP | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | 0.75 | 1.00 |
| Pres Equip Rpl | 6013PRES | 0.75 | 1.00 |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| Customer Credit | 6015 CC | n/a | n/a |
| EDirect | 6021 DIRI | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
10 years.
Analysis period is the same as the lifetime.

**Measure Cost**
Incremental Cost (\$) = (127 x $hp_{compressor}$) + 1446

Where:

127 and 1446[237] = compressor motor nominal hp to incremental cost conversion factor and offset

[235] Calculated demand impacts (kW) represent diversified kW demand savings over each typical hour that compressed air system is operating. Therefore, for shifts that totally encompass the peak capacity periods, the coincidence factor equals 100%. For shifts that only encompass a portion of the peak capacity period, the coincidence factor represents the portion of the peak capacity period included in the shift hours.
[236] Based on professional judgment and current market activity as reported by several compressed air equipment vendors. See “Compiled Data Request Results.xls” for details.

$hp_{compressor}$ = compressor motor nominal hp

**Incentive Level**
The incentive for this measure is half the calculated incremental cost.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil-fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

## Compressor Factors by Control Type[238]

| Control Type | Compressor Factor |
|---|---|
| Modulating w/ BD | 0.890 |
| Variable speed drive | 0.705 |

[237] Conversion factor and offset based on a linear regression analysis of the relationship between air compressor motor nominal horsepower and incremental cost. Several Vermont vendors were surveyed to determine the cost of equipment. See “Compressed Air Analysis.xls” and “Compiled Data Request Results.xls” for incremental cost details.
[238] 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. “See “BHP Weighted Compressed Air Load Profiles.xls” for source data and calculations (The “variable speed drive” compressor factor has been adjusted up from the 0.675 presented in the analysis to 0.705 to account for the additional power draw of the VSD).

# Cycling Dryers

Measure Number: I-F-4-a (Business Energy Services, Compressed Air End Use)

**Version Date & Revision History**
Draft date: Portfolio 53
Effective date: 1/1/08
End date: TBD

**Referenced Documents:** "Compressed Air Analysis.xls", "BHP Weighted Compressed Air Load Profiles v3.xls", "Compiled Data Request Results.xls", "Air Dryer Calc.xls"

**Description**
Use of a refrigerated dryer that cycles on and off as required by the demand for compressed air instead of running continuously. **This measure only applies to dryers with capacities of 600 cfm and below.** Larger dryers will be handled on a custom basis.

**Algorithms**[239]

**Energy Savings**
$\Delta kWh = [(4 \times hp_{compressor}) \times 0.0087 \times HOURS \times (1 - APC)] \times RTD$

**Demand Savings**
$\Delta kW = \Delta kWh / HOURS$

Where:

| | |
|---|---|
| $\Delta kWh$ | = gross customer annual kWh savings for the measure |
| $hp_{compressor}$ | = compressor motor nominal hp |
| 4[240] | = approximate compressor output CFM per compressor motor nominal hp |
| 0.0087[241] | = compressor CFM to baseline dryer kW conversion factor |
| HOURS | = compressor total hours of operation (see Operating Hours section) |
| APC[242] | = Average % Capacity; average operating capacity of compressor (65%) |
| RTD | = Chilled Coil Response Time Derate (0.925) (from "Air Dryer Calc.xls") |
| $\Delta kW$ | = gross customer kW savings for the measure |

**Baseline Efficiencies – Retrofit or Replacement**
The baseline equipment is a non-cycling refrigerated air dryer with a capacity of 600 cfm or below.

**High Efficiency**
The high efficiency equipment is a cycling refrigerated air dryer with a capacity of 600 cfm or below.

**Operating Hours**
Single shift (8/5) – 1976 hours (7 AM – 3 PM, weekdays, minus some holidays and scheduled down time)
2-shift (16/5) – 3952 hours (7AM – 11 PM, weekdays, minus some holidays and scheduled down time)
3-shift (24/5) – 5928 hours (24 hours per day, weekdays, minus some holidays and scheduled down time)
4-shift (24/7) – 8320 hours (24 hours per day, 7 days a week minus some holidays and scheduled down time)

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239 See "Compressed Air Analysis.xls" for algorithm details.
240 Manufacturer's data suggests that cfm output per compressor hp ranges from 4 to 5. As used in the algorithm, the lower estimate will slightly underestimate savings.
241 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. See "Compressed Air Analysis.xls" for source calculations.
242 Based on an analysis of load profiles from 50 facilities using air compressors 40 hp and below. See "BHP Weighted Compressed Air Load Profiles.xls" for source calculations.

**Loadshape**[243]
Loadshape #44: Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape #45: Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape #46: Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape #47: Indust. 4-shift (24/7) (e.g., comp. air, lights)

**Freeridership/Spillover Factors**[244]

| | | | |
|---|---|---|---|
| Measure Category | | Compressed Air | |
| Measure Code | | CMPDRYER | |
| Product Description | | Air Dryer | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | 0.50 | 1.00 |
| Cust Equip Rpl | 6013CUST | 0.50 | 1.00 |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Prescriptive | 6013FRMP | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | 0.50 | 1.00 |
| Pres Equip Rpl | 6013PRES | 0.50 | 1.00 |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| Customer Credit | 6015 CC | n/a | n/a |
| EDirect | 6021 DIRI | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
10 years.
Analysis period is the same as the lifetime.

**Measure Cost**[245]
The incremental cost for this measure is $750.

**Incentive Level**
The incentive for this measure is $375.

[243] Calculated demand impacts (kW) represent diversified kW demand savings over each typical hour that compressed air system is operating. Therefore, for shifts that totally encompass the peak capacity periods, the coincidence factor equals 100%. For shifts that only encompass a portion of the peak capacity period, the coincidence factor represents the portion of the peak capacity period included in the shift hours.
[244] Based on professional judgment and current market activity as reported by several compressed air equipment vendors. See “Compiled Data Request Results.xls” for details.
[245] See “Compressed Air Analysis.xls” and “Compiled Data Request Results.xls” for incremental cost details.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil-fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**
None.

# Air-Entraining Air Nozzles

Measure Number: I-F-5-a (Business Energy Services, Compressed Air End Use)

**Version Date & Revision History**
Draft date: Portfolio 53
Effective date: 1/1/08
End date: TBD

**Referenced Documents:** "Compressed Air Analysis.xls", "BHP Weighted Compressed Air Load Profiles v3.xls", "Compiled Data Request Results.xls"

**Description**
Air entraining air nozzles use compressed air to entrain and amplify atmospheric air into a stream, thus increasing pressure with minimal compressed air use. They are used as replacements for stationary air nozzles in a production application, or on handheld guns.

**Algorithms**[246]

**Energy Savings**
$\Delta kWh = (CFM_b - CFM_e) \times COMP \times HOURS \times \%USE$

**Demand Savings**
$\Delta kW = \Delta kWh / HOURS$

Where:

$\Delta kWh$ = gross customer annual kWh savings for the measure
$CFM_b$ = Baseline Nozzle CFM (26 CFM - assumes 1/8" diameter orifice)
$CFM_e$ = Efficient Nozzle CFM (14 CFM)
COMP = Compressor kW/CFM - the average amount of electrical demand in kW required to produce one cubic foot of air at 100 PSI (see Average Compressor kW/CFM Table in the Reference Tables section)
HOURS = compressor total operating hours (see Operating Hours section)
%USE = percent of the compressor total operating hours that the nozzle is in use (5% for 3 seconds of use per minute) [247]
$\Delta kW$ = gross customer kW savings for the measure

**Baseline Efficiencies – Retrofit or Replacement**
The baseline equipment is an open copper tube of 1/8" orifice diameter or an inefficient air gun using 26 cfm or more.

**High Efficiency**
The high efficiency equipment is an air nozzle capable of amplifying the air stream by a factor of 25 using 14 cfm or less.

**Operating Hours**
Single shift (8/5) – 1976 hours (7 AM – 3 PM, weekdays, minus some holidays and scheduled down time)
2-shift (16/5) – 3952 hours (7AM – 11 PM, weekdays, minus some holidays and scheduled down time)
3-shift (24/5) – 5928 hours (24 hours per day, weekdays, minus some holidays and scheduled down time)

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[246] See "Compressed Air Analysis.xls" for algorithm details.
[247] 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.

4-shift (24/7) – 8320 hours (24 hours per day, 7 days a week minus some holidays and scheduled down time)

**Loadshape**[248]
Loadshape #44: Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape #45: Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape #46: Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape #47: Indust. 4-shift (24/7) (e.g., comp. air, lights)

**Freeridership/Spillover Factors**[249]

| | | | |
|---|---|---|---|
| Measure Category | | Compressed Air | |
| Measure Code | | CMPNOZZL | |
| Product Description | | Air Nozzles | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | 0.90 | 1.00 |
| Cust Equip Rpl | 6013CUST | 0.90 | 1.00 |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Prescriptive | 6013FRMP | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | 0.90 | 1.00 |
| Pres Equip Rpl | 6013PRES | 0.90 | 1.00 |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| Customer Credit | 6015 CC | n/a | n/a |
| EDirect | 6021 DIRI | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
10 years.
Analysis period is the same as the lifetime.

**Measure Cost**[250]
$14 per air nozzle.

[248] Calculated demand impacts (kW) represent diversified kW demand savings over each typical hour that compressed air system is operating. Therefore, for shifts that totally encompass the peak capacity periods, the coincidence factor equals 100%. For shifts that only encompass a portion of the peak capacity period, the coincidence factor represents the portion of the peak capacity period included in the shift hours.
[249] Based on professional judgment and current market activity as reported by several compressed air equipment vendors. See “Compiled Data Request Results.xls” for details.
[250] See “Compressed Air Analysis.xls” for incremental cost details.

**Incentive Level**
$7 per air nozzle.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil-fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

## Average Compressor kW/CFM[251]

| Compressor Control Type | Average Compressor kW/CFM |
|---|---|
| Modulating w/ BD | 0.32 |
| Load/No Load w/ 1 gal/CFM | 0.32 |
| Load/No Load w/ 3 gal/CFM | 0.30 |
| Load/No Load w/ 5 gal/CFM | 0.28 |
| Variable Speed w/ Unloading | 0.23 |

[251] 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. See "Compressed Air Analysis.xls" for source calculations and "BHP Weighted Compressed Air Load Profiles.xls" for source data.

# No Loss Condensate Drains

Measure Number: I-F-7-a (Business Energy Services, Compressed Air End Use)

**Version Date & Revision History**
Draft date: Portfolio 53
Effective date: 1/1/08
End date: TBD

**Referenced Documents:** "Compressed Air Analysis.xls", "BHP Weighted Compressed Air Load Profiles v3.xls", "Compiled Data Request Results.xls"

**Description**
When air is compressed, water in the form of condensation is squeezed out of the compressed air and collects in piping and storage tanks. The water must be drained so as not to interfere with the flow of compressed air and so it will not corrode the piping or tank. Many drains are controlled by a timer and open an orifice for a programmed set amount of time, regardless of the level of the condensate. Thus compressed air is allowed to escape after the condensate has drained. Timed drains typically continue to operate even when the compressor is down, effectively bleeding off useful stored air that must be remade when the compressor is restarted. No Loss Condensate drains are controlled by a sensor and only open when there is a need to drain condensate, and close before compressed air can escape.

**Algorithms**[252]

**Energy Savings**
ΔkWh = ALR x COMP x OPEN x AF x PNC

**Demand Savings**
ΔkW = ΔkWh / HOURS

Where:

| | |
|---|---|
| ΔkWh | = gross customer annual kWh savings for the measure |
| ALR | = Air Loss Rate - an hourly average rate for the timed drain dependent on Drain Orifice Diameter and Pressure, expressed in CFM (see Average Air Loss Rates in the Reference Tables section) . The default value, where the actual baseline system is unknown, shall be 100.9 CFM.[253] |
| COMP | = Compressor kW/CFM - the average amount of electrical demand in kW required to produce one cubic foot of air at 100 PSI (see Average Compressor kW/CFM Table in the Reference Tables section) |
| OPEN[254] | = hours per year the timed drain is open (146 – assuming 10 second drain operation every 10 minutes) |
| AF | = Adjustment factor to account for the fact that the system may run out of compressed air due to leakage and timed drains when the compressor is down. Savings are only claimed for the average of the compressor hours and the total hours per year (see Adjustment Factors (AF) by Compressor Operating Hours). |
| PNC | = % Not Condensate - percentage of time that compressed air escapes instead of condensate (75% - conservative assumption based on professional judgment) |
| HOURS | = compressor total operating hours (see Operating Hours section) |

[252] See "Compressed Air Analysis.xls" for algorithm details.
[253] 100.9 CFM based on an orifice size of ¼" and a typical system pressure of 100 psi. Orifice sizes for timed drains found in EVT's research range from 5/32" to 9/16", with the most common size being 7/16"; ¼" is considered a reasonably conservative estimate of average size. 100 psi is a conservative estimate of average system pressure; most systems are run at higher pressure than 100 psi.
[254] Based on EVT experience, 10 seconds of drain operation every 10 minutes is a conservative estimate. Many facilities simply use the default timed drain setting or adjust the drain to the highest allowable frequency and duration. Both practices are excessive for most operations.

$\Delta kW$ = gross customer kW savings for the measure

**Baseline Efficiencies – Retrofit or Replacement**
The baseline equipment is a timed drain that operates according to a preset schedule regardless of the presence of condensate.

**High Efficiency**
The high efficiency equipment is a no loss condensate drain controlled by a sensor and only opens when there is a need to drain condensate and closes before any compressed air is vented.

**Operating Hours**
Single shift (8/5) – 1976 hours (7 AM – 3 PM, weekdays, minus some holidays and scheduled down time)
2-shift (16/5) – 3952 hours (7AM – 11 PM, weekdays, minus some holidays and scheduled down time)
3-shift (24/5) – 5928 hours (24 hours per day, weekdays, minus some holidays and scheduled down time)
4-shift (24/7) – 8320 hours (24 hours per day, 7 days a week minus some holidays and scheduled down time)

**Loadshape[255]**
Loadshape #44: Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape #45: Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape #46: Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape #47: Indust. 4-shift (24/7) (e.g., comp. air, lights)

[255] Calculated demand impacts (kW) represent diversified kW demand savings over each typical hour that compressed air system is operating. Therefore, for shifts that totally encompass the peak capacity periods, the coincidence factor equals 100%. For shifts that only encompass a portion of the peak capacity period, the coincidence factor represents the portion of the peak capacity period included in the shift hours.

**Freeridership/Spillover Factors**[256]

| Measure Category | | Compressed Air | |
|---|---|---|---|
| Measure Code | | CMPDRAIN | |
| Product Description | | No Loss Condensate Drain | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | 0.95 | 1.00 |
| Cust Equip Rpl | 6013CUST | 0.95 | 1.00 |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Prescriptive | 6013FRMP | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | 0.95 | 1.00 |
| Pres Equip Rpl | 6013PRES | 0.95 | 1.00 |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| Customer Credit | 6015 CC | n/a | n/a |
| EDirect | 6021 DIRI | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
5 years.
Analysis period is the same as the lifetime.

**Measure Cost**[257]
Assume an incremental cost of $200.

**Incentive Level**
The incentive for this measure is $100 per unit.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil-fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

[256] Based on professional judgment and current market activity as reported by several compressed air equipment vendors. See "Compiled Data Request Results.xls" for details.
[257] See "Compressed Air Analysis.xls" and "Compiled Data Request Results.xls" for incremental cost details.

**Reference Tables**

## Average Air Loss Rates (CFM)

| 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 | 23.10 | 92.0 | 206.6 |
| **95** | 0.38 | 1.51 | 6.02 | 24.16 | 96.5 | 216.8 |
| **100** | 0.40 | 1.55 | 6.31 | 25.22 | 100.9 | 227.0 |
| **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 |

Source: US DOE Compressed Air Tip Sheet #3, August 2004, from Fundamentals for Compressed Air Systems Training offered by the Compressed Air Challenge

## Average Compressor kW/CFM[258]

| Compressor Control Type | Average Compressor kW/CFM |
|---|---|
| Modulating w/ BD | 0.32 |
| Load/No Load w/ 1 gal/CFM | 0.32 |
| Load/No Load w/ 3 gal/CFM | 0.30 |
| Load/No Load w/ 5 gal/CFM | 0.28 |
| Variable Speed w/ Unloading | 0.23 |

## Adjustment Factors (AF) by Compressor Operating Hours

| Compressor Operating Hours | AF |
|---|---|
| Single Shift – 2080 Hours | 0.62 |
| 2-Shift – 4160 Hours | 0.74 |
| 3-Shift – 6240 Hours | 0.86 |
| 4-Shift – 8320 Hours | 0.97 |

[258] 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. See “Compressed Air Analysis.xls” for source calculations and “BHP Weighted Compressed Air Load Profiles.xls” for source data.

# Air Receivers for Load/No Load Compressors

Measure Number: I-F-8-a (Business Energy Services, Compressed Air End Use)

**Version Date & Revision History**
Draft date: Portfolio 53
Effective date: 1/1/08
End date: TBD

**Referenced Documents:** "Compressed Air Analysis.xls", "BHP Weighted Compressed Air Load Profiles v3.xls", "Compiled Data Request Results.xls"

**Description**
Using an air receiver (a storage tank) will buffer the air demands of the system on the compressor, thus eliminating short cycling. Although a load/no load compressor unloads in response to lowered demand, it does so over a period of time to prevent lubrication oil from foaming. Therefore, reducing the number of cycles reduces the number of transition times from load to no load and saves energy. Savings are calculated using representative baseline and efficient demand numbers for compressor capacities according to the facility's load shape, and the number of hours the compressor runs at that capacity. Demand curves are as per DOE data for load/no load compressors and various gallon per CFM storage ratios.

**Algorithms**[259]

**Energy Savings**
$\Delta kWh = 0.9 \text{ x } hp_{compressor} \text{ x HOURS x } (CF_b - CF_e)$

**Demand Savings**
$\Delta kW = \Delta kWh$ / HOURS

Where:

| | |
|---|---|
| $\Delta kWh$ | = gross customer annual kWh savings for the measure |
| $hp_{compressor}$ | = compressor motor nominal hp |
| 0.9[260] | = compressor motor nominal hp to full load kW conversion factor |
| HOURS | = compressor total hours of operation (see Operating Hours section) |
| $CF_b$ | = baseline compressor factor (see "Compressor Factors by Control Type" in Reference Tables section). The default value shall be 0.890, based on a Modulating Compressor with Blow Down. |
| $CF_e$ | = efficient compressor factor (see "Compressor Factors by Control Type" in Reference Tables section). The default value shall be 0.812, based on a Load/No Load Compressor with 4 gallons of storgage per cfm. |

**Baseline Efficiencies – Retrofit or Replacement**
The baseline equipment is a load/no load compressor with a 1 gal/cfm storage ratio or a modulating w/ BD compressor.

**High Efficiency**
The high efficiency equipment is a load/no load compressor with a 4 gal/cfm storage ratio or greater.

**Operating Hours**
Single shift (8/5) – 1976 hours (7 AM – 3 PM, weekdays, minus some holidays and scheduled down time)
2-shift (16/5) – 3952 hours (7AM – 11 PM, weekdays, minus some holidays and scheduled down time)

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[259] See "Compressed Air Analysis.xls" for algorithm details.
[260] 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 on Long Island. See "BHP Weighted Compressed Air Load Profiles v2.xls".

3-shift (24/5) – 5928 hours (24 hours per day, weekdays, minus some holidays and scheduled down time)
4-shift (24/7) – 8320 hours (24 hours per day, 7 days a week minus some holidays and scheduled down time)

**Loadshape[261]**
Loadshape #44: Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape #45: Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape #46: Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape #47: Indust. 4-shift (24/7) (e.g., comp. air, lights)

**Freeridership/Spillover Factors[262]**

| Measure Category | | Compressed Air | |
|---|---|---|---|
| Measure Code | | CMPRECVR | |
| Product Description | | Air Receiver | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | 0.90 | 1.00 |
| Cust Equip Rpl | 6013CUST | 0.90 | 1.00 |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Prescriptive | 6013FRMP | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | 0.90 | 1.00 |
| Pres Equip Rpl | 6013PRES | 0.90 | 1.00 |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| Customer Credit | 6015 CC | n/a | n/a |
| EDirect | 6021 DIRI | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
10 years.
Analysis period is the same as the lifetime.

**Measure Cost**
Incremental Cost ($) = 5 x ($TANK_e$ – $TANK_b$)

Where:

[261] Calculated demand impacts (kW) represent diversified kW demand savings over each typical hour that compressed air system is operating. Therefore, for shifts that totally encompass the peak capacity periods, the coincidence factor equals 100%. For shifts that only encompass a portion of the peak capacity period, the coincidence factor represents the portion of the peak capacity period included in the shift hours.
[262] Based on professional judgment and current market activity as reported by several compressed air equipment vendors. See "Compiled Data Request Results.xls" for details.

$5^{263}$ = air receiver tank size (gals) to equipment cost conversion factor
$TANK_e$ = efficient tank size (gal)
$TANK_b$ = existing tank size (gal)

**Incentive Level**
The incentive for this measure is half the calculated incremental cost.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil-fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

## Compressor Factors by Control Type[264]

| Control Type | Compressor Factor |
|---|---|
| Modulating w/ Blow Down | 0.890 |
| Load/No Load with 1 gal/CFM storage | 0.909 |
| Load/No Load with 3 gal/CFM storage | 0.831 |
| Load/No Load with 4 gal/CFM storage | 0.812 |
| Load/No Load with 5 gal/CFM storage | 0.806 |

[263] Conversion factor based on a linear regression analysis of the relationship between air receiver storage capacity and incremental cost. See "Compressed Air Analysis.xls" for source calculations and costs.
[264] 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. "See "BHP Weighted Compressed Air Load Profiles v3.xls" for source data and calculations.

## Multiple End Uses

# New Construction Core Performance Package

Measure Number: I-N-1-a (Business Energy Services, Multiple End Uses)

**Version Date & Revision History:**
Draft date: Portfolio 53
Effective date: 1/1/07
End date: TBD

**Referenced Documents:** "Measure Level Model Outputs – All Buildings", "Package Level Model Outputs – All Buildings.xls", "Weighted Lifetime and Commissioning Factor.xls", "Enhanced Measures & Load Shapes v.2.xls", "Core Performance Summary Table.xls", "VT Core Performance Cost Estimates 11.14.07.xls", "Core Performance Overview Memo 02.25.08.doc", 2005 Vermont Guidelines for Energy Efficient Commercial Construction, *Core Performance Guide – Vermont Edition*

**Description**
Applies to new office, retail, or school buildings ≥ 10,000 sf and ≤ 70,000 sf that meet or exceed the performance requirements as defined in Section 2 of the *Core Performance Guide – Vermont Edition.* Specific measures include high-efficiency heating and cooling equipment, improved envelope and fenestration, lighting controls and improved lighting power density, demand control ventilation, and dual enthalpy economizers.

**Energy Savings**
$\Delta kWh = kWh_{SF} \times SF \times OTF$

**Demand Savings**
$\Delta kW = \Delta kWh / RATIO_{kWh\text{-}kW}$

Where:

| | |
|---|---|
| $\Delta kWh$ | =gross customer annual kWh savings for the measure |
| $kWh_{SF}$ | =annual customer kWh savings per square foot building area (see "Vermont Core Performance - kWh Savings per $ft^2$" in the Reference Tables section below) |
| SF | =building area in square feet |
| OTF | =operational testing factor. OTF = 1.0 if Section 1 of the *Core Performance Guide – Vermont Edition* is completed, 0.95 otherwise. |
| $\Delta kW$ | =gross customer connected load kW savings for the measure |
| $RATIO_{kWh\text{-}kW}$ | =kWh/kW ratio (see "Vermont Core Performance – kWh/kW Ratios" in the Reference Table section) |

**Baseline Efficiencies**
Building that meets Commercial Building Energy Standards (CBES) for Vermont (see 2005 Vermont Guidelines for Energy Efficient Commercial Construction).

**High Efficiency**
Building that meets or exceeds the performance requirements as defined in the *Core Performance Guide – Vermont Edition.*

**Operating Hours**
Not applicable.

**Loadshapes**[265]

| EndUse | # | Winter-on kWh | Winter-off kWh | Summer-on kWh | Summer-off kWh | Winter kW | Summer kW |
|---|---|---|---|---|---|---|---|
| Core Performance – Office w/ Pkg VAV and Chiller | 78 | 32.2% | 21.3% | 30.7% | 15.8% | 13.2% | 56.1% |
| Core Performance – Office w/ Pkg RTU and HW baseboard | 79 | 41.8% | 14.6% | 31.0% | 12.7% | 18.7% | 63.5% |
| Core Performance – Office w/ Pkg RTU and Furnace | 80 | 38.0% | 15.2% | 32.4% | 14.4% | 14.6% | 57.5% |
| Core Performance – Office w/ Water Source HP | 81 | 34.5% | 21.7% | 27.9% | 15.9% | 22.3% | 74.0% |
| Core Performance – School w/ Unit Vent. and Pkg units | 82 | 73.9% | 8.2% | 14.7% | 3.2% | 27.7% | 8.8% |
| Core Performance – Retail w/ Pkg RTU and Furnace | 83 | 35.7% | 17.7% | 31.1% | 15.5% | 16.0% | 39.5% |

[265] See “Enhanced Measures & Load Shapes v.2.xls” for more details.

**Freeridership/Spillover Factors**

| Measure Category | | Design Incentives | |
|---|---|---|---|
| Measure Codes | | DSNCOREP | |
| Product Description | | Core Performance Building | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | $1 \times 0.95 = 0.95$ [266] | 1.25 [267] |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | 1.0 | 1.25 |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6012MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| Customer Credit | 6015 CC | n/a | n/a |
| EDirect | 6021 DIRI | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
13.8 years (represents a savings-based weighted average lifetime of all measures within the core package. See "Weighted Lifetime and Commissioning Factor.xls" for details).
Analysis period is the same as the lifetime.

**Measure Cost**
$2.15 per square foot for non-heat pump mechanical systems; $1.95 per square foot for heat pump mechanical systems (see "Core Performance Summary Table.xls" and "VT Core Performance Cost Estimates 11.14.07.xls" for more details).

**Incentive Level**
$0.50 per $ft^2$ building area.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
$\Delta MMBtu = MMBtu_{SF} \times SF$

[266] Freeridership of 0% per agreement between DPS and EVT. All Act 250 measures will also have a 5% Adjustment Factor applied, which will be implemented through the Freeridership factor.

[267] Spillover of 25% for the year 2008 per agreement between DPS and EVT (TAG agreement 9/29/2006).

Where:

$\Delta MMBtu$ = gross customer annual MMBtu fossil fuel savings for the measure
$MMBtu_{SF}$ = annual customer MMBtu savings per square foot building area (see "Vermont Core Performance - MMBtu Savings per ft$^2$" in the Reference Tables section below)
SF = building area in square feet

**Water Descriptions**

There are no water algorithms or default values for this measure.

**Reference Tables**

| Vermont Core Performance - kWh Savings per ft$^2$ [268] | | |
|---|---|---|
| Building Type | Mechanical System | Energy Savings (kWh/ ft$^2$) |
| Office | Non-Heat Pump | 1.5 |
| | Heat Pump | 2.1 |
| School | | 0.6 |
| Retail | | 2.1 |

| Vermont Core Performance – kWh/kW Ratios [269] | | |
|---|---|---|
| Building Type | Mechanical System | kWh/kW Ratio |
| Office | Non-Heat Pump | 1950 |
| | Heat Pump | 2670 |
| School | | 2210 |
| Retail | | 1040 |

| Vermont Core Performance - MMBtu Savings per ft$^2$ [270] | | |
|---|---|---|
| Building Type | Mechanical System | Fossil Fuel Savings (MMBtu/ ft$^2$) |
| Office | Non-Heat Pump | 0.003 |
| | Heat Pump | 0.004 |
| School | | 0.009 |
| Retail | | 0.024 |

[268] See reference files "Core Performance Summary Table.xls" and "Package Level Model Outputs - All Buildings.xls" for details.
[269] See reference files "Core Performance Summary Table.xls" and "Enhanced Measures & Load Shapes v.2.xls" for details.
[270] See reference files "Core Performance Summary Table.xls" and "Package Level Model Outputs - All Buildings.xls" for details.

**Hot Water End Use**

# Heat Recovery Units for Dairy Farms

Measure Number: I-K-2-a (Business Energy Services, Hot Water End Use)

**Version Date & Revision History**

Draft date: Portfolio 77
Effective date: 1/1/2012
End date: TBD

Referenced Documents: AG HRU Analysis.xls

**Description**

A system used in dairy applications that uses waste heat from the compressor of a refrigerated milk cooling system to pre-heat water for either an electric or fossil fuel water heating system.

**Algorithms**

**Heat Recover Unit (Electric Savings)**[271]

**Demand Savings**

$\Delta$kW = 4.475 kW

**Energy Savings**

$\Delta$kWh = 6,378 kWh

**Heat Recover Unit (Fossil Fuel Savings)**[272]

**Energy Savings**

$\Delta$MMBTU= 52.46 MMBTU

Where:

| | |
|---|---|
| $\Delta$kW | = gross customer connected load kW savings for the measure |
| $\Delta$kWh | = gross customer average annual kWh savings for the measure |
| $\Delta$MMBTU | = gross customer average annual MMBTU savings for the measure |

**Baseline Efficiencies – Retrofit or Replacement**

The baseline reflects no heat recovery from the refrigerator compressor[273].

**High Efficiency**

The high efficiency case is installation and use of a heat recovery unit on the refrigerator compressor.

**Operating Hours**

N/A.

**Loadshapes**

Loadshape #122, Farm Plate Cooler / Heat Recovery Unit

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[271] Savings estimates are the average savings claimed for EVT custom projects from 2003 through 2012, see AG HRU Analysis.xls

[272] Savings estimates are the average savings claimed for EVT custom projects from 2003 through 2011, see AG HRU Analysis.xls

[273] While a heat recovery unit would be baseline for a new construction project, farmers typically re-use old equipment when extensively renovating old facilities. New construction, due to construction of new facilities, is rare and EVT staff has only heard of one case (between 2006 and 2012) where a new construction project resulted in purchase of new equipment.

**Freeridership/Spillover Factors**

| Measure Category | | Hot Water Efficiency | |
|---|---|---|---|
| **Measure Code** | | HWEHRCMP | |
| **Product Description** | | Hot Water Heat Recovery, Compressor | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | 1.00 | 1.00 |
| Farm Rx | 6013FRMP | 1.00 | 1.00 |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.[274]

**Lifetime**
10 years.

**Measure Cost[275]**
Heat Recovery Unit (Electric or Fossil Fuel Savings): $3,523

**O&M Cost Adjustments**
There are no standard operation and maintenance cost adjustments used for this measure.

**Fossil Fuel Descriptions**
There are no fossil-fuel algorithms or default savings when electric savings is claimed for this measure.

[274] This equipment has no moving parts or controls and therefore rarely experiences downtime prior to failure due to corrosion at the end of service life.
[275] Value derived from Efficiency Vermont custom data 2003-2012, see AG HRU Analysis.xls

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**
None

## Space Heating End Use
# Envelope

Measure Number: I-M-1-c (Business Energy Services)

**Version Date & Revision History**
Draft date: Portfolio 79
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**
1. 2005 Vermont Guidelines for Energy Efficient Commercial Construction, Table 802.2(1) and 802.2(2);
2. 2011 Vermont Commercial Building Energy Standards, tables 502.1(1) through 502.3

**Description**
Building envelope components with R-values exceeding the Vermont Guidelines for Energy Efficient Commercial Construction.

**Algorithms**

The savings for windows and glass door assemblies, roof assemblies, above-grade wall assemblies, skylights, and floors over outdoor air or unconditioned space should be calculated using effective whole-assembly R-values and the following algorithms:

**Energy Savings**
$\Delta MMBTU = HDD \times 24 \times A \times [(1/R_{base} - 1/R_{effic})] / \eta / 10^6$

Where:

$\Delta$MMBTU = gross customer annual MMBTU fuel savings for the measure
HDD = heating degree days determined on a site-specific and application-specific basis (4400 typical HDD for high development areas in Vermont, using 50 degree F base temperature)
24 = hours/day
A = area of increased insulation
$R_{base}$ = baseline effective whole-assembly thermal resistance value (hr-ft$^2$-°F/BTU)
$R_{effic}$ = efficient effective whole-assembly thermal resistance value (hr-ft$^2$-°F/BTU)[1]
$\eta$ = space heating system efficiency including distribution losses
$10^6$ = conversion from BTU to MMBTU

The savings for slab insulation and below-grade walls are calculated on a custom basis with baseline technologies established in the reference tables.

**Baseline Efficiencies – New or Replacement**
For all business new construction projects commencing construction prior to January 3rd, 2012 OR initiated with Efficiency Vermont prior to January 3rd, 2012, but completed on or after January 3rd, 2012, savings should be calculated using “2005 Vermont Guidelines for Energy Efficient Commercial Construction” as baseline. See Reference Tables section.

For all business new construction projects commencing construction after January 3rd, 2012 and iniated with Efficiency Vermont on or after January 3rd, 2012, regardless of when they are completed, savings shall be calculated using “2011 Vermont Commercial Building Energy Standards” as baseline. See Reference Tables section.

**High Efficiency**
Building envelope more efficient than the minimum efficiencies in the Vermont Guidelines for Energy Efficient Commercial Construction.

**Operating Hours**
Heating degree-days determined on a site-specific and application-specific basis.

**Loadshapes**
Not applicable

**Freeridership/Spillover Factors**

| **Measure Category** | | **Envelope** | |
|---|---|---|---|
| Measure Codes | | TSHNACWL, TSHWINDO, TSHNFNDN | |
| **Product Description** | | Efficient Envelope | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | 0.95 | 1.05 |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | 0.95 | 1.05 |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

* Freeridership of 0% per agreement between DPS and EVT.  All Act 250 measures will also have a 5% Adjustment Factor applied, which will be implemented through the Freeridership factor.

**Persistence**
The persistence factor is assumed to be one.
**Lifetimes**
30 years.
Analysis period is the same as the lifetime.

**Measure Cost**
The incremental cost for this measure is site-specific.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
$\Delta MMBTU = HDD \times 24 \times A \times [(1/R_{base} - 1/R_{effic})] / \eta / 10^6$

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

## 2005 Vermont Guidelines for Energy Efficient Commercial Construction

To be used as the baseline for projects initiated prior to 1/3/2012

| Measure Description - Doors and Windows | Maximum U-Factor for Entire Assembly | Minimum R-Value for Entire Assembly |
|---|---|---|
| Windows/Glass Doors w/ Framing Materials other than Metal | U-0.35 | 2.9 |
| Windows/Glass Doors w/ Metal framing - Curtain Wall/Storefront | U-0.45 | 2.2 |
| Windows/Glass Doors w/ Metal framing - Entrance Door | U-0. 80 | 1.3 |
| Windows/Glass Doors w/ Metal framing - All Other | U-0.50 | 2.0 |
| Skylight, Glass (0 – 5.0% of roof) | U-0.60 | 1.7 |
| Skylight, Plastic (0 – 5.0% of roof) | U-0.60 | 1.7 |

| **2005 Vermont Guidelines for Energy Efficient Commercial Construction** To be used as the baseline for projects initiated initiated prior to 1/3/2012 | |
|---|---|
| **Measure Description** | **Solar Heat Gain Coefficient (SHGC)** |
| Vertical Fenestration (50% max of gross above-grade wall area) | |
| - All Frame Types – Projection Factor <0.25 | 0.4 |
| - All Frame Types – 0.25 < Projection Factor > 0.5 | 0.55 |
| - All Frame Types – Projection Factor ≥ 0.5 | NR |
| Skylights | |
| - Glass | 0.4 |
| - Plastic | 0.62 |

NR = No Requirement

| **2005 Vermont Guidelines for Energy Efficient Commercial Construction**<br>To be used as the baseline for projects initiated prior to 1/3/2012 | | | |
|---|---|---|---|
| **Measure Description - Roof, walls and floors** | **Maximum Overall Factor for Entire Assembly** | **Minimum Effective R-Value for Entire Assembly** | **Minimum R-Value for Added Insulation** |
| Roof - Insulation entirely above deck | U-0.040 | R-25.0 | R-24 ci |
| Roof - Metal building | U-0.051 | R-19.6 | R-19 + 10 (with R-5 thermal blocks)<br>or R-30 (with R-5 thermal blocks) |
| Roof - Steel joist | U-0.027 | R-37.0 | R-30 + R-5 ci<br>(with R-5 thermal blocks) |
| Roof - Attic and other | U-0.027 | R-37.0 | R-38 |
| Above-grade walls - Mass | U-0.104 | R-9.6 | R-9.5 ci |
| Above-grade walls - Metal Building | U-0.070 | R-14.3 | R-19 or<br>R-6 + R-13 |
| Above-grade walls - Metal framed | U-0.064 | R-15.6 | R-13 + R-7.5 ci |
| Above-grade walls - Wood framed or other | U-0.064 | R-15.6 | R-19 or<br>R-7.5 ci or<br>R-13 + R-3.8 ci |
| Below-grade walls | C-0.092 [1] | R-10.9 | R-10 ci |
| Floor - Mass | U-0.074 | R-13.9 | R-10ci |
| Floor - Steel joist | U-0.038 | R-26.3 | R-30 |
| Floor - Wood frame and other | U-0.033 | R-30.3 | R-30 |
| Floor - Slab-on-grade - Unheated slab | F-0.64 [2] | $R_F$-1.6 [3] | R-10 for 48 inches |
| Floor - Slab-on-grade - Heated slab | F-0.55 [2] | $R_F$-1.6 [3] | R-10 for entire slab<br>(under slab and perimeter) |
| Opaque Doors - Swinging | U-0.050 | R-2.0 | NR |
| Opaque Doors - Roll-up or Sliding | NR | NR | R-10 |

Notes:
ci = Continuous Insulation
NR = No Requirement
1. The C and U-Factors are expressed in the same units but the C-Factor does not include soil or air films.
2. F-Factor is the perimeter heat loss for slab-on-grade floors, expressed in Btu/h/ft/deg F
3. $R_F$ is the equivalent R-value per linear foot (in hr-ft-˚F/BTU), based on the slab F-Factor

# 2011 Vermont Commercial Building Energy Standards

To be used as the baseline for projects initiated on or after 1/3/2012

**TABLE 502.1(1)**
**BUILDING ENVELOPE REQUIREMENTS–OPAQUE ASSEMBLIES AND ELEMENTS[a,b]**

| COMPONENT | MAXIMUM OVERALL *U*-FACTOR[a] | | MINIMUM *R*-VALUES | |
|---|---|---|---|---|
| | All other | Group R | All other | Group R |
| **Roofs** | | | | |
| Insulation entirely above deck | U-0.032 | | R-30ci | |
| Metal buildings[c, d] | U-0.049 | | See Table 502.1(2) and Table 502.1(3) for assembly descriptions and assembly *U*-factors | |
| Attic and other | U-0.027 | | R-38 | |
| **Walls, Above grade** | | | | |
| Mass | U-0.080 | U-0.071 | R-13.3ci | R-15.2ci |
| Metal building[c] | U-0.054 | | R-11 + R-13ci or R-19.5ci | |
| Metal framed | U-0.064 | | R-13 + R-7.5ci or R-13ci | |
| Wood-framed and other | U-0.051 | | R-13 + R-7.5ci or<br>R-20 + R-3.8ci or<br>R-23 or R-15ci | |
| **Walls, Below grade[e]** | | | | |
| Below-grade wall | C-0.092 | | R-10ci | |
| **Floors** | | | | |
| Mass | U-0.064 | U-0.057 | R-12.5ci | R-14.6ci |
| Joist/framing-metal | U-0.038 | U-0.032 | R-30 | R-38[f] |
| Joist/framing—wood and other | U-0.033 | | R-30 | |
| **Slab-on-grade floors** | | | | |
| Unheated slabs | F-0.480 | F-0.450 | R-10 for 48 in. below | R-15 for 48 in. below |
| Heated slabs[g] | F-0.550 | | R-10 for entire slab | |
| **Opaque doors** | | | | |
| Swinging | U-0.37 | | N/A | |
| Roll-up or sliding | U-0.20 | | N/A | |
| Upward-acting, sectional | N/A | | R-10 | |

For SI: 1 inch = 25.4 mm, ci = continuous insulation.

a. *U*-Factors include overall *F*-Factors and *C*-Factors.

b. For all envelope categories except metal building walls and metal building roofs, the use of opaque assembly *U*-factors, *C*-factors and *F*-factors from ASHRAE 90.1-2007 Appendix A, including Addendum "G", shall be permitted, provided the construction complies with the applicable construction details from such appendix. Alternatively, assembly *U*-factors for metal buildings shall be determined following ASHRAE 90.1-2007 Appendix A9 methodology.

c. Refer to Table 502.1(3) for metal building roof assembly *U*-factors and Table 502.1(4) for metal building wall assembly *U*-factors.

d. A minimum R-3 thermal spacer block between the purlins and the metal roof panels is required, unless compliance is shown by the overall assembly *U*-factor.

e. Where heated slabs are placed below grade, below-grade walls shall comply with the exterior insulation requirements for heated slabs.

f. Steel floor joist systems shall be R-38 minimum for residential structures.

g. Insulation placed under entire heated slab and around perimeter.

**TABLE 502.1(2)**
**BUILDING ENVELOPE REQUIREMENTS–METAL BUILDING ASSEMBLY DESCRIPTIONS**

| BUILDING ENVELOPE REQUIREMENTS-METAL BUILDING ASSEMBLY DESCRIPTIONS | DESCRIPTION | REFERENCE |
|---|---|---|
| | **ROOFS** | |
| Single layer plus continuous insulation (See Table 502.1(3) for qualifying assemblies) | The first rated *R*-value of insulation is for insulation installed perpendicular to and draped over purlins and then compressed when the metal roof panels are attached. A minimum R-3 thermal spacer block between the purlins and the metal roof panels is required, unless compliance is shown by the overall assembly *U*-factor.<br><br>The second rated *R*-value is for continuous insulation (e.g., insulation boards or blankets), it is assumed that the insulation is installed below the purlins and is uninterrupted by framing members. Insulation exposed to the conditioned space or semiheated space shall have a facing, and all insulation seams shall be continuously sealed to provide a continuous air barrier. | ANSI/ASHRAE/IESNA 90.1-2007 including Addendum "G" Section A2.3.2 |
| Double layer plus continuous insulation (See Table 502.1(3) for qualifying assemblies) | The first rated *R*-value of insulation is for insulation installed perpendicular to and draped over purlins.<br><br>The second rated *R*-value of insulation is for unfaced insulation installed above the first layer and parallel to the purlins and then compressed when the metal roof panels are attached. A minimum R-3 thermal spacer block between the purlins and the metal roof panels is required, unless compliance is shown by the overall assembly *U*-factor.<br><br>The third rated *R*-value is for continuous insulation (e.g., insulation boards or blankets), it is assumed that the insulation is installed below the purlins and is uninterrupted by framing members. Insulation exposed to the conditioned space or semiheated space shall have a facing, and all insulation seams shall be continuously sealed to provide a continuous air barrier. | ANSI/ASHRAE/IESNA 90.1-2007 including Addendum "G" Section A2.3.2 |
| Liner system (Ls) (See Table 502.1(3) for qualifying assemblies) | A continuous membrane installed below the purlins and uninterrupted by framing members. Uncompressed, unfaced insulation rests on top of the membrane between the purlins.<br><br>For multilayer installations, the last rated *R*-value of insulation is for unfaced insulation draped over purlins and then compressed when the metal roof panels are attached. A minimum R-3 thermal spacer block between the purlins and the metal roof panels is required, unless compliance is shown by the overall assembly *U*-factor. | ANSI/ASHRAE/IESNA 90.1-2007 including Addendum "G" Section A2.3.2 |
| Filled Cavity (Fc) (See Table 502.1(3) for Qualifying Assemblies) | The first rated R-value of insulation is for faced insulation installed parallel to the purlins.<br><br>The second rated R-value of insulation is for unfaced insulation installed above the first layer, parallel to and between the purlins and compressed when the metal roof panels are attached. The face of the first layer of insulation is of sufficient width to be continuously sealed to the top flange of the purlins and to accommodate the full thickness of the second layer of insulation.<br><br>A supporting structure retains the bottom of the first layer at the prescribed depth required for the full thickness of the second layer of insulation being installed above it. A minimum R-5 thermal spacer block between the purlins and the metal roof panels is required, unless compliance is shown by the overall assembly U-factor. | ANSI/ASHRAE/IESNA 90.1-2007 including Addendum "G" Section A2.3.2 |

*(continued)*

**TABLE 502.1(2)—continued**
**BUILDING ENVELOPE REQUIREMENTS–METAL BUILDING ASSEMBLY DESCRIPTIONS**

| BUILDING ENVELOPE REQUIREMENTS-METAL BUILDING ASSEMBLY DESCRIPTIONS | DESCRIPTION | REFERENCE |
|---|---|---|
| | WALLS | |
| R-11 + R-13ci | The first rated *R*-Value of insulation is for insulation compressed between metal wall panels and the steel structure.<br><br>The second rated *R*-value is for continuous insulation (e.g., insulation boards). It is assumed that the insulation boards are installed on the inside of the girts and uninterrupted by the framing members.<br><br>Insulation exposed to the conditioned space or semi-heated space shall have a facing, and all insulation seams shall be continuously sealed to provide a continuous air barrier. | ANSI/ASHRAE/IESNA 90.1-2007 including Addendum "G" Section A3.2.2 |
| R-19.5ci | The rated R-value is for continuous insulation (e.g., insulation boards). It is assumed that the insulation boards are installed on the inside of the girts and uninterrupted by the framing members.<br><br>Insulation exposed to the conditioned space or semi-heated space shall have a facing, and all insulation seams shall be continuously sealed to provide a continuous air barrier. | ANSI/ASHRAE/IESNA 90.1-2007 including Addendum "G" Section A3.2.2 |

**TABLE 502.1(3)**
**ASSEMBLY *U*-FACTORS FOR METAL BUILDING ROOFS**

| INSULATION SYSTEM | RATED *R*-VALUE OF INSULATION | OVERALL *U*-FACTOR FOR ENTIRE BASE ROOF ASSEMBLY | OVERALL *U*-FACTOR FOR ASSEMBLY OF BASE ROOF PLUS CONTINUOUS INSULATION (UNINTERRUPTED BY FRAMING) Rated *R*-Value of Continuous Insulation | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Standing Seam Roofs with Thermal Spacer Blocks[a]** | | | **R-6.5** | **R-13** | **R-19.5** | **R-26** | **R-32.5** | **R-39** |
| Single layer[b] | None | — | — | — | 0.049 | 0.037 | 0.030 | 0.025 |
| | R-10 | — | — | 0.046 | 0.035 | 0.029 | 0.024 | 0.021 |
| | R-11 | — | — | 0.045 | 0.035 | 0.028 | 0.024 | 0.021 |
| | R-13 | — | — | 0.044 | 0.034 | 0.028 | 0.024 | 0.020 |
| | R-16 | — | — | 0.043 | 0.033 | 0.027 | 0.023 | 0.020 |
| | R-19 | — | — | 0.040 | 0.031 | 0.026 | 0.022 | 0.020 |
| Double layer[b] | R-10 + R-10 | — | — | 0.041 | 0.032 | 0.027 | 0.023 | 0.020 |
| | R-10 + R-11 | — | — | 0.041 | 0.032 | 0.027 | 0.023 | 0.020 |
| | R-11 + R-11 | — | — | 0.040 | 0.032 | 0.026 | 0.023 | 0.020 |
| | R-10 + R13 | — | — | 0.040 | 0.032 | 0.026 | 0.023 | 0.020 |
| | R-11 + R-13 | — | — | 0.040 | 0.032 | 0.026 | 0.022 | 0.020 |
| | R-13 + R-13 | — | — | 0.038 | 0.030 | 0.025 | 0.022 | 0.019 |
| | R-10 + R-19 | — | — | 0.038 | 0.030 | 0.025 | 0.022 | 0.019 |
| | R-11 + R-19 | — | 0.049 | 0.037 | 0.030 | 0.025 | 0.022 | 0.019 |
| | R-13 + R-19 | — | 0.047 | 0.036 | 0.029 | 0.025 | 0.021 | 0.019 |
| | R-16 + R-19 | — | 0.046 | 0.035 | 0.029 | 0.024 | 0.021 | 0.018 |
| | R-19 + R-19 | — | 0.043 | 0.034 | 0.028 | 0.023 | 0.020 | 0.018 |
| Liner system[b] | R-19 + R-11 Ls | 0.035 | — | — | — | — | — | — |
| | R-25 + R-11 Ls | 0.031 | | | | | | |
| | R-30 + R-11 Ls | 0.029 | | | | | | |
| | R-25 + R-11+ R-11 Ls | 0.026 | | | | | | |
| Filled cavity[c] | R-10 + R-19 Fc | 0.057 | 0.042 | 0.033 | 0.027 | 0.023 | 0.020 | 0.018 |
| **Standing Seam Roofs without Thermal Spacer Blocks** | | | | | | | | |
| Liner system | R-19 + R-11 Ls | 0.040 | — | — | — | — | — | — |
| **Thru-fastened Roofs without Thermal Spacer Blocks** | | | | | | | | |
| Liner system | *R*-19 + R-11 Ls | 0.044 | — | — | — | — | — | — |
| (Multiple *R*-values are listed in order from inside to outside) | | | | | | | | |

a. A standing seam roof clip that provides a minimum 1.5 in. distance between the top of the purlins and the underside of the metal roof panels is required.
b. A minimum R-3 thermal spacer block is required.
c. A minimum R-5 thermal spacer block is required.

**TABLE 502.1(4)**
**ASSEMBLY *U*-FACTORS FOR METAL BUILDING WALLS**

| INSULATION SYSTEM | RATED *R*-VALUE OF INSULATION | OVERALL *U*-FACTORS FOR ASSEMBLY OF BASE WALL PLUS CONTINUOUS INSULATION (UNINTERRUPTED BY FRAMING) Rated *R*-value of Continuous Insulation | | | | |
|---|---|---|---|---|---|---|
| **Single Layer** | | **R-13** | **R-19.5** | **R-26** | **R-32.5** | **R-39** |
| | None | — | 0.049 | 0.037 | 0.030 | 0.025 |
| | R-10 | 0.054 | 0.040 | 0.032 | 0.026 | 0.023 |
| | R-11 | 0.054 | 0.040 | 0.032 | 0.026 | 0.023 |
| | R-13 | 0.052 | 0.039 | 0.031 | 0.026 | 0.022 |
| | R-16 | 0.051 | 0.039 | 0.031 | 0.026 | 0.022 |
| | R-19 | 0.050 | 0.038 | 0.03 | 0.025 | 0.022 |

**TABLE 502.3**
**BUILDING ENVELOPE REQUIREMENTS: FENESTRATION**

| | |
|---|---|
| **Vertical fenestration (40% maximum of above-grade wall)** | |
| **Framing materials other than metal with or without metal reinforcement or cladding** | |
| *U*-factor | 0.35 |
| **Metal framing with or without thermal break** | |
| Curtain wall/storefront *U*-factor | 0.42 |
| Entrance door *U*-factor | 0.80 |
| All other *U*-factor[a] | 0.50 |
| **SHGC-all frame types** | |
| SHGC: $PF < 0.25$ | 0.40 |
| SHGC: $0.25 \le PF < 0.5$ | NR |
| SHGC: $PF \ge 0.5$ | NR |
| **Skylights (3% maximum)** | |
| *U*-factor | 0.60 |
| SHGC | 0.40 |

NR = No requirement.
*PF* = Projection factor (see Section 502.3.2).
a. All others includes operable windows, fixed windows and nonentrance doors.

# Multifamily Program

## Lighting End Use
# Lighting Fixtures

Measure Number: III-A-2-d (Multifamily New Construction Program, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 74
Effective Date: 1/1/2012
End Date: TBD

**Referenced Documents:**

1) MF 2012 EISA Adjustments.xls

**Description**
This measure characterization describes savings assumptions for interior fixtures installed through the Multi Family program.

In-unit fixtures: For in unit fixtures a single prescriptive savings assumption will be used for Hardwired Fluorescent Fixtures, Circline and LED downlights (to streamline implementation and ensure consistency with other market sectors). The Multi Family program requires 100% of rooms to have at least one fixture and that all fixtures be hard wired high efficacy fixtures (CFL, HPT8 or LED). The 2011 RBES code requires 50% of fixtures to have high efficacy lamps.

Common area fixtures: Assumptions are provided for Hardwired Fluorescent Fixtures, Circline, High Performance T8 and LED downlights and hours of use assumptions provided for different locations. The 2011 RBES code requires 50% of fixtures to have high efficacy lamps.

Exterior fixtures: Exterior fixtures on the common meter (i.e. not tenant controlled) will be analyzed with Lighting Power Density (See Lighting Power Density TRM entry for more information).

Lighting Controls: Lighting Controls will be analyzed using the assumptions presented in the Business Energy Services Lighting Controls TRM entry.

**Savings Algorithms**

**Demand Savings**
$\Delta kW = ((Watts_{BASE} - Watts_{EE}) / 1000) * ISR$

**Energy Savings**
$\Delta kWh = \Delta kW \times HOURS$

Where:

| | |
|---|---|
| $\Delta kW$ | = gross customer connected load kW savings for the measure |
| $Watts_{BASE}$ | = Baseline connected kW (see table below) |
| $Watts_{EE}$ | = Energy efficient connected kW (see table below) |
| ISR | = in service rate or the percentage of units rebated that actually get used<br>= 1.0 |
| $\Delta kWh$ | = gross customer annual kWh savings for the measure |
| HOURS | = average hours of use per year (dependent on fixture for in unit and location for common area – see section below) |

**Baseline Efficiencies – New or Replacement**

The 2011 RBES code requires 50% of fixtures to have high efficacy lamps. Efficiency Vermont will therefore assume a baseline made up of 50% high efficacy as defined by the Code and 50% baseline lamps. The table below specifies the baseline assumption for each fixture type.

**High Efficiency**
The Multi Family program requires 100% of rooms to have at least one fixture and that all fixtures be hard wired high efficacy fixtures (CFL, HPT8 or LED).
The table below specifies the common efficient fixtures. Any other fixtures installed will use the wattage assumptions in the C&I Lighting TRM entries and the hours of use specified below[276].

**In unit Fixtures**

| Efficient Fixture | Baseline Fixture Assumption | Efficient Watts | Baseline Watts | Demand Savings (kW) | Energy Savings (kWh)[277] |
|---|---|---|---|---|---|
| **Hardwired CFL lamp (1)** | **0.5 x Incandescent lamp<br>0.5 x CFL lamp** | 29.9 | 54.25 | 0.0244 | 23.1 |
| **Circline fixture (2)** | **1 x Incandescent lamp<br>1 x CFL lamp** | 32 | 74 | 0.042 | 39.9 |
| **2 Lamp High Performance T8 (3)** | **2 x Standard T8 lamp** | 49 | 59 | 0.01 | 9.5 |
| **2 x 17W Standard T8 with HPT8 ballast (3)** | **2 x 17W Standard T8 lamp** | 26 | 34 | 0.008 | 7.6 |
| **LED Downlight (4)** | **0.5 x Incandescent Downlight<br>0.5 x CFL Downlight** | 12 | 40 | 0.028 | 34.7 |

Notes:
1. Hardwired CFL fixture is consistent with Efficient Products Interior Fluorescent Fixture delta watts of 48.7. Since 50% are assumed to be CFL, this delta watts is halved.
2. The baseline watts for the 32W Circline fixtures assumes 0.5 * 2 x 60W incandescent and 0.5 * 2 x 14W CFL.
3. The assumed wattages for the High Performance T8 measure are equal to those found in the Business Energy Services High Performance T8 TRM entry.
4. The baseline watts for the LED downlight assumes 0.5 * 65W incandescent (wattage consistent with Efficient Product's Solid State (LED) Recessed Downlight TRM entry baseline) and 0.5 * equivalent 15W CFL.

**Common Area Fixtures**

| Efficient Fixture | Baseline Fixture Assumption | Efficient Watts | Baseline Watts | Demand Savings (kW) | Energy Savings (kWh) |
|---|---|---|---|---|---|
| **Hardwired CFL lamp** | **0.5 x Incandescent lamp<br>0.5 x CFL lamp** | 29.9 | 49.5 | 0.0196 | Hours of Use dependent on location |
| **Circline fixture** | **1 x Incandescent lamp<br>1 x CFL lamp** | 32 | 74 | 0.042 | |
| **2 Lamp High Performance T8** | **2 x Standard T8 lamp** | 49 | 59 | 0.0105 | |
| **LED Downlight** | **0.5 x Incandescent Downlight<br>0.5 x CFL Downlight** | 12 | 40 | 0.028 | |

[276] Any measure with a baseline of incandescent will apply only 50% of the savings to account for the code baseline, any with a standard T8 baseline will apply full savings.
[277] Hours of use provided in 'Operating Hours' section below.

| | | | | | |
|---|---|---|---|---|---|
| **Screw based LED bulbs (<10W)** | **0.5 x Incandescent 0.5 x CFL** | 6.5 | 20.3 | 0.014 | |

Notes:
1. The baseline watts for the Screw based LED bulb assumes 0.5 * 33.3W incandescent and 0.5 * 7.2W CFL (wattage consistent with assumptions in Efficient Product's ENERGY STAR Integrated Screw Based SSL (LED) Lamps TRM entry)

**Baseline Adjustment**
In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W and 40W in 2014. The baseline for this measure will become EISA qualified Incandescent or Halogen bulbs.

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012, 2013 or 2014 depending on the assumed baseline wattage.

The appropriate adjustments are provided below (see MF 2012 EISA Adjustments.xls for details):

| Measure | Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|---|
| Hardwired CFL lamp (in-unit) | 2012 | 0.69 | 1 |
| Hardwired CFL lamp (Common area – 8760 hours) | 2012 | 0.69 | 1 |
| Hardwired CFL lamp (Common area – 4380 hours) | 2012 | 0.69 | 1 |
| Circline (in-unit) | 2012 | 0.60 | 2 |
| Circline (Common area – 8760 hours) | 2012 | 0.60 | 2 |
| Circline (Common area – 4380 hours) | 2012 | 0.60 | 2 |
| Screw based LED bulbs (<10W) (Common area – 8760 hours) | 2012 | 0.84 | 2 |
| Screw based LED bulbs (<10W) (Common area – 4380 hours) | 2012 | 0.84 | 2 |

**Operating Hours**
The assumed hours of operation are specified in the table below and are consistent with the assumptions from other markets for the same applications:

| | Measure or Location | Annual Hours of Use |
|---|---|---|
| **In Unit Lighting** | Hardwired CFL Fixture | 949 |
| | Circline Fixture | 949 |
| | HPT8 Fixture | 949 |
| | LED Downlight | 1241 |
| **Common Area Lighting**[278] | Indoor Hall/Stairway | 8760 |
| | Corridor | 8760 |
| | Laundry/common areas | 4380 |

[278] If different hours are appropriate, based on conversation with building owner or observations of usage, then custom hours of use will be used.

**Loadshapes**
Loadshape #1, Residential Indoor Lighting
Loadshape #25, Flat

**Freeridership/Spillover Factors**

| Measure Category | | Lighting Hardwired Fixture | | Lighting Hardwired Fixture | |
|---|---|---|---|---|---|
| Measure Code | | LFHCNFIX, LFHCRFIX | | LFHST8TW | |
| Product Description | | Compact fluorescent interior fixture, Circline fluorescent fixture | | New Super T8 Troffer/Wrap | |
| Track Name | Track No. | Freerider | Spillover | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | n/a | n/a | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a | n/a | n/a |
| LIMF Retrofit | 6017RETR | 1.0 | 1.0 | 1.0 | 1.0 |
| LIMF NC | 6018LINC | 0.9 | 1.1 | 1.0 | 1.0 |
| LIMF Rehab | 6018LIRH | 0.9 | 1.1 | 1.0 | 1.0 |
| MF Mkt NC | 6019MFNC | 0.86 | 1.1 | 1.0 | 1.0 |
| MF Mkt Retro | 6020MFMR | 0.9 | 1.05 | 1.0 | 1.0 |
| C&I Lplus | 6021LPLU | n/a | n/a | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a | n/a | n/a |

| Measure Category | | Lighting Hardwired Fixture | | Light Bulbs/Lamps | |
|---|---|---|---|---|---|
| Measure Code | | LFHRDLED, | | LBLLEDSC | |
| Product Description | | Solid State Recessed Downlight | | LED – Integral Screw Based Lamp | |
| Track Name | Track No. | Freerider | Spillover | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | n/a | n/a | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a | n/a | n/a |

| | | | | | |
|---|---|---|---|---|---|
| Pres Equip Rpl | 6013PRES | n/a | n/a | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a | n/a | n/a |
| LIMF Retrofit | 6017RETR | 1.0 | 1.0 | 1.0 | 1.0 |
| LIMF NC | 6018LINC | 0.9 | 1.0 | 0.9 | 1.0 |
| LIMF Rehab | 6018LIRH | 0.9 | 1.0 | 0.9 | 1.0 |
| MF Mkt NC | 6019MFNC | 0.88 | 1.1 | 0.88 | 1.1 |
| MF Mkt Retro | 6020MFMR | 0.9 | 1.0 | 0.9 | 1.0 |
| C&I Lplus | 6021LPLU | n/a | n/a | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
**Hardwired CFL and Circline Fixtures**: Fixture analysis period is 20 years, although savings will only be claimed until 2020, so the savings lifetime is 8 years for 2012, 7 years for 2013 etc.

**Fluorescent Replacement Lamp and Ballast**:
The measure life for HPT8 is assumed to be 20 years.
Analysis period is the same as lifetime.

**LED Downlight and Screw based LED**
The ENERGY STAR specification requires 70% lumen maintenance at 25,000 hours for Omnidirectional lamps. In unit bulbs therefore assume to have life of 25000/1241 = 20.1 years, common areas with 8760 hours have life of 2.8 years and common areas with 4380 hours have life of 5.7 years.
Analysis period is equal to measure life.

**Incremental Costs per Unit**
Incremental cost per installed fixture is presented in the table below.

| | Measure | Incremental Cost Assumption per Fixture |
|---|---|---|
| **In Unit Lighting** | Hardwired CFL Fixture | $10 |
| | Circline Fixture | $17.50 |
| | LED Downlight | $50 |
| **Common Area Lighting** | Hardwired CFL lamp | $10 |
| | Circline fixture | $17.50 |
| | 2 x 17W Standard T8 with HPT8 ballast | $17.50 |
| | 2 Lamp High Performance T8 | $17.50 |
| | LED Downlight | $50 |
| | Screw based LED bulbs (<10W) | $28.75 |

All costs are based on mixed baselines as presented above. Costs of lamps are consistent with other TRM entries with similar measures.

**O&M Cost Adjustments**

The O&M adjustments are provided in two tables below. Table A is for those measures impacted by the EISA baseline shift regulation. Due to the change in baseline replacement cost over the life of the measure, a single annual levelized replacement cost for the baseline and efficient case is calculated (see MF 2012 EISA Adjustments.xls for details). Table B is for those measures not impacted by the EISA regulation and therefore the O&M assumptions can be incorporated in the standard way.

A. EISA impacted measure levelized annual replacement costs.

| | Measure | Annual baseline replacement cost | Annual efficient replacement cost |
|---|---|---|---|
| **In Unit Lighting** | Hardwired CFL Fixture | $1.33 | $0.38 |
| | Circline Fixture | $1.16 | $0.18 |
| **Common Area Lighting (8760 hours)** | Hardwired CFL lamp | $24.44 | $16.59 |
| | Circline fixture | $17.88 | $10.11 |
| | Screw based LED bulbs (<10W) | $8.25 | n/a |
| **Common Area Lighting (4380 hours)** | Hardwired CFL lamp | $11.23 | $7.25 |
| | Circline fixture | $7.98 | $4.01 |
| | Screw based LED bulbs (<10W) | $9.24 | n/a |

B. Non EISA impacted measures Lamp and Ballast O & M Cost Assumptions

| **Measure** | **Baseline Measure** | | | | **Efficient Measure** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Comp 1** | | **Comp 2** | | **Comp 1** | | **Comp 2** | |
| | **Life** | **Cost** | **Life** | **Cost** | **Life** | **Cost** | **Life** | **Cost** |
| LED Downlight (in unit) | 4.4 | $4.09[279] | | | | | | |
| LED Downlight (common area – 8760 hours) | 0.6 | $6.76[280] | | | | | | |
| LED Downlight (common area – 4380 hours) | 1.3 | $6.76 | | | | | | |

[279] Based on mix of incandescent and CFL baseline (see MF 2012 EISA Adjustments.xls for details).
[280] Includes standard labor rate of $2.67

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 x 17W Standard T8 with HPT8 ballast (in unit) | n/a[281] | | | | | | | |
| 2 Lamp HPT8 (in unit) | n/a[282] | | | | | | | |
| 2 Lamp HPT8 (common area – 8760 hours) | 2.28 | $5.17[283] | 8.0 | $30[284] | 2.74 | $7.67[285] | 8.0 | $47.5[286] |
| 2 Lamp HPT8 (common area – 4380 hours) | 4.57 | $5.17 | 15.9 | $30 | 5.48 | $7.67 | 15.9 | $47.5 |

[281] No replacements assumed within the analysis period for either baseline or efficient case.
[282] No replacements assumed within the analysis period for either baseline or efficient case.
[283] Baseline lamp life is assumed to be 20,000 hours. Cost includes lamp cost of $2.50 and labor cost of $2.67.
[284] Baseline ballast life is assumed to be 70,000 hours. Cost includes ballast cost of $15 and labor cost or $15.
[285] Efficient lamp life is assumed to be 24,000 hours. Cost includes lamp cost of $5.00 and labor cost of $2.67.
[286] Efficient ballast life is assumed to be 70,000 hours. Cost includes ballast cost of $32.50 and labor cost or $15.

# Standard CFL Direct Install

Measure Number: III-A-4-d (Multifamily New Construction Program, Low Income Multifamily Retrofit, Market Rate Multifamily Retrofit, Lighting End Use)

**Version Date & Revision History**:
Draft date: Portfolio 76
Effective date: 1/1/2012
End date: 12/31/2014

**Referenced Documents:**

1. DI Cost Query.xls, Direct Install Prescriptive Lighting TAG.doc
2. Residential Lighting Markdown Impact Evaluation, Nexus Market Research, RLW Analytics, and GDS Associated, January 20, 2009
3. MF 2012 EISA Adjustments.xls
4. Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)

**Description**
A compact fluorescent lamp replaces an incandescent bulb in an in-unit interior lighting fixture or a tenant controlled exterior lighting fixture in a multifamily direct install application.

**Algorithms**
**Demand Savings**
$\Delta kW = ((Watts_{BASE} - Watts_{EE}) / 1000) * ISR$

| Year | Algorithm | ΔkW |
|---|---|---|
| 2012 | (49.0 / 1000) * 0.8 | 0.0392 |
| 2013 | (43.6 / 1000) * 0.8 | 0.0349 |
| 2014 | (37.0 / 1000) * 0.8 | 0.0296 |

**Energy Savings**
$\Delta kWh = \Delta kW \times HOURS$

| Year | ΔkWh |
|---|---|
| 2012 | 27.2 |
| 2013 | 24.2 |
| 2014 | 20.5 |

Where:

$\Delta kW$ = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW
$Watts_{EE}$ = Energy efficient connected kW[287]
$\Delta kWh$ = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units rebated that actually get used = 0.8[288]
HOURS = average hours of use per year = 694[289]

**Baseline Efficiencies – New or Replacement**
The baseline is an incandescent bulb.

[287] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011.
[288] 0.8 ISR based on TAG 2009 agreement.
[289] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011.

**Baseline Adjustment**
In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become Halogen bulbs (see percentages in O&M table below).

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012. For example, measures installed in 2012, the full savings (as calculated above in the Algorithm section) will be claimed for the first two years, and the adjusted savings will be claimed for the remainder of the measure life. The appropriate adjustments are provided below (see MF 2012 EISA Adjustments.xls s for details on how adjustment is calculated):

| Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|
| 2012 | 0.66 | 2 |
| 2013 | 0.77 | 1 |
| 2014 | 0.88 | 1 |

**High Efficiency**
High efficiency is an ENERGY STAR compact fluorescent bulb.
Delta watts based on NEEP RLS, 2011.

**Operating Hours**[290]
Operating hours will be assumed as 1.9 hours per day or 694 hours per year.

**Loadshape**
Loadshape #1, Residential Indoor Lighting
Loadshape #2, Residential Outdoor Lighting

**Freeridership/Spillover Factors**

| Measure Category | | Lighting End-Use | |
|---|---|---|---|
| Measure Code | | LBLCFBLB | |
| Product Description | | Compact Fluorescent Screw-base bulb | |
| Track Name | Track No. | Freerider | Spillover |
| LIMF Retrofit | 6017RETR | 1.0 | 1.0 |
| LIMF NC | 6018LINC | 1.0 | 1.0 |
| LIMF Rehab | 6018LIRH | 1.0 | 1.0 |
| MF Mkt NC | 6019MFNC | 1.0 | 1.0 |
| MF Mkt Retro | 6020MFMR | 0.9 | 1.05 |

**Persistence**
The persistence factor is assumed to be 90% as agreed to by EVT and the DPS (TAG 2007).

**Lifetimes**
Bulb life is assumed to be 8500 hours, based on agreement between EVT and the DPS (TAG 2009). At 694 hours per year and including the 90% persistence factor this equates to 11 years. A provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore the measure life will reduce each year and be equal to the number of years remaining to 2020; in 2012 this will be 8 years, in 2013 this will be 7 years.

290 Ibid.

Analysis period is the same as the lifetime.

**Measure Cost** [291]
The average installed cost is assumed to be $6.09 ($2.50 for the bulb and $3.59 for labor).

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Methodology for Computing O&M Savings**

In order to account for the shift in baseline due to the Federal Legislation, the levelized baseline replacement cost over the lifetime of the CFL was calculated (see MF 2012 EISA Adjustments.xls). The key assumptions used in this calculation are documented below:

| | Incandescent | Halogen | CFL |
|---|---|---|---|
| Replacement Cost | $0.50 | $1.50 | $2.50 |
| Component Life (hours) | 1000 | 1000 | 8500 |
| Baseline % in 2009-2011 | 100% | 0% | 0% |
| Baseline % in 2012 | 67% | 33% | 0% |
| Baseline % in 2013 | 33% | 67% | 0% |
| Baseline % in 2014 onward | 0% | 100% | 0% |
| Baseline % in 2020 onward | 0% | 0% | 100% |

The calculation results in a levelized assumption of $0.93 baseline replacement cost every 1 year for CFL installations in 2012, $0.96 every year for installations in 2013, and $0.98 for installations in 2014. This adjustment will be recalculated for subsequent years.

[291] $2.50 for CFL is based on TAG 2011 agreement to use recommendation from NEEP Residential Lighting Survey, 2011. Labor rate consistent with other measures.

# CFL Installed by Owner

Measure Number: III-A-6-a (Multifamily New Construction Program, Low Income Multifamily Retrofit, Market Rate Multifamily Retrofit, Lighting End Use)

**Version Date & Revision History**:
Draft date: Portfolio 74
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**

1. DI Cost Query.xls, Direct Install Prescriptive Lighting TAG.doc
2. Residential Lighting Markdown Impact Evaluation, Nexus Market Research, RLW Analytics, and GDS Associated, January 20, 2009
3. MF 2012 EISA Adjustments.xls

**Description**

A compact fluorescent lamp is installed by a Multi Family building owner, replacing an incandescent bulb in an in-unit interior lighting fixture or a tenant controlled exterior lighting fixture. .

**Algorithms**

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

| Year | Algorithm | ΔkW |
|---|---|---|
| 2012 | (49.0 / 1000) * 0.75 | 0.0368 |
| 2013 | (43.6 / 1000) * 0.75 | 0.0327 |
| 2014 | (37.0 / 1000) * 0.75 | 0.028 |

**Energy Savings**

$\Delta$kWh = $\Delta kW \times HOURS$

| Year | ΔkWh |
|---|---|
| 2012 | 25.5 |
| 2013 | 22.7 |
| 2014 | 19.3 |

Where:

$\Delta$kW = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW
$Watts_{EE}$ = Energy efficient connected kW[292]
$\Delta$kWh = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units provided that actually get used = 0.75[293]
HOURS = average hours of use per year = 694[294]

[292] Based on TAG 2011 agreement to use recommendation from NEEP Residential Lighting Survey, 2011.
[293] An In Service Rate of 0.75 is used for an owner installed bulb. This is lower than the Direct Install ISR assumption and is consistent with the Efficiency Kit TRM entry, which is based on results from a similar program performed in Colorado, which found installation rates of over 90% for products in an Easy Savings Kit; *FINAL REPORT: TIER 1 WORKSHOP MODEL 2007-2008, Prepared for the Governor's Energy Office by Energy Outreach Colorado, July 3, 2008*.
[294] Based on TAG 2011 agreement to use recommendation from NEEP Residential Lighting Survey, 2011.

**Baseline Efficiencies – New or Replacement**
The baseline is an incandescent bulb.

**Baseline Adjustment**
In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become Halogen bulbs (see percentages in O&M table below).

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012. For example, measures installed in 2012, the full savings (as calculated above in the Algorithm section) will be claimed for the first two years, and the adjusted savings will be claimed for the remainder of the measure life.
The appropriate adjustments are provided below (see MF 2012 EISA Adjustments.xls for details on how adjustment is calculated):

| Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|
| 2012 | 0.66 | 2 |
| 2013 | 0.77 | 1 |
| 2014 | 0.88 | 1 |

**High Efficiency**
High efficiency is an ENERGY STAR compact fluorescent bulb.

**Operating Hours**[295]
Operating hours will be assumed as 1.9 hours per day or 694 hours per year.

**Loadshape**
Loadshape #1, Residential Indoor Lighting
Loadshape #2, Residential Outdoor Lighting

**Freeridership/Spillover Factors**

| Measure Category | | Lighting End-Use | |
|---|---|---|---|
| Measure Code | | LBLCFBLB | |
| Product Description | | Compact Fluorescent Screw-base bulb | |
| Track Name | Track No. | Freerider | Spillover |
| LIMF Retrofit | 6017RETR | 1.0 | 1.0 |
| LIMF NC | 6018LINC | 1.0 | 1.0 |
| LIMF Rehab | 6018LIRH | 1.0 | 1.0 |
| MF Mkt NC | 6019MFNC | 1.0 | 1.0 |
| MF Mkt Retro | 6020MFMR | 0.9 | 1.05 |

**Persistence**
The persistence factor is assumed to be 90% as agreed to by EVT and the DPS (TAG 2007).

**Lifetimes**
Bulb life is assumed to be 8500 hours, based on agreement between EVT and the DPS (TAG 2009). At 694 hours per year and including the 90% persistence factor this equates to 11 years. A provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore the measure life will reduce

[295] Ibid.

each year and be equal to the number of years remaining to 2020; so for 2012 this will be 8 years, 2013 7 years.

Analysis period is the same as the lifetime.

**Measure Cost** [296]
The average installed cost is assumed to be $6.09 ($2.50 for the bulb and $3.59 for labor).

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Methodology for Computing O&M Savings**

In order to account for the shift in baseline due to the Federal Legislation, the levelized baseline replacement cost over the lifetime of the CFL was calculated (see MF 2012 EISA Adjustments.xls). The key assumptions used in this calculation are documented below:

| | Incandescent | Halogen | CFL |
|---|---|---|---|
| Replacement Cost | $0.50 | $1.50 | $2.50 |
| Component Life (hours) | 1000 | 1000 | 8500 |
| Baseline % in 2009-2011 | 100% | 0% | 0% |
| Baseline % in 2012 | 67% | 33% | 0% |
| Baseline % in 2013 | 33% | 67% | 0% |
| Baseline % in 2014 onward | 0% | 100% | 0% |
| Baseline % in 2020 onward | 0% | 0% | 100% |

The calculation results in a levelized assumption of $0.93 baseline replacement cost every 1 year for CFL installations in 2012, $0.96 every year for installations in 2013, and $0.98 for installations in 2014. This adjustment will be recalculated for subsequent years.

[296] $2.50 for CFL is based on TAG 2011 agreement to use recommendation from NEEP Residential Lighting Survey, 2011. Labor rate consistent with other measures.

# Specialty CFL Direct Install

Measure Number: III-A-7-a (Low Income Multifamily Program, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 75
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**

1. 2009 to 2011 bulbs installed.xlsx
2. Xenergy, 1998; "Process and Impact Evaluation of Joint Utilities Starlights Residential Lighting Program".

**Description**
An existing incandescent bulb is replaced with a lower wattage ENERGY STAR qualified specialty compact fluorescent bulb through a Direct Install program. Specialty CFL bulbs are defined as lamps for general illumination that use fluorescent light emitting technology and an integrated electronic ballast with or without a standard Edison screw-base. They can be dimmable, designed for special applications, have special color enhancement properties or have screw-bases that are not standard Edison bases, and include A-lamps, candelabras, G-lamps (globe), reflectors, torpedoes, dimmables, and 3-way bulbs. This TRM should be used for both interior and exterior installations, the only difference being the loadshape. Note specialty bulbs are currently exempt from EISA regulations.

**Algorithms**

**Demand Savings**
$\Delta kW = ((\Delta Watts) / 1000) \times ISR$
$\Delta kW(Res. <=15W) = ((43.9) / 1000) \times 0.8 = 0.0351$
$\Delta kW(Res. >15W) = ((62.6) / 1000) \times 0.8 = 0.0501$

**Energy Savings**
$\Delta kWh = \Delta kW \times HOURS$
$\Delta kWh\ (Res. <=15W) = (0.0351 \times 694) = 24.4$
$\Delta kWh\ (Res. >15W) = (0.0501 \times 694) = 34.8$

Where:

$\Delta kW$ = gross customer connected load kW savings for the measure
$\Delta Watts$ = Average delta watts between specialty CFL and incandescent $Watts_{BASE} - Watts_{EE}$[297]
ISR = in service rate or the percentage of units rebated that actually get used[298]
$\Delta kWh$ = gross customer annual kWh savings for the measure
HOURS = average hours of use per year

**Baseline Efficiencies – New or Replacement**
The baseline condition is an incandescent specialty light bulb.

**High Efficiency**
High efficiency is an ENERGY STAR qualified specialty compact fluorescent lamp.

[297] The delta watts is calculated by finding the weighted average wattage of specialty bulbs installed in Existing Homes, Low Income and RNC from 01/2009-04/2011. The equivalent incandescent wattage was used to calculate delta watts. See 2009 to 2011 bulbs installed.xlsx
[298] ISR is assumed to be equal to standard CFL Direct Install measure, and is based on a 2009 TAG agreement.

**Operating Hours**
Assumed to be 1.9 hours a day or 694 hours per year [299].

**Loadshape**
Loadshape #1: Residential Indoor Lighting
Loadshape #2: Residential Outdoor Lighting

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Freeridership/Spillover Factors**

| Measure Category | | Light Bulbs/Lamps | |
|---|---|---|---|
| Measure Code | | LBLCFSPD | |
| Product Description | | Compact Fluorescent – Specialty Bulb Direct Install | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | 1 | 1 |
| LIMF NC | 6018LINC | 1 | 1 |
| LIMF Rehab | 6018LIRH | 1 | 1 |
| MF Mkt NC | 6019MFNC | 1 | 1 |
| MF Mkt Retro | 6020MFMR | 1 | 1 |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | 1 | 1 |
| RES Retrofit | 6036RETR | 0.9 | 1 |
| RNC VESH | 6038VESH | 1 | 1 |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be 90% as agreed to by EVT and the DPS (TAG 2007).

[299] Hours of use are based on TAG 2011 agreement to use the NEEP Residential Lighting Survey, 2011 proposed values.

**Lifetimes**
Bulb life is assumed to be 8500 hours, based on agreement between EVT and the DPS (TAG 2009). The measure life, including the 90% persistence factor is therefore assumed to be 8500/694 * 0.9 = 11 years. Analysis period is the same as the lifetime.

**Measure Cost**[300]

| | | |
|---|---|---|
| Cost (Watts <=15) | = $8.16 + $3.59 (labor) | = $11.75 |
| Cost (Watts >15) | = $8.84 + $3.59 (labor) | = $12.43 |

**Incentive Level**
The incentive level is equal to the measure cost (these bulbs are free to the customer).

**O&M Cost Adjustments**
O& M cost adjustments are based on component costs provided in the reference table below.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**
**Component Costs and Lifetimes Used in Computing O&M Savings**

**Residential**

| | Baseline Measures | |
|---|---|---|
| Component | Cost[301] | Life[302] |
| Lamp<=15W | $2.71 | 1.4 |
| Lamp>15W | $4.29 | 1.4 |

300 Incremental cost of bulb is consistent with the assumptions from the NEEP Residential Lighting Survey, 2011. This evaluation did not provide the <=15W and >15W categories and so the costs from EVT's analysis of incremental costs are adjusted such that the average matches the values from the NEEP study. Labor cost is consistent with the standard bulb direct install measures.
301 Baseline cost is consistent with the assumptions from the NEEP Residential Lighting Survey, 2011. This evaluation did not provide the <=15W and >15W categories and so the costs from EVT's analysis of baseline costs are adjusted such that the average matches the values from the NEEP study
302 Based on the assumption that the incandescent bulb rated life is 1000 hours. 1000/694 = 1.4years.

**Clothes Washing End Use**

# Common Area Commercial Clothes Dryer Fuel Switch

Measure Number: III-B-1-b (Multifamily New Construction Program, Clothes Washing End Use)

**Version Date & Revision History**

Draft date: Portfolio 74
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**

1) ea_template_3h_MFDryer.xls
2) Incremental Dryer Costs.xls

**Description**

Install a commercial-grade propane- or natural gas-fired clothes dryer instead of electric clothes dryer in a central on-site laundry facility.

**Algorithms**

**Energy Savings**

$$\Delta kWh = NumUnits \times kWh_{save} / NumDryers$$

Where:

$\Delta kWh$ = gross annual customer kWh savings per clothes dryer for the measure
NumUnits = number of residential units served by the central laundry facility
NumDryers = total number of clothes dryers in central laundry facility
$kWh_{save}$ = annual customer kWh savings per residential unit for the measure
= 675 kWh[303] / apartment

**Demand Savings**

$$\Delta kW = \Delta kWh_{save} / HOURS \times NumUnits / NumDryers$$

Where:

HOURS = Full load hours
= 176[304]

**Baseline Efficiencies – New or Replacement**

Baseline efficiency is an electric dryer used in conjunction with a standard top-loading clothes washer.

**High Efficiency**

High efficiency is a propane or natural gas dryer used in conjunction with a standard top-loading clothes washer.

**Loadshape**

Loadshape #9, Residential Clothes Washer

**Freeridership/ Spillover Factors**

| Measure Category | Other Fuel Switch |
|---|---|

[303] See ea_template_3h_MFDryer.xls for calculation. Savings assumes a 2 bedroom unit with three residents. Tool adjusts dryer usage assumption from MEF to calculate dryer usage per load (for heat only, not motor usage). Assumes 261 clothes washing loads per unit (apartment) and 90% of the washer loads being dried in the dryer (to equal 244 loads dried). When possible this value will be calculated with the specifics of the installation using the ea_template.xls tool.

[304] Assuming 235 loads of laundry dried and estimate average run time of 45 minutes.

| Measure Code | | OTFYNPROP; OTFYNNGAS | |
|---|---|---|---|
| Product Description | | Clothes Dryer Fuel Switch | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | 1.0 | 1.0 |
| LIMF NC | 6018LINC | 0.7 | 1.0 |
| LIMF Rehab | 6018LIRH | 0.7 | 1.0 |
| MF Mkt NC | 6019MFNC | 0.7 | 1.0 |
| MF Mkt Retro | 6020MFMR | 0.9 | 1.0 |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
14 years (same as for clothes washers in DPS screening of Efficiency Utility Core programs).
Analysis period is 30 years (fuel switch).

**Incremental Cost per Dryer**
The average purchase cost for a gas dryer is $618 and for an equivalent electric dryer is $535, making the incremental cost for each unit $83. The cost to run gas line and hook up the dryer is approximately $280. Therefore the incremental cost for a gas dryer is assumed to be $363[305].

**O&M Cost Adjustments**
Within the 30 year analysis period of this fuel switch, after 14 and 28 years the dryer would be required to be replaced and so a cost of $618 for the efficient case and $535 for the baseline case will be incorporated.

**Fossil Fuel Descriptions**

$\Delta$MMBtu = -2.60 MMBtu [306] (negative indicates increase in fuel consumption)

[305] Based on 2011 EVT survey of local installers and gas companies, see Incremental Dryer Costs.xls.

**Water Descriptions**

There are no water algorithms or default values for this measure.

[306] Assumes 95% combustion efficiency for gas dryer (per 6/01 agreement between EVT and DPS) and 100% efficiency for electric dryer.

# Common Area Commercial Clothes Washer

Measure Number: III-B-2-e (Multifamily New Construction Program, Clothes Washing End Use)

**Version Date & Revision History**
Draft date: Portfolio 81
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**
1) 2013 MF Common Clothes Washer Savings.xls

**Description**
Install in a central onsite laundry facility a commercial-grade clothes washer meeting minimum qualifying efficiency standards of ENERGY STAR, CEE Tier 2 or CEE Tier 3, Most Efficient or Top Ten instead of a new standard baseline unit. Efficiency levels are defined below.

**Algorithms**

**Energy Savings**
Per unit Energy and Demand savings are presented in the reference tables below, and are dependent on the fuel type of the DHW system and the dryer. The calculations are based on analysis of previous year's rebated units through Efficient Products (see Efficient Product measure for write up of savings methodology). The savings are presented for each efficiency level in the reference table below titled "Customer Energy Savings by Water Heater and Dryer Fuel Type", and the calculation can be reviewed in 2013 MF Common Clothes Washer Savings.xls. Note these savings are for one unit usage. Total savings is therefore calculated by multiplying by number of units (apartments) using the clothes washer as presented below:

$$\Delta kWh = NumUnits \times kWh_{save} / NumWashers$$

Where:

$\Delta$kWh = gross annual customer kWh savings per clothes washer for the measure
NumUnits = number of residential units (apartments) served by the central laundry facility
$kWh_{save}$ = annual customer kWh savings per residential unit for the measure
NumWashers = total number of clothes washers in central laundry facility

**Demand Savings**

$$\Delta kW = NumUnits \times kW_{save} / NumWashers$$

Where:

$\Delta$kW = gross annual customer kW savings per clothes washer for the measure
kWsave = annual customer kW savings per residential unit for the measure

**Baseline Efficiencies – New or Replacement**
Baseline efficiency is a top-loading commercial-grade clothes washer. The federal baseline MEF of 1.26 is inflated by 20% to 1.51 for savings comparison to account for non-qualifying models that are higher than the federal baseline MEF.

**High Efficiency**
High efficiency is defined as any model meeting or exceeding ENERGY STAR, CEE Tier 2 or Tier 3 standards as of 1/1/2011, ENERGY STAR Most Efficient or Top Ten as defined in the following table:

| Efficiency Level | Modified Energy Factor (MEF) | Water Factor (WF) |
|---|---|---|
| ENERGY STAR | >= 2.0 | <= 6.0 |
| CEE TIER 2 | >= 2.20 | <= 4.5 |
| CEE TIER 3 | >= 2.40 | <= 4.0 |

| | | |
|---|---|---|
| ENERGY STAR Most Efficient (as of 1/1/2013) | >= 2.4 (for units <=2.5 ft3)<br>>= 3.2 (for units >2.5 ft3) | <= 4.5 (for units <=2.5 ft3)<br><= 3.0 (for units >2.5 ft3) |
| Top Ten | Defined as the ten most efficient units available. | |

The modified energy factor (MEF) measures energy consumption of the total laundry cycle (unit operation, washing and drying); the higher the number, the greater the efficiency.

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

Energy and water savings estimates are based on the weighted average MEF factor for qualifying models based on the models rebated during the previous calendar year, except Top Ten which is based upon averaging the units provided on the website (http://www.toptenusa.org/Top-Ten-Clothes-Washers) as of September 2012.

**Operating Cycles**
265 clothes washer cycles / per apartment / year [307]

**Operating Hours**
265 operating hours / per apartment / year [308]

**Loadshape**
Loadshape #9, Residential Clothes Washing, Vermont State Screening Tool.

**Freeridership/Spillover Factors**

| **Measure Category** | | **Cooking and Laundry** | | | | | |
|---|---|---|---|---|---|---|---|
| **Product Description** | | **Efficient Clothes Washer** | | | | | |
| **Measure Code** | | **CKLESWRP, CKLC2WRP** | | **CKLC3WRP** | | **CKLMEWRP, CKLTTWRP** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** | **Freerider** | **Spillover** | **Freerider** | **Spillover** |
| LIMF NC | 6018LINC | 0.75 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| LIMF Rehab | 6018LIRH | 0.75 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| MF Mkt NC | 6019MFNC | 0.5 | 1.0 | 0.75 | 1.0 | 0.95 | 1.2 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
14 years[309] (same as in DPS screening of Efficiency Utility Core programs).
Analysis period is the same as the lifetime.

**Measure Cost**
The incremental cost for this measure is provided below[310]:

| Efficiency Level | Incremental Cost |
|---|---|
| ENERGY STAR | $385 |
| CEE Tier 2 | $650 |

[307] EVT found the average household size in MF buildings from the 2010 Census data (1.6 people, compared to 2.3 for single family) and using the values for number of loads for different household sizes (from DOE Technical Support Document U.S. Department of Energy, Final Rule Technical Support Document (TSD): Energy Efficiency Standards for Consumer Products: Clothes Washers, December, 2000. Page 7-6) and the 322 used for single families we estimate the number of loads for a MF building to be 265 per unit. See file 2013 MF Common Clothes Washer Savings.xls .
[308] Assume one hour per cycle.
[309] Based on DOE Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_standard.xlsm.
[310] Based on EVT field study of clothes washer costs, see 2013 MF Common Clothes Washer Savings.xls. Measure cost is higher than in-unit clothes washers since the common units are larger commercial and more expensive models.

| | |
|---|---|
| CEE Tier 3 | $900 |
| ENERGY STAR Most Efficient | $1250 |
| Top Ten | $1300 |

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**

$\Delta$MMBtu = NumUnits × $MMBtu_{save}$. / NumWashers

Where:

$\Delta$MMBtu = gross annual fossil fuel energy savings in MMBtu (million Btu) per clothes washer for the measure
NumUnits = number of residential units served by the central laundry facility
$MMBtu_{save}$ = annual *customer* MMBtu of fossil fuel savings per residential unit for the measure from reference table below
NumWashers = total number of clothes washers in central laundry facility

**Water Descriptions**
$\Delta$CCF = NumUnits × $CCF_{save}$ / NumWashers

Where:

$\Delta$CCF = annual *customer* water savings per clothes washer in CCF (hundreds of cubic feet)
NumUnits = number of residential units served by the central laundry facility
$CCF_{save}$ [311] = annual *customer* water savings per clothes washer per residential unit for the measure, in CCF (hundreds of cubic feet)
= 2.4(ENERGY STAR), 6.1 (Tier 2) or 5.8 (Tier 3), 6.9 (Most Efficient) and 6.3 (Top Ten)
NumWashers = total number of clothes washers in central laundry facility

**Reference Tables**
Customer Energy Savings by Water Heater and Dryer Fuel Type[312]

**ENERGY STAR:**

| | Per Unit (Apartment) Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 133 | 0.50 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 49 | 0.18 | 0 | 0.34 | 0 |
| Electric Dryer/Natural Gas DHW | 49 | 0.18 | 0 | 0 | 0.34 |
| Electric Dryer/Oil DHW | 49 | 0.18 | 0.34 | 0 | 0 |
| Propane Dryer/Electric DHW | 85 | 0.32 | 0 | 0.16 | 0 |
| Propane Dryer/Propane DHW | 1 | 0.01 | 0 | 0.50 | 0 |
| Propane Dryer/Oil DHW | 1 | 0.01 | 0.50 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 85 | 0.32 | 0 | 0 | 0.16 |
| Natural Gas Dryer/Natural Gas DHW | 1 | 0.01 | 0 | 0 | 0.50 |
| Natural Gas Dryer/Oil DHW | 1 | 0.01 | 0.50 | 0 | 0.00 |

311 Water savings based on weighted average of 261 clothes washer cycles per year. See file 2013 MF Common Clothes Washer Savings.xls
312 Where dryer and DHW use different fossil fuels, savings are combined under the DHW fossil fuel because a single measure can only have one fuel type for screening purposes and the DHW savings are larger than the Dryer savings.

**Tier 2:**

| | Per Unit (Apartment) Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 227 | 0.86 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 89 | 0.34 | 0 | 0.55 | 0 |
| Electric Dryer/Natural Gas DHW | 89 | 0.34 | 0 | 0 | 0.55 |
| Electric Dryer/Oil DHW | 89 | 0.34 | 0.55 | 0 | 0 |
| Propane Dryer/Electric DHW | 144 | 0.54 | 0 | 0.28 | 0 |
| Propane Dryer/Propane DHW | 6 | 0.02 | 0 | 0.84 | 0 |
| Propane Dryer/Oil DHW | 6 | 0.02 | 0.84 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 144 | 0.54 | 0 | 0 | 0.28 |
| Natural Gas Dryer/Natural Gas DHW | 6 | 0.02 | 0 | 0 | 0.84 |
| Natural Gas Dryer/Oil DHW | 6 | 0.02 | 0.84 | 0 | 0.00 |

**Tier 3:**

| | Per Unit (Apartment) Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 286 | 1.08 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 102 | 0.39 | 0 | 0.73 | 0 |
| Electric Dryer/Natural Gas DHW | 102 | 0.39 | 0 | 0 | 0.73 |
| Electric Dryer/Oil DHW | 102 | 0.39 | 0.73 | 0 | 0 |
| Propane Dryer/Electric DHW | 188 | 0.71 | 0 | 0.33 | 0 |
| Propane Dryer/Propane DHW | 5 | 0.02 | 0 | 1.07 | 0 |
| Propane Dryer/Oil DHW | 5 | 0.02 | 1.07 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 188 | 0.71 | 0 | 0 | 0.33 |
| Natural Gas Dryer/Natural Gas DHW | 5 | 0.02 | 0 | 0 | 1.07 |
| Natural Gas Dryer/Oil DHW | 5 | 0.02 | 1.07 | 0 | 0.00 |

**Most Efficient:**

| | Per Unit (Apartment) Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 366 | 1.38 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 135 | 0.51 | 0 | 0.92 | 0 |
| Electric Dryer/Natural Gas DHW | 135 | 0.51 | 0 | 0 | 0.92 |
| Electric Dryer/Oil DHW | 135 | 0.51 | 0.92 | 0 | 0 |
| Propane Dryer/Electric DHW | 238 | 0.90 | 0 | 0.44 | 0 |
| Propane Dryer/Propane DHW | 7 | 0.02 | 0 | 1.36 | 0 |
| Propane Dryer/Oil DHW | 7 | 0.02 | 1.36 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 238 | 0.90 | 0 | 0 | 0.44 |
| Natural Gas Dryer/Natural Gas DHW | 7 | 0.02 | 0 | 0 | 1.36 |
| Natural Gas Dryer/Oil DHW | 7 | 0.02 | 1.36 | 0 | 0.00 |

**Top Ten:**

| | Per Unit (Apartment) Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 398 | 1.50 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 155 | 0.58 | 0 | 0.97 | 0 |
| Electric Dryer/Natural Gas DHW | 155 | 0.58 | 0 | 0 | 0.97 |
| Electric Dryer/Oil DHW | 155 | 0.58 | 0.97 | 0 | 0 |
| Propane Dryer/Electric DHW | 251 | 0.95 | 0 | 0.50 | 0 |
| Propane Dryer/Propane DHW | 8 | 0.03 | 0 | 1.47 | 0 |
| Propane Dryer/Oil DHW | 8 | 0.03 | 1.47 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 251 | 0.95 | 0 | 0 | 0.50 |
| Natural Gas Dryer/Natural Gas DHW | 8 | 0.03 | 0 | 0 | 1.47 |
| Natural Gas Dryer/Oil DHW | 8 | 0.03 | 1.47 | 0 | 0.00 |

# In-unit Energy Efficient Clothes Washer

Measure Number: III-B-3-b (Multifamily New Construction Program, Clothes Washing End Use)

**Version Date & Revision History**
Draft date: Portfolio 81
Effective date: 1/1/2013
End date: TBD

**Referenced Documents**:
1) 2013 MF In unit Clothes Washer Savings.xls;
2) 2009 VT Appliance Data_TRMCostAnalysis.xls
3) tablehc11.10.pdf

**Description**
In unit clothes washers are installed exceeding minimum qualifying efficiency standards established as ENERGY STAR, CEE Tier 2 or CEE Tier 3, Most Efficient or Top Ten instead of a new standard baseline unit. Efficiency levels are defined below.

**Algorithms**

**Energy Savings**
Energy and Demand Savings are presented in the reference tables below, and are dependent on the fuel type of the DHW system and the dryer. The calculations are based on analysis of rebated units through Efficient Products (see Efficient Product measure for write up of savings methodology). The savings are presented for each efficiency level in the reference table "Customer Energy Savings by Water Heater and Dryer Fuel Type", and 2013 MF In unit Clothes Washer Savings.xls.

**Demand Savings**

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

Where:

$\Delta kWh$ = gross customer annual kWh savings for the measure
$\Delta kW$ = gross customer connected load kW savings for the measure
Hours = Operating hours of clothes washer
= 265

**Baseline Efficiencies – New or Replacement**
The baseline efficiency is determined according to the modified energy factor (MEF) that takes into account the energy and water required per clothes washer cycle, including energy required by the clothes dryer per clothes washer cycle. The federal baseline MEF of 1.26 is inflated by 20% to 1.51 for savings comparison to account for non-qualifying models that are higher than the federal baseline MEF.

**High Efficiency**
High efficiency is defined as any model meeting or exceeding ENERGY STAR, CEE Tier 2 or Tier 3 standards as of 1/1/2011, ENERGY STAR Most Efficient or Top Ten as defined in the following table:

| Efficiency Level | Modified Energy Factor (MEF) | Water Factor (WF) |
|---|---|---|
| ENERGY STAR | >= 2.0 | <= 6.0 |
| CEE TIER 2 | >= 2.20 | <= 4.5 |
| CEE TIER 3 | >= 2.40 | <= 4.0 |
| ENERGY STAR Most Efficient (as of 1/1/2013) | >= 2.4 (for units <=2.5 ft3)<br>>= 3.2 (for units >2.5 ft3) | <= 4.5 (for units <=2.5 ft3)<br><= 3.0 (for units >2.5 ft3) |
| Top Ten | Defined as the ten most efficient units available. | |

The modified energy factor (MEF) measures energy consumption of the total laundry cycle (unit operation, washing and drying); the higher the number, the greater the efficiency.

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

Energy and water savings estimates are based on the weighted average MEF factor for qualifying models based on the models rebated during the previous calendar year, except Top Ten which is based upon averaging the units provided on the website (http://www.toptenusa.org/Top-Ten-Clothes-Washers) as of September 2012

**Operating Cycles**
265 clothes washer cycles / year [313]

**Operating Hours**
265 operating hours / year [314]

**Loadshape**
Loadshape #9, Residential Clothes Washing, Vermont State Screening Tool.

**Freeridership/Spillover Factors**

| **Measure Category** | | **Cooking and Laundry** | | | | | |
|---|---|---|---|---|---|---|---|
| **Product Description** | | **Efficient Clothes Washer** | | | | | |
| **Measure Code** | | **CKLESWRP, CKLC2WRP** | | **CKLC3WRP** | | **CKLMEWRP, CKLTTWRP** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** | **Freerider** | **Spillover** | **Freerider** | **Spillover** |
| C&I Retrofit | 6012CNIR | n/a | n/a | n/a | n/a | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a | n/a | n/a | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a | n/a | n/a | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a | n/a | n/a | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a | n/a | n/a | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a | n/a | n/a | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a | n/a | n/a | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a | n/a | n/a | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a | n/a | n/a | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a | n/a | n/a | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a | n/a | n/a | n/a | n/a |
| LIMF NC | 6018LINC | 0.75 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| LIMF Rehab | 6018LIRH | 0.75 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| MF Mkt NC | 6019MFNC | 0.5 | 1.0 | 0.75 | 1.0 | 0.95 | 1.2 |
| MF Mkt Retro | 6020MFMR | n/a | n/a | n/a | n/a | n/a | n/a |
| C&I Lplus | 6021LPLU | n/a | n/a | n/a | n/a | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a | n/a | n/a | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a | n/a | n/a | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a | n/a | n/a | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a | n/a | n/a | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a | n/a | n/a | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a | n/a | n/a | n/a | n/a |

[313] EVT found the average household size in MF buildings from the 2010 Census data (1.6 people, compared to 2.3 for single family) and using the values for number of loads for different household sizes (from DOE Technical Support Document U.S. Department of Energy, Final Rule Technical Support Document (TSD): Energy Efficiency Standards for Consumer Products: Clothes Washers, December, 2000. Page 7-6) and the 322 used for single families we estimate the number of loads for a MF building to be 265. See 2013 MF In unit Clothes Washer Savings.xls for calculation.
[314] Assume one hour per cycle.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| GMP HP | 6046RETR | n/a | n/a | n/a | n/a | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a | n/a | n/a | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a | n/a | n/a | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a | n/a | n/a | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
14 years[315] (same as DPS screening of Efficiency Utility program).
Analysis period is the same as the lifetime.

**Measure Cost**
The incremental cost for this measure is provided in the table below[316]:

| Efficiency Level | Incremental Cost |
|---|---|
| ENERGY STAR | $225 |
| CEE Tier 2 | $250 |
| CEE Tier 3 | $350 |
| ENERGY STAR Most Efficient | $500 |
| Top Ten | $510 |

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
Fossil Fuel savings are dependent on the DHW and Dryer fuel type and are presented in the tables below.

**Water Descriptions**
The water savings for each efficiency level are presented below:

| Efficiency Level | WF | ΔWater (CCF per year) |
|---|---|---|
| Federal Standard | 7.93 | 0.0 |
| ENERGY STAR | 5.41 | 2.4 |
| CEE Tier 2 | 3.61 | 6.2 |
| CEE Tier 3 | 3.51 | 5.9 |
| ENERGY STAR Most Efficient | 2.90 | 7.0 |
| Top Ten | 3.54 | 6.4 |

**Reference Tables**
**Customer Energy Savings by Water Heater and Dryer Fuel Type[317]**

**ENERGY STAR:**

| | Per Unit Savings |
|---|---|

[315] Based on DOE Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_standard.xlsm.
[316] Based on weighted average of top loading and front loading units (based on available product from the CEC Appliance database) and cost data from Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_standard.xlsm. See '2013 In Unit Clothes Washer Savings.xls' for details.
[317] Where dryer and DHW use different fossil fuels, savings are combined under the DHW fossil fuel because a single measure can only have one fuel type for screening purposes and the DHW savings are larger than the Dryer savings.

| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
|---|---|---|---|---|---|
| Electric Dryer/Electric DHW | 133 | 0.50 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 49 | 0.18 | 0 | 0.34 | 0 |
| Electric Dryer/Natural Gas DHW | 49 | 0.18 | 0 | 0 | 0.34 |
| Electric Dryer/Oil DHW | 49 | 0.18 | 0.34 | 0 | 0 |
| Propane Dryer/Electric DHW | 85 | 0.32 | 0 | 0.16 | 0 |
| Propane Dryer/Propane DHW | 1 | 0.01 | 0 | 0.50 | 0 |
| Propane Dryer/Oil DHW | 1 | 0.01 | 0.50 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 85 | 0.32 | 0 | 0 | 0.16 |
| Natural Gas Dryer/Natural Gas DHW | 1 | 0.01 | 0 | 0 | 0.50 |
| Natural Gas Dryer/Oil DHW | 1 | 0.01 | 0.50 | 0 | 0.00 |

**Tier 2:**

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 227 | 0.86 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 89 | 0.34 | 0 | 0.55 | 0 |
| Electric Dryer/Natural Gas DHW | 89 | 0.34 | 0 | 0 | 0.55 |
| Electric Dryer/Oil DHW | 89 | 0.34 | 0.55 | 0 | 0 |
| Propane Dryer/Electric DHW | 144 | 0.54 | 0 | 0.28 | 0 |
| Propane Dryer/Propane DHW | 6 | 0.02 | 0 | 0.84 | 0 |
| Propane Dryer/Oil DHW | 6 | 0.02 | 0.84 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 144 | 0.54 | 0 | 0 | 0.28 |
| Natural Gas Dryer/Natural Gas DHW | 6 | 0.02 | 0 | 0 | 0.84 |
| Natural Gas Dryer/Oil DHW | 6 | 0.02 | 0.84 | 0 | 0.00 |

**Tier 3:**

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 286 | 1.08 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 102 | 0.39 | 0 | 0.73 | 0 |
| Electric Dryer/Natural Gas DHW | 102 | 0.39 | 0 | 0 | 0.73 |
| Electric Dryer/Oil DHW | 102 | 0.39 | 0.73 | 0 | 0 |
| Propane Dryer/Electric DHW | 188 | 0.71 | 0 | 0.33 | 0 |
| Propane Dryer/Propane DHW | 5 | 0.02 | 0 | 1.07 | 0 |
| Propane Dryer/Oil DHW | 5 | 0.02 | 1.07 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 188 | 0.71 | 0 | 0 | 0.33 |
| Natural Gas Dryer/Natural Gas DHW | 5 | 0.02 | 0 | 0 | 1.07 |
| Natural Gas Dryer/Oil DHW | 5 | 0.02 | 1.07 | 0 | 0.00 |

**Most Efficient:**

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 366 | 1.38 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 135 | 0.51 | 0 | 0.92 | 0 |
| Electric Dryer/Natural Gas DHW | 135 | 0.51 | 0 | 0 | 0.92 |
| Electric Dryer/Oil DHW | 135 | 0.51 | 0.92 | 0 | 0 |
| Propane Dryer/Electric DHW | 238 | 0.90 | 0 | 0.44 | 0 |
| Propane Dryer/Propane DHW | 7 | 0.02 | 0 | 1.36 | 0 |
| Propane Dryer/Oil DHW | 7 | 0.02 | 1.36 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 238 | 0.90 | 0 | 0 | 0.44 |
| Natural Gas Dryer/Natural Gas DHW | 7 | 0.02 | 0 | 0 | 1.36 |
| Natural Gas Dryer/Oil DHW | 7 | 0.02 | 1.36 | 0 | 0.00 |

**Top Ten:**

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 398 | 1.50 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 155 | 0.58 | 0 | 0.97 | 0 |
| Electric Dryer/Natural Gas DHW | 155 | 0.58 | 0 | 0 | 0.97 |
| Electric Dryer/Oil DHW | 155 | 0.58 | 0.97 | 0 | 0 |
| Propane Dryer/Electric DHW | 251 | 0.95 | 0 | 0.50 | 0 |
| Propane Dryer/Propane DHW | 8 | 0.03 | 0 | 1.47 | 0 |
| Propane Dryer/Oil DHW | 8 | 0.03 | 1.47 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 251 | 0.95 | 0 | 0 | 0.50 |
| Natural Gas Dryer/Natural Gas DHW | 8 | 0.03 | 0 | 0 | 1.47 |
| Natural Gas Dryer/Oil DHW | 8 | 0.03 | 1.47 | 0 | 0.00 |

# In-Unit Clothes Washer Retrofit

Measure Number: III-B-4-b (Low Income Multifamily Retrofit, Market Rate Multifamily Retrofit, Clothes Washing End Use)

**Version Date & Revision History**
Draft date: Portfolio 81
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**

1) 2013 MF Clothes Washer Savings_retrofit.xls
2) 2009 VT Appliance Data_TRMCostAnalysis.xls

**Description**
This is an early retrofit measure of an existing in unit inefficient clothes washer with a new clothes washer exceeding minimum qualifying efficiency standards established as ENERGY STAR, CEE Tier 2 or CEE Tier 3, Most Efficient or Top Ten (defined below). Savings are calculated between the average energy usage of an existing unit and that of the efficient unit for the remaining life of the existing unit, plus the savings between an average baseline unit and the efficient unit for the remainder of the measure life.

**Algorithms**

**Energy Savings**
Energy and Demand Savings are presented in the reference tables below, and are dependent on the fuel type of the DHW system and the dryer. The calculations are based on analysis of previous year's rebated units, see 2013 MF In unit Clothes Washer Savings.xls.

**Demand Savings**

$\Delta kW = \Delta kWh/Hours$

Where:

$\Delta kWh$ = gross customer annual kWh savings for the measure
$\Delta kW$ = gross customer connected load kW savings for the measure
Hours = Operating hours of clothes washer
= 265

**Baseline Efficiencies – New or Replacement**
The baseline efficiency is determined according to the modified energy factor (MEF) that takes into account the energy and water required per clothes washer cycle, including energy required by the clothes dryer per clothes washer cycle. For the purpose of this measure it is assumed that the remaining life of the existing clothes washer is 3 years (i.e. it is 11 years in to its 14 year life). The federal baseline for clothes washers prior to 2004 was 0.817 MEF[318], and the average value of units tested in a 2001 DOE market assessment was 1.164. For the remaining 11 years of the new clothes washer, the current federal baseline MEF of 1.26 is inflated by 20% to 1.51 to account for a transforming market.

**High Efficiency**
High efficiency is defined as any model meeting or exceeding the efficiency standards presented below.

| Efficiency Level | Modified Energy Factor (MEF) | Water Factor (WF) |
|---|---|---|
| ENERGY STAR | >= 2.0 | <= 6.0 |
| CEE TIER 2 | >= 2.20 | <= 4.5 |
| CEE TIER 3 | >= 2.40 | <= 4.0 |

[318] http://www.cee1.org/resid/seha/rwsh/press-rel.php3

| | | |
|---|---|---|
| ENERGY STAR Most Efficient (as of 1/1/2013) | >= 2.4 (for units <=2.5 ft3)<br>>= 3.2 (for units >2.5 ft3) | <= 4.5 (for units <=2.5 ft3)<br><= 3.0 (for units >2.5 ft3) |
| Top Ten | Defined as the ten most efficient units available. | |

The modified energy factor (MEF) measures energy consumption of the total laundry cycle (unit operation, washing and drying); the higher the number, the greater the efficiency.

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

Energy and water savings estimates are based on the weighted average MEF factor for qualifying models based on the models rebated during the previous calendar year, except Top Ten which is based upon averaging the units provided on the website (http://www.toptenusa.org/Top-Ten-Clothes-Washers) as of September 2012

**Operating Cycles**

265 clothes washer cycles / year [319]

**Operating Hours**

265 operating hours / year [320]

**Loadshape**

Loadshape #9, Residential Clothes Washing, Vermont State Screening Tool.

**Freeridership/Spillover Factors**

| Measure Category | | Cooking and Laundry | |
|---|---|---|---|
| Measure Code | | CKLESWER, CKLT2WER, CKLT3WER, CKLMEWER, CKLTTWER | |
| Product Description | | Energy Star Clothes Washer Early Replacement | |
| Track Name | Track No. | Freerider | Spillover |
| LIMF Retrofit | 6017RETR | 1.0 | 1.0 |
| MF Mkt Retro | 6020MFMR | 0.9 | 1.0 |

**Persistence**

The persistence factor is assumed to be one.

**Lifetimes**

14 years (same as DPS screening of Efficiency Utility program).
Analysis period is the same as the lifetime.

**Measure Cost**

The full measure cost assumption is provided below:

| Efficiency Level | Full Measure Cost |
|---|---|
| ENERGY STAR | $825 |
| CEE Tier 2 | $850 |
| CEE Tier 3 | $950 |
| ENERGY STAR Most Efficient | $1100 |
| Top Ten | $1110 |

[319] EVT found the average household size in MF buildings from the 2010 Census data (1.6 people, compared to 2.3 for single family) and using the values for number of loads for different household sizes (from DOE Technical Support Document U.S. Department of Energy, Final Rule Technical Support Document (TSD): Energy Efficiency Standards for Consumer Products: Clothes Washers, December, 2000. Page 7-6) and the 322 used for single families we estimate the number of loads for a MF building to be 265. See 2013 MF In unit Clothes Washer Savings.xls for calculation.

[320] Assume one hour per cycle.

The deferred (for 3 years) baseline replacement clothes washer cost is assumed to be $600.[321]

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
See reference tables below

**Water Descriptions**
The water savings for each efficiency level are presented below:

| Efficiency Level | WF | ΔWater (CCF per year) Remaining life of existing unit ( first 3 years) | Remaining measure life (Next 11 years) | Weighted average for use in screening[322] |
|---|---|---|---|---|
| Existing unit | 12.87[323] | n/a | n/a | |
| Federal Standard | 7.93 | n/a | n/a | |
| ENERGY STAR | 5.41 | 7.2 | 2.4 | 3.4 |
| CEE Tier 2 | 3.61 | 13.3 | 6.2 | 7.7 |
| CEE Tier 3 | 3.51 | 12.4 | 5.9 | 7.3 |
| ENERGY STAR Most Efficient | 2.90 | 13.8 | 7.0 | 8.5 |
| Top Ten | 3.54 | 13.6 | 6.4 | 7.9 |

**Reference Tables**

**Customer Energy Savings by Water Heater and Dryer Fuel Type[324]**

**ENERGY STAR**
For remaining life of existing unit (first 3 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 276 | 1.05 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 142 | 0.54 | 0 | 0.58 | 0 |
| Electric Dryer/Natural Gas DHW | 142 | 0.54 | 0 | 0 | 0.58 |
| Electric Dryer/Oil DHW | 142 | 0.54 | 0.58 | 0 | 0 |
| Propane Dryer/Electric DHW | 144 | 0.54 | 0 | 0.45 | 0 |
| Propane Dryer/Propane DHW | 9 | 0.04 | 0 | 1.03 | 0 |
| Propane Dryer/Oil DHW | 9 | 0.04 | 1.03 | 0.00 | 0 |

[321] Based on weighted average of top loading and front loading units (based on available product from the CEC Appliance database) and cost data from Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_standard.xlsm. See '2013 MF In unit Clothes Washer Savings_Retrofit.xls' for details.
[322] Efficiency Vermont's screening tool does not allow for mid-life savings adjustments for water, thus a single value is required.
[323] US DOE, Life Cycle Cost Model, spreadsheet dated December 1999 (http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/lcc_spreadsheet.xls), indicates 38.61 gallons of water per cycle. Assume average size of 3 cu ft gives 12.87 WF assumption. http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/lcc_spreadsheet.xls
[324] Where dryer and DHW use different fossil fuels, savings are combined under the DHW fossil fuel because a single measure can only have one fuel type for screening purposes and the DHW savings are larger than the dryer savings.

| | | | | | |
|---|---|---|---|---|---|
| Natural Gas Dryer/Electric DHW | 144 | 0.54 | 0 | 0 | 0.45 |
| Natural Gas Dryer/Natural Gas DHW | 9 | 0.04 | 0 | 0 | 1.03 |
| Natural Gas Dryer/Oil DHW | 9 | 0.04 | 1.03 | 0 | 0.00 |

For remaining measure life (Next 11 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 133 | 0.50 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 49 | 0.18 | 0 | 0.36 | 0 |
| Electric Dryer/Natural Gas DHW | 49 | 0.18 | 0 | 0 | 0.36 |
| Electric Dryer/Oil DHW | 49 | 0.18 | 0.36 | 0 | 0 |
| Propane Dryer/Electric DHW | 85 | 0.32 | 0 | 0.16 | 0 |
| Propane Dryer/Propane DHW | 1 | 0.01 | 0 | 0.52 | 0 |
| Propane Dryer/Oil DHW | 1 | 0.01 | 0.52 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 85 | 0.32 | 0 | 0 | 0.16 |
| Natural Gas Dryer/Natural Gas DHW | 1 | 0.01 | 0 | 0 | 0.52 |
| Natural Gas Dryer/Oil DHW | 1 | 0.01 | 0.52 | 0 | 0.00 |

**CEE T2**

For remaining life of existing unit (first 3 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 439 | 1.66 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 227 | 0.86 | 0 | 0.91 | 0 |
| Electric Dryer/Natural Gas DHW | 227 | 0.86 | 0 | 0 | 0.91 |
| Electric Dryer/Oil DHW | 227 | 0.86 | 0.91 | 0 | 0 |
| Propane Dryer/Electric DHW | 230 | 0.87 | 0 | 0.71 | 0 |
| Propane Dryer/Propane DHW | 18 | 0.07 | 0 | 1.63 | 0 |
| Propane Dryer/Oil DHW | 18 | 0.07 | 1.63 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 230 | 0.87 | 0 | 0 | 0.71 |
| Natural Gas Dryer/Natural Gas DHW | 18 | 0.07 | 0 | 0 | 1.63 |
| Natural Gas Dryer/Oil DHW | 18 | 0.07 | 1.63 | 0 | 0.00 |

For remaining measure life (Next 11 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 227 | 0.86 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 89 | 0.34 | 0 | 0.59 | 0 |
| Electric Dryer/Natural Gas DHW | 89 | 0.34 | 0 | 0 | 0.59 |
| Electric Dryer/Oil DHW | 89 | 0.34 | 0.59 | 0 | 0 |

| | | | | | |
|---|---|---|---|---|---|
| Propane Dryer/Electric DHW | 144 | 0.54 | 0 | 0.28 | 0 |
| Propane Dryer/Propane DHW | 6 | 0.02 | 0 | 0.88 | 0 |
| Propane Dryer/Oil DHW | 6 | 0.02 | 0.88 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 144 | 0.54 | 0 | 0 | 0.28 |
| Natural Gas Dryer/Natural Gas DHW | 6 | 0.02 | 0 | 0 | 0.88 |
| Natural Gas Dryer/Oil DHW | 6 | 0.02 | 0.88 | 0 | 0.00 |

**CEE T3**

For remaining life of existing unit (first 3 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 482 | 1.82 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 229 | 0.87 | 0 | 1.09 | 0 |
| Electric Dryer/Natural Gas DHW | 229 | 0.87 | 0 | 0 | 1.09 |
| Electric Dryer/Oil DHW | 229 | 0.87 | 1.09 | 0 | 0 |
| Propane Dryer/Electric DHW | 268 | 1.01 | 0 | 0.73 | 0 |
| Propane Dryer/Propane DHW | 15 | 0.06 | 0 | 1.82 | 0 |
| Propane Dryer/Oil DHW | 15 | 0.06 | 1.82 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 268 | 1.01 | 0 | 0 | 0.73 |
| Natural Gas Dryer/Natural Gas DHW | 15 | 0.06 | 0 | 0 | 1.82 |
| Natural Gas Dryer/Oil DHW | 15 | 0.06 | 1.82 | 0 | 0.00 |

For remaining measure life (Next 11 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 286 | 1.08 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 102 | 0.39 | 0 | 0.79 | 0 |
| Electric Dryer/Natural Gas DHW | 102 | 0.39 | 0 | 0 | 0.79 |
| Electric Dryer/Oil DHW | 102 | 0.39 | 0.79 | 0 | 0 |
| Propane Dryer/Electric DHW | 188 | 0.71 | 0 | 0.33 | 0 |
| Propane Dryer/Propane DHW | 5 | 0.02 | 0 | 1.12 | 0 |
| Propane Dryer/Oil DHW | 5 | 0.02 | 1.12 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 188 | 0.71 | 0 | 0 | 0.33 |
| Natural Gas Dryer/Natural Gas DHW | 5 | 0.02 | 0 | 0 | 1.12 |
| Natural Gas Dryer/Oil DHW | 5 | 0.02 | 1.12 | 0 | 0.00 |

**Most Efficient**

For remaining life of existing unit (first 3 years):

| | Per Unit Savings |
|---|---|

| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
|---|---|---|---|---|---|
| Electric Dryer/Electric DHW | 571 | 2.16 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 268 | 1.01 | 0 | 1.30 | 0 |
| Electric Dryer/Natural Gas DHW | 268 | 1.01 | 0 | 0 | 1.30 |
| Electric Dryer/Oil DHW | 268 | 1.01 | 1.30 | 0 | 0 |
| Propane Dryer/Electric DHW | 321 | 1.21 | 0 | 0.85 | 0 |
| Propane Dryer/Propane DHW | 18 | 0.07 | 0 | 2.16 | 0 |
| Propane Dryer/Oil DHW | 18 | 0.07 | 2.16 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 321 | 1.21 | 0 | 0 | 0.85 |
| Natural Gas Dryer/Natural Gas DHW | 18 | 0.07 | 0 | 0 | 2.16 |
| Natural Gas Dryer/Oil DHW | 18 | 0.07 | 2.16 | 0 | 0.00 |

For remaining measure life (Next 11 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 366 | 1.38 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 135 | 0.51 | 0 | 0.99 | 0 |
| Electric Dryer/Natural Gas DHW | 135 | 0.51 | 0 | 0 | 0.99 |
| Electric Dryer/Oil DHW | 135 | 0.51 | 0.99 | 0 | 0 |
| Propane Dryer/Electric DHW | 238 | 0.90 | 0 | 0.44 | 0 |
| Propane Dryer/Propane DHW | 7 | 0.02 | 0 | 1.43 | 0 |
| Propane Dryer/Oil DHW | 7 | 0.02 | 1.43 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 238 | 0.90 | 0 | 0 | 0.44 |
| Natural Gas Dryer/Natural Gas DHW | 7 | 0.02 | 0 | 0 | 1.43 |
| Natural Gas Dryer/Oil DHW | 7 | 0.02 | 1.43 | 0 | 0.00 |

**Top Ten**

For remaining life of existing unit (first 3 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 613 | 2.32 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 294 | 1.11 | 0 | 1.37 | 0 |
| Electric Dryer/Natural Gas DHW | 294 | 1.11 | 0 | 0 | 1.37 |
| Electric Dryer/Oil DHW | 294 | 1.11 | 1.37 | 0 | 0 |
| Propane Dryer/Electric DHW | 339 | 1.28 | 0 | 0.94 | 0 |
| Propane Dryer/Propane DHW | 20 | 0.08 | 0 | 2.31 | 0 |
| Propane Dryer/Oil DHW | 20 | 0.08 | 2.31 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 339 | 1.28 | 0 | 0 | 0.94 |
| Natural Gas Dryer/Natural Gas DHW | 20 | 0.08 | 0 | 0 | 2.31 |
| Natural Gas Dryer/Oil DHW | 20 | 0.08 | 2.31 | 0 | 0.00 |

For remaining measure life (Next 11 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 398 | 1.50 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 155 | 0.58 | 0 | 1.05 | 0 |
| Electric Dryer/Natural Gas DHW | 155 | 0.58 | 0 | 0 | 1.05 |
| Electric Dryer/Oil DHW | 155 | 0.58 | 1.05 | 0 | 0 |
| Propane Dryer/Electric DHW | 251 | 0.95 | 0 | 0.50 | 0 |
| Propane Dryer/Propane DHW | 8 | 0.03 | 0 | 1.55 | 0 |
| Propane Dryer/Oil DHW | 8 | 0.03 | 1.55 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 251 | 0.95 | 0 | 0 | 0.50 |
| Natural Gas Dryer/Natural Gas DHW | 8 | 0.03 | 0 | 0 | 1.55 |
| Natural Gas Dryer/Oil DHW | 8 | 0.03 | 1.55 | 0 | 0.00 |

# Common Area Clothes Washer Retrofit

Measure Number: III-B-5-b (Low Income Multifamily Retrofit, Market Rate Multifamily Retrofit, Clothes Washing End Use)

**Version Date & Revision History**
Draft date: Portfolio 81
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**
1) 2013 MF Common Clothes Washer Savings_retrofit.xls

**Description**
This is an early retrofit measure of an existing inefficient clothes washer in a central onsite laundry facility, with a new clothes washer exceeding minimum qualifying efficiency standards established as ENERGY STAR, CEE Tier 2 or CEE Tier 3 Most Efficient or Top Ten (defined below).. Savings are calculated between the average energy usage of an existing unit and that of the efficient unit for the remaining life of the existing unit, plus the savings between an average baseline unit and the efficient unit for the remainder of the measure life. Note these savings are for one unit usage. Total savings is therefore calculated by multiplying by number of units (apartments) using the clothes washer as presented below:

**Algorithms**

**Energy Savings**
Energy and Demand Savings are presented in the reference tables below, and are dependent on the fuel type of the DHW system and the dryer. The calculations are based on analysis of previous year's rebated units through Efficient Products (see Efficient Product measure for write up of savings methodology). The savings are presented for each efficiency level in the reference table below titled "Customer Energy Savings by Water Heater and Dryer Fuel Type", and the calculation can be reviewed in 2013 MF Common Clothes Washer Savings.xls.
Note these savings are for one unit (apartment) usage. Total savings is therefore calculated by multiplying by number of units using the clothes washer as presented below:

$$\Delta kWh = NumUnits \times kWh_{save} / NumWashers$$

Where:

$\Delta kWh$ = gross annual customer kWh savings per clothes washer for the measure
NumUnits = number of residential units (apartments) served by the central laundry facility
$kWh_{save}$ = annual customer kWh savings per residential unit for the measure
NumWashers = total number of clothes washers in central laundry facility

**Demand Savings**

$$\Delta kW = NumUnits \times kW_{save} / NumWashers$$

Where:

$\Delta kW$ = gross annual customer kW savings per clothes washer for the measure
kWsave = annual customer kW savings per residential unit for the measure

**Baseline Efficiencies – New or Replacement**
The baseline efficiency is determined according to the modified energy factor (MEF) that takes into account the energy and water required per clothes washer cycle, including energy required by the clothes dryer per clothes washer cycle. For the purpose of this measure it is assumed that the remaining life of the existing clothes washer is 3 years (i.e. it is 11 years in to its 14 year life). The federal baseline for clothes washers prior to 2004 was 0.817 MEF[325], and the average value of units tested in a 2001 DOE market assessment was 1.164. For the remaining 11 years of the new

[325] http://www.cee1.org/resid/seha/rwsh/press-rel.php3

clothes washer, the current federal baseline MEF of 1.26 is inflated by 20% to 1.51 to account for a transforming market. See 2013 MF Common Clothes Washer Savings_retrofit.xls for more details.

**High Efficiency**
High efficiency is defined as any model meeting or exceeding the efficiency standards presented below.

| Efficiency Level | Modified Energy Factor (MEF) | Water Factor (WF) |
|---|---|---|
| ENERGY STAR | >= 2.0 | <= 6.0 |
| CEE TIER 2 | >= 2.20 | <= 4.5 |
| CEE TIER 3 | >= 2.40 | <= 4.0 |
| ENERGY STAR Most Efficient (as of 1/1/2013) | >= 2.4 (for units <=2.5 ft3)<br>>= 3.2 (for units >2.5 ft3) | <= 4.5 (for units <=2.5 ft3)<br><= 3.0 (for units >2.5 ft3) |
| Top Ten | Defined as the ten most efficient units available. | |

The modified energy factor (MEF) measures energy consumption of the total laundry cycle (unit operation, washing and drying); the higher the number, the greater the efficiency.

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

Energy and water savings estimates are based on the weighted average MEF factor for qualifying models based on the models rebated during the previous calendar year, except Top Ten which is based upon averaging the units provided on the website (http://www.toptenusa.org/Top-Ten-Clothes-Washers) as of September 2012.

**Operating Cycles**
265 clothes washer cycles / per apartment / year [326]

**Operating Hours**
265 operating hours / apartment / year [327]

**Loadshape**
Loadshape #9, Residential Clothes Washing, Vermont State Screening Tool.

**Freeridership/Spillover Factors**

| Measure Category | | Cooking and Laundry | |
|---|---|---|---|
| Measure Code | | CKLESWER, CKLT2WER, CKLT3WER, CKLMEWER, CKLTTWER | |
| Product Description | | Energy Star Clothes Washer Early Replacement | |
| Track Name | Track No. | Freerider | Spillover |
| LIMF Retrofit | 6017RETR | 1.0 | 1.0 |
| MF Mkt Retro | 6020MFMR | 0.9 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
14 years [328] (same as DPS screening of Efficiency Utility program).

[326] EVT found the average household size in MF buildings from the 2010 Census data (1.6 people, compared to 2.3 for single family) and using the values for number of loads for different household sizes (from DOE Technical Support Document U.S. Department of Energy, Final Rule Technical Support Document (TSD): Energy Efficiency Standards for Consumer Products: Clothes Washers, December, 2000. Page 7-6) and the 322 used for single families we estimate the number of loads for a MF building to be 265 per unit. See file 2013 MF Common Clothes Washer Savings_Retrofit.xls.
[327] Assume one hour per cycle.

Analysis period is the same as the lifetime.

**Measure Cost**
The full measure cost assumption is provided below[329]:

| Efficiency Level | Full Measure Cost |
|---|---|
| ENERGY STAR | $1035 |
| CEE Tier 2 | $1300 |
| CEE Tier 3 | $1550 |
| ENERGY STAR Most Efficient | $1900 |
| Top Ten | $1950 |

The deferred (for 3 years) baseline replacement clothes washer cost is assumed to be $650.[330]

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
See reference tables below

MMBtu = NumUnits × $MMBtu_{save}$. / NumWashers

Where:

ΔMMBtu = gross annual fossil fuel energy savings in MMBtu (million Btu) per clothes washer for the measure
NumUnits = number of residential units served by the central laundry facility
$MMBtu_{save}$ = annual *customer* MMBtu of fossil fuel savings per residential unit for the measure from reference table below
NumWashers = total number of clothes washers in central laundry facility

**Water Descriptions**
ΔCCF = NumUnits × $CCF_{save}$ / NumWashers

Where:

ΔCCF = annual *customer* water savings per clothes washer in CCF (hundreds of cubic feet)
NumUnits = number of residential units served by the central laundry facility
$CCF_{save}$ [331] = annual *customer* water savings per clothes washer per residential unit for the measure, in CCF (hundreds of cubic feet)

| Efficiency Level | WF | ΔWater (CCF per year) |
|---|---|---|

[328] Based on DOE Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_standard.xlsm.
[329] Based on EVT field study of clothes washer costs, see 2013 MF Common Clothes Washer Savings_retrofit.xls. Measure cost is higher than in-unit clothes washers since the common units are larger commercial and more expensive models.
[330] Based on weighted average of top loading and front loading units (based on available product from the CEC Appliance database) and cost data from Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_standard.xlsm. See '2013 MF In unit Clothes Washer Savings_Retrofit.xls' for details.
[331] Water savings based on weighted average of 261. See file 2013 MF Common Clothes Washer Savings_Retrofit.xls.

| | | Remaining life of existing unit (first 3 years) | Remaining measure life (Next 11 years) | Weighted average for use in screening[332] |
|---|---|---|---|---|
| Existing unit | 12.87[333] | n/a | n/a | n/a |
| Federal Standard | 7.93 | n/a | n/a | n/a |
| ENERGY STAR | 5.41 | 7.2 | 2.4 | 3.4 |
| CEE Tier 2 | 3.61 | 13.1 | 6.1 | 7.6 |
| CEE Tier 3 | 3.51 | 12.3 | 5.8 | 7.2 |
| ENERGY STAR Most Efficient | 2.90 | 13.6 | 6.9 | 8.3 |
| Top Ten | 3.54 | 13.4 | 6.3 | 7.8 |

NumWashers = total number of clothes washers in central laundry facility

**Reference Tables**

**Customer Energy Savings by Water Heater and Dryer Fuel Type**[334]

**ENERGY STAR**

For remaining life of existing unit (first 3 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 276 | 1.05 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 142 | 0.54 | 0 | 0.58 | 0 |
| Electric Dryer/Natural Gas DHW | 142 | 0.54 | 0 | 0 | 0.58 |
| Electric Dryer/Oil DHW | 142 | 0.54 | 0.58 | 0 | 0 |
| Propane Dryer/Electric DHW | 144 | 0.54 | 0 | 0.45 | 0 |
| Propane Dryer/Propane DHW | 9 | 0.04 | 0 | 1.03 | 0 |
| Propane Dryer/Oil DHW | 9 | 0.04 | 1.03 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 144 | 0.54 | 0 | 0 | 0.45 |
| Natural Gas Dryer/Natural Gas DHW | 9 | 0.04 | 0 | 0 | 1.03 |
| Natural Gas Dryer/Oil DHW | 9 | 0.04 | 1.03 | 0 | 0.00 |

For remaining measure life (Next 11 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 133 | 0.50 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 49 | 0.18 | 0 | 0.36 | 0 |
| Electric Dryer/Natural Gas DHW | 49 | 0.18 | 0 | 0 | 0.36 |

[332] Efficiency Vermont's screening tool does not allow for mid-life savings adjustments for water, thus a single value is required.
[333] US DOE, Life Cycle Cost Model, spreadsheet dated December 1999 (http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/lcc_spreadsheet.xls) , indicates 38.61 gallons of water per cycle. Assume average size of 3 cu ft gives 12.87 WF assumption. http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/lcc_spreadsheet.xls
[334] Where dryer and DHW use different fossil fuels, savings are combined under the DHW fossil fuel because a single measure can only have one fuel type for screening purposes and the DHW savings are larger than the dryer savings.

| | | | | | |
|---|---|---|---|---|---|
| Electric Dryer/Oil DHW | 49 | 0.18 | 0.36 | 0 | 0 |
| Propane Dryer/Electric DHW | 85 | 0.32 | 0 | 0.16 | 0 |
| Propane Dryer/Propane DHW | 1 | 0.01 | 0 | 0.52 | 0 |
| Propane Dryer/Oil DHW | 1 | 0.01 | 0.52 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 85 | 0.32 | 0 | 0 | 0.16 |
| Natural Gas Dryer/Natural Gas DHW | 1 | 0.01 | 0 | 0 | 0.52 |
| Natural Gas Dryer/Oil DHW | 1 | 0.01 | 0.52 | 0 | 0.00 |

**CEE T2**

For remaining life of existing unit (first 3 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 439 | 1.66 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 227 | 0.86 | 0 | 0.91 | 0 |
| Electric Dryer/Natural Gas DHW | 227 | 0.86 | 0 | 0 | 0.91 |
| Electric Dryer/Oil DHW | 227 | 0.86 | 0.91 | 0 | 0 |
| Propane Dryer/Electric DHW | 230 | 0.87 | 0 | 0.71 | 0 |
| Propane Dryer/Propane DHW | 18 | 0.07 | 0 | 1.63 | 0 |
| Propane Dryer/Oil DHW | 18 | 0.07 | 1.63 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 230 | 0.87 | 0 | 0 | 0.71 |
| Natural Gas Dryer/Natural Gas DHW | 18 | 0.07 | 0 | 0 | 1.63 |
| Natural Gas Dryer/Oil DHW | 18 | 0.07 | 1.63 | 0 | 0.00 |

For remaining measure life (Next 11 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 227 | 0.86 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 89 | 0.34 | 0 | 0.59 | 0 |
| Electric Dryer/Natural Gas DHW | 89 | 0.34 | 0 | 0 | 0.59 |
| Electric Dryer/Oil DHW | 89 | 0.34 | 0.59 | 0 | 0 |
| Propane Dryer/Electric DHW | 144 | 0.54 | 0 | 0.28 | 0 |
| Propane Dryer/Propane DHW | 6 | 0.02 | 0 | 0.88 | 0 |
| Propane Dryer/Oil DHW | 6 | 0.02 | 0.88 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 144 | 0.54 | 0 | 0 | 0.28 |
| Natural Gas Dryer/Natural Gas DHW | 6 | 0.02 | 0 | 0 | 0.88 |
| Natural Gas Dryer/Oil DHW | 6 | 0.02 | 0.88 | 0 | 0.00 |

**CEE T3**

For remaining life of existing unit (first 3 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 482 | 1.82 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 229 | 0.87 | 0 | 1.09 | 0 |
| Electric Dryer/Natural Gas DHW | 229 | 0.87 | 0 | 0 | 1.09 |
| Electric Dryer/Oil DHW | 229 | 0.87 | 1.09 | 0 | 0 |
| Propane Dryer/Electric DHW | 268 | 1.01 | 0 | 0.73 | 0 |
| Propane Dryer/Propane DHW | 15 | 0.06 | 0 | 1.82 | 0 |
| Propane Dryer/Oil DHW | 15 | 0.06 | 1.82 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 268 | 1.01 | 0 | 0 | 0.73 |
| Natural Gas Dryer/Natural Gas DHW | 15 | 0.06 | 0 | 0 | 1.82 |
| Natural Gas Dryer/Oil DHW | 15 | 0.06 | 1.82 | 0 | 0.00 |

For remaining measure life (Next 11 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 286 | 1.08 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 102 | 0.39 | 0 | 0.79 | 0 |
| Electric Dryer/Natural Gas DHW | 102 | 0.39 | 0 | 0 | 0.79 |
| Electric Dryer/Oil DHW | 102 | 0.39 | 0.79 | 0 | 0 |
| Propane Dryer/Electric DHW | 188 | 0.71 | 0 | 0.33 | 0 |
| Propane Dryer/Propane DHW | 5 | 0.02 | 0 | 1.12 | 0 |
| Propane Dryer/Oil DHW | 5 | 0.02 | 1.12 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 188 | 0.71 | 0 | 0 | 0.33 |
| Natural Gas Dryer/Natural Gas DHW | 5 | 0.02 | 0 | 0 | 1.12 |
| Natural Gas Dryer/Oil DHW | 5 | 0.02 | 1.12 | 0 | 0.00 |

**Most Efficient**

For remaining life of existing unit (first 3 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 571 | 2.16 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 268 | 1.01 | 0 | 1.30 | 0 |
| Electric Dryer/Natural Gas DHW | 268 | 1.01 | 0 | 0 | 1.30 |
| Electric Dryer/Oil DHW | 268 | 1.01 | 1.30 | 0 | 0 |
| Propane Dryer/Electric DHW | 321 | 1.21 | 0 | 0.85 | 0 |
| Propane Dryer/Propane DHW | 18 | 0.07 | 0 | 2.16 | 0 |
| Propane Dryer/Oil DHW | 18 | 0.07 | 2.16 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 321 | 1.21 | 0 | 0 | 0.85 |

| | | | | | |
|---|---|---|---|---|---|
| Natural Gas Dryer/Natural Gas DHW | 18 | 0.07 | 0 | 0 | 2.16 |
| Natural Gas Dryer/Oil DHW | 18 | 0.07 | 2.16 | 0 | 0.00 |

For remaining measure life (Next 11 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 366 | 1.38 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 135 | 0.51 | 0 | 0.99 | 0 |
| Electric Dryer/Natural Gas DHW | 135 | 0.51 | 0 | 0 | 0.99 |
| Electric Dryer/Oil DHW | 135 | 0.51 | 0.99 | 0 | 0 |
| Propane Dryer/Electric DHW | 238 | 0.90 | 0 | 0.44 | 0 |
| Propane Dryer/Propane DHW | 7 | 0.02 | 0 | 1.43 | 0 |
| Propane Dryer/Oil DHW | 7 | 0.02 | 1.43 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 238 | 0.90 | 0 | 0 | 0.44 |
| Natural Gas Dryer/Natural Gas DHW | 7 | 0.02 | 0 | 0 | 1.43 |
| Natural Gas Dryer/Oil DHW | 7 | 0.02 | 1.43 | 0 | 0.00 |

**Top Ten**

For remaining life of existing unit (first 3 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 613 | 2.32 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 294 | 1.11 | 0 | 1.37 | 0 |
| Electric Dryer/Natural Gas DHW | 294 | 1.11 | 0 | 0 | 1.37 |
| Electric Dryer/Oil DHW | 294 | 1.11 | 1.37 | 0 | 0 |
| Propane Dryer/Electric DHW | 339 | 1.28 | 0 | 0.94 | 0 |
| Propane Dryer/Propane DHW | 20 | 0.08 | 0 | 2.31 | 0 |
| Propane Dryer/Oil DHW | 20 | 0.08 | 2.31 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 339 | 1.28 | 0 | 0 | 0.94 |
| Natural Gas Dryer/Natural Gas DHW | 20 | 0.08 | 0 | 0 | 2.31 |
| Natural Gas Dryer/Oil DHW | 20 | 0.08 | 2.31 | 0 | 0.00 |

For remaining measure life (Next 11 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 398 | 1.50 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 155 | 0.58 | 0 | 1.05 | 0 |
| Electric Dryer/Natural Gas DHW | 155 | 0.58 | 0 | 0 | 1.05 |
| Electric Dryer/Oil DHW | 155 | 0.58 | 1.05 | 0 | 0 |
| Propane Dryer/Electric DHW | 251 | 0.95 | 0 | 0.50 | 0 |
| Propane Dryer/Propane DHW | 8 | 0.03 | 0 | 1.55 | 0 |

| | | | | | |
|---|---|---|---|---|---|
| Propane Dryer/Oil DHW | 8 | 0.03 | 1.55 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 251 | 0.95 | 0 | 0 | 0.50 |
| Natural Gas Dryer/Natural Gas DHW | 8 | 0.03 | 0 | 0 | 1.55 |
| Natural Gas Dryer/Oil DHW | 8 | 0.03 | 1.55 | 0 | 0.00 |

## Refrigeration End Use
# Energy Efficient Refrigerators

Measure Number: III-C-1-e (Multifamily New Construction Program, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 74
Effective: 1/1/2012
End: TBD

**Referenced Documents:** 1) 2011 RF Savings Analysis.xls;
2) 2009 VT Appliance Data w doc_CostAnalysisTRM
3) SFvMF Refrigerator Retrofit.xls

**Description**
A refrigerator meeting either Energy Star specifications or the higher efficiency specifications of a CEE Tier 2, or CEE Tier 3 rated refrigerator is installed instead of a new unit of baseline efficiency.

**Algorithms**

**Energy Savings**[335]

**ENERGY STAR:**
$\Delta kWh = (kWh_{base} - kWh_{ES}) * MF_{size\ factor}$
$= (578.8 – 463.0) * 0.72$
$= 83.4$

**CEE Tier 2:**
$\Delta kWh = (kWh_{base} - kWh_{CT2}) * MF_{size\ factor}$
$\Delta kWh = (578.8 – 434.1) * 0.72$
$= 104.2$

**CEE Tier 3:**
$\Delta kWh_{CT3} = (kWh_{base} - kWh_{CT3}) * MF_{size\ factor}$
$\Delta kWh_{CT3} = (578.8 – 405.1) * 0.72$
$= 125.1$

Where:

| | |
|---|---|
| $\Delta kW$ | = gross customer connected load kW savings for the measure |
| $kWh_{base}$ | = Baseline unit consumption |
| $kWh_{ES}$ | = Energy-Star unit consumption |
| $kWh_{CT2}$ | = CEE Tier 2 unit consumption |
| $kWh_{CT3}$ | = CEE Tier 3 unit consumption |
| $\Delta kWh$ | = gross customer annual kWh savings for the measure |
| HOURS | = average hours of use per year |
| $MF_{size\ factor}$ | = Factor applied to the savings derived based on Residential Program to account for smaller units being installed in Multi Family buildings. = 0.72[336] |

[335] Delta watts is based on analysis of previous year's rebated units through Efficient Products, see 2011 RF Savings Analysis.xls. When this characterization is updated, this TRM entry will be adjusted accordingly.
[336] Size Factor is calculated by comparing the average MF retrofitted energy savings per unit (525kwh) to the average single family residential retrofitted energy savings (726kWh) indicating a 72% savings factor. See SFvMF Refrigerator Retrofit.xls.

**Demand Savings**[337]

**ENERGY STAR:**

$\Delta kW = \Delta kWh_{ES}$ / Hours

$\Delta kW = 83.4 / 5000$

$= 0.0167$

**CEE Tier 2:**

$\Delta kW = \Delta kWh_{CT2}$ / Hours

$\Delta kW = 104.2/ 5000$

$= 0.0208$

**CEE Tier 3:**

$\Delta kW_{CT3} = \Delta kWh_{CT3}$ / Hours

$\Delta kW_{CT3} = 125.1 / 5000$

$=0.0250$

**Baseline Efficiencies – New**

Baseline efficiency is an existing refrigerator or new refrigerator meeting the minimum federal efficiency standard for refrigerator efficiency.

**High Efficiency**

The High Efficiency level is a refrigerator meeting Energy Star specifications for efficiency effective on April 28th, 2008 (20% above federal standard), a refrigerator meeting CEE Tier 2 specifications (25% above federal standard), or meeting CEE Tier 3 specifications (30% above federal standards).

**Operating Hours**

5000 hours / year

**Loadshape**

Loadshape #4, Residential Refrigeration

**Freeridership/ Spillover Factors**

| Measure Category | | Refrigeration | |
|---|---|---|---|
| Measure Codes | | RFRESRRP, RFRESRT2, RFRESRT3 | |
| Product Description | | Energy Star refrigerator, CEE Tier 2, CEE Tier 3 | |
| Track Name | Track No. | Freerider | Spillover |
| LIMF NC | 6018LINC | 1.0 | 1.0 |
| LIMF Rehab | 6018LIRH | 1.0 | 1.0 |
| MF Mkt NC | 6019MFNC | 0.9 | 1.0 |

**Persistence**

The persistence factor is assumed to be one.

**Lifetimes**

17 years (same as in DPS screening of Efficiency Utility Core programs).
Analysis period is the same as the lifetime.

**Measure Cost**

The incremental cost to the Energy Star level is $49, to CEE Tier 2 level is $105 and to CEE Tier 3 is $158[338].

[337] Based on analysis of previous year's rebated units, see 2011 RF Savings Analysis.xls.

[338] Based on review of data from the Northeast Regional ENERGY STAR Consumer Products Initiative; “2009 ENERGY STAR Appliances Practices Report”, submitted by Lockheed Martin, December 2009. See 2009 VT

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

Appliance Data_TRMCostAnalysis.xlsfor data. These incremental costs ($70 for ENERGY STAR, $150 for CEE Tier 2 and $225 for CEE Tier 3) are multiplied by the 70% size factor to account for the smaller units being installed in MF.

# Refrigerator Early Replacement

Measure Number: III-C-2-b
(Low Income Multifamily Retrofit, Market Rate Multifamily Retrofit, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 80
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**

1) 2012 Refrigerator Retrofit Savings.xls
2) SFvMF Refrigerator Retrofit.xls
3) http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf
4) Refrigerator kW Calculations.xls

**Description**
This is an early replacement measure of an existing pre-2001 inefficient refrigerator with a new refrigerator exceeding minimum qualifying efficiency standards established as Energy Star or optionally CEE Tier 2 and CEE Tier 3. Savings are calculated between the average energy usage of an existing unit and that of a higher efficiency unit for the remaining life of the existing unit, plus the savings between an average baseline unit and that of a higher efficiency unit for the remainder of the measure life. Prior to 2012, eligibility was restricted to pre-1993 refrigerators. Efficiency Vermont has decided to expand eligibility to the next refrigerator standard change (2001). The estimated decrease in consumption of a post-1993 / pre-2001 unit over a pre-1993 unit is 43%. EVT has assumed that 30% of the future replacements will fall in to the 1993-2001 category[339] and have adjusted the savings accordingly (see '2012 Refrigerator Retrofit Savings.xls' for more details). We will review this assumption after a year and adjust as necessary.

**Algorithms**

**Energy Savings**
Savings are based on applying a multifamily size factor adjustment (72%) to the single family based values.

| | | |
|---|---|---|
| ΔkWh – Energy Star for remaining life of existing unit (3 years) | = 709 * 0.72 | = 510 kWh |
| ΔkWh – CEE Tier 2 for remaining life of existing unit (3 years) | = 737 * 0.72 | = 530 kWh |
| ΔkWh – CEE Tier 3 for remaining life of existing unit (3 years) | = 764 * 0.72 | = 550 kWh |
| ΔkWh – Energy Star for remaining measure life (9 years) | = 113 * 0.72 | = 81 kWh |
| ΔkWh – CEE Tier 2 for remaining measure life (9 years) | = 141 * 0.72 | = 102 kWh |
| ΔkWh – CEE Tier 3 for remaining measure life (9 years) | = 169 * 0.72 | = 122 kWh |

**Demand Savings**
ΔkW = ΔkWh/Hours

| | | |
|---|---|---|
| ΔkW – Energy Star for remaining life of existing unit (3 years) | = 510/8477 | = 0.060 kW |
| ΔkW – CEE Tier 2 for remaining life of existing unit (3 years) | = 530/8477 | = 0.063 kW |
| ΔkW – CEE Tier 3 for remaining life of existing unit (3 years) | = 550/8477 | = 0.065 kW |
| ΔkW – Energy Star for remaining measure life (9 years) | = 81/8477 | = 0.010 kW |
| ΔkW – CEE Tier 2 for remaining measure life (9 years) | = 102/8477 | = 0.012 kW |
| ΔkW – CEE Tier 3 for remaining measure life (9 years) | = 122/8477 | = 0.014 kW |

Where:

[339] Based upon conversations with the weatherization agencies.

ΔkWh = gross customer annual kWh savings for the measure

HOURS = Equivalent Full Load Hours
= 8477[340]

ΔkW = gross customer connected load kW savings for the measure

$MF_{size\ factor}$ = Factor applied to the savings derived based on Residential Program to account for smaller units being installed in Multi Family buildings.
= 0.72[341]

**Baseline Efficiencies – New or Replacement**

The existing pre-2001 refrigerator baseline consumption is estimated using actual meter measurements from replacements installed through EVT from 2008-2009[342]. For the purpose of this measure it is assumed that the remaining life of the existing refrigerator is 3 years. For the remaining 14 years of the new refrigerator, the 2001 federal minimum standard is set as the baseline efficiency. See 2012 Refrigerator Retrofit Savings.xls for more details.

**High Efficiency**

High efficiency is defined as any model meeting or exceeding 2007 Energy Star standard – currently set to 20% over the 2001 federal minimum standard or optionally 25% or 30% to meet CEE Tier 2 or Tier 3. EVT's energy savings estimates are based on the weighted average test measurements for qualifying models based on the models rebated during the previous calendar year.

**Loadshape**

Loadshape #4, Residential Refrigerator

**Freeridership/Spillover Factors**

| Measure Category | | Refrigeration | |
|---|---|---|---|
| Measure Code | | RFRESRER, RFRT2RER, RFRT3RER | |
| Product Description | | Energy Star Refrigerator Early Replacement | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | 1.0 | 1.0 |
| LIMF NC | 6018LINC | n/a | n/a |

[340] The Summer and Winter Coincident kW are calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. To calculate an Equivalent Full Load Hours the UEC (* PartUse) is divided by the summer coincident kW (956 * .779)/0.088 = 8477 hours. The summer coincidence factor is therefore assumed to be 1.0 and a winter coincidence factor calculated as the relative winter to summer kW result from the algorithm. For the calculation see "Refrigerator kW Calculations.xls".

[341] Size Factor is calculated by comparing the average MF retrofitted energy savings per unit (525kwh) to the average single family residential retrofitted energy savings (726kWh) indicating a 72% savings factor. See SFvMF Refrigerator Retrofit.xls.

[342] Note that in 2009 this measure became prescriptive and so individual unit consumption values were no longer tracked.

| | | | |
|---|---|---|---|
| LIMF Rehab | 6018LIRH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| MF Mkt Retro | 6020MFMR | 0.9 | 1.0 |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
12 Years[343]
Analysis period is the same as the lifetime.

**Measure Cost**
The initial measure cost for an Energy Star refrigerator is $533, Tier 2 is $612, Tier 3 is $670. The avoided replacement cost (after 3 years) of a baseline refrigerator is $504.[344]

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel savings for this measure.

**Water Descriptions**
There are no water savings for this measure.

343 From ENERGY STAR calculator: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?e678-f5e6&e678-f5e6

344 Measure costs are based on review of data from the Northeast Regional ENERGY STAR Consumer Products Initiative; "2009 ENERGY STAR Appliances Practices Report", submitted by Lockheed Martin, December 2009. See 2009 VT Appliance Data_TRMCostAnalysis.xlsfor data. ESTAR incremental cost reduced to $40 based on ENERGY STAR Calculator; http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?e678-f5e6&e678-f5e6
These calculated full costs ($740 for ENERGY STAR, $850 for CEE Tier 2, $930 for CEE Tier 3 and $700 for a baseline unit) are multiplied by the 72% size factor to account for the smaller units being installed in MF.

# Freezer Early Replacement

Measure Number: III-C-5-a
(Low Income Multifamily Retrofit, Market Rate Multifamily Retrofit, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 80
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**

1) 2012 Freezer Retrofit Savings.xls;
2) 2009 VT Appliance Data_TRMCostAnalysis.xls
3) http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf
4) Refrigerator kW Calculations.xls

**Description**
This is an early replacement measure of an existing pre-2001 inefficient freezer with a new freezer exceeding minimum qualifying efficiency standards established as ENERGY STAR. Savings are calculated between the average energy usage of an existing unit and that of a higher efficiency unit for the remaining life of the existing unit, plus the savings between an average baseline unit and that of a higher efficiency unit for the remainder of the measure life. Prior to 2012, eligibility was restricted to pre-1993 refrigerators. Efficiency Vermont has decided to expand eligibility to the next freezer standard change (2001). The estimated decrease in consumption of a post-1993 / pre-2001 unit over a pre-1993 unit is 25%. EVT has assumed that 30% of the future replacements will fall in to the 1993-2001 category[345] and have adjusted the savings accordingly (see '2012 Freezer Retrofit Savings.xls' for more details). We will review this assumption after a year and adjust as necessary.

**Algorithms**

**Energy Savings**
Savings are based on applying a multifamily size factor adjustment (72%) to the single family based values.

ΔkWh – ENERGY STAR for remaining life of existing unit (3 years) = 269 * 0.72 = 194 kWh
ΔkWh – ENERGY STAR for remaining measure life (9 years) = 52.5 * 0.72 = 37.8 kWh

**Demand Savings**
ΔkW = ΔkWh/Hours

ΔkW – ENERGY STAR for remaining life of existing unit (3 years) = 194/8477 = 0.023 kW
ΔkW – ENERGY STAR for remaining measure life (9 years) = 37.8/8477 = 0.0045 kW

Where:
ΔkWh = gross customer annual kWh savings for the measure
HOURS = Equivalent Full Load Hours
= 8477[346]
ΔkW = gross customer connected load kW savings for the measure

[345] Based upon conversations with the weatherization agencies.
[346] The Summer and Winter Coincident kW are calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. To calculate an Equivalent Full Load Hours the UEC (* PartUse) is divided by the summer coincident kW (956 * .779)/0.088 = 8477 hours. The summer coincidence factor is therefore assumed to be 1.0 and a winter coincidence factor calculated as the relative winter to summer kW result from the algorithm. For the calculation see "Refrigerator kW Calculations.xls".

**Baseline Efficiencies – New or Replacement**
The existing pre-2001 freezer baseline efficiency is estimated by calculating the estimated kWh for an equivalent unit at the Federal Standard in 1990 and 1993 for all units incentivized through the Efficient Product program in 2009-2010[347]. For the purpose of this measure it is assumed that the remaining life of the existing freezer is 3 years. For the remaining 14 years of the new freezer, the 2001 Federal minimum standard is set as the baseline efficiency.

**High Efficiency**
High efficiency is defined as any model meeting or exceeding 2007 ENERGY STAR standard – currently set to 10% over the 2001 Federal minimum standard .

**Loadshape**
Loadshape #4, Residential Refrigerator

**Freeridership/Spillover Factors**

| Measure Category | | Refrigeration | |
|---|---|---|---|
| Measure Code | | RFRESFZR | |
| Product Description | | Energy Star Freezer Early Replacement | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | 0.9 | 1.0 |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | 0.9 | 1.0 |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| MF Mkt Retro | 6020MFMR | 0.9 | 1.0 |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |
| RES Retrofit | 6036RETR | 0.9 | 1.0 |
| RNC VESH | 6038VESH | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

[347] Energy usage algorithms taken from: http://eec.ucdavis.edu/ACEEE/1994-96/1996/VOL09/207.PDF and http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf. Note that in 2010 this measure became prescriptive and so individual unit consumption values were no longer tracked.

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
12 Years[348]
Analysis period is the same as the lifetime.

**Measure Cost**
The full cost for an ENERGY STAR unit is $360. The cost of a baseline replacement freezer is $335.[349]

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**
N/A

[348] From ENERGY STAR calculator: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?e678-f5e6&e678-f5e6

[349] Based on review of data from the Northeast Regional ENERGY STAR Consumer Products Initiative; "2009 ENERGY STAR Appliances Practices Report", submitted by Lockheed Martin, December 2009. See 2009 VT Appliance Data_TRMCostAnalysis.xlsfor data. These calculated full costs ($500 for ENERGY STAR and $465 for a baseline unit) are multiplied by the 72% size factor to account for the smaller units being installed in MF.

# Refrigerator Early Removal

Measure Number: III-C-3-a
(Low Income Multifamily Retrofit, Market Rate Multifamily Retrofit, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 80
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**

1. ADM Evaluation Study of the 2004-05 Statewide Residential Appliance Recycling Program;
2. KEMA Residential Refrigerator Recycling Ninth Year Retention Study;
3. Opinion Dynamics; "Fridge & Freezer Recycle Rewards Program PY4 Metering Study: DRAFT Savings Results"
4. The Cadmus Group et al., "Residential Retrofit High Impact Measure Evaluation Report", prepared for the California Public Utilities Commission, February 8, 2010
5. Appliance Recycling data2008-2012_V2.xls
6. Refrigerator kW Calculations.xls

**Description**
This is an early retirement measure for the removal of an existing inefficient secondary refrigerator from service observed during a site visit by a weatherization agency, Home Performance contractor or Efficiency Vermont staff member. The contractor has signed an agreement that the unit will be rendered permanently inoperable and properly recycled or disposed of. The program will target refrigerators with an age greater than 10 years, although data from the Efficient Product program suggests the average age of retired units is over 30 years. Savings are calculated for the estimated energy consumption during the remaining life of the existing unit.

**Algorithms**

**Energy Savings**
$\Delta kWh = UEC * PartUse * MF_{size\ factor}$
$= 956 * 0.779 * 0.72$
$= 537$ kWh

**Demand Savings**
$\Delta kW = \Delta kWh/Hours$
$= 537/8477$
$= 0.063$ kW

Where:

| | |
|---|---|
| ΔkWh | = gross customer annual kWh savings for the measure |
| UEC | = Unit Energy Consumption |
| | = 956 kWh[350] |
| PartUse | = adjustment factor for weighted partial use of appliance |
| | = 0.779[351] |

[350] Unit Energy Consumption is based upon review of the data collected by Jaco from units retired in the program from 2009-2012. To estimate the consumption of the retired units EVT used a regression equation with multiple attributes from a recent Illinois evaluation (Opinion Dynamics; "Fridge & Freezer Recycle Rewards Program PY4 Metering Study: DRAFT Savings Results"). The regression analysis is likely the most accurate for a large enough population. For information see "Appliance Recycling data2008-2012_V2.xls".

| | |
|---|---|
| $MF_{size\ factor}$ | = Factor applied to the savings based on Residential Program to account for smaller units being installed in Multi Family buildings.<br>= 0.72[352] |
| HOURS | = Equivalent Full Load Hours<br>= 8477[353] |
| $\Delta kW$ | = gross customer connected load kW savings for the measure |

**Baseline Efficiencies – New or Replacement**

The existing refrigerator baseline consumption is based upon data collected by Jaco from units retired in the Efficient Products program from 2009-2012 and adjusted for part use consumption and smaller units in Multi Family buildings.

**High Efficiency**

N/A

**Loadshape**

Loadshape #4, Residential Refrigerator

**Freeridership/Spillover Factors**

| Measure Category | | Refrigeration | |
|---|---|---|---|
| Measure Code | | RFRRERPS | |
| Product Description | | Multi Family Refrigerator Early Retirement | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6012MFMR | 1.0 | 1.0 |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | 1.0 | 1.0 |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | 1.0 | 1.0 |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |

351 Based on analysis of Jaco data. Participants were asked how much the refrigerator was run through the year. The data was weighted assuming the response "All months" equaled 12 months, "Summer" or "Winter" equaled 3 months and "Spring/Fall" equaled 6 months.

352 Size Factor is calculated by comparing the average MF retrofitted energy savings per unit (525kwh) to the average single family residential retrofitted energy savings (726kWh) indicating a 72% savings factor. See SFvMF Refrigerator Retrofit.xls.

353 The Summer and Winter Coincident kW are calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. To calculate an Equivalent Full Load Hours the UEC (* PartUse) is divided by the summer coincident kW (956 * .779)/0.088 = 8477 hours. The summer coincidence factor is therefore assumed to be 1.0 and a winter coincidence factor calculated as the relative winter to summer kW result from the algorithm. For the calculation see "Refrigerator kW Calculations.xls".

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
8 years [354]
Analysis period is the same as the lifetime.

**Measure Cost**
The cost of pickup and recycling of the refrigerator is $50 based upon agreement with contractors or vendors who will collect secondary units when replacing the primary unit. Contractors have signed an agreement that the units will be recycled and not placed on the secondary market.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel savings for this measure.

**Water Descriptions**
There are no water savings for this measure.

[354] KEMA "Residential refrigerator recycling ninth year retention study", 2004

# Freezer Early Removal

Measure Number: III-C-4-a
(Low Income Multifamily Retrofit, Market Rate Multifamily Retrofit, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 80
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**

1. ADM Evaluation Study of the 2004-05 Statewide Residential Appliance Recycling Program;
2. KEMA Residential Refrigerator Recycling Ninth Year Retention Study;
3. Opinion Dynamics; "Fridge & Freezer Recycle Rewards Program PY4 Metering Study: DRAFT Savings Results"
4. The Cadmus Group et al., "Residential Retrofit High Impact Measure Evaluation Report", prepared for the California Public Utilities Commission, February 8, 2010
5. Appliance Recycling data2008-2012_V2.xls
6. Refrigerator kW Calculations.xls

**Description**
This is an early retirement measure for the removal of an existing inefficient freezer from service observed during a site visit by a weatherization agency, Home Performance contractor or Efficiency Vermont staff member. The contractor has signed an agreement that the unit will be rendered permanently inoperable and properly recycled or disposed of. . The program will target freezers with an age greater than 10 years, although data from the Efficient Product program suggests the average age of retired units is over 30 years. Savings are calculated for the estimated energy consumption during the remaining life of the existing unit.

**Algorithms**
**Energy Savings**

$\Delta kWh = UEC * PartUse * MF_{size\ factor}$
$= 1231 * 0.777 * 0.72$
$= 689\ kWh$

**Demand Savings**

$\Delta kW = \Delta kWh/Hours$
$= 689 / 8477$
$= 0.081\ kW$

Where:

| | |
|---|---|
| ΔkWh | = gross customer annual kWh savings for the measure |
| UEC | = Unit Energy Consumption |
| | = 1231 kWh[355] |
| PartUse | = adjustment factor for weighted partial use of appliance |
| | = 0.777[356] |

[355] Unit Energy Consumption is based upon review of the data collected by Jaco from units retired in the program from 2009-2012. To estimate the consumption of the retired units EVT used a regression equation with multiple attributes from a recent Illinois evaluation (Opinion Dynamics; "Fridge & Freezer Recycle Rewards Program PY4 Metering Study: DRAFT Savings Results"). For information see "Appliance Recycling data2008-2012_V2.xls".
[356] Based on analysis of Jaco data. Participants were asked how much the freezer was run through the year. The data was weighted assuming the response "All months" equaled 12 months, "Summer" or "Winter" equaled 3 months and "Spring/Fall" equaled 6 months.

| | |
|---|---|
| $MF_{size\ factor}$ | = Factor applied to the savings derived based on Residential Program to account for smaller units being installed in Multi Family buildings.<br>= 0.72[357] |
| HOURS | = Equivalent Full Load Hours<br>= 8477[358] |
| ΔkW | = gross customer connected load kW savings for the measure |

**Baseline Efficiencies – New or Replacement**

The existing freezer baseline consumption is based upon data collected by Jaco from units retired in the Efficient Products program from 2009-2012 and adjusted for part use consumption.

**High Efficiency**

N/A

**Loadshape**

Loadshape #4, Residential Refrigerator

**Freeridership/Spillover Factors**

| Measure Category | | Refrigeration | |
|---|---|---|---|
| Measure Code | | RFRFERPS | |
| Product Description | | Freezer Early Retirement | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6012MFMR | 1.0 | 1.0 |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | 1.0 | 1.0 |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | 1.0 | 1.0 |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |

**Persistence**

The persistence factor is assumed to be one.

**Lifetimes**

8 years [359] Analysis period is the same as the lifetime.

[357] Size Factor is calculated by comparing the average MF retrofitted energy savings per unit (525kwh) to the average single family residential retrofitted energy savings (726kWh) indicating a 72% savings factor. See SFvMF Refrigerator Retrofit.xls.

[358] The Summer and Winter Coincident kW are calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. To calculate an Equivalent Full Load Hours the UEC (* PartUse) is divided by the summer coincident kW (956 * .779)/0.088 = 8477 hours. The summer coincidence factor is therefore assumed to be 1.0 and a winter coincidence factor calculated as the relative winter to summer kW result from the algorithm. For the calculation see “Refrigerator kW Calculations.xls”.

[359] KEMA “Residential refrigerator recycling ninth year retention study”, 2004

**Measure Cost**
The cost of pickup and recycling of the refrigerator is $50 based upon agreement with contractors or vendors who will collect secondary units when replacing the primary unit. Contractors have signed an agreement that the units will be recycled and not placed on the secondary market.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel savings for this measure.

**Water Descriptions**
There are no water savings for this measure.

## Hot Water End Use
# Low Flow Showerhead

Measure Number: III-D-5-c (Multifamily New Construction Program, Low Income Multifamily Retrofit, Market Rate Multifamily Retrofit, Hot Water End Use)

**Version Date & Revision History**
Draft date: Portfolio 81
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**Referenced Documents**:
1. Energy Policy Act of 1992
2. 2010 Census
3. NREL, National Residential Efficiency Measures Database
4. AWWA, Residential End Uses of Water, 1999, http://www.allianceforwaterefficiency.org/residential-end-uses-of-water-study-1999.aspx
5. CADMUS and Opinion Dynamics, "Showerhead and Faucet Aerator Meter Study," prepared for the Michigan Evaluation Working Group, 2013.
6. East Bay Municipal Utility District; "Water Conservation Market Penetration Study" http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf
7. SBW Consulting, Evaluation for the Bonneville Power Authority, 1994, http://www.bpa.gov/energy/n/reports/evaluation/residential/faucet_aerator.cfm
8. Champlain Water District, 2010 Water Quality Report, http://www.cwd-h2o.org/vertical/Sites/%7B0A660058-838C-4456-B2E9-CCDA30420B07%7D/uploads/2011_Water_Quality_Report1.pdf

**Description**
An existing shower head with a high flow rate is replaced with new unit that has a low flow rate. This is a retrofit measure.

**Algorithms**

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

$\Delta kWh$[360] $= (((GPM_{base} \times min/person/day_{base} - GPM_{efficient} \times min/person/day_{efficient}) \times \# \ people \times days/year\ ) / SH/home\ ) \times 8.3 \times (TEMP_{sh} - TEMP_{in}) / DHW\ Recovery\ Efficiency / 3412 \times ISR$

Where:

$GPM_{base}$ = Gallons Per Minute of baseline shower head
= 2.02 [361]

$GPM_{efficient}$ = Gallons Per Minute of low flow shower head
= 1.5 [362]

$min/person/day_{base}$ = Average minutes in the shower per person per day with baseline showerhead
= 4.7 [363]

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[360] Note, the algorithm and variables are provided as documentation for the deemed savings result provided which should be claimed for all shower head installations.
[361] Mean showerhead GPM, 4. AWWA, Residential End Uses of Water, 1999, http://www.allianceforwaterefficiency.org/residential-end-uses-of-water-study-1999.aspx
[362] EVT program documentation as of November 2012
[363] Based on 7.8 minutes per shower and 0.6 showers per person per day (7.8 × 0.6 = 4.7 minutes per person per day); CADMUS and Opinion Dynamics, "Showerhead and Faucet Aerator Meter Study," prepared for the Michigan Evaluation Working Group, 2013.

$min/person/day_{efficient}$ = Average minutes in the shower per person per day with low flow showerhead
= 4.7 [364]

\# people = Average number of people per household
= 1.6 [365]

days/y = Days shower used per year
= 365

SH/home = Average number of showers in the home
= 1.0 [366]

8.3 = Constant to convert gallons to lbs

$TEMP_{sh}$ = Assumed temperature of water used by shower head
= 101F[367]

$TEMP_{in}$ = Assumed temperature of water entering house
= 54 F[368]

DHW Recovery Efficiency = Recovery efficiency of electric water heater
= 0.98 [369]

3412 = Constant to converts BTU to kWh

ISR = In Service Rate
= 0.95 [370]

$$\Delta kWh = [((2.02 \times 4.7 - 1.5 \times 4.7) \times 1.6 \times 365) / 1.0] \times 8.3 \times (101-54) / 0.98 / 3412 \times 0.95$$

$$= 158 \text{ kWh}$$

**Demand Savings**

$$\Delta kW = \Delta kWh / hours$$

Where:

Hours = Operating hours from Residential DHW Conservation Loadshape[371]
= 3427

$$\Delta kW = 158 \text{ kWh} / 3427$$
$$= 0.0460 \text{ kW}$$

**Baseline Efficiencies – New or Replacement**

The baseline condition is an existing shower head with a high flow.

**High Efficiency**

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[364] Ibid.

[365] Average people per household in Vermont multi-family buildings, 2010 Census

[366] Estimate based on review of a number of studies:

a. East Bay Municipal Utility District; "Water Conservation Market Penetration Study" http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf
b. AWWA, Residential End Uses of Water, 1999, http://www.allianceforwaterefficiency.org/residential-end-uses-of-water-study-1999.aspx
c. SBW Consulting, Evaluation for the Bonneville Power Authority, 1994, http://www.bpa.gov/energy/n/reports/evaluation/residential/faucet_aerator.cfm

[367] CADMUS and Opinion Dynamics, "Showerhead and Faucet Aerator Meter Study," prepared for the Michigan Evaluation Working Group, 2013.

[368] Champlain Water District, 2010 Water Quality Report, http://www.cwd-h2o.org/vertical/Sites/%7B0A660058-838C-4456-B2E9-CCDA30420B07%7D/uploads/2011_Water_Quality_Report1.pdf

[369] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

[370] Navigant, 2013, Draft Evaluation of Multi-Family Home Energy Savings Program for ComEd PY4 and Nicor Gas PY1

[371] Based on Itron eShapes (8760 data) and adjusted for diversity within the hour

High efficiency is a low flow shower head.

**Loadshape**
For DHW systems not on Utility Controlled DHW program (Default):
Loadshape #8, Residential DHW Conservation

For DHW systems on Utility Controlled DHW program:
Loadshape #54, Controlled DHW Conservation

**Freeridership/Spillover Factors**

| | | | |
|---|---|---|---|
| Measure Category | | Hot Water | |
| Measure Code | | HWESHOWR | |
| Product Description | | Low Flow Shower Head | |
| Track Name | Track No. | Freerider | Spillover |
| LIMF Retrofit | 6017RETR | 1.0 | 1.0 |
| LIMF NC | 6018LINC | 1.0 | 1.0 |
| LIMF Rehab | 6018LIRH | 1.0 | 1.0 |
| MF Mkt NC | 6019MFNC | 0.9 | 1.0 |
| MF Mkt Retro | 6020MFMR | 0.9 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
9 years (same as in DPS screening of Efficiency Utility Core programs).
Analysis period is the same as the lifetime.

**Measure Cost**
The incremental cost for low-flow shower heads is presumed to be zero for new construction or major rehab projects, and $15 for retrofit applications.[372]

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure

**Fossil Fuel Descriptions**[373]
If fossil fuel water heating:
$\Delta$MMBtu $= ((\Delta kWh \times \eta WH_{electric}) / \eta WH_{combustion}) \times 0.003412$

Where:
$\eta WH_{electric}$ = Recovery efficiency of electric water heater
= 0.98 [374]
$\eta WH_{combustion}$ = Recovery efficiency of fossil fuel water heater
= 0.76 [375]

[372] Includes showerhead cost of $2.5 for a regular, $2.97 for chrome and $7.26 for handheld, plus labor installation costs.
[373] Fossil fuel savings based on efficiency factors of .62 for oil, natural gas, and liquid propane high efficiency stand alone DHW heaters as approved by the VT- DPS and used by Efficiency Vermont. Efficiency factor of .88 is used for electric DHW heater.
[374] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40
[375] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

Other factors as defined above

$$\Delta MMBtu = ((158 \times 0.98) / 0.76) \times 0.003412$$

$$= 0.695 \text{ MMBtu}$$

**Water Descriptions**

$\Delta CCF = ((GPM_{base} \times min/person/day_{base} - GPM_{efficient} \times min/person/day_{efficient}) \times \# \; people \times days/year) / (SH/home \times 748)$

Where:

$\Delta CCF$ = customer water savings in hundreds of cubic feet for the measure

748 = Conversion from gallons to CCF

Other factors are as defined above

$$\Delta CCF = ((2.02 \times 4.7 - 1.5 \times 4.7) \times 1.6 \times 365) / (1.0 \times 748)$$

$$= 1.91 \text{ CCF}$$

# Low Flow Faucet Aerator

Measure Number: III-D-6-c (Multifamily New Construction Program, Low Income Multifamily Retrofit, Market Rate Multifamily Retrofit , Hot Water End Use)

**Version Date & Revision History**
Draft date: Portfolio 81
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**Referenced Documents**:

1. DOE, "Energy and Water Conservation Standards," Federal Register Vol. 63, No. 52, March 18, 1998, 13307
2. AWWA, Residential End Uses of Water, 1999, http://www.allianceforwaterefficiency.org/residential-end-uses-of-water-study-1999.aspx
3. Ontario Energy Board, "Measures and Assumptions for Demand Side Management Planning."
4. East Bay Municipal Utility District; "Water Conservation Market Penetration Study" http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf
5. CADMUS and Opinion Dynamics, "Showerhead and Faucet Aerator Meter Study," prepared for the Michigan Evaluation Working Group, 2013.
6. Champlain Water District, 2010 Water Quality Report, http://www.cwd-h2o.org/vertical/Sites/%7B0A660058-838C-4456-B2E9-CCDA30420B07%7D/uploads/2011_Water_Quality_Report1.pdf
7. NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40
8. 2010 Census

**Description**
An existing faucet aerator with a high flow rate is replaced with new unit that has a low flow rate. This is a retrofit measure.

**Algorithms**

**Energy Savings**

If electric domestic water heater:

$\Delta$kWh[376] $= (((GPM_{base} – GPM_{efficient}) / GPM_{base} \times \#\ people \times gpcd \times days/year \times DR) / (F/home)) \times 8.3 \times (TEMP_{ft} - TEMP_{in}) / DHW\ Recovery\ Efficiency / 3412$

Where:

$GPM_{base}$ = Gallons Per Minute of baseline faucet
= 2.2 [377]

$GPM_{efficient}$ = Gallons Per Minute of low flow faucet
= 1.5 or
= 1.0

# people = Average number of people per household
= 1.6 [378]

gpcd = Average gallons per person per day using faucets
= 10.9 [379]

376 Note, the algorithm and variables are provided as documentation for the deemed savings result provided which should be claimed for all faucet aerator installations.
377 In 1998, the Department of Energy adopted a maximum flow rate standard of 2.2 GPM at 60 psi for all faucets: DOE, "Energy and Water Conservation Standards," Federal Register Vol. 63, No. 52, March 18, 1998, 13307
378 Average people per household in Vermont multi-family buildings, 2010 Census
379 AWWA, Residential End Uses of Water, 1999, http://www.allianceforwaterefficiency.org/residential-end-uses-of-water-study-1999.aspx

days/y = Days faucet used per year
= 365

DR = Percentage of water flowing down drain (if water is collected in a sink, a faucet aerator will not result in any saved water)
= 50% [380]

F/home = Average number of faucets in the home
= 2.3 [381]

8.3 = Constant to convert gallons to lbs

$TEMP_{ft}$ = Assumed temperature of water used by faucet
= 88 F[382]

$TEMP_{in}$ = Assumed temperature of water entering house
= 54 F[383]

DHW Recovery Efficiency = Recovery efficiency of electric water heater
= 0.98 [384]

3412 = Constant to converts BTU to kWh

Aerator at 1.5 gpm

$$\Delta kWh = ((2.2 - 1.5) / 2.2 \times 1.6 \times 10.9 \times 365 \times 0.5) / 2.3 \times 8.3 \times (88 - 54) / 0.98 / 3412$$

$$= 37.2 \text{ kWh}$$

Aerator at 1.0 gpm

$$\Delta kWh = ((2.2 - 1.0) / 2.2 \times 1.6 \times 10.9 \times 365 \times 0.5) / 2.3 \times 8.3 \times (88 - 54) / 0.98 / 3412$$

$$= 63.7 \text{ kWh}$$

**Demand Savings**

$\Delta$kW = $\Delta$kWh / hours

Where:

Hours = Operating hours from Residential DHW Conservation Loadshape[385]
= 3427

Aerator at 1.5 gpm

$\Delta$kW = 37.2 kWh / 3427
= 0.0108 kW

Aerator at 1.0 gpm

$\Delta$kW = 63.7 kWh / 3427
= 0.0186 kW

**Baseline Efficiencies – New or Replacement**

The baseline condition is an existing faucet aerator using 2.2 gpm.

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[380] Estimate consistent with Ontario Energy Board, "Measures and Assumptions for Demand Side Management Planning."

[381] Estimate based on East Bay Municipal Utility District; "Water Conservation Market Penetration Study" http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf

[382] Weighted average of kitchen (93F) and bathroom (86F) faucet use temperatures, CADMUS and Opinion Dynamics, "Showerhead and Faucet Aerator Meter Study," prepared for the Michigan Evaluation Working Group, 2013.

[383] Champlain Water District, 2010 Water Quality Report, http://www.cwd-h2o.org/vertical/Sites/%7B0A660058-838C-4456-B2E9-CCDA30420B07%7D/uploads/2011_Water_Quality_Report1.pdf

[384] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

[385] Based on Itron eShapes (8760 data) and adjusted for diversity within the hour

**High Efficiency**
High efficiency is a low flow aerator, 1.5 or 1.0 gpm.

**Loadshape**
For DHW systems not on Utility Controlled DHW program (Default):
Loadshape #8, Residential DHW Conservation

For DHW systems on Utility Controlled DHW program:
Loadshape #54, Controlled DHW Conservation

**Freeridership/Spillover Factors**

| Measure Category | | Hot Water | |
|---|---|---|---|
| Measure Code | | HWEFAUCT | |
| Product Description | | Low Flow Faucet Aerator | |
| Track Name | Track No. | Freerider | Spillover |
| LIMF Retrofit | 6017RETR | 1.0 | 1.0 |
| LIMF NC | 6018LINC | 1.0 | 1.0 |
| LIMF Rehab | 6018LIRH | 1.0 | 1.0 |
| MF Mkt NC | 6019MFNC | 0.9 | 1.0 |
| MF Mkt Retro | 6020MFMR | 0.9 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
The expected lifetime of the measure is 9 years (same as in DPS screening of Efficiency Utility Core programs). Analysis period is the same as the lifetime.

**Measure Cost**
The incremental cost for low-flow faucet aerators is presumed to be zero for new construction or major rehab projects, and $10 for retrofit applications.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure

**Fossil Fuel Descriptions**[386]
If fossil fuel water heating:
$\Delta$MMBtu $= ((\Delta kWh \times \eta WH_{electric}) / \eta WH_{combustion}) \times 0.003412$

Where:
$\eta WH_{electric}$ = Recovery efficiency of electric water heater
= 0.98 [387]
$\eta WH_{combustion}$ = Recovery efficiency of fossil fuel water heater
= 0.76 [388]
Other factors as defined above

Aerator at 1.5 gpm

[386] Fossil fuel savings based on efficiency factors of .62 for oil, natural gas, and liquid propane high efficiency stand-alone DHW heaters as approved by the VT- DPS and used by Efficiency Vermont. Efficiency factor of .88 is used for electric DHW heater.
[387] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40
[388] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

$\Delta MMBtu = ((24.4 \times 0.98) / 0.76) \times 0.003412$

$= 0.107\ MMBtu$

Aerator at 1.0 gpm

$\Delta MMBtu = ((41.9 \times 0.98) / 0.76) \times 0.003412$

$= 0.184\ MMBtu$

**Water Descriptions**

$\Delta CCF = ((GPM_{base} - GPM_{efficient}) / GPM_{base} \times \#\ people \times gpcd \times days/year \times DR) / (F/home \times 748)$

Where:

$\Delta CCF$ = customer water savings in hundreds of cubic feet for the measure

748 = Conversion from gallons to CCF

Other factors are as defined above

Aerator at 1.5 gpm

$\Delta CCF = ((2.2 - 1.5) / 2.2 \times 1.6 \times 10.9 \times 365 \times 0.5) / (2.3 \times 748)$

$= 0.589\ CCF$

Aerator at 1.0 gpm

$\Delta CCF = ((2.2 - 1.0) / 2.2 \times 1.6 \times 10.9 \times 365 \times 0.5) / (2.3 \times 748)$

$= 1.01\ CCF$

# Domestic Hot Water Recirculation Pipe Insulation

Measure Number: III-D-7-a (Multifamily New Construction Program, Low Income Multifamily Retrofit, Market Rate Multifamily Retrofit, Space Heating End Use)

**Version Date & Revision History**
Draft date: Portfolio 74
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**

1. Domestic Water Re-heat_MF.xls
2. GDS Associates 2007 "Measure Life Report"; http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf
3. MeasureCost_StevePitkin6-15-11.xls

**Description**
Domestic Hot Water Recirculation Pipe that is continuously circulating is insulated with 1.5 or 2 inches of insulation instead of a baseline level of 0.5 inch.

**Algorithms**

**Energy and Demand Savings**
n/a

**Baseline Efficiency**
Domestic Hot Water Recirculation Pipe insulated with 0.5 inch of insulation.

**Efficient Efficiency**
Domestic Hot Water Recirculation Pipe insulated with 1.5 or 2 inches of insulation.

**Loadshape**
Loadshape #25, Flat (8760 hours)

**Freeridership/Spillover Factors**

| Measure Category | | Domestic Hot Water End Use | |
|---|---|---|---|
| Measure Code | | HWERECIN | |
| Product Description | | Domestic Hot Water Recirculation Pipe | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | 1.0 | 1.0 |
| LIMF Rehab | 6018LIRH | 1.0 | 1.0 |

| | | | |
|---|---|---|---|
| MF Mkt NC | 6019MFNC | 1.0 | 1.0 |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetime**
20 years[389].
Analysis period is the same as the lifetime.

**Incremental Cost per Unit**
The incremental cost is assumed to be $0.50 per linear foot for 1.5 inch pipe insulation and $1.0 per linear foot for 2 inch pipe insulation[390].

**Fossil Fuel Descriptions**
Deemed fossil fuel savings per linear foot of DHW circulation pipe are provided below[391].

| DHW fuel source | MMBtu Savings for Insulation Thickness per Linear Foot | |
|---|---|---|
| | 1.5” | 2” |
| Natural Gas or LP | 0.0382 | 0.0443 |
| Oil | 0.0422 | 0.049 |

Assumes an average 1” circulation pipe. The boiler efficiency is assumed to be Tier 1 standard (i.e. 94% for gas, 85% for oil). Savings are based on the following pipe heat loss table[392]:

| Insulation Thickness | Pipe Heat Loss (btu/lf-yr) | | | | |
|---|---|---|---|---|---|
| | 1/2" | 3/4" | 1" | 1-1/4" | 1-1/2" |
| Bare Pipe | 181,300 | 218,900 | 265,700 | 325,800 | 367,200 |
| 0.5 | 59,750 | 67,800 | 79,320 | 98,350 | 110,400 |
| 1 | 42,440 | 50,990 | 53,010 | 68,110 | 68,980 |
| 1.5 | 34,540 | 40,000 | 43,440 | 48,510 | 54,880 |

389 Consistent with GDS Associates 2007 “Measure Life Report”; http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf
390 Cost estimates provided by Steve Pitkin, construction project manager and cost estimator. See ‘MeasureCost_StevePitkin6-15-11.xls’ for more information.
391 Calculated using EVT developed spreadsheet tool ‘Domestic Water Re-heat_MF.xls’.
392 Taken from free software called “3EPlusv4” developed by NAIMA, the North American Insulation Manufacturer's Association. The delta T used to develop the pipe heat loss table was 50 degrees (120 degree water in the pipe and 70 degree ambient temperature). The software can be download here: http://www.pipeinsulation.org/pages_v4/download.html

| | | | | | |
|---|---|---|---|---|---|
| 2 | 30,620 | 34,830 | 37,660 | 44,650 | 43,570 |
| 2.5 | 26,750 | 29,910 | 33,910 | 39,460 | 39,470 |

**Reference Tables**

None

# Boiler Hot Water Distribution Pipe Insulation

Measure Number: III-D-8-a (Multifamily New Construction Program, Low Income Multifamily Retrofit, Market Rate Multifamily Retrofit, Space Heating End Use)

**Version Date & Revision History**
Draft date: Portfolio 74
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**

1. Boiler_Distribution_Pipe Insulation.xls
2. GDS Associates 2007 "Measure Life Report"; http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf
3. MeasureCost_StevePitkin6-15-11.xls
4. Boiler with Reset_Hot Water Temp.xls'

**Description**
Boiler hot water recirculation pipe that is continuously circulating during the heating season (assumed to be when outside temperature is about 65 degrees F) is insulated with 1.5 or 2 inches of insulation instead of a baseline level of 1 inch.

**Algorithms**

**Energy and Demand Savings**
n/a

**Baseline Efficiency**
Boiler Hot Water Recirculation Pipe insulated with 1 inch of insulation as required by CBES 2011 code.

**Efficient Efficiency**
Boiler Hot Water Recirculation Pipe insulated with 1.5 or 2 inches of insulation.

**Loadshape**
n/a

**Freeridership/Spillover Factors**

| Measure Category | | Heating End Use | |
|---|---|---|---|
| Measure Code | | HWEBREIN | |
| Product Description | | Boiler Hot Water Recirculation Pipe | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | 1.0 | 1.0 |

| | | | |
|---|---|---|---|
| LIMF Rehab | 6018LIRH | 1.0 | 1.0 |
| MF Mkt NC | 6019MFNC | 1.0 | 1.0 |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetime**
20 years[393].
Analysis period is the same as the lifetime.

**Incremental Cost per Unit**
The incremental cost is assumed to be $0.50 per linear foot for 1.5 inch pipe insulation and $1.0 per linear foot for 2 inch pipe insulation[394].

**Fossil Fuel Descriptions**
Deemed fossil fuel savings per linear foot of boiler circulation pipe are based on the following algorithm:

MMBtu/ft = ((Circulation Temp - Ambient Temp) x Operating Hours x ($U_{Base}$ – $U_{Eff}$) * SA/ft ) / µHeat / 1,000,000

Where

| | |
|---|---|
| Circulation $Temp_{no\ reset\ control}$ | = 180°F |
| Circulation $Temp_{gas\ boilers\ w/reset}$ | = 132°F |
| Circulation $Temp_{oil\ boilers\ w/reset}$ | = 146°F[395] |
| Ambient Temp | = 65°F |
| Operating Hours | = 6260[396] |
| $U_{Base}$ | = U Factor of 1” insulation<br>= 1/3.5<br>= 0.286 |
| $U_{Eff}$ | = U Factor of 1.5” or 2” insulation<br>= 0.190 (1/(3.5*1.5))<br>or 0.143 (1/(3.5*2)) |
| SA/ft | = Surface Area per foot of pipe |

393 Consistent with GDS Associates 2007 “Measure Life Report”; http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf
394 Cost estimates provided by Steve Pitkin, construction project manager and cost estimator. See ‘MeasureCost_StevePitkin6-15-11.xls’ for more information.
395 Circulation temperatures for boilers with reset controls were calculated assuming 180°F water when outside air is below zero and at 60°F outside air we assume reset controls reduce the temperature to 100°F for gas-fired boilers and 140°F for oil (typically oil boilers are not reset as much as gas boilers due to thermal and condensing issues), and assume a linear relationship between those two points. See ‘Boiler with Reset_Hot Water Temp.xls’ for calculation.
396 Number of hours where outside temperature is below 60°F, based on Bin Analysis see Pipe Insulation.xls.

= 0.295[397] (assuming 1" pipe diameter)

μHeat = Boiler efficiency assumed to be Tier 1 standard

= 94% for gas, 85% for oil

Deemed values presented below. For calculation see Boiler_Distribution_Pipe Insulation.xls.

| DHW fuel source | MMBtu Savings for Insulation Thickness per Linear Foot | |
|---|---|---|
| | 1.5" | 2" |
| Gas (no reset control) | 0.022 | 0.032 |
| Oil (no reset control) | 0.024 | 0.036 |
| Gas (with reset control) | 0.013 | 0.019 |
| Oil (with reset control) | 0.017 | 0.025 |

**Reference Tables**

None

[397] Based on ASHRAE look up tables.

# Drain Water Heat Recovery Device

Measure Number: III-D-9-a (Multifamily New Construction Program, Hot Water End Use)

**Version Date & Revision History**
Draft date: Portfolio 74
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**

1. Energy Savings calculations based on *Drain Water Heat Recovery Characterization and Modeling – Final Report, C. Zaloum, M. Lafrance, J Gusdorf, 2007.*
2. DWHR Calculator.xls

**Description**
Drain water heat exchanger installed to capture and reuse energy from main drain pipe to preheat incoming cold water to water heater and shower. This measure is only applicable to units serving 2 or more apartments and is not supported for buildings with natural gas since it has been found to not be cost effective.

**Algorithms**

**Demand Savings**
N/A

**Energy Savings**[398]
$\Delta$kWh = $(0.017 \times \varepsilon \times 8.623 \times HS \times 365 / (DHW_e)) * FLAG$

Where:

| | |
|---|---|
| $\Delta$kWh | = gross customer annual kWh savings for the measure (kWh) |
| 0.017 | = 60/1000/3.6 (minutes/watts/megajoules) |
| $\varepsilon$ | = Drain Water Heat Recovery device efficiency[399] |
| 8.623 | = Heat Flux[400] |
| HS | = Household/Apartment Shower Minutes/Day [(Bedrooms + 1) x 5.3[401]] |
| 365 | = Days per year |
| $DHW_e$ | = Domestic Hot Water Recovery Efficiency |
| | = 0.98 [402] |
| FLAG | = 1 if domestic hot water system is electric; 0 otherwise |

**Baseline Efficiencies – New or Replacement**
The baseline condition is an existing or proposed main drain pipe without heat recovery.

398 Energy Savings calculations based on *Drain Water Heat Recovery Characterization and Modeling – Final Report, C. Zaloum, M. Lafrance, J Gusdorf, 2007*,p. 29
399 For example efficiencies see Zaloum, Lafrance, Gusdorf , p. 13.
400 Assumed Showerhead flow of 1.5 gpm, Incoming Cold Water Temp of 55°F, Shower Water Temp of 105°F and a drop of 6°F from shower to drain. See 'DWHR Calculator.xls' for details of the calculation.
401 5.3 minutes per person per day is derived from EPA WaterSense document (http://www.epa.gov/watersense/docs/home_suppstat508.pdf) which suggests 11.6 gallons of water per person per day for shower use. This was based on a 1999 study (http://www.waterrf.org/ProjectsReports/PublicReportLibrary/RFR90781_1999_241A.pdf) that metered 1088 households for 4 weeks. The average flow rate for these showers was 2.2 gpm making the number of minutes per day 11.6/2.2 = 5.27 minutes.
402 Electric water heaters have recovery efficiency of 98%: http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576

**High Efficiency**
High efficiency is installation of drain water heat recovery device.

**Operating Hours**
N/A

**Loadshape**
Loadshape #8, Residential DHW conserve

**Freeridership/ Spillover Factors**

| Measure Category | | Hot Water End Use | |
|---|---|---|---|
| Measure Code | | HWEDRAIN | |
| Product Description | | Drain Water Heat Recovery | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | 1.0 | 1.0 |
| LIMF Rehab | 6018LIRH | 1.0 | 1.0 |
| MF Mkt NC | 6019MFNC | 1.0 | 1.0 |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
25 years[403]

**Measure Cost**
The incremental cost for drain water heat recovery device varies based on the length of the device and the application.

[403] Conservative estimate based on product manufacturer published expected lifetime.

| | Length | Application | Device Cost[404] | Installation Cost[405] | Total Cost |
|---|---|---|---|---|---|
| SHORT DWHR Device | 36" – 40" | New Construction | $560 | $100 | $660 |
| | 36" – 40" | Retrofit | $560 | $200 | $760 |
| MEDIUM DWHR Device | 60" | New Construction | $702 | $100 | $802 |
| | 60" | Retrofit | $702 | $200 | $902 |
| LONG DWHR Device | 80" | New Construction | $980 | $200 | $1180 |
| | 80" | Retrofit | $980 | $300 | $1280 |
| EXTRA-LONG DWHR Device | 100"-120" | New Construction | $1200 | $200 | $1400 |
| | 100"-120" | Retrofit | $1200 | $300 | $1500 |

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure

**Fossil Fuel Descriptions**

$\Delta$MMBtu = (0.017 x $\varepsilon$ x 8.623 x HS x 365 /DHWe) x 0.003412 x (1-FLAG)

Where:

$\Delta$MMBtu = Annual MMBtu fossil fuel savings per residential unit for the measure
$\Delta$kWh = kWh savings calculated above
0.003412 = Converts kWh to MMBtu
$DHW_e$ = Fuel Domestic Hot Water Recovery Efficiency
= 86% if gas, 78% if oil[406]
FLAG = 1 if domestic hot water system is electric; 0 otherwise

**Reference Tables**
None

[404] Device Costs based on available pricing August 2011. Prices vary based on quantity, location, and retailer.
[405] Installation costs for retrofit application assumes typical accessibility of main drain line.
[406] Assume Tier 1 efficiency level boilers (94% gas or 85% oil) with indirect water heaters (efficiency assumed to be 0.92 * boiler efficiency).

## Ventilation End Use

# Residential Fan—Quiet, Exhaust-Only Continuous Ventilation

Measure Number: III-E-1-b (Multifamily New Construction Program, Low Income Multifamily Retrofit, Market Rate Multifamily Retrofit, Ventilation End Use)

**Version Date & Revision History**

Draft date: Portfolio 74
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**

3. Residential Vent Fan Assessment.xls
4. GDS Associates Measure Life Report "Residential and C&I Lighting and HVAC measures"
5. ASHRAE 62.2 Section 4.1 Whole House Ventilation

**Description**

This market opportunity is defined by the need for continuous mechanical ventilation due to reduced air-infiltration from a tighter building shell. In retrofit projects, existing fans may be too loud, or insufficient in other ways, to be operated as required for proper ventilation. This measure assumes a fan capacity of 50 CFM rated at less than 2.0 sones at 0.1 inches of water column static pressure. This measure may be applied to larger capacity, up to 130 CFM, efficient fans with bi-level controls because the savings and incremental costs are very similar. All eligible installations shall be sized to provide the mechanical ventilation rate indicated by ASHRAE 62.2.

**Algorithms**

**Demand Savings**

$\Delta kW = CFM * (1/Fan_{Efficiency, Baseline} - 1/Fan_{Efficiency, Effcient})/1000$
$= 50 * (1/3.1 – 1/8.3)/1000$
$= 0.01$ kW

Where:

CFM = Nominal Capacity of the exhaust fan, 50 CFM[407]
$Fan_{Efficiency, Baseline}$ = Average efficacy for baseline fan, 3.1 CFM/Watt[408]
$Fan_{Efficiency, Effcient}$ = Average efficacy for efficient fan, 8.3 CFM/Watt [409]

**Energy Savings**

$\Delta kWh$ = Hours * $\Delta kW$
= 8760 * 0.01
= 87.6 kWh

Where:

$\Delta kW$ = connected load kW savings per qualified ventilation fan and controls.
Hours = assumed annual run hours, 8760 for continuous ventilation.

**Baseline Efficiencies – New or Replacement**

New standard efficiency (average CFM/Watt of 3.1[410]) exhaust-only ventilation fan, quiet (< 2.0 sones[411]) operating in accordance with recommended ventilation rate indicated by ASHRAE 62.2[412]

---

407 50CFM is the closest available fan size to ASHRAE 62.2 Section 4.1 Whole House Ventilation rates based upon typical square footage and bedrooms.

408 Average of CFM/Watt values at two static pressures of 0.1 and 0.25 inches of water column for quiet fans rated for 50 CFM. Based on fan information gathered and referenced in the spreadsheet, "Residential Vent Fan Assessment.xls"

409 Average of CFM/Watt values at two static pressures of 0.1 and 0.25 inches of water column for quiet fans rated for 50 CFM. Based on fan information gathered and referenced in the spreadsheet, "Residential Vent Fan Assessment.xls"

410 Average of efficacies at static pressures of 0.1 and 0.25 inches of water column.

**High Efficiency**
New efficient (average CFM/watt of 8.3 ) exhaust-only ventilation fan, quiet (< 2.0 sones) Continuous operation in accordance with recommended ventilation rate indicated by ASHRAE 62.2[413]

**Operating Hours**
Continuous, 8760.

**Loadshape**
Loadshape # 25: Flat (8760 hours)

**Freeridership/Spillover Factors**

| Measure Category | | Ventilation | |
|---|---|---|---|
| Measure Code | | VNTXCEIL, | |
| Product Description | | Exhaust fan, ceiling, | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | 1.0 | 1.0 |
| LIMF NC | 6018LINC | 1.0 | 1.0 |
| LIMF Rehab | 6018LIRH | 0.95 | 1.1 |
| MF Mkt NC | 6019MFNC | 0.9 | 1.0 |
| MF Mkt Retro | 6020MFMR | 1.0 | 1.0 |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | 1.0 | 1.0 |
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |
| RES Retrofit | 6036RETR | 0.9 | 1.0 |
| RNC VESH | 6038VESH | 0.95 | 1.1 |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetime**

---
[411] Rated fan sound level at a static pressure of 0.1 inches of water column.
[412] On/off cycling controls may be required of baseline fans larger than 50CFM.
[413] Bi-level controls may be used by efficient fans larger than 50 CFM

19 years[414]
Analysis period is the same as the lifetime.

**Incremental Cost per Unit**
Incremental cost per installed fan is $43.50 for quiet, efficient fans.[415]

**Reference Tables**
None

[414] Conservative estimate based upon GDS Associates Measure Life Report "Residential and C&I Lighting and HVAC measures" 25 years for whole-house fans, and 19 for thermostatically-controlled attic fans.
[415] See the Fan Info worksheet of the spreadsheet "Residential Vent Fan Assessment.xls"

### Space Heating End Use
# Comprehensive Thermal Measure

Measure Number: III-F-3-a (Multifamily New Construction Program, Space Heating End Use)

**Version Date & Revision History**
Draft date: Portfolio 74
Effective date: 1/1/2012
End date: TBD

**Reference Documents:**

1. MeasureCost_StevePitkin6-15-11.xls

**Description**
This measure characterization documents key assumptions for a package of shell and HVAC measures performed to meet the requirements of the MultiFamily program (Tier 1 measures). It also documents assumptions for a number of additional measures that may be included and incentivized (Tier 2 measures).

**Algorithms**

**Energy and Demand Savings**
Energy (kWh and MMBtu) and Demand (kW) savings will be calculated using REMRate as part of the ENERGY STAR Rating process for buildings 3 stories or less. REMRate will provide the thermal shell, heating, cooling and hot water savings that will be claimed for the project. Note there will be two REMRate ratings performed for each building:

1. <u>As Built Rating</u>: based on all measures installed to provide ENERGY STAR certification and customer savings estimate to property owner.
2. <u>In Program Rating</u>: will be the basis for Efficiency Vermont savings claim by removing “extraordinary measures” from the As Built rating to extract project savings from non – screening measures. The In Program Rating will be compared to a User Defined Reference Home, which will represent the same building built to baseline specifications defined below.

Energy consultants may recommend additional measures and provide extra incentives, as long as they are tested for and pass the cost effectiveness test. The costs for these measures however will be provided on a custom basis.

**Baseline and New Efficiencies**
The following table presents the baseline assumptions for each component together with the minimum Tier 1 requirements for participation in the Multi Family program. Also provided is a list of additional Tier 2 measures which are eligible for additional incentives.

| | Baseline | Minimum TIER 1 Upgrade Measure Requirements | Tier 2 Upgrade Measures |
|---|---|---|---|
| **Heating** | 84% AFUE gas or oil boiler | Staged 94% AFUE gas boilers<br>Or<br>Staged 85% AFUE oil boilers | Staged 95% AFUE gas boilers<br>Or<br>Staged 91% AFUE oil boilers<br>Or<br>Staged 85% AFUE pellet boilers (not if NG boiler baseline) |
| **Domestic Hot Water** | Indirect DHW off an 84% gas or oil boiler | Indirect DHW off a 94% gas boiler<br>Or | Indirect DHW off a 95% gas boiler<br>Or |

| | | | |
|---|---|---|---|
| | | Indirect DHW off a 85% oil boiler | Indirect DHW off a 91% oil boiler |
| | 80% standalone DHW tanks | 96% condensing DHW units | |
| **Cooling (if included. Assume 1.5 tons per unit)** | Central AC - 13 SEER, 11EER (Federal Standard) | Central AC - 14.5 SEER, 12 EER (ESTAR) | Central AC - 15 SEER, 12.5 EER (CEE T2) |
| | Mini-splits - 14 SEER, 12 EER | Mini-splits - 17 SEER, 13 EER | |
| **Air Leakage** | 5 ACH50 (0.667 cfm50/sq ft) | 4 ACH50 (0.533 cfm50/sq ft) | 3 ACH50 (0.4 cfm50/sq ft) |
| **Insulation** | R-49 attic insulation | R-55 attic insulation | |
| | R-20 wall insulation | R-25 wall insulation | |
| | R-5 slab edge | R-15 slab edge | |
| | R-15 foundation wall insulation | R-20 foundation wall insulation | |

**"Extraordinary" Non Screening Measures**
The following measures do not pass Efficiency Vermont's cost effectiveness tests and therefore are not supported by the program. The costs and savings for these measures are therefore not included in the project and will be removed from the In Program Rating model:

| **In Program Rating Adjustments** | | |
|---|---|---|
| **Component** | **As Built** | **In Program Rating Modeled for energy savings** |
| Domestic Hot Water | Solar domestic hot water | None |
| Ventilation | Heat or Energy Recovery Ventilation | Exhaust only ventilation |
| Windows | U-Value lower than .28 | U-.28 |
| Ceiling/Attic Insulation | Greater than R-60 (cavity) | R-60 |
| Wall insulation | Greater than R-25 (cavity) | R-25 |

These measures may be added to projects when custom analysis of savings and installed costs demonstrate cost effectiveness.

**Loadshape**
Loadshape #5, Residential Space Heat
Loadshape #7, Residential DHW insulation
Loadshape #11, Residential A/C

**Freeridership/Spillover Factors**

| | | | |
|---|---|---|---|
| Measure Category | | Comprehensive Thermal Measure | |
| Measure Code | | TSHCOMPH, TSHCOMPC, HWECOMP1 | |
| Product Description | | REMRate calculated heating, cooling and DHW savings | |
| Track Name | Track No. | Freerider | Spillover |

| | | | |
|---|---|---|---|
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | 1.0 | 1.0 |
| LIMF Rehab | 6018LIRH | 1.0 | 1.0 |
| MF Mkt NC | 6019MFNC | 0.9 | 1.1 |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetime**[416]
Heating Savings: 25 years
AC Savings: 15 years
DHW Savings: 15 years
Analysis period is the same as the lifetime.

**Incremental Cost per Unit**
**Tier 1 Comprehensive Thermal Package**

| | **Incremental Cost Assumption Per Unit** | | | | | |
|---|---|---|---|---|---|---|
| **Number of Units** | **1-5** | **6-10** | **11-15** | **16-20** | **21-25** | **26+** |
| Heating Savings (heating system and shell upgrades) | $ 2,554 | $2,159 | $1,764 | $1,369 | $974 | $500 |
| Air Conditioning Savings (AC systems) | $300 | $270 | $240 | $211 | $181 | $145 |
| DHW Savings | $0 | $0 | $0 | $0 | $0 | $0 |
| **Total Cost (with cooling)** | $2,854 | $2,429 | $2,004 | $1,580 | $1,155 | $731 |
| **Total Cost (without** | $2,554 | $2,159 | $1,764 | $1,369 | $974 | $500 |

[416] Consistent with lifetime estimates used by Efficiency Vermont in the state screening tool.

| cooling) | | | | | | |
|---|---|---|---|---|---|---|

Notes:
1. Incremental costs used are based on the least expensive options provided, since this is the cost required to meet approved efficiency levels. Any costs associated with alternate decisions that the participant may make to achieve similar efficiency levels are not be included.
2. DHW Savings has a zero measure cost since there is no increment in cost between an indirect tank off a 84% boiler or an indirect tank off a 94% boiler. The incremental cost of the boiler itself is captured in the heating savings.
3. Incremental costs were modeled using a 5 unit and a 31 unit building and cost estimates were provided by Steve Pitkin, construction project manager and cost estimator. See 'MeasureCost_StevePitkin6-15-11.xls' for more information. Clearly the incremental cost per unit is much higher for smaller buildings than larger buildings so the per unit cost assumptions are extrapolated for different building sizes assuming a linear relationship.

**Tier 2: Additional Screening Measures**

| | **Incremental Cost Assumption (Tier 1 to Tier 2) per unit** | | | | | |
|---|---|---|---|---|---|---|
| **Number of Units** | **1-5** | **6-10** | **11-15** | **16-20** | **21-25** | **26+** |
| Staged 95% AFUE gas boilers | $0 | $1 | $2 | $4 | $5 | $6 |
| Staged 91% AFUE oil boilers | $840 | $698 | $555 | $413 | $271 | $128 |
| Staged 85% AFUE pellet boilers | $1,760 | $1,711 | $1,661 | $1,612 | $1,562 | $1,513 |
| Indirect DHW off a 95% gas boiler | $0 | $0 | $0 | $0 | $0 | $0 |
| Indirect DHW off a 91% oil boiler | $0 | $0 | $0 | $0 | $0 | $0 |
| Central AC - 15 SEER, 12.5 EER (CEE T2) | $220 | $187 | $154 | $121 | $88 | $55 |
| 3 ACH50 (0.4 cfm50/sq ft) | $767 | $679 | $591 | $502 | $414 | $325 |

These costs will be included above the Tier 1 level costs if these measures are included in the project.

**Reference Tables**
None

# Outdoor Reset Control

Measure Number: III-F-4-a (Multifamily New Construction Program, Space Heating End Use)

**Version Date & Revision History**
Draft date: Portfolio 74
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**

1) http://www.dteenergy.com/pdfs/boilerResetFactSheet.pdf
2) http://www.heat-timer.com/en/EducationDetail.aspx?Id=3
3) http://www.arcmech.com/images/fm/pdir17/OutdoorResetARCreduced.pdf

**Description**
A boiler outdoor reset control regulates the boiler water temperature used for space heating, reducing the temperature when the outside temperature is higher, during fall and spring, improving boiler efficiency and reducing heat loss off the circulating loop. Outdoor reset controls are typically standard on high efficiency gas boiler models, but are an add on for oil boiler units. This measure characterization documents additional savings that will be claimed when an efficient boiler is installed in place of a baseline model without the controls. The AFUE rating used to claim savings for this upgrade (in the Comprehensive Thermal Measure) does not capture savings associated with the Outdoor Reset Control. Note that if specifics from the installation are available (i.e. the length and insulation level of the circulating loop, the boiler size and run time), then a custom tool will be used to capture site specific savings.

**Algorithms**

**Energy and Demand Savings**
n/a

**Baseline Efficiency**
Standard boiler without outdoor reset control.

**Efficient Efficiency**
Boiler with outdoor reset control.

**Loadshape**
n/a. No electric savings.

**Freeridership/Spillover Factors**

| Measure Category | | Space Heating End Use | |
|---|---|---|---|
| Measure Code | | SHECONTR | |
| Product Description | | Staged boiler controls with outdoor reset | |
| Track Name | Track No. | Freerider | Spillover |
| LIMF NC | 6018LINC | 1.0 | 1.0 |
| LIMF Rehab | 6018LIRH | 1.0 | 1.0 |
| MF Mkt NC | 6019MFNC | 1.0 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetime**
15 years
Analysis period is the same as the lifetime.

**Incremental Cost per Unit**

Outdoor reset control is standard on high efficiency gas boiler models. The incremental cost of this measure is therefore assumed to be $0, since the incremental cost of the boiler is captured in the Comprehensive Thermal measure.
For high efficiency oil boiler models, outdoor reset controls are not standard but an optional add on. For oil boilers therefore the incremental cost is assumed to be $1000[417].

**Fossil Fuel Descriptions[418]**

$\Delta$MMBtu = SF * Annual Heat Load

Where

| | |
|---|---|
| SF | = Savings Factor for Boilers with Outdoor Reset control |
| | = 5%[419] |
| Annual Heat Load | = Annual Heating Load of building served by boilers (MMBtu/year) |
| | = Custom (based on heating load result from modeling) |

**Reference Tables**

None

[417] Based on EVT conversations with local HVAC contractors.

[418] If specifics from the installation are available (i.e. the length and insulation level of the circulating loop, the boiler size and run time), then a custom tool will be used to capture site specific savings.

[419] Conservative estimate based on a number of sources:

1. "5%"; http://www.dteenergy.com/pdfs/boilerResetFactSheet.pdf
2. "15% or more"; http://www.heat-timer.com/en/EducationDetail.aspx?Id=3
3. "5 to 30%"; http://www.arcmech.com/images/fm/pdir17/OutdoorResetARCreduced.pdf

# Efficient Products Program

## Clothes Washing End Use

# ENERGY STAR Clothes Washer

Measure Number: IV-A-1-o (Efficient Products Program, Clothes Washing End Use)

**Version Date & Revision History**
Draft date: Portfolio 81
Effective date: 1/1/2013
End date: TBD

**Referenced Documents**:
1) 2013 Clothes Washer Savings.xls;
2) 2009 RECS_HC3.8 Appliances in Northeast Region.xls

**Description**
Clothes washers exceeding minimum qualifying efficiency standards established as ENERGY STAR, CEE Tier 2 or Tier 3 as of 1/1/2011, Most Efficient and Top Ten as defined below:

| Efficiency Level | Modified Energy Factor (MEF) | Water Factor (WF) |
|---|---|---|
| Federal Standard | >= 1.26 | <= 9.5 |
| ENERGY STAR | >= 2.0 | <= 6.0 |
| CEE TIER 2 | >= 2.20 | <= 4.5 |
| CEE TIER 3 | >= 2.40 | <= 4.0 |
| ENERGY STAR Most Efficient (as of 1/1/2013) | >= 2.4 (for units <=2.5 ft3)<br>>= 3.2 (for units >2.5 ft3) | <= 4.5 (for units <=2.5 ft3)<br><= 3.0 (for units >2.5 ft3) |
| Top Ten (as of 09/2012) | Defined as the ten most efficient units available. | |

The modified energy factor (MEF) measures energy consumption of the total laundry cycle (unit operation, washing and drying); the higher the number, the greater the efficiency.

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

**Algorithms**

**Energy Savings**

1. Calculate clothes washer savings based on Modified Energy Factor (MEF).

   The Modified Energy Factor (MEF) includes unit operation, water heating and drying energy use: *"MEF 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"* [420].

   The hot water and dryer savings calculated here assumes electric DHW and Dryer (this will be separated in Step 2).

   MEFsavings = Capacity * (1/MEFbase - 1/MEFeff) * Ncycles

[420] Definition provided on the Energy star website.

Where

Capacity = Clothes Washer capacity (cubic feet)
= Values provided in table below[421]

MEFbase = Modified Energy Factor of baseline unit
= 1.51[422]

MEFeff = Modified Energy Factor of efficient unit
= Values provided in table below[423]

Ncycles = Number of Cycles per year
= 322[424]

MEFsavings is provided below:

| Efficiency Level | MEF | Capacity | MEFSavings (kWh) |
|---|---|---|---|
| Federal Standard | 1.51 | Assumed equal to efficient unit | 0.0 |
| ENERGY STAR | 2.09 | 2.75 | 161.56 |
| CEE Tier 2 | 2.23 | 4.05 | 276.65 |
| CEE Tier 3 | 2.68 | 3.75 | 347.83 |
| ENERGY STAR Most Efficient | 3.25 | 3.91 | 445.70 |
| Top Ten | 3.38 | 4.11 | 484.32 |

2. Break out savings calculated in Step 1 for electric DHW and electric dryer, plus water pump savings

ΔkWh = [(Capacity * 1/MEFbase * Ncycles) * (%CWbase + (%DHWbase * %Electric_DHW) + (%Dryerbase * %Electric_Dryer)] - [(Capacity * 1/MEFeff * Ncycles) * (%CWeff + (%DHWeff * %Electric_DHW) + (%Dryereff * %Electric_Dryer)]

*Where:*

%CW = Percentage of total energy consumption for Clothes Washer operation

%DHW = Percentage of total energy consumption used for water heating

%Dryer = Percentage of total energy consumption for dryer operation
(dependent on efficiency level – see table below)

| | Percentage of Total Energy Consumption[425] | | |
|---|---|---|---|
| | %CW | %DHW | %Dryer |
| Baseline | 6% | 35% | 59% |
| ENERGY STAR | 7% | 24% | 68% |
| CEE Tier 2 | 7% | 23% | 70% |
| CEE Tier 3 | 9% | 12% | 79% |
| ENERGY STAR Most Efficient | 10% | 3% | 87% |

421 Based on average of units incentivized through the program, September 2011 to August 2012, see 2013 Clothes Washer Analysis.xls

422 The federal baseline MEF of 1.26 is inflated by 20% to 1.51 to account for non-qualifying models that are higher than the federal baseline MEF.

423 Based on average of units incentivized through the program, September 2011 to August 2012.

424 Weighted average of 322 clothes washer cycles per year. 2009 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section: http://www.eia.gov/consumption/residential/data/2009/

425 The percentage of total energy consumption that is used for the machine, heating the hot water or by the dryer is different depending on the efficiency of the unit. Values are based on a weighted average of top loading and front loading units (based on available product from the CEC Appliance database) and consumption data from Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_standard.xlsm. See "2013 Clothes Washer Analysis.xls" for the calculation.

| | | | |
|---|---|---|---|
| Top Ten | 10% | 3% | 87% |

%Electric_DHW = Percentage of DHW savings assumed to be electric
= 31.0%[426]

%Electric_Dryer = Percentage of dryer savings assumed to be electric
= 84.0%[427]

The prescriptive kWH savings based on values provided above are:

| | ΔkWH |
|---|---|
| ENERGY STAR | 81.8 |
| CEE Tier 2 | 144.4 |
| CEE Tier 3 | 174.5 |
| ENERGY STAR Most Efficient | 226.6 |
| Top Ten | 251.5 |

**Demand Savings**

ΔkW = ΔkWh/Hours

Where:

ΔkWh = gross customer annual kWh savings for the measure
ΔkW = gross customer connected load kW savings for the measure
Hours = assumed annual run hours of clothes washer
= 322

| | ΔkW |
|---|---|
| ENERGY STAR | 0.25 |
| CEE Tier 2 | 0.45 |
| CEE Tier 3 | 0.54 |
| ENERGY STAR Most Efficient | 0.70 |
| Top Ten | 0.78 |

**Baseline Efficiencies – New or Replacement**

The baseline efficiency is determined according to the modified energy factor (MEF) that takes into account the energy and water required per clothes washer cycle, including energy required by the clothes dryer per clothes washer cycle. The federal baseline MEF of 1.26 is inflated by 20% to 1.51 for savings comparison to account for non-qualifying models that are higher than the federal baseline MEF.

**High Efficiency**

High efficiency is defined as any model meeting or exceeding ENERGY STAR, CEE Tier 2 or Tier 3 standards as of 1/1/2011, ENERGY STAR Most Efficient of Top Ten as defined in the following table:

| Efficiency Level | Modified Energy Factor (MEF) | Water Factor (WF) |
|---|---|---|
| ENERGY STAR | >= 2.0 | <= 6.0 |
| CEE TIER 2 | >= 2.20 | <= 4.5 |
| CEE TIER 3 | >= 2.40 | <= 4.0 |
| ENERGY STAR Most Efficient | >= 2.4 (for units <=2.5 ft3) | <= 4.5 (for units <=2.5 ft3) |

[426] Based on 'Vermont Single-Family Existing Homes Onsite Report', 2/15/2013, p67.
[427] Ibid, p80.

| | | |
|---|---|---|
| (as of 1/1/2013) | >= 3.2 (for units >2.5 ft3) | <= 3.0 (for units >2.5 ft3) |
| Top Ten | Defined as the ten most efficient units available. | |

Energy and water savings estimates are based on the weighted average MEF factor for qualifying models based on the models rebated during the previous calendar year, except Top Ten which is based upon averaging the units provided on the website (http://www.toptenusa.org/Top-Ten-Clothes-Washers) as of September 2012.

**Operating Cycles**
322 clothes washer cycles / year [428]

**Operating Hours**
322 operating hours / year [429]

**Loadshape**
Loadshape #9, Residential Clothes Washing, Vermont State Screening Tool.

**Freeridership/Spillover Factors**

| **Measure Category** | | **Cooking and Laundry** | | | | | |
|---|---|---|---|---|---|---|---|
| **Product Description** | | **Efficient Clothes Washer** | | | | | |
| **Measure Code** | | **CKLESWRP, CKLC2WRP** | | **CKLC3WRP** | | **CKLMEWRP, CKLTTWRP** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** | **Freerider** | **Spillover** | **Freerider** | **Spillover** |
| Efficient Products | 6032EPEP | 0.5 | 1.0 | 0.9 | 1.1 | 0.95 | 1.2 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
14 years[430] (same as DPS screening of Efficiency Utility program).
Analysis period is the same as the lifetime.

**Measure Cost**
The incremental cost for this measure is provided in the table below[431]:

| Efficiency Level | Incremental Cost |
|---|---|
| ENERGY STAR | $225 |
| CEE Tier 2 | $250 |
| CEE Tier 3 | $350 |
| ENERGY STAR Most Efficient | $500 |
| Top Ten | $510 |

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**

[428] Weighted average of 322 clothes washer cycles per year. 2009 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section: http://www.eia.gov/consumption/residential/data/2009/
[429] Assume one hour per cycle.
[430] Based on DOE Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_standard.xlsm.
[431] Based on weighted average of top loading and front loading units (based on available product from the CEC Appliance database) and cost data from Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_standard.xlsm. See '2013 Clothes Washer Analysis.xls' for details.

Break out savings calculated in Step 1 of electric energy savings (MEF savings) and extract Natural Gas, LP and Oil DHW and Natural Gas and LP dryer savings from total savings:

ΔMMBtu = [(Capacity * 1/MEFbase * Ncycles) * ((%DHWbase * %Fuel_DHW * R_eff) + (%Dryerbase * %Fuel_dryer)] - [(Capacity * 1/MEFeff * Ncycles) * ((%DHWeff * %Fuel_DHW * R_eff) + (%Dryereff * %Fuel_Dryer)] * MMBtu_convert

Where:

R_eff = Recovery efficiency factor
= 1.26[432]

MMBtu _convert = Convertion factor from kWh to MMBtu
= 0.003413

%Fuel_DHW = Percentage of DHW savings assumed to be non electric[433]

| DHW fuel | %Fuel _DHW |
|---|---|
| Natural Gas | 20.0% |
| LP Gas | 12.0% |
| Oil | 37.0% |

%Gas_Dryer = Percentage of dryer savings assumed to be Natural Gas[434]

| Dryer fuel | %Gas_Dryer |
|---|---|
| Natural Gas | 5.0% |
| LP Gas | 11.0% |

Other factors as defined above

The prescriptive MMBtu savings are:

| | ΔMMBtu | | |
|---|---|---|---|
| | NG | LP | Oil |
| ENERGY STAR | 0.10 | 0.07 | 0.16 |
| CEE Tier 2 | 0.16 | 0.12 | 0.27 |
| CEE Tier 3 | 0.21 | 0.16 | 0.36 |
| ENERGY STAR Most Efficient | 0.27 | 0.20 | 0.45 |
| Top Ten | 0.29 | 0.22 | 0.47 |

**Water Descriptions**

ΔWater (CCF) = (Capacity * (WFbase - WFeff)) * Ncycles

Where

WFbase = Water Factor of baseline clothes washer
= 7.93[435]

WFeff = Water Factor of efficient clothes washer
= Values provided below[436].

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

[433] Based on 'Vermont Single-Family Existing Homes Onsite Report', 2/15/2013, p67.

[434] Ibid, p80.

[435] Average WF of post 1/1/2007, non-ENERGY STAR units.

[436] Based on average of units incentivized through the program, September 2011 to August 2012, see 2013 Clothes Washer Analysis.xls

The prescriptive water savings for each efficiency level are presented below:

| Efficiency Level | WF | ∆Water (CCF per year) |
|---|---|---|
| Federal Standard | 7.93 | 0.0 |
| ENERGY STAR | 5.41 | 3.0 |
| CEE Tier 2 | 3.61 | 7.5 |
| CEE Tier 3 | 3.51 | 7.1 |
| ENERGY STAR Most Efficient | 2.90 | 8.5 |
| Top Ten | 3.54 | 7.8 |

# ENERGY STAR Clothes Dryer

Measure Number: IV-A-2-a (Efficient Products Program, Clothes Washing End Use)

**Version Date & Revision History**
Draft date: Portfolio 87c
Effective date: 9/1/2014
End date: TBD

**Referenced Documents**:

1) 2014 Clothes Dryer Analysis with HVAC Impact.xlsx;
2) ENERGY STAR® Program Requirements Product Specification for Clothes Dryers Version 1.0
3) 2014 ENERGY STAR® Emerging Technology Advanced Clothes Dryers Criteria
4) ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis.xlsx
5) Appendix J2 To Subpart B Of Part 430—Uniform Test Method For Measuring The Energy Consumption Ofautomatic And Semi-Automatic Clothes Washers
6) ENERGY STAR Dryer Specification NEEA Amended comments Mar 26 2013
7) 2011-04-18_TSD_Chapter_8_Life-Cycle_Cost_and_Payback_Period_Analyses
8) 2013 Vermont Single-Family Existing Homes Onsite Report
9) 2014 Emerging Technology Award _Advanced Clothes Dryer Models

**Description**
Clothes dryers exceeding minimum qualifying efficiency standards established as ENERGY STAR or 2014 Emerging Technology Award as of 9/1/2014, based on Combined Energy Factor (CEF), as described below under High Efficiency.

The CEF measures energy consumption of the total dryer cycle (standby usage, dryer heating and operation) in units of weight (lbs) of clothing dried per kWh of electricity; the higher the number, the greater the efficiency. In the case of gas dryers, the CEF combines both the gas and electric usage into a single CEF metric also measured in units of weight of clothing dried per kWh of electricity.

**Baseline Efficiencies – New or Replacement**
The baseline efficiency is determined according to the combined energy factor (CEF) that takes into account the active and standby energy required per clothes dryer cycle. The baseline combined energy factor (CEF) was derived in the ENERGY STAR Version 1.0 analysis by multipling 2015 federal standards by the average change in a dryers' assessed CEF between the required (Appendix D1) and optional (Appendix D2) test procedure required by the ENERGY STAR eligibility requirements.

**High Efficiency**
High efficiency is defined as any model meeting or exceeding ENERGY STAR or 2014 Emerging Technology Award criteria, as defined in the following table:

| Efficiency Level | Combined Energy Factor (CEF) Lbs / kWh |
|---|---|
| ENERGY STAR (Electric) | >= 3.93 in "Normal" setting |
| ENERGY STAR (Gas) | >= 3.48 in "Normal" setting |
| 2014 Emerging Technology Award (Electric)[437] | >= 4.3 in "Normal" setting<br>>= 5.3 in "Most Efficient" setting |

[437] Although the 2014 Emerging Technology Award criteria are the basis for program eligibility, the actual performance measurements from the 11/3/2014 list of 2014 Emerging Technology Award Winning Dryers are used for characterizing the measure savings for the ventless Whirlpool and the vented LG award winning dryer models. The performance specification is anticipated to change later in 2015 based on new ENERGY STAR Most Efficient and/or CEE tiered specifications. Eligibility for the current award criteria is anticipated to end on December 31st, 2014.

Energy savings estimates are based on the resulting product from multiplying the average CEF of ENERGY STAR qualified dryers on 9/15/2014 and the average load weight associated with the available paired washer model capacities. The average capacities are used to look up the average load size in the U.S. DOE clothes washer test procedure (10 CFR 430, Subpart B, Appendix J2 Table 5.1).

**Algorithms**

**Electric Energy Savings**

$\Delta kWh = Weight * (1/CEF_{base} - 1/CEF_{eff}) * \%Elec * \%Washer * N_{cycles} + HVAC_{ventless}$

Where

| | |
|---|---|
| $\Delta kWh$ | = gross customer annual kWh savings for the measure |
| Weight | = Average clothes dryer load weight (lbs) based on DOE average test load size of paired washer.<br>= 10.4 lbs [438] |
| $CEF_{base}$ | = Combined Energy Factor of baseline unit based on full cycle testing of conventional dryers [439]<br>= Values provided in table below |
| $CEF_{eff}$ | = Combined Energy Factor of efficient unit<br>= Values provided in table below |
| $N_{cycles}$ | = Number of Cycles per year<br>= 322[440] |
| %Elec | = Percentage of electric to total energy for dryer operation<br>= Values provided in table below |
| %Washer | = Reduction in dryer savings from efficient clothes washers[441]<br>= Values provided in table below |
| $HVAC_{ventless}$ | = HVAC In-direct electric savings from ventless dryer[442]<br>= 3 kWh for ETA ventless dryer; 0 kWh for all others |

[438] Based on average of ENERGY STAR qualified dryers on 9/15/2014 and available paired washer model capacity. This average capacity is then used to look up the average load size in the U.S. DOE clothes washer test procedure (10 CFR 430, Subpart B, Appendix J2 Table 5.1), see 2014 Clothes Dryer Analysis with HVAC Impact.xlsx

[439] The Combined Energy Factor (CEF) includes standby usage, dryer heating and operation electric use: *"The clothes dryer test load weight in pounds divided by the sum of the per cycle standby and off mode energy consumption and either the total per-cycle electric dryer energy consumption or the total per-cycle gas dryer energy consumption expressed in kilowatt hours (kWh)."* Definition provided in the ENERGY STAR® Program Requirements Product Specification for Clothes Dryers Eligibility Criteria Version 1.0

[440] Weighted average of 322 clothes washer cycles per year based on the Efficiency Vermont 2014 Technical Resource Manual clothes washer measure characterization. A field evaluation completed by NEEA in 50 homes in the Northwest found a higher number of annual dryer cycles (337) than currently represented in the RECS data. Federal standard employs a 0.91 field use factor, based on RECS 2009 survey data suggesting not all clothes washer loads are dried. However, NEEA found a higher number of dryer loads, noting users may not have consolidated their loads to the extent EPA assumed.
http://www.energystar.gov/sites/default/files/specs//ENERGY%20STAR%20Dryer%20Specification%20NEEA%20Amended%20comments%20Mar%2026%202013.pdf. Page 7.

[441] The percentage of energy reduction reflects the amount of dryer energy already captured by the performance of efficient clothes washers. The effective performance of paired clothes washers for both the ENERGY STAR and 2014 ETA dryers reflect the market share and relative remaining moisture content for clothes washers both in-program (rebated) and out-of-program (non-rebated). See 2014 Clothes Dryer Analysis with HVAC Impact.xlsx.

[442] HVAC In-direct savings for ventless dryers are based on the penetration of cooling systems, heating fuel types and corresponding efficiencies identified in the 'Vermont Single-Family Existing Homes Onsite Report', 2/15/2013, see HVAC Inputs tab in 2014 Clothes Dryer Analysis with HVAC Impact.xlsx.

| | Percentage of Total Energy Consumption[443] | |
|---|---|---|
| | %Elec (Electric) | %Heat (Gas) |
| ENERGY STAR (Standard Electric) | 100% | 0% |
| ENERGY STAR (Standard Gas) | 19% | 81% |

Dryer savings are provided below:

| Efficiency Level | CEF (lbs/kWh) | Load Weight (lbs) | % Energy Reduction from Paired Efficient Washers | HVAC Impact from Ventless Dryers (kWh) | Annual Dryer Savings (kWh) |
|---|---|---|---|---|---|
| ENERGY STAR Version 1.0 Estimated Baseline (Electric)[444] | 3.11 | 10.4 | N/A | N/A | N/A |
| ENERGY STAR Version 1.0 Estimated Baseline (Gas) [445] | 2.84 | | N/A | | N/A |
| ENERGY STAR (Standard Electric) | 3.93 | | 14% | | 194 |
| ENERGY STAR (Standard Gas) | 3.48 | | 14% | | 36[446] |
| 2014 Emerging Technology Award Vented (Electric) | 4.35 / 5.6 | | 16% | | 366[447] |
| 2014 Emerging Technology Award Ventless (Electric) | 5.43 / 6.17 | | 14% | 3 | 446 |

**Electric Demand Savings**

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

Where:

$\Delta$kW = gross customer connected load kW savings for the measure

Hours = assumed annual run hours of clothes dryer
= Ncycles * 1 Hour
= 322[448]

[443] The percentage of individual energy consumption used by the machine (%Elec) and separately for heating (%Heat) the dryer drum was derived from the ENERGY STAR Version 1.0 analysis; see 2014 Clothes Dryer Analysis with HVAC Impact.xlsx

[444] The federal standard electric baseline CEF was derived in the ENERGY STAR Version 1.0 analysis by multipling 2015 standard by the average change in gas dryers' assessed CEF between Appendix D1 and Appendix D2: 3.73 - (3.73 x 0.166)

[445] The federal standard gas baseline CEF was derived in the ENERGY STAR Version 1.0 analysis by multipling 2015 standard by the average change in gas dryers' assessed CEF between Appendix D1 and Appendix D2: 3.30 - (3.30 x 0.139)

[446] Savings calculated represent only the portion attributed to the electric operation – motor and controls - of the ENERGY STAR gas dryers

[447] Estimates a 75/25 split of consumer preference for dryer settings between "most efficient" and "normal" to estimate cumulative annual energy savings. This split is based on the default setting (as shipped) in the most efficient setting and energy savings driver for early adopters, see 2014 Clothes Dryer Analysis with HVAC Impact.xlsx.

[448] Weighted average of 322 clothes washer cycles per year based on the Efficiency Vermont 2014 Technical Resource Manual clothes washer measure characterization. Federal standard employs a 0.91 field use factor, based on RECS 2009 survey data suggesting not all clothes washer loads are dried, but in earlier proceedings DOE references a higher percentage (0.96) for households with a dryer. A field evaluation completed by NEEA in 50 homes in the Northwest found a higher number of annual dryer cycles (337) than currently represented in the RECS data, noting users may not have consolidated their loads to the extent EPA assumed and were doing a significant percentage of "touch up" loads. Approximately one hour per cycle based on the ENERGY STAR clothes dryer qualified product list as of 9/15/2014. http://www.energystar.gov/sites/default/files/specs//ENERGY%20STAR%20Dryer%20Specification%20NEEA%20Amended%20comments%20Mar%2026%202013.pdf. Page 7.

| | ΔkW |
|---|---|
| ENERGY STAR (Standard Electric) | 0.54 |
| ENERGY STAR (Standard Gas) | 0.12 |
| 2014 Emerging Technology Award Vented (Electric) | 0.91 |
| 2014 Emerging Technology Award Ventless (Electric) | 1.09 |

**Fossil Fuel Savings**

Break out savings calculated above in gas energy savings (Dryer savings) and extract Natural Gas and LP dryer heat savings from total savings:

$$\Delta MMBtu_{fuel} = Weight * (1/CEF_{base} - 1/CEF_{eff}) * (1\text{-}\%Elec) * \%Washer * N_{cycles}] * MMBtu\_convert * \%\ Fuel\_Dryer + \Delta MMBtu_{ventless}$$

Where:

$\Delta MMBtu_{fuel}$ = gross customer annual MMBtu savings for the measure, by fuel type
MMBtu _convert = Convertion factor from kWh to MMBtu
= 0.003413
$\Delta MMBtu_{ventless}$[449] = HVAC In-direct fossil fuel savings from ventless dryer, by fuel type
= Values provided in table below for ETA Ventless dryers; zero for all others
% Fuel_Dryer = Percentage of dryer savings by fuel type[450]

| Dryer fuel | % Fuel_Dryer |
|---|---|
| Natural Gas | 31% |
| LP Gas | 69% |

Other factors as defined above

The prescriptive annual MMBtu savings per unit are:

| | Total MMBtu | NG | LP | Oil | Wood |
|---|---|---|---|---|---|
| ENERGY STAR (Electric) | 0 | 0 | 0 | 0 | 0 |
| ENERGY STAR (Gas) | 0.51 | 0.16 | 0.35 | 0 | 0 |
| 2014 Emerging Technology Award Vented (Electric) | 0 | 0 | 0 | 0 | 0 |
| 2014 Emerging Technology Award Ventless (Electric) | 0.39 | 0.05 | 0.05 | 0.17 | 0.13 |

**Water Savings**
There are no water savings.

**Operating Hours**
322 operating hours / year [451]

**Loadshape**
Loadshape #9, Residential Clothes Washing, Vermont State Screening Tool.

[449] HVAC In-direct savings for ventless dryers are based on the penetration of cooling systems, heating fuel types and corresponding efficiencies identified in the 'Vermont Single-Family Existing Homes Onsite Report', 2/15/2013, see HVAC Inputs tab in 2014 Clothes Dryer Analysis with HVAC Impact.xlsx.
[450] Based on 'Vermont Single-Family Existing Homes Onsite Report', 2/15/2013, p67.
[451] Aprroximately one hour per cycle based on the ENERGY STAR clothes dryer qualified product list as of 9/15/2014.

**Freeridership/Spillover Factors**

| Measure Category | | Cooking and Laundry | | | | | |
|---|---|---|---|---|---|---|---|
| **Product Description** | | **Efficient Clothes Dryer** | | | | | |
| **Measure Code** | | **ENERGY STAR elec** | | **ENERGY STAR gas** | | **2014 Emerging Technology Award** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** | **Freerider** | **Spillover** | **Freerider** | **Spillover** |
| Efficient Products | 6032EPEP | 0.9 | 1.1 | 0.9 | 1.1 | 1.0 | 1.2 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
12 years[452]
Analysis period is the same as the lifetime.

**Measure Cost**
The incremental cost for this measure is provided in the table below[453]:

| Efficiency Level | Incremental Cost |
|---|---|
| ENERGY STAR | $61 |
| 2014 Emerging Technology Award | $412 |

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

[452] Based on average lifetime in DOE Buildings Data Book http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=5.7.15
[453] See 2014 Clothes Dryer Analysis with HVAC Impact.xlsx. Based on DOE Life-Cycle Cost and Payback Period analysis Table 8.3.1, http://www.regulations.gov/contentStreamer?objectId=0900006480c8ee12&disposition=attachment&contentType=pdf

**Refrigeration End Use**
# ENERGY STAR Refrigerator

Measure Number: IV-B-1-i (Efficient Products Program, Refrigeration End Use)

**Version Date & Revision History**
Draft: Portfolio 81
Effective: 1/1/2013
End: TBD

Referenced Documents:
1) 2013 RF Savings Analysis.xls;
2) 2009 VT Appliance Data w doc_CostAnalysisTRM
3) Refrigerator kW Calculations.xls

**Description**
A refrigerator of baseline efficiency is replaced by a new refrigerator meeting either Energy Star specifications or the higher efficiency specifications of a CEE Tier 2, or CEE Tier 3 rated refrigerator.

**Algorithms**

**Energy Savings**[454]

**ENERGY STAR:**

$\Delta kWh = kWh_{base} - kWh_{ES}$
$= 600.4 – 480.3$
$= 120.1$

**CEE Tier 2:**

$\Delta kWh = kWh_{base} - kWh_{CT2}$
$\Delta kWh = 600.4 – 450.3$
$= 150.1$

**CEE Tier 3:**

$\Delta kWh_{CT3} = kWh_{base} - kWh_{CT3}$
$\Delta kWh_{CT3} = 600.4 – 420.3$
$= 180.1$

**Demand Savings**[455]

**ENERGY STAR:**

$\Delta kW = \Delta kWh_{ES}$ / Hours
$\Delta kW = 120.1 / 8477$
$= 0.014$

**CEE Tier 2:**

$\Delta kW = \Delta kWh_{CT2}$ / Hours
$\Delta kW = 150.1 / 8477$
$= 0.018$

[454] Based on analysis of previous year's rebated units, see 2013 RF Savings Analysis.xls.
[455] Based on analysis of previous year's rebated units, see 2013 RF Savings Analysis.xls.

**CEE Tier 3:**

$\Delta kW_{CT3} = \Delta kWh_{CT3}$ / Hours

$\Delta kW_{CT3} = 180.1 / 8477$

$= 0.021$

Where:

| | |
|---|---|
| $\Delta kW$ | = gross customer connected load kW savings for the measure |
| $kWh_{base}$ | = Baseline unit consumption |
| $kWh_{ES}$ | = Energy-Star unit consumption |
| $kWh_{CT2}$ | = CEE Tier 2 unit consumption |
| $kWh_{CT3}$ | = CEE Tier 3 unit consumption |
| $\Delta kWh$ | = gross customer annual kWh savings for the measure |
| HOURS | = Equivalent Full Load Hours |
| | = 8477[456] |

**Baseline Efficiencies – New or Replacement**

Baseline efficiency is a refrigerator meeting the minimum federal efficiency standard for refrigerator efficiency.

**High Efficiency**

The High Efficiency level is a refrigerator meeting Energy Star specifications for efficiency effective on April 28th, 2008 (20% above federal standard), a refrigerator meeting CEE Tier 2 specifications (25% above federal standard), or meeting CEE Tier 3 specifications (30% above federal standards).

**Loadshape**

Loadshape #4, Residential Refrigeration, Vermont State Cost-Effectiveness Screening Tool.

**Freeridership[457]/Spillover Factors[458]**

| Measure Category | | Refrigeration | |
|---|---|---|---|
| Measure Codes | | RFRESRRP, RFRESRT2, RFRESRT3 | |
| Product Description | | Energy Star refrigerator, CEE Tier 2, CEE Tier 3 | |
| Track Name | Track No. | Freerider | Spillover |
| Efficient Products | 6032EPEP | 0.67 | 1.33 |

**Persistence**

The persistence factor is assumed to be one.

**Lifetimes**

12 Years[459]

Analysis period is the same as the lifetime.

**Measure Cost**

The incremental cost to the Energy Star level is $40[460], to CEE Tier 2 level is $150 and to CEE Tier 3 is $225[461].

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456 The Summer and Winter Coincident kW are calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. To calculate an Equivalent Full Load Hours the UEC (* PartUse) is divided by the summer coincident kW (956 * .779)/0.088 = 8477 hours. The summer coincidence factor is therefore assumed to be 1.0 and a winter coincidence factor calculated as the relative winter to summer kW result from the algorithm. For the calculation see "Refrigerator kW Calculations.xls".

457 The 33% freerider rate assumes that after the rebate is made available the market share in VT will increase to 30% for ENERGY STAR refrigerators.

458 The estimated spillover rate of 33% is consistent with both past Efficiency Vermont experience for clothes washers and qualitative reports from manufacturers and large retailers regarding the number of customers who do not cash rebate coupons-

459 From ENERGY STAR calculator: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?e678-f5e6&e678-f5e6

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

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[460] From ENERGY STAR Calculator; based on Appliance Magazine, Market Research Report, January 2011; http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?e678-f5e6&e678-f5e6
[461] Based on review of data from the Northeast Regional ENERGY STAR Consumer Products Initiative; "2009 ENERGY STAR Appliances Practices Report", submitted by Lockheed Martin, December 2009. See 2009 VT Appliance Data_TRMCostAnalysis.xlsfor data.

# ENERGY STAR Freezer

Measure Number: IV-B-2-c (Efficient Products Program, Refrigeration End Use)

**Version Date & Revision History**

| | |
|---|---|
| Draft: | Portfolio 81 |
| Effective: | 1/1/2013 |
| End: | TBD |

**Referenced Documents:**

1) 2003 D&R Int. Freezer Fact Sheet,
2) 2011 Freezer Savings.xls
3) 2009 VT Appliance Data_TRMCostAnalysis.xls
4) Refrigerator kW Calculations.xls

**Description**

An ENERGY STAR qualifying residential freezer replaces a freezer of baseline efficiency.

**Algorithms**

**Demand Savings**

$\Delta kW = \Delta kWh/Hours$

$\Delta kW = 52.5 / 8477$

$= 0.006$

**Energy Savings** [462]

$\Delta kWh = kWh_{Base} - kWh_{ESTAR}$

$\Delta kWh = 507.1 – 454.6$

$= 52.5$ kWh

Where:

| | |
|---|---|
| $\Delta kW$ | = gross customer connected load kW savings for the measure |
| $kWh_{BASE}$ | = Baseline kWh consumption per year |
| $kWh_{ESTAR}$ | = ENERGY STAR kWh consumption per year |
| $\Delta kWh$ | = gross customer annual kWh savings for the measure |
| HOURS | = Equivalent Full Load Hours |
| | = 8477[463] |

**Baseline Efficiencies – New or Replacement**

Baseline efficiency is a residential freezer meeting the minimum federal efficiency standard for freezer efficiency.

**High Efficiency**

The High Efficiency level is a freezer meeting ENERGY STAR specifications for efficiency established January 1, 2003 (at least 10% more.efficient than federal standard units).

[462] Base and Energy Star consumption estimates are based on last 18 months of Efficiency Vermont incentivized units, see 2011 Freezer Savings.xls for more details.

[463] The Summer and Winter Coincident kW are calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. To calculate an Equivalent Full Load Hours the UEC (* PartUse) is divided by the summer coincident kW (956 * .779)/0.088 = 8477 hours. The summer coincidence factor is therefore assumed to be 1.0 and a winter coincidence factor calculated as the relative winter to summer kW result from the algorithm. For the calculation see “Refrigerator kW Calculations.xls”.

**Loadshape**
Loadshape #4, Residential Refrigeration, Vermont State Cost-Effectiveness Screening Tool.

**Freeridership / Spillover Factors**

| | | | |
|---|---|---|---|
| Measure Category | | Refrigeration | |
| Measure Codes | | RFRESFZP | |
| Product Description | | Energy Star Freezer | |
| Track Name | Track No. | Freerider | Spillover |
| Efficient Products | 6032EPEP | 0.67 | 1.33 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
16 years[464]
Analysis period is the same as the lifetime.

**Measure Cost**
The incremental cost for this measure is $35[465].

**Incentive Level**
The incentive level for this measure is $25.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

[464] Source: 2003 D&R Int. Freezer Fact Sheet
[465] Based on review of data from the Northeast Regional ENERGY STAR Consumer Products Initiative; "2009 ENERGY STAR Appliances Practices Report", submitted by Lockheed Martin, December 2009. See 2009 VT Appliance Data_TRMCostAnalysis.xlsfor data.

# Refrigerator Early Removal

Measure Number: IV-B-3-b (Residential Efficient Products, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 80
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**

1. ADM Evaluation Study of the 2004-05 Statewide Residential Appliance Recycling Program;
2. KEMA Residential Refrigerator Recycling Ninth Year Retention Study;
3. Opinion Dynamics; "Fridge & Freezer Recycle Rewards Program PY4 Metering Study: DRAFT Savings Results"
4. The Cadmus Group et al., "Residential Retrofit High Impact Measure Evaluation Report", prepared for the California Public Utilities Commission, February 8, 2010
5. Appliance Recycling data2008-2012_V2.xls
6. Refrigerator kW Calculations.xls

**Description**
This is an early retirement measure for the removal of an existing inefficient secondary refrigerator from service. The program will target refrigerators with an age greater than 10 years, though data from units removed through the program suggests the average age of retired units is over 30 years. Savings are calculated for the estimated energy consumption during the remaining life of the existing unit.

**Algorithms**

**Energy Savings**
$\Delta$kWh = UEC * PartUse
= 956 * 0.779
= 745 kWh

**Demand Savings**
$\Delta$kW = $\Delta$kWh/Hours
= 745/8477
= 0.088 kW

Where:

$\Delta$kWh = gross customer annual kWh savings for the measure
UEC = Unit Energy Consumption
= 956 kWh[466]
PartUse = adjustment factor for weighted partial use of appliance
= 0.779[467]
HOURS = Equivalent Full Load Hours
= 8477[468]

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466 Unit Energy Consumption is based upon review of the data collected by Jaco from units retired in the program from 2009-2012. To estimate the consumption of the retired units EVT used a regression equation with multiple attributes from a recent Illinois evaluation (Opinion Dynamics; "Fridge & Freezer Recycle Rewards Program PY4 Metering Study: DRAFT Savings Results. For information see "Appliance Recycling data2008-2012_V2.xls".
467 Based on analysis of Jaco data. Participants were asked how much the refrigerator was run through the year. The data was weighted assuming the response "All months" equaled 12 months, "Summer" or "Winter" equaled 3 months and "Spring/Fall" equaled 6 months.
468 The Summer and Winter Coincident kW are calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. To calculate an Equivalent

$\Delta$kW = gross customer connected load kW savings for the measure

**Baseline Efficiencies – New or Replacement**
The existing refrigerator baseline consumption is based upon data collected by Jaco from units retired in the program from 2009-2012 and adjusted for part use consumption.

**High Efficiency**
N/A

**Loadshape**
Loadshape #4, Residential Refrigerator

**Freeridership/Spillover Factors**

| Measure Category | | Refrigeration | |
|---|---|---|---|
| Measure Code | | RFRRERPS | |
| Product Description | | Refrigerator Early Retirement | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6012MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | .62[469] | 1.1[470] |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
8 years [471]
Analysis period is the same as the lifetime.

**Measure Cost**
The cost of the administrative, pickup and recycling of the refrigerator is $110 based upon cost provided by Jaco.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

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Full Load Hours the UEC (* PartUse) is divided by the summer coincident kW (956 * .779)/0.088 = 8477 hours. The summer coincidence factor is therefore assumed to be 1.0 and a winter coincidence factor calculated as the relative winter to summer kW result from the algorithm. For the calculation see "Refrigerator kW Calculations.xls".
[469] ADM Evaluation Study, p. 3-30 for secondary refrigerators
[470] EVT estimate of effect of campaign awareness of energy consumption of older refrigerators
[471] KEMA "Residential refrigerator recycling ninth year retention study", 2004

**Fossil Fuel Descriptions**
There are no fossil fuel savings for this measure.

**Water Descriptions**
There are no water savings for this measure.

# Freezer Early Removal

Measure Number: IV-B-4-b (Residential Efficient Products, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 80
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**

1. ADM Evaluation Study of the 2004-05 Statewide Residential Appliance Recycling Program;
2. KEMA Residential Refrigerator Recycling Ninth Year Retention Study;
3. Opinion Dynamics; “Fridge & Freezer Recycle Rewards Program PY4 Metering Study: DRAFT Savings Results”
4. The Cadmus Group et al., “Residential Retrofit High Impact Measure Evaluation Report”, prepared for the California Public Utilities Commission, February 8, 2010
5. Appliance Recycling data2008-2012_V2.xls
6. Refrigerator kW Calculations.xls

**Description**
This is an early retirement measure for the removal of an existing inefficient freezer from service. The program will target freezers with an age greater than 10 years, although data suggests the average age of retired units is over 30 years. Savings are calculated for the estimated energy consumption during the remaining life of the existing unit.

**Algorithms**
**Energy Savings**
ΔkWh = UEC * PartUse
= 1231 * 0.777
= 956 kWh

**Demand Savings**
ΔkW = ΔkWh/Hours
= 956 /8477
= 0.113 kW

Where:
ΔkWh = gross customer annual kWh savings for the measure
UEC = Unit Energy Consumption
= 1231kWh[472]
PartUse = adjustment factor for weighted partial use of appliance
= 0.777[473]
HOURS = Equivalent Full Load Hours
= 8477[474]

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[472] Unit Energy Consumption is based upon review of the data collected by Jaco from units retired in the program from 2009-2012. To estimate the consumption of the retired units EVT used a regression equation with multiple attributes from a recent Illinois evaluation (Opinion Dynamics; “Fridge & Freezer Recycle Rewards Program PY4 Metering Study: DRAFT Savings Results”). For information see “Appliance Recycling data2008-2012_V2.xls”.
[473] Based on analysis of Jaco data. Participants were asked how much the freezer was run through the year. The data was weighted assuming the response “All months” equaled 12 months, “Summer” or “Winter” equaled 3 months and “Spring/Fall” equaled 6 months.
[474] The Summer and Winter Coincident kW are calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. To calculate an Equivalent Full Load Hours the UEC (* PartUse) is divided by the summer coincident kW (956 * .779)/0.088 = 8477 hours. The summer coincidence factor is therefore assumed to be 1.0 and a winter coincidence factor calculated as the relative winter to summer kW result from the algorithm. For the calculation see “Refrigerator kW Calculations.xls”.

$\Delta kW$ = gross customer connected load kW savings for the measure

**Baseline Efficiencies – New or Replacement**
The existing freezer baseline consumption is based upon data collected by Jaco from units retired in the program from 2009-2012 and adjusted for part use consumption.

**High Efficiency**
N/A

**Loadshape**
Loadshape #4, Residential Refrigerator

**Freeridership/Spillover Factors**

| Measure Category | | Refrigeration | |
|---|---|---|---|
| Measure Code | | RFRFERPS | |
| Product Description | | Freezer Early Retirement | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6012MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | .71[475] | 1.1[476] |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
8 years [477] Analysis period is the same as the lifetime.

**Measure Cost**
The cost of the administrative, pickup and recycling of the refrigerator is $110 based upon cost provided by Jaco.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel savings for this measure.

475 ADM Evaluation Study, p. 3-30 for secondary refrigerators
476 EVT estimate of effect of campaign awareness of energy consumption of older refrigerators
477 KEMA "Residential refrigerator recycling ninth year retention study", 2004

**Water Descriptions**

There are no water savings for this measure.

## Air Conditioning End Use

# Energy Star Dehumidifiers

Measure Number: IV-D-2-b (Efficient Products Program, Air Conditioning End Use)

**Version Date & Revision History**
Draft: Portfolio 82
Effective: 1/1/2013
End: TBD

**Referenced Documents:** 2013 Dehumidifier Calcs.xls

**Description**
A dehumidifier meeting the new minimum qualifying efficiency standard established by ENERGY STAR Program (Version 3.0), effective 10/1/2012 is purchased and installed in a residential setting in place of a unit that meets the minimum federal standard efficiency.

**Algorithms**

**Energy Savings**
ΔkWh = (((Avg Capacity * 0.473) / 24) * Hours) * (1 / (L/kWh_Base) – 1 / (L/kWh_Eff))

Where:

| | |
|---|---|
| Avg Capacity | = Average capacity of the unit (pints/day) |
| 0.473 | = Constant to convert Pints to Liters |
| 24 | = Constant to convert Liters/day to Liters/hour |
| Hours | = Run hours per year<br>= 1632 [478] |
| L/kWh_Base | = Baseline unit liters of water per kWh consumed, as provided in tables below |
| L/kWh_Eff | = Efficient unit liters of water per kWh consumed, as provided in tables below |

Annual kWh results for each capacity class are presented below using the average of the capacity range and an average value to be used for prescriptive savings calculations where the capacity is not tracked.

| Capacity (pints/day) Range | Capacity Used | Federal Standard Criteria (≥ L/kWh) | ENERGY STAR Criteria (≥ L/kWh) | Annual kWh Federal Standard | Annual kWh ENERGY STAR | Annual kWh Savings |
|---|---|---|---|---|---|---|
| ≤25 | 20 | 1.35 | 1.85 | 477 | 348 | 129 |
| > 25 to ≤35 | 30 | 1.35 | 1.85 | 715 | 522 | 193 |
| > 35 to ≤45 | 40 | 1.5 | 1.85 | 858 | 695 | 162 |

[478] Based on 68 days of 24 hour operation; ENERGY STAR Dehumidifier Calculator http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?f3f7-6a8b&f3f7-6a8b

| | | | | | | |
|---|---|---|---|---|---|---|
| > 45 to ≤ 54 | 50 | 1.6 | 1.85 | 1005 | 869 | 136 |
| > 54 to ≤ 75 | 65 | 1.7 | 1.85 | 1230 | 1130 | 100 |
| > 75 to ≤ 185 | 130 | 2.5 | 2.8 | 1673 | 1493 | 179 |
| Average[479] | 52 | 1.58 | 1.88 | 105 | 888 | 169 |

**Demand Savings**

$\Delta kW = \Delta kWh/Hours$

Where:

Hours = Annual operating hours
= 1632 hours

| Capacity (pints/day) Range | ΔkW |
|---|---|
| ≤25 | 0.079 |
| > 25 to ≤35 | 0.118 |
| > 35 to ≤45 | 0.099 |
| > 45 to ≤ 54 | 0.083 |
| > 54 to ≤ 75 | 0.061 |
| > 75 to ≤ 185 | 0.110 |
| Average | 0.103 |

**Baseline Efficiencies – New or Replacement**

Baseline efficiency is a dehumidifier that meets the Federal Standard efficiency standards as defined below[480]:

| Capacity (pints/day) | Federal Standard Criteria (L/kWh) |
|---|---|
| ≤35 | ≥1.35 |
| > 35 to ≤45 | ≥1.50 |
| > 45 to ≤ 54 | ≥1.60 |
| > 54 to ≤ 75 | ≥1.70 |
| > 75 to ≤ 185 | ≥2.50 |

**High Efficiency**

High efficiency is defined as any model meeting or exceeding ENERGY STAR qualifying efficiency standard established by the current ENERGY STAR (Version 3.0)
Performance Criteria for ENERGY STAR Qualified Dehumidifiers:

[479] The average is based on a weighted average by the number of product available on the ENERGY STAR Qualified Product List as of 3/6/2013.
[480] The Federal Standard for Dehumidifiers changed as of October 2012; https://www.federalregister.gov/articles/2010/12/02/2010-29756/energy-conservation-program-for-consumer-products-test-procedures-for-residential-dishwashers#h-11

| Product Capacity (Pints/Day) | Energy Factor Under Test Conditions (L/kWh) |
|---|---|
| < 75 | ≥ 1.85 |
| 75 ≤ 185 | ≥ 2.80 |

**Loadshape**
Loadshape #73, Residential Dehumidifiers

Freeridership/Spillover Factors

| Measure Category | | Air Conditioning Efficiency | |
|---|---|---|---|
| Measure Codes | | ACEDEHUM | |
| Product Description | | ENERGY STAR Dehumidifier | |
| Track Name | Track No. | Freerider | Spillover |
| Efficient Products | 6032EPEP | 0.77 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
12 years[481]
Analysis period is the same as the lifetime.

**Measure Cost**
The assumed incremental capital cost for this measure is $60[482]

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure

**Fossil Fuel Descriptions**
There are no fossil fuel algorithm or default values for this measure

**Water Descriptions**
There are no water algorithms or default values for this measure

[481] ENERGY STAR Dehumidifier Calculator
http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?f3f7-6a8b&f3f7-6a8b

[482] Based on available data from the Department of Energy's Life Cycle Cost analysis spreadsheet, weighted by available ENERGY STAR product. See "2013 Dehumidifier calcs.xlsx'.

## Lighting End Use
# Commercial CFL

Measure Number: IV-E-1-o (Efficient Products Program, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 76
Effective date: 1/1/12
End date: 12/31/14

**Referenced Documents:**

1) RLW Analytics; "Development of Common Demand Impacts Standards for Energy Efficiency Measures/Programs for the ISO Forward Capacity Market (FCM)".
2) "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993.
3) Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)
4) 2012 EISA Adjustment Calculations.xls

**Description**
An existing incandescent screw-in bulb is replaced with a lower wattage ENERGY STAR qualified compact fluorescent screw-in bulb

**Algorithms**
**Demand Savings**[483]
$\Delta kW$ $= ((\Delta Watts) /1000) \times ISR \times WHF_d$

| Year | Algorithm | ΔkW |
|---|---|---|
| 2012 | (49.0 / 1000) * 0.77 * 1.082 | 0.0408 |
| 2013 | (43.6 / 1000) * 0.77 * 1.082 | 0.0363 |
| 2014 | (37.0 / 1000) * 0.77 * 1.082 | 0.0308 |

**Energy Savings**
$\Delta kWh$ $= ((\Delta Watts) /1000) \times HOURS \times ISR \times WHF_e$

| Year | Algorithm | ΔkWh |
|---|---|---|
| 2012 | (49.0 / 1000) * 2800 * 0.77 * 1.033 | 109.1 |
| 2013 | (43.6 / 1000) * 2800 * 0.77 * 1.033 | 97.1 |
| 2014 | (37.0 / 1000) * 2800 * 0.77 * 1.033 | 82.3 |

Where:

$\Delta Watts$ $= Watts_{BASE} - Watts_{EE}$[484]
$\Delta kW$ = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW
$Watts_{EE}$ = Energy efficient connected kW
$\Delta kWh$ = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units rebated that actually get used
$WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.082 (calculated as 1 +

[483] Assumed difference in wattage between installed CFL and the incandescent bulb it replaces. Based on EVT analysis of CFLs rebated through Efficient Products Program.
[484] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011

$(0.47*0.67*.808) / 3.1))$[485]. The cooling savings are only added to the summer peak savings.

$WHF_e$ = Waste heat factor for energy to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.033 (calculated as 1 + $((0.47*0.29*.75) / 2.5))$[486].

HOURS = average hours of use per year

**Waste Heat Adjustment**

Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF). See above.

**Heating Increased Usage**

$$\Delta MMBTU_{WH} = (\Delta kWh / WHF_e) \times 0.003413 \times (1 - OA) \times AR \times HF \times DFH / HEff$$

| Year | Algorithm | ΔMMBtu |
|---|---|---|
| 2012 | $(109.1 / 1.033) \times 0.003413 \times (1 - 0.25) \times 0.70 \times 0.39 \times 0.95 / 0.79$ | 0.0888 |
| 2013 | $(97 / 1.033) \times 0.003413 \times (1 - 0.25) \times 0.70 \times 0.39 \times 0.95 / 0.79$ | 0.0789 |
| 2014 | $(82.3 / 1.033) \times 0.003413 \times (1 - 0.25) \times 0.70 \times 0.39 \times 0.95 / 0.79$ | 0.0700 |

Where:

$\Delta MMBTU_{WH}$ = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.

0.003413 = Conversion from kWh to MMBTU

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[487].

AR = Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of commercial buildings within 15 feet of exterior wall.

HF = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont for commercial lighting[488]

DFH = Percent of lighting in heated spaces, assumed to be 95%

HEff = Average heating system efficiency, assumed to be 79%[489]

Oil heating is assumed typical for commercial buildings.

**Baseline Efficiencies – New or Replacement**

The baseline condition is an incandescent light bulb.

[485] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 33% average outside air; and 80.8% coincidence of cooling with the summer peak period. See WasteHeatAdjustment.doc for additional discussion.

[486] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 25% average outside air; and 29% of annual lighting energy contributes to cooling load. See "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993 and WasteHeatAdjustment.doc for additional discussion.

[487] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

[488] From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993. Efficiency Vermont does not calculate interactive effects for residential lighting.

[489] Based on average efficiency for furnaces and boilers of varied sizes in ASHRAE 90.1.1999, assumed to represent typical commercial building stock in Vermont.

**Baseline Adjustment**
In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become EISA qualified incandescent or Halogen bulbs.

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012, 2013 or 2014 depending on the assumed baseline wattage (note if a mix of bulbs is assumed, the adjustment always occurs in 2012).

The appropriate adjustments are provided below (see 2012 EISA Adjustment Calculations.xls for details):

| Measure | Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|---|
| Commercial EP Standard CFL | 2012 | 0.65 | 2 |
| | 2013 | 0.78 | 1 |
| | 2014 | 0.88 | 1 |

**High Efficiency**
High efficiency is an ENERGY STAR qualified compact fluorescent lamp.

**Operating Hours**
2800 hours / year[490]

**Loadshape**
Loadshape #101: Commercial EP Lighting[491]

**Freeridership/Spillover Factors**

| Measure Category | | Light Bulbs/Lamps | | | | | |
|---|---|---|---|---|---|---|---|
| Measure Code | | LBLCFCOM | | | | | |
| Product Description | | Compact Fluorescent screw-base bulbs - Commercial | | | | | |
| | | 2012 | | 2013 | | 2014 | |
| Track Name | Track No. | Freerider | Spillover | Freerider | Spillover | Freerider | Spillover |
| Efficient Products | 6032EPEP | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
Assuming the rated life of the CFL is 10,000 hours, the measure life is 10,000/2800 = 3.57 years. This is increased to account for those bulbs that are not included in the In Service Rate but are purchased as spares. The "Residential Lighting Markdown Impact Evaluation" completed by Nexus Market Research, RLW Analytics, and GDS Associated, January 20, 2009, indicates that the Lifetime In Service Rate is 97%, indicating that (97%-77%) 20% are future installs. 20% of installations are therefore assumed to have a measure life equivalent to two CFLs (3.57*2) 7.14years, giving a weighted measure life of 4.3 years.

**Measure Cost[492]**
The incremental cost for this measure is as follows

| Year | Measure |
|---|---|

[490] Based on agreement made during Savings Verification 2009.
[491] Based on Commercial "Other" Lighting coincidence factors from RLW Analytics; "Development of Common Demand Impacts Standards for Energy Efficiency Measures/Programs for the ISO Forward Capacity Market (FCM)". Agreement made during Savings Verification 2009.
[492] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011

| | Cost |
|---|---|
| 2012 | $1.90 |
| 2013 | $1.80 |
| 2014 | $1.50 |

**O&M Cost Adjustments**
O& M cost adjustments are based on component costs provided in the reference table below.

**Fossil Fuel Descriptions**
See Heating Increased Usage above.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

**Methodology for Computing O&M Savings**
In order to account for the shift in baseline due to the Federal Legislation, the levelized baseline replacement cost over the lifetime of the CFL was calculated (see CFL baseline savings shift.xls). The key assumptions used in this calculation are documented below:

| | Incandescent | Halogen |
|---|---|---|
| Replacement Cost | $0.50 | $1.50 |
| Component Life (hours) | 1000 | 1000 |
| Baseline % in 2012 | 67% | 33% |
| Baseline % in 2013 | 33% | 67% |
| Baseline % in 2014 onward | 0% | 100% |

The calculation results in a levelized assumption of $3.48 baseline replacement cost every 1 year for CFL installations in 2012, $4.61 for installations in 2013 and $4.80 for installations in 2014. This adjustment will be recalculated for subsequent years..

# Torchiere

Measure Number: IV-E-3-k (Efficient Products Program, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 82
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**
1. 2005_lighting_wattage_EPP.xls
2. NREL, National Residential Efficiency Measures Database

**Description**
A high efficiency ENERGY STAR torchiere replaces a halogen or incandescent torchiere.

**Algorithms**

**Demand Savings**

$\Delta kW = (\Delta Watts / 1000) \times ISR \times WHF_d$
$\Delta kW(Residential) = ((116 / 1000) \times 0.83) \times 1.0 = 0.0963$ kW
$\Delta kW(Commercial) = ((116 / 1000) \times 0.9) \times 1.082 = 0.113$ kW

Where:

| | |
|---|---|
| $\Delta kW$ | = gross customer connected load kW savings for the measure |
| $\Delta Watts$ | = $Watts_{BASE} - Watts_{EE}$<br>= 116 [493] |
| 1000 | = Conversion of Watts to kilowatts |
| $Watts_{BASE}$ | = Baseline connected kW |
| $Watts_{EE}$ | = Energy efficient connected kW |
| ISR | = In service rate or the percentage of units rebated that actually get used<br>Residential = 0.83 [494]<br>Commercial = 0.9 [495] |
| $WHF_d$ | = Waste heat factor for demand to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.082 (calculated as 1 + (0.47*0.67*.808) / 3.1))[496]. The cooling savings are only added to the summer peak savings. |

**Energy Savings**

$\Delta kWh = \Delta kW \times HOURS \times WHF_e / WHF_d$
$\Delta kWh$ (Residential) $= (0.0963 \times 694) \times 1.0 / 1.0 = 66.8$ kWh
$\Delta kWh$ (Commercial) $= (0.115 \times 2800) \times 1.033 / 1.1 = 302$ kWh

Where:

$\Delta kWh$ = gross customer annual kWh savings for the measure

[493] EVT and DPS October 2004 negotiated delta. Number still consistent with 56 Watt average of over 11,000 EVT incented fixtures between 2002 and 2012, and new halogen fixtures available between 150 and 200 Watts.
[494] Used to establish EVT TRB goals based on a September 2000 negotiated agreement between EVT and VT DPS.
[495] 2005 TAG agreement
[496] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 33% average outside air; and 80.8% coincidence of cooling with the summer peak period. See WasteHeatAdjustment.doc for additional discussion.

$WHF_e$ = Waste heat factor for energy to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.033 (calculated as 1 + ((0.47*0.29*0.75) / 3.1)).[497]

HOURS = average hours of use per year
Residential: 694 hours / year[498]
Commercial: 2,800 hours / year[499]

Other variables as defined above

**Baseline Efficiencies – New or Replacement**
The baseline condition is halogen torchiere with sufficient usage to justify replacement.

**High Efficiency**
High efficiency is an ENERGY STAR torchiere designed for operation with pin-based CFLs.

**Loadshape**
Residential: Loadshape, #1: Residential Indoor Lighting
Commercial: Loadshape #101: Commercial EP Lighting

**Freeridership/Spillover Factors**

| Measure Category | | Light Bulb/Lamps | |
|---|---|---|---|
| Measure Code | | LBLTORCH | |
| Product Description | | Torchiere, Compact Fluorescent | |
| Track Name | Track No. | Freerider | Spillover |
| Efficient Products | 6032EPEP | 0.94 | 1.03 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
5 years[500]
Analysis period is the same as the lifetime.

**Measure Cost**
The incremental cost for this measure is -$10,[501] i.e. the efficient case cost less.

**Incentive Level**
The incentive level for this measure is $5.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure

**Fossil Fuel Descriptions**

**Waste Heat Adjustment**
Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF). See above.

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[497] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 25% average outside air; and 29% of annual lighting energy contributes to cooling load. See "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993 and WasteHeatAdjustment.doc for additional discussion.
[498] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011.
[499] Based on agreement made during Savings Verification 2009.
[500] NREL, Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=5&ctId=43
[501] Ibid.

**Heating Increased Usage**

$\Delta MMBTU_{WH} = (\Delta kWh / WHF_e) \times 0.003413 \times (1 – OA) \times AR \times HF \times DFH / HEff$

$\Delta MMBTU_{WH}$ (Residential) $= (66.8 / 1.0) \times 0.003412 \times (1– 0.25) \times 1.0 \times 0.0 \times 0.95 / 0.79 = 0.0$

$\Delta MMBTU_{WH}$ (Commercial) $= (302 / 1.033) \times 0.003412 \times (1– 0.25) \times 0.70 \times 0.39 \times 0.95 / 0.79 = 0.246$

Where:

$\Delta MMBTU_{WH}$ = gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.

0.003413 = conversion from kWh to MMBTU

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[502].

AR = Typical aspect ratio factor. ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of building within 15 feet of exterior wall.

HF = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont[503]

DFH = Percent of lighting in heated spaces. For prescriptive lighting, assumed to be 95%

HEff = Average heating system efficiency. For prescriptive lighting, assumed to be 79%.[504]

Oil heating is assumed typical for commercial buildings.

**Water Descriptions**

There are no water algorithms or default values for this measure.

[502] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

[503] From “Calculating lighting and HVAC interactions”, Table 1, ASHRAE Journal November 1993.

[504] See WasteHeatAdjustment.doc.

# Dedicated CF Table Lamps

Measure Number: IV-E-4-g (Efficient Products Program, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 76
Effective date: 1/1/12
End date: 12/31/14

**Referenced Documents**:
1) RLW Analytics; "Development of Common Demand Impacts Standards for Energy Efficiency Measures/Programs for the ISO Forward Capacity Market (FCM)".
2) "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993.
3) Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)
4) 2012 EISA Adjustment Calculations.xls

**Description**
A table lamp dedicated to use with a compact fluorescent bulb replaces a table lamp with an incandescent bulb.

**Algorithms**
**Demand Savings**[505]
$\Delta$kW = (($\Delta$Watts) /1000) × ISR × $WHF_d$

| Market | Year | Algorithm | ΔkW |
|---|---|---|---|
| Residential | 2012 | (49.0 / 1000) * 0.95 * 1.0 | 0.0466 |
| | 2013 | (43.6 / 1000) * 0.95 * 1.0 | 0.0414 |
| | 2014 | (37.0 / 1000) * 0.95 * 1.0 | 0.0352 |
| Commercial | 2012 | (49.0 / 1000) * 0.9 * 1.082 | 0.0477 |
| | 2013 | (43.6 / 1000) * 0.9 * 1.082 | 0.0425 |
| | 2014 | (37.0 / 1000) * 0.9 * 1.082 | 0.0360 |

**Energy Savings**
$\Delta$kWh = (($\Delta$Watts) /1000) × HOURS × ISR × $WHF_e$

| Market | Year | Algorithm | ΔkWh |
|---|---|---|---|
| Residential | 2012 | (49.0 / 1000) * 694 * 0.95 * 1.0 | 32.3 |
| | 2013 | (43.6 / 1000) * 694 * 0.95 * 1.0 | 28.7 |
| | 2014 | (37.0 / 1000) * 694 * 0.95 * 1.0 | 24.4 |
| Commercial | 2012 | (49.0 / 1000) * 2800 * 0.9 * 1.033 | 127.5 |
| | 2013 | (43.6 / 1000) * 2800 * 0.9 * 1.033 | 113.6 |
| | 2014 | (37.0 / 1000) * 2800 * 0.9 * 1.033 | 96.2 |

Where:
$\Delta$Watts = $Watts_{BASE} - Watts_{EE}$[506]
$\Delta$kW = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW
$Watts_{EE}$ = Energy efficient connected kW
$\Delta$kWh = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units rebated that actually get used[507]

505 Assumed difference in wattage between installed CFL and the incandescent bulb it replaces. Based on EVT analysis of CFLs rebated through Efficient Products Program.
506 Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011
507 ISR differs for residential and commercial applications. See table below for ISR in each application.

$WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.082 (calculated as 1 + (0.47*0.67*.808) / 3.1))[508]. The cooling savings are only added to the summer peak savings.

$WHF_e$ = Waste heat factor for energy to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.033 (calculated as 1 + ((0.47*0.29*.75) / 2.5))[509].

HOURS = average hours of use per year

**Waste Heat Adjustment**

Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF). See above.

**Heating Increased Usage**

$\Delta MMBTU_{WH}$ = $(\Delta kWh / WHF_e) \times 0.003413 \times (1 - OA) \times AR \times HF \times DFH / HEff$

$\Delta MMBTU_{WH}$ (Residential) = 0.0

$\Delta MMBTU_{WH}$ (Commercial) =

| Year | Algorithm | ΔMMBtu |
| --- | --- | --- |
| 2012 | $(127.5 / 1.033) \times 0.003413 \times (1-0.25) \times 0.70 \times 0.39 \times 0.95 / 0.79$ | 0.10 |
| 2013 | $(113.6 / 1.033) \times 0.003413 \times (1-0.25) \times 0.70 \times 0.39 \times 0.95 / 0.79$ | 0.09 |
| 2014 | $(96.2 / 1.033) \times 0.003413 \times (1-0.25) \times 0.70 \times 0.39 \times 0.95 / 0.79$ | 0.078 |

Where:

$\Delta MMBTU_{WH}$ = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.

0.003413 = Conversion from kWh to MMBTU

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[510].

AR = Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of commercial buildings within 15 feet of exterior wall. The assumed aspect ratio for residential buildings is 100%.

HF = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont for commercial lighting, assumed 0.0 for residential lighting [511]

DFH = Percent of lighting in heated spaces, assumed to be 95%

HEff = Average heating system efficiency, assumed to be 79%[512]

Oil heating is assumed typical for commercial buildings.

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[508] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 33% average outside air; and 80.8% coincidence of cooling with the summer peak period. See WasteHeatAdjustment.doc for additional discussion.

[509] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 25% average outside air; and 29% of annual lighting energy contributes to cooling load. See "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993 and WasteHeatAdjustment.doc for additional discussion.

[510] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

[511] From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993. Efficiency Vermont does not calculate interactive effects for residential lighting.

[512] Based on average efficiency for furnaces and boilers of varied sizes in ASHRAE 90.1.1999, assumed to represent typical commercial building stock in Vermont.

**Baseline Efficiencies – New or Replacement**
The Baseline reflects a table lamp with an incandescent bulb.

**Baseline Adjustment**
In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become EISA qualified incandescent or Halogen bulbs.

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012, 2013 or 2014 depending on the assumed baseline wattage (note if a mix of bulbs is assumed, the adjustment always occurs in 2012).

The appropriate adjustments are provided below (see 2012 EISA Adjustment Calculations.xls for details):

| Measure | Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|---|
| Dedicated CF Table Lamp (RES) | 2012 | 0.66 | 2 |
| | 2013 | 0.77 | 1 |
| | 2014 | 0.88 | 1 |
| Dedicated CF Table Lamp (C&I) | 2012 | 0.66 | 2 |
| | 2013 | 0.77 | 1 |
| | 2014 | 0.88 | 1 |

**High Efficiency**
The High Efficiency reflects a table lamp that is dedicated for use with a plug-in compact fluorescent bulb. These lamps are inoperable with an incandescent bulb.

**Operating Hours**
Residential: 694 hours / year[513]
Commercial: 2800[514] hours / year

**Loadshape**
Residential:, Loadshape, #1: Residential Indoor Lighting
Commercial: Loadshape #101: Commercial EP Lighting[515]

**Freeridership/Spillover Factors**

| **Measure Category** | | **Light Bulbs/Lamps** | | | | | |
|---|---|---|---|---|---|---|---|
| **Measure Code** | | **LBLTABLE** | | | | | |
| **Product Description** | | **Table/Desk Lamp, Compact Fluorescent** | | | | | |
| | | **2012** | | **2013** | | **2014** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** | **Freerider** | **Spillover** | **Freerider** | **Spillover** |
| Efficient Products | 6032EPEP | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
10 years.

[513] Consistent with lamp assumption based on NEEP RLS, 2011.
[514] Based on agreement made during Savings Verification 2009.
[515] Based on Commercial "Other" Lighting coincidence factors from RLW Analytics; "Development of Common Demand Impacts Standards for Energy Efficiency Measures/Programs for the ISO Forward Capacity Market (FCM)". Agreement made during Savings Verification 2009.

Note: a provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore the analysis period (i.e. the life of the savings) is reduced to the number of years remaining to 2020. So for installations in 2012, the measure life is 8 years, for 2013 7 years.

**Measure Cost**

The incremental cost for this measure is $32[516]

**Annual Operations and Maintenance Savings**

Because compact fluorescent lamps last much longer than incandescent bulbs, CFLs offer significant operation and maintenance (O&M) savings over the life of the fixture for avoided incandescent lamps and the labor to install them. The following assumptions are used to calculate the O&M savings:
Incandescent bulb cost: $0.50 per bulb
Life of incandescent bulb: 1000 hours
Labor cost to replace any kind of lamp (C&I only): $2.67 per lamp (8 minutes at $20/hour)
EISA qualified bulb cost: $1.50 per bulb
Life of EISA qualified bulb: 1000 hours
CFL lamp cost: $2.5 per lamp
Life of CFL lamp: 8,500 hours (RES), 10,000 hours (C&I)

The O&M calculation results in a levelized annual baseline replacement cost as presented below (see EISA Adjustment Calculations.xls for details) [517]:

| Measure | Year Installed | Annual baseline replacement cost | Annual efficient replacement cost |
|---|---|---|---|
| Dedicated CF Table Lamp (RES) | 2012 | $0.98 | $0.00 |
| | 2013 | $1.03 | $0.00 |
| | 2014 | $1.06 | $0.00 |
| Dedicated CF Table Lamp (C&I) | 2012 | $11.68 | $1.30 |
| | 2013 | $12.07 | $1.30 |
| | 2014 | $12.40 | $1.30 |

This adjustment will be recalculated for subsequent years

**Fossil Fuel Descriptions**

See Heating Increased Usage above.

**Water Descriptions**

There are no water algorithms or default values for this measure.

**Reference Tables**

[516] ENERGY STAR Qualified Lighting Savings Calculator default incremental cost input for interior fixture.
[517] Note: As described above, the measure life is reduced to the number of years remaining until 2020 when the EISA legislation makes the CFL the baseline. The O&M calculation takes the entire stream of replacements for both the baseline and efficient cases over the actual expected lifetime (10 years) and converts to a levelized annual cost over the reduced measure 'savings' lifetime.

# Dedicated CF Floor Lamp

Measure Number: IV-E-7-f (Efficient Products Program, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 76
Effective date: 1/1/12
End date: 12/31/14

**Referenced Documents:**

1) RLW Analytics; "Development of Common Demand Impacts Standards for Energy Efficiency Measures/Programs for the ISO Forward Capacity Market (FCM)".
2) "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993.
3) Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)
4) 2012 EISA Adjustment Calculations.xls

**Description**
An existing floor lamp with incandescent bulbs is replaced by a dedicated ENERGY STAR floor lamp wired for exclusive use with pin-based compact fluorescent lamps.

**Algorithms**
**Demand Savings**
$\Delta kW = ((\Delta Watts) / 1000) * ISR \times WHF_d$

| Market | Year | Algorithm | ΔkW |
|---|---|---|---|
| Residential | 2012 | (49.0 / 1000) * 0.95 * 1.0 | 0.0466 |
| | 2013 | (43.6 / 1000) * 0.95 * 1.0 | 0.0414 |
| | 2014 | (37.0 / 1000) * 0.95 * 1.0 | 0.0352 |
| Commercial | 2012 | (49.0 / 1000) * 0.9 * 1.082 | 0.0477 |
| | 2013 | (43.6 / 1000) * 0.9 * 1.082 | 0.0425 |
| | 2014 | (37.0 / 1000) * 0.9 * 1.082 | 0.0360 |

**Energy Savings**
$\Delta kWh = ((\Delta Watts) / 1000) \times HOURS \times ISR \times WHF_e$

| Market | Year | Algorithm | ΔkWh |
|---|---|---|---|
| Residential | 2012 | (49.0 / 1000) * 912 * 0.95 * 1.0 | 42.5 |
| | 2013 | (43.6 / 1000) * 912 * 0.95 * 1.0 | 37.8 |
| | 2014 | (37.0 / 1000) * 912 * 0.95 * 1.0 | 32.1 |
| Commercial | 2012 | (49.0 / 1000) * 2800 * 0.9 * 1.033 | 127.5 |
| | 2013 | (43.6 / 1000) * 2800 * 0.9 * 1.033 | 113.6 |
| | 2014 | (37.0 / 1000) * 2800 * 0.9 * 1.033 | 96.2 |

Where:

$\Delta Watts$ = $Watts_{BASE} - Watts_{EE}$[518]
$\Delta kW$ = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW
$Watts_{EE}$ = Energy efficient connected kW
$\Delta kWh$ = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units rebated that actually get used[519]
$WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.082 (calculated as 1 +

[518] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011
[519] ISR differs for residential and commercial applications. See table below for ISR in each application.

(0.47*0.67*.808) / 3.1))[520]. The cooling savings are only added to the summer peak savings.

$WHF_e$ = Waste heat factor for energy to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.033 (calculated as 1 + ((0.47*0.29*.75) / 2.5))[521].

HOURS = average hours of use per year[522]

**Waste Heat Adjustment**

Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF). See above.

**Heating Increased Usage**

$\Delta MMBTU_{WH}$ = $(\Delta kWh / WHF_e) \times 0.003413 \times (1 – OA) \times AR \times HF \times DFH / HEff$

$\Delta MMBTU_{WH}$ (Residential) = 0.0

$\Delta MMBTU_{WH}$ (Commercial) =

| Year | Algorithm | ΔMMBtu |
|---|---|---|
| 2012 | (127.5 / 1.033) × 0.003413 × (1– 0.25) × 0.70 × 0.39 × 0.95 / 0.79 | 0.10 |
| 2013 | (113.6 / 1.033) × 0.003413 × (1– 0.25) × 0.70 × 0.39 × 0.95 / 0.79 | 0.09 |
| 2014 | (96.2 / 1.033) × 0.003413 × (1– 0.25) × 0.70 × 0.39 × 0.95 / 0.79 | 0.078 |

Where:

$\Delta MMBTU_{WH}$ = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.

0.003413 = Conversion from kWh to MMBTU

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[523].

AR = Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of commercial buildings within 15 feet of exterior wall. The assumed aspect ratio for residential buildings is 100%.

HF = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont for commercial lighting, assumed 0.0 for residential lighting [524]

DFH = Percent of lighting in heated spaces, assumed to be 95%

HEff = Average heating system efficiency, assumed to be 79%[525]

Oil heating is assumed typical for commercial buildings.

**Baseline Efficiencies – New or Replacement**

The baseline condition is an interior incandescent light.

[520] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 33% average outside air; and 80.8% coincidence of cooling with the summer peak period. See WasteHeatAdjustment.doc for additional discussion.

[521] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 25% average outside air; and 29% of annual lighting energy contributes to cooling load. See "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993 and WasteHeatAdjustment.doc for additional discussion.

[522] Hours of usage differs for residential and commercial applications. See table below for HOURS at each application.

[523] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

[524] From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993. Efficiency Vermont does not calculate interactive effects for residential lighting.

[525] Based on average efficiency for furnaces and boilers of varied sizes in ASHRAE 90.1.1999, assumed to represent typical commercial building stock in Vermont.

**Baseline Adjustment**
In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become EISA qualified incandescent or Halogen bulbs.

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012, 2013 or 2014 depending on the assumed baseline wattage (note if a mix of bulbs is assumed, the adjustment always occurs in 2012).

The appropriate adjustments are provided below (see 2012 EISA Adjustment Calculations.xls for details):

| Measure | Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|---|
| Dedicated CF Floor Lamp (RES) | 2012 | 0.66 | 2 |
| | 2013 | 0.77 | 1 |
| | 2014 | 0.88 | 1 |
| Dedicated CF Floor Lamp (C&I) | 2012 | 0.66 | 2 |
| | 2013 | 0.77 | 1 |
| | 2014 | 0.88 | 1 |

**High Efficiency**
High efficiency is an interior fluorescent fixture.

**Operating Hours**
Residential Applications: 949 hours / year
Commercial Applications: 2800[526] hours / year

**Loadshape**
Residential:, Loadshape, #1: Residential Indoor Lighting
Commercial: Loadshape #101: Commercial EP Lighting[527]

**Freeridership/Spillover Factors**

| **Measure Category** | | **Light Bulbs/Lamps** | | | | | |
|---|---|---|---|---|---|---|---|
| **Measure Code** | | **LBLFLOOR** | | | | | |
| **Product Description** | | **Floor Lamp, Compact Fluorescent** | | | | | |
| | | **2012** | | **2013** | | **2014** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** | **Freerider** | **Spillover** | **Freerider** | **Spillover** |
| Efficient Products | 6032EPEP | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
10 years.
Note: a provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore the analysis period (i.e. the life of the savings) is reduced to the number of years remaining to 2020. So for installations in 2012, the measure life is 8 years, for 2013 7 years.

[526] Based on agreement made during Savings Verification 2009.
[527] Based on Commercial "Other" Lighting coincidence factors from RLW Analytics; "Development of Common Demand Impacts Standards for Energy Efficiency Measures/Programs for the ISO Forward Capacity Market (FCM)". Agreement made during Savings Verification 2009.

**Measure Cost**
The incremental cost for this measure is $32[528]

**Annual Operations and Maintenance Savings**
Because compact fluorescent lamps last much longer than incandescent bulbs, CFLs offer significant operation and maintenance (O&M) savings over the life of the fixture for avoided incandescent lamps and the labor to install them. The following assumptions are used to calculate the O&M savings:
Incandescent bulb cost: $0.50 per bulb
Life of incandescent bulb: 1000 hours
Labor cost to replace any kind of lamp (C&I only): $2.67 per lamp (8 minutes at $20/hour)
EISA qualified bulb cost: $1.50 per bulb
Life of EISA qualified bulb: 1000 hours
CFL lamp cost: $7.50 per lamp
Life of CFL lamp: 8,500 hours (RES), 10,000 hours (C&I)

The O&M calculation results in a levelized annual baseline replacement cost as presented below (see 2012 EISA Adjustment Calculations.xls for details) [529]:

| Measure | Year Installed | Annual baseline replacement cost | Annual efficient replacement cost |
|---|---|---|---|
| Dedicated CF Table Lamp (RES) | 2012 | $1.42 | $0.10 |
| | 2013 | $1.58 | $0.10 |
| | 2014 | $1.75 | $0.10 |
| Dedicated CF Table Lamp (C&I) | 2012 | $12.01 | $2.55 |
| | 2013 | $12.64 | $2.55 |
| | 2014 | $13.29 | $2.55 |

This adjustment will be recalculated for subsequent years

**Fossil Fuel Descriptions**
See Heating Increased Usage above.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

[528] ENERGY STAR Qualified Lighting Savings Calculator default incremental cost input for interior fixture.
[529] Note: As described above, the measure life is reduced to the number of years remaining until 2020 when the EISA legislation makes the CFL the baseline. The O&M calculation takes the entire stream of replacements for both the baseline and efficient cases over the actual expected lifetime (10 years) and converts to a levelized annual cost over the reduced measure 'savings' lifetime.

# Interior Fluorescent Fixture

Measure Number: IV-E-5-h (Efficient Products Program, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 76
Effective date: 1/1/12
End date: 12/31/14

**Referenced Documents:**

1) RLW Analytics; "Development of Common Demand Impacts Standards for Energy Efficiency Measures/Programs for the ISO Forward Capacity Market (FCM)".
2) "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993.
3) 2005 RLW memo following on from NMR, RLW Analytics "Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs"
4) Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)
5) 2012 EISA Adjustment Calculations.xls

**Description**
An existing lighting fixture with incandescent bulbs is replaced by an ENERGY STAR lighting fixture wired for exclusive use with pin-based compact fluorescent lamps in an interior setting.

**Algorithms**
**Demand Savings**
$\Delta kW = ((\Delta Watts) / 1000) \times ISR \times WHF_d$

| Market | Year | Algorithm | ΔkW |
|---|---|---|---|
| Residential | 2012 | (49.0 / 1000) * 0.95 * 1.0 | 0.0466 |
| | 2013 | (43.6 / 1000) * 0.95 * 1.0 | 0.0414 |
| | 2014 | (37.0 / 1000) * 0.95 * 1.0 | 0.0352 |
| Commercial | 2012 | (49.0 / 1000) * 0.9 * 1.082 | 0.0477 |
| | 2013 | (43.6 / 1000) * 0.9 * 1.082 | 0.0425 |
| | 2014 | (37.0 / 1000) * 0.9 * 1.082 | 0.0360 |

**Energy Savings**
$\Delta kWh = ((\Delta Watts) / 1000) \times HOURS \times ISR \times WHF_e$

| Market | Year | Algorithm | ΔkWh |
|---|---|---|---|
| Residential | 2012 | (49.0 / 1000) * 912 * 0.95 * 1.0 | 42.5 |
| | 2013 | (43.6 / 1000) * 912 * 0.95 * 1.0 | 37.8 |
| | 2014 | (37.0 / 1000) * 912 * 0.95 * 1.0 | 32.1 |
| Commercial | 2012 | (49.0 / 1000) * 2800 * 0.9 * 1.033 | 127.5 |
| | 2013 | (43.6 / 1000) * 2800 * 0.9 * 1.033 | 113.6 |
| | 2014 | (37.0 / 1000) * 2800 * 0.9 * 1.033 | 96.2 |

Where:

$\Delta Watts$ = $Watts_{BASE} - Watts_{EE}$[530]
$\Delta kW$ = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW
$Watts_{EE}$ = Energy efficient connected kW
$\Delta kWh$ = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units rebated that actually get used[531]

[530] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011
[531] ISR differs for residential and commercial applications. See table below for ISR at each application.

$WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.082 (calculated as 1 + (0.47*0.67*.808) / 3.1))[532]. The cooling savings are only added to the summer peak savings.

$WHF_e$ = Waste heat factor for energy to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.033 (calculated as 1 + ((0.47*0.29*.75) / 2.5))[533].

HOURS = average hours of use per year[534]

**Waste Heat Adjustment**

Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF). See above.

**Heating Increased Usage**

$\Delta MMBTU_{WH}$ = $(\Delta kWh / WHF_e) \times 0.003413 \times (1 – OA) \times AR \times HF \times DFH / HEff$

$\Delta MMBTU_{WH}$ (Residential) = 0.0

$\Delta MMBTU_{WH}$ (Commercial) =

| Year | Algorithm | ΔMMBtu |
|---|---|---|
| 2012 | (127.5 / 1.033) × 0.003413 × (1– 0.25) × 0.70 × 0.39 × 0.95 / 0.79 | 0.10 |
| 2013 | (113.6 / 1.033) × 0.003413 × (1– 0.25) × 0.70 × 0.39 × 0.95 / 0.79 | 0.09 |
| 2014 | (96.2 / 1.033) × 0.003413 × (1– 0.25) × 0.70 × 0.39 × 0.95 / 0.79 | 0.078 |

Where:

$\Delta MMBTU_{WH}$ = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.

0.003413 = Conversion from kWh to MMBTU

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[535].

AR = Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of commercial buildings within 15 feet of exterior wall. The assumed aspect ratio for residential buildings is 100%.

HF = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont for commercial lighting, assumed 0.0 for residential lighting [536]

DFH = Percent of lighting in heated spaces, assumed to be 95%

HEff = Average heating system efficiency, assumed to be 79%[537]

[532] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 33% average outside air; and 80.8% coincidence of cooling with the summer peak period. See WasteHeatAdjustment.doc for additional discussion.

[533] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 25% average outside air; and 29% of annual lighting energy contributes to cooling load. See "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993 and WasteHeatAdjustment.doc for additional discussion.

[534] Hours of usage differs for residential and commercial applications. See table below for HOURS at each application.

[535] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

[536] From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993. Efficiency Vermont does not calculate interactive effects for residential lighting.

[537] Based on average efficiency for furnaces and boilers of varied sizes in ASHRAE 90.1.1999, assumed to represent typical commercial building stock in Vermont.

Oil heating is assumed typical for commercial buildings.

**Baseline Efficiencies – New or Replacement**
The baseline condition is an interior incandescent light.

**Baseline Adjustment**
In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become EISA qualified incandescent or Halogen bulbs.

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012, 2013 or 2014 depending on the assumed baseline wattage (note if a mix of bulbs is assumed, the adjustment always occurs in 2012).

The appropriate adjustments are provided below (see 2012 EISA Adjustment Calculations.xls for details):

| Measure | Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|---|
| Interior Fixture (RES) | 2012 | 0.66 | 2 |
| | 2013 | 0.77 | 1 |
| | 2014 | 0.88 | 1 |
| Interior Fixture (C&I) | 2012 | 0.66 | 2 |
| | 2013 | 0.77 | 1 |
| | 2014 | 0.88 | 1 |

**High Efficiency**
High efficiency is a interior fluorescent fixture.

**Operating Hours**
Residential Applications: 912 hours / year (2.5 hrs per day)[538]
Commercial Applications: 2800[539] hours / year

**Loadshape**
Residential: Loadshape, #1 - Residential Indoor Lighting
Commercial: Loadshape #101: Commercial EP Lighting[540]

**Freeridership/Spillover Factors**

| **Measure Category** | | **Lighting Hardwired Fixture** | | | | | |
|---|---|---|---|---|---|---|---|
| **Measure Code** | | LFHCNFIX | | | | | |
| **Product Description** | | **Compact Fluorescent Interior Fixture** | | | | | |
| | | **2012** | | **2013** | | **2014** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** | **Freerider** | **Spillover** | **Freerider** | **Spillover** |
| Efficient Products | 6032EPEP | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

538 Based upon 2005 results from RLW Metering study (2005 RLW memo following on from “Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs”)
539 Based on agreement made during Savings Verification 2009.
540 Based on Commercial “Other” Lighting coincidence factors from RLW Analytics; “Development of Common Demand Impacts Standards for Energy Efficiency Measures/Programs for the ISO Forward Capacity Market (FCM)”. Agreement made during Savings Verification 2009.

**Lifetimes**
Residential: 20 years.
Commercial: 15 years.
Note: a provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore the analysis period (i.e. the life of the savings) is reduced to the number of years remaining to 2020. So for installations in 2012, the measure life is 8 years, for 2013 7 years.

**Measure Cost**
The incremental cost for this measure is $32[541]

**Annual Operations and Maintenance Savings**
Because compact fluorescent lamps last much longer than incandescent bulbs, CFLs offer significant operation and maintenance (O&M) savings over the life of the fixture for avoided incandescent lamps and the labor to install them. The following assumptions are used to calculate the O&M savings:
Incandescent bulb cost: $0.50 per bulb
Life of incandescent bulb: 1000 hours
Labor cost to replace any kind of lamp (C&I only): $2.67 per lamp (8 minutes at $20/hour)
EISA qualified bulb cost: $1.50 per bulb
Life of EISA qualified bulb: 1000 hours
CFL lamp cost: $2.50 per lamp
Life of CFL lamp: 8,500 hours (RES), 10,000 hours (C&I)
CFL ballast replacement cost: $14 (RES), $19 (C&I including labor)
Life of CFL ballast: 24,959 hours (RES), 45,850 (C&I)

The O&M calculation results in a levelized annual baseline replacement cost as presented below (see EISA Adjustment Calculations.xls for details) [542]:

| Measure | Year Installed | Annual baseline replacement cost | Annual efficient replacement cost |
|---|---|---|---|
| Interior Fixture (RES) | 2012 | $1.57 | $0.32 |
| | 2013 | $1.48 | $0.32 |
| | 2014 | $1.35 | $0.32 |
| Interior Fixture (C&I) | 2012 | $12.46 | $2.07 |
| | 2013 | $11.49 | $2.07 |
| | 2014 | $10.34 | $2.07 |

This adjustment will be recalculated for subsequent years

**Fossil Fuel Descriptions**
See Heating Increased Usage above.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**
None

[541] ENERGY STAR Qualified Lighting Savings Calculator default incremental cost input for interior fixture.
[542] Note: As described above, the measure life is reduced to the number of years remaining until 2020 when the EISA legislation makes the CFL the baseline. The O&M calculation takes the entire stream of replacements for both the baseline and efficient cases over the actual expected lifetime (20 or 15 years) and converts to a levelized annual cost over the reduced measure 'savings' lifetime.

# Exterior Fluorescent Fixture

Measure Number: IV-E-6-i (Efficient Products Program, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 76
Effective date: 1/1/12
End date: 12/31/14

**Referenced Documents:**
1) "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993.
2) Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)
3) 2005 RLW memo following on from NMR, RLW Analytics "Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs"
4) 2012 EISA Adjustment Calculations.xls

**Description**
An existing lighting fixture with incandescent bulbs is replaced by an ENERGY STAR lighting fixture wired for exclusive use with pin-based compact fluorescent lamps in an exterior setting.

**Algorithms**
**Demand Savings**[543]
$\Delta$kW = (($\Delta$Watts) /1000)* ISR

| Market | Year | Algorithm | $\Delta$kW |
|---|---|---|---|
| Residential | 2012 | (94.7 / 1000) * 0.87 | 0.082 |
| | 2013 | (84.3 / 1000) * 0.87 | 0.073 |
| | 2014 | (71.5 / 1000) * 0.87 | 0.062 |
| Commercial | 2012 | (94.7 / 1000) * 0.9 | 0.085 |
| | 2013 | (84.3 / 1000) * 0.9 | 0.076 |
| | 2014 | (71.5 / 1000) * 0.9 | 0.064 |

**Energy Savings**
$\Delta$kWh = (($\Delta$Watts) /1000) $\times$ HOURS $\times$ ISR

| Market | Year | Algorithm | $\Delta$kWh |
|---|---|---|---|
| Residential | 2012 | (94.7 / 1000) * 1642.5 * 0.87 | 135.3 |
| | 2013 | (84.3 / 1000) * 1642.5 * 0.87 | 120.5 |
| | 2014 | (71.5 / 1000) * 1642.5 * 0.87 | 102.2 |
| Commercial | 2012 | (94.7 / 1000) * 3059 * 0.9 | 260.7 |
| | 2013 | (84.3 / 1000) * 3059 * 0.9 | 232.1 |
| | 2014 | (71.5 / 1000) * 3059 * 0.9 | 196.8 |

Where:
$\Delta$Watts = $Watts_{BASE} – Watts_{EE}$[544]
$\Delta$kW = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW
$Watts_{EE}$ = Energy efficient connected kW
$\Delta$kWh = gross customer annual kWh savings for the measure

[543] Based on EVT analysis of Exterior Residential and Commercial Florescent Fixtures rebated through Efficient Products Program
[544] 2012 delta watts is equal to 2011 assumption. Subsequent years delta watts is reduced at the same rate as interior assumption which is based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011, to account for EISA impacts.

| | |
|---|---|
| ISR | = In service rate or the percentage of units rebated that actually get used[545] |
| HOURS | = average hours of use per year |

**Baseline Efficiencies – New or Replacement**
The baseline condition is an exterior incandescent light fixture.

**Baseline Adjustment**
In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become EISA qualified incandescent or Halogen bulbs.

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012, 2013 or 2014 depending on the assumed baseline wattage (note if a mix of bulbs is assumed, the adjustment always occurs in 2012).
The appropriate adjustments are provided below (see EISA Adjustment Calculations.xls for details):

| Measure | Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|---|
| Exterior Fixture (RES) | 2012 | 0.66 | 2 |
| | 2013 | 0.77 | 1 |
| | 2014 | 0.88 | 1 |
| Exterior Fixture (C&I) | 2012 | 0.66 | 2 |
| | 2013 | 0.77 | 1 |
| | 2014 | 0.88 | 1 |

**High Efficiency**
High efficiency is an ENERGY STAR qualified exterior fluorescent fixture.

**Operating Hours**
Residential Applications: 1642.5 hours / year[546].
Commercial Applications: 3,059 hours / year[547]

**Loadshape**
Residential: Loadshape #2 - Residential Outdoor Lighting
Commercial: Loadshape #13 - Commercial Outdoor Lighting,
Source: Vermont State Cost-Effectiveness Screening Tool.

**Freeridership/Spillover Factors**

| **Measure Category** | | **Lighting Hardwired Fixture** | | | | | |
|---|---|---|---|---|---|---|---|
| **Measure Code** | | LFHCEFIX | | | | | |
| **Product Description** | | **Compact fluorescent exterior fixture** | | | | | |
| | | **2012** | | **2013** | | **2014** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** | **Freerider** | **Spillover** | **Freerider** | **Spillover** |
| Efficient Products | 6032EPEP | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

545 ISR differs for residential and commercial applications. See table below for ISR at each application.
546 2005 RLW memo following on from NMR, RLW Analytics "Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs"
547 Commercial Usage rate based on 8.4 hours daily burn time consistent with load profile for commercial outdoor lighting in Vermont State Cost Effectiveness Screening tool.

**Lifetimes**
Residential: 20 years.
Commercial: 15 years.
Note: a provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore the analysis period (i.e. the life of the savings) is reduced to the number of years remaining to 2020. So for installations in 2012, the measure life is 8 years, for 2013 7 years.

**Measure Cost**
The incremental cost for this measure is $17[548]

**Annual Operations and Maintenance Savings**
Because compact fluorescent lamps last much longer than incandescent bulbs, CFLs offer significant operation and maintenance (O&M) savings over the life of the fixture for avoided incandescent lamps and the labor to install them. The following assumptions are used to calculate the O&M savings:
Incandescent bulb cost: $0.50 per bulb
Life of incandescent bulb: 1000 hours
Labor cost to replace any kind of lamp (C&I only): $2.67 per lamp (8 minutes at $20/hour)
EISA qualified bulb cost: $1.50 per bulb
Life of EISA qualified bulb: 1000 hours
CFL lamp cost: $2.50 per lamp
Life of CFL lamp: 8,500 hours (RES), 10,000 hours (C&I)
CFL ballast replacement cost: $14 (RES), $19 (C&I including labor)
Life of CFL ballast: 24,959 hours (RES), 45,850 (C&I)

The O&M calculation results in a levelized annual baseline replacement cost as presented below (see 2012 EISA Adjustment Calculations.xls for details) [549]:

| Measure | Year Installed | Annual baseline replacement cost | Annual efficient replacement cost |
|---|---|---|---|
| Exterior Fixture (RES) | 2012 | $2.99 | $1.30 |
| | 2013 | $2.76 | $1.30 |
| | 2014 | $2.52 | $1.30 |
| Exterior Fixture (C&I) | 2012 | $14.01 | $2.40 |
| | 2013 | $12.70 | $2.40 |
| | 2014 | $11.35 | $2.40 |

This adjustment will be recalculated for subsequent years

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**
**Fluorescent Fixture Hours of Use and In Use Rates by Customer Type**

| | Average Annual Hours of Use | Average In Service Rate |
|---|---|---|
| Residential | 1642.5 | 0.87 |

[548] ENERGY STAR Qualified Lighting Savings Calculator default incremental cost input for exterior fixtures.
[549] Note: As described above, the measure life is reduced to the number of years remaining until 2020 when the EISA legislation makes the CFL the baseline. The O&M calculation takes the entire stream of replacements for both the baseline and efficient cases over the actual expected lifetime (20 or 15 years) and converts to a levelized annual cost over the reduced measure 'savings' lifetime.

| | | |
|---|---|---|
| Commercial | 3,059 | 0.9 |

# Solid State (LED) Recessed Downlight

Measure Number: IV-E-8-c (Efficient Products Program, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 77
Effective date: 1/1/2011
End date: TBD

**Referenced Documents:**
1) WasteHeatAdjustment.doc;
2) "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993

**Description**
An LED Downlight is used in place of an incandescent downlight. The downlight must be tested by the DOE Caliper Testing Program or Independent 3rd party testing with results shown to meet the upcoming Energy Star Specification for Solid State Luminaires. This Specification will take effect September 31st, 2008, and can be downloaded from http://www.netl.doe.gov/ssl/. See Reference Table of Energy Star requirements for recessed downlights.

**Algorithms**
**Demand Savings**
$\Delta kW = ((Watts_{BASE} - Watts_{EE}) /1000) \times ISR \times WHF_d$
$\Delta kW(Residential) = ((65 - 12) / 1000) \times 0.95) \times 1.0 = 0.05035$
$\Delta kW(Commercial) = ((65 - 12) / 1000) \times 0.95 ) \times 1.082 = 0.054479$

**Energy Savings**
$\Delta kWh = ((Watts_{BASE} - Watts_{EE}) /1000) \times HOURS \times ISR \times WHF_e$
$\Delta kWh\ (Residential) = ((65 - 12) / 1000) \times 1241 \times 0.95 \times 1.0 = 62.48$
$\Delta kWh\ (Commercial) = ((65 - 12) / 1000) \times 2800 \times 0.95 \times 1.033 = 145.63$

Where:

$\Delta kW$ = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW.[550]
$Watts_{EE}$ = Energy efficient connected kW.[551]
$\Delta kWh$ = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units rebated that actually get used[552]
$WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.082 (calculated as 1 + (0.47*0.67*.808) / 3.1))[553]. The cooling savings are only added to the summer peak savings.
$WHF_e$ = Waste heat factor for energy to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.033 (calculated as 1 + ((0.47*0.29*.75) / 2.5))[554].
HOURS = average hours of use per year[555]

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[550] Baseline wattage based on 65 Watt BR30 incandescent bulb.
[551] Energy Efficient wattage based on 12 Watt LR6 Downlight from LLF Inc.
[552] ISR differs for residential and commercial applications. See table below for ISR in each application.
[553] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 33% average outside air; and 80.8% coincidence of cooling with the summer peak period. See WasteHeatAdjustment.doc for additional discussion.
[554] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 25% average outside air; and 29% of annual lighting energy contributes to cooling load. See "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993 and WasteHeatAdjustment.doc for additional discussion.
[555] Hours of usage differs for residential and commercial applications. See table below for HOURS at each application.

**Waste Heat Adjustment**

Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF). See above.

**Heating Increased Usage**

$\Delta MMBTU_{WH}$ = $(\Delta kWh / WHF_e) \times 0.003413 \times AR \times HF / 0.75$

$\Delta MMBTU_{WH}$ (Residential) = $(62.48 / 1.033) \times 0.003413 \times (1-0.25) \times 0.70 \times 0.0 \times 0.95 / 0.79 = 0.0$

$\Delta MMBTU_{WH}$ (Commercial) = $(145.63/ 1.033) \times 0.003413 \times (1-0.25) \times 0.70 \times 0.39 \times 0.95 / 0.79 =$ 0.11847

Where:

| | |
|---|---|
| $\Delta MMBTU_{WH}$ | = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat. |
| 0.003413 | = Conversion from kWh to MMBTU |
| OA | = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[556]. |
| AR | = Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of commercial buildings within 15 feet of exterior wall. The assumed aspect ratio for residential buildings is 100%. |
| HF | = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont for commercial lighting, assumed 0.0 for residential lighting [557] |
| DFH | = Percent of lighting in heated spaces, assumed to be 95% |
| HEff | = Average heating system efficiency, assumed to be 79%[558] |

Oil heating is assumed typical for commercial.

**Baseline Efficiencies – New or Replacement**

The baseline condition is a 65 watt BR30 incandescent fixture installed in a screw-base socket.

**High Efficiency**

High Efficiency is a downlight that has been tested by the DOE Caliper Testing Program or Independent 3rd party testing with results shown to meet the upcoming Energy Star Specification for Solid State Luminaires. This Specification will take effect September 31st, 2008, and can be downloaded from http://www.netl.doe.gov/ssl/ . See Reference Table of Energy Star requirements for recessed downlights.

**Operating Hours**

Residential: 1,241 hours / year

Commercial: 2,800 hours / year[559]

**Loadshape**

Residential: Loadshape, #1 - Residential Indoor Lighting; Commercial: Loadshape; #101: Commercial EP Lighting[560]

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556 Based on 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air." See WasteHeatAdjustment.doc

557 From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993. Efficiency Vermont does not calculate interactive effects for residential lighting.

558 Based on average efficiency for furnaces and boilers of varied sizes in ASHRAE 90.1.1999, assumed to represent typical commercial building stock in Vermont. See WasteHeatAdjustment.doc.

559 Based on agreement made during Savings Verification 2009.

560 Based on Commercial "Other" Lighting coincidence factors from RLW Analytics; "Development of Common Demand Impacts Standards for Energy Efficiency Measures/Programs for the ISO Forward Capacity Market (FCM)". Agreement made during Savings Verification 2009.

**Freeridership/Spillover Factors**

| Measure Category | | LED | |
|---|---|---|---|
| Measure Code | | LFHRDLED | |
| Product Description | | Solid State Recessed Downlight | |
| Track Name | Track No. | Freerider | Spillover |
| Efficient Products | 6032EPEP | 0.94 | 1.25 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
Lifetime is a function of the average hours of use of the lumenaire. The Energy Star Specification for Solid State Recessed Downlights requires luminaires to maintain at least 70% initial light output for 25,000 hrs in a residential application and 35,000 hours in a commercial application. Based on these lifetimes, LED Recessed Downlights rebated through this program are expected to have a life of 20.1 years for residential applications (assumed average daily usage of 3.4 hours) and 12.5 years for commercial applications (assumed annual usage of 2800 hours).
Analysis period is 20 years for residential installations, 12.5 years for commercial installations..

**Measure Cost**
The incremental cost for this measure is $44.35

**O&M Cost Adjustments**
O& M cost adjustments are based on component costs provided in the reference table below.

**Fossil Fuel Descriptions**
See Heating Increased Usage above.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

**Hours of Use, In Use Rates, and Waste Heat Factors by Customer Type**

| | Average Annual Hours of Use | Average In Service Rate | $WHF_d$ | $WHF_e$ | AR | HF |
|---|---|---|---|---|---|---|
| Residential | 1,241 | 0.95 | 1.0 | 1.0 | 1.0 | 0.0 |
| Commercial | 2,800[561] | 0.95 | 1.082 | 1.033 | 0.7 | 0.39 |

**Component Costs and Lifetimes Used in Computing O&M Savings Residential**

| Component | Market | Baseline Measures | |
|---|---|---|---|
| | | Cost | Life[562] |
| Lamp | Residential | $4.67 | 1.13 |
| | Commercial | $4.67 | 0.71 |

**Partial List of Energy Star Requirements for Solid State Recessed Downlights**

| | |
|---|---|
| Lumen Depreciation / Lifetime | LED shall deliver at least 70% of initial lumens for the minimum number of hours specified below:<br>• >= 25,000 hrs Residential Indoor<br>• >= 35,000 hrs Commercial |

[561] Based on agreement made during Savings Verification 2009.
[562] Based on standard assumption of 2000 hours lamp life for baseline bulb 65 watt BR30 incandescent.

| | |
|---|---|
| Minimum CRI | 75 |
| Minimum Light Output | <= 4.5” Aperture: 345 lumens (initial)<br>> 4.5” Aperture: 575 lumens (initial) |
| Zonal Lumen Density Requirement | Luminaire shall deliver a total of 75% lumens (initial) within the 0-60 zone (bilaterally symmetrical) |
| Minimum Luminaire Efficacy | 35 lm/w |
| Allowable CCTs | • 2700K, 3000K, and 3500K for residential products<br>• No restrictions for commercial |
| Reduced Air Leakage | Recessed downlights intended for installation in insulated ceilings shall be IC rated and be leak tested per ASTM E283 to demonstrate no more than 2.0 cfm at 75 Pascals pressure difference. The luminaire must include a label certifying “sirtight” or similar designation to show accordance with ASTM E283. |
| Minimum Warranty | 3 years |
| • Eligible Products must meet the full requirements of the Energy Star specification. The complete Energy Star Specification for Solid State Luminaires can be obtained at www.netl.doe.gov | |

# Free CFL

Measure Number: IV-E-9-c (Efficient Products Program, Lighting End Use)

**Version Date & Revision History:**
Draft date: Portfolio 76
Effective date: 01/01/12
End date: 12/31/14

**Referenced Documents:**

1) EKOS Porchlight Report- December 2006.pdf
2) Residential Lighting Markdown Impact Evaluation, Nexus Market Research, RLW Analytics, and GDS Associated, January 20, 2009
3) Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)
4) 2012 EISA Adjustment Calculations.xls

**Description**
An existing incandescent screw-in bulb is replaced with a lower wattage ENERGY STAR qualified compact fluorescent screw-in bulb that was received free of charge at a Efficiency Vermont event or as part of a targeted campaign, and is installed in a Residential fixture.

**Algorithms**
**Demand Savings**
$\Delta kW$ $= ((\Delta Watts) / 1000) \times ISR$

| Year | Algorithm | ΔkW |
|---|---|---|
| 2012 | (49.0 / 1000) * 0.5 | 0.0245 |
| 2013 | (43.6 / 1000) * 0.5 | 0.0218 |
| 2014 | (37.0 / 1000) * 0.5 | 0.0185 |

**Energy Savings**
$\Delta kWh$ $= ((\Delta Watts) / 1000) \times HOURS \times ISR$

| Year | Algorithm | ΔkWh |
|---|---|---|
| 2012 | (49.0 / 1000) * 694 * 0.5 | 17.0 |
| 2013 | (43.6 / 1000) * 694 * 0.5 | 15.1 |
| 2014 | (37.0 / 1000) * 694 * 0.5 | 12.8 |

Where:

$\Delta Watts$ $= Watts_{BASE} - Watts_{EE}$[563]
$\Delta kW$ = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW
$Watts_{EE}$ = Energy efficient connected kW
$\Delta kWh$ = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units given out that actually get used[564]
HOURS = average hours of use per year

**Waste Heat Adjustment**
N/A

**Heating Increased Usage**

[563] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011
[564] Efficiency Vermont will assume an In Service Rate for a Free CFL of 50%. An EKOS study of a free CFL campaign, 'Project Porchlight' in Ottawa, found an install rate of 70% of those who could recall receiving the bulb. A 50% ISR is considered a conservative assumption, especially when the bulbs will be accompanied by marketing material explaining the benefits. The state-wide CFL media campaign set to launch in January,2008 will also increase in-service rates by significantly raising awareness of the benefits of CFLs.

N/A

**Baseline Efficiencies – New or Replacement**
The baseline condition is an incandescent light bulb.

**Baseline Adjustment**
In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become Halogen bulbs (see percentages in O&M table below).

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012, 2013 or 2014 depending on the assumed baseline wattage (note if a mix of bulbs is assumed, the adjustment always occurs in 2012).

The appropriate adjustments are provided below (see 2012 EISA Adjustment Calculations.xls for details)

| Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|
| 2012 | 0.66 | 2 |
| 2013 | 0.77 | 1 |
| 2014 | 0.88 | 1 |

**High Efficiency**
High efficiency is an ENERGY STAR qualified compact fluorescent lamp.

**Operating Hours**
Operating hours will be assumed as 1.9 hours per day or 694 hours per year[565].

**Loadshape**
Residential: Loadshape #1: Residential Indoor Lighting
Source: Vermont State Cost-Effectiveness Screening Tool.

**Freeridership/Spillover Factors**

| Measure Category | | Light Bulbs/Lamps | |
|---|---|---|---|
| Measure Code | | LBLCFFRE | |
| Product Description | | Free Compact Fluorescent screw-base bulbs | |
| Track Name | Track No. | Freerider | Spillover |
| Efficient Products | 6032EPEP | 1.0 | 1.0 |
| RES Retrofit | 6036RETR | 1.0 | 1.0 |

**Persistence**
The persistence factor is assumed to be 90%.

**Lifetimes**
CFLs rebated through this program are assumed to have a rated life of 8,500 hours.
Bulb life is assumed to be 8500 hours, based on agreement between EVT and the DPS (TAG 2009). At 694 hours per year and including the 90% persistence factor this equates to 11 years. A provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore the measure life will reduce each year and be equal to the number of years remaining to 2020; so for 2012 this will be 8 years, 2013 7 years.

[565] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011.

**Measure Cost**[566]

The incremental cost for this measure is as follows

| Year | Measure Cost |
|---|---|
| 2012 | $1.90 |
| 2013 | $1.80 |
| 2014 | $1.50 |

**Fossil Fuel Descriptions**

N/A

**Water Descriptions**

There are no water algorithms or default values for this measure.

**Reference Tables**

**Methodology for Computing O&M Savings**

In order to account for the shift in baseline due to the Federal Legislation, the levelized baseline replacement cost over the lifetime of the CFL was calculated (see 2012 EISA Adjustment Calculations.xls). The key assumptions used in this calculation are documented below:

| | Incandescent | Halogen |
|---|---|---|
| Replacement Cost | $0.50 | $1.50 |
| Component Life (hours) | 1000 | 1000 |
| Baseline % in 2012 | 67% | 33% |
| Baseline % in 2013 | 33% | 67% |
| Baseline % in 2014 onward | 0% | 100% |

The calculation results in a levelized assumption of $0.93 baseline replacement cost every 1 year for CFL installations in 2012, $0.96 every year for installations in 2013, and $0.97 for installations in 2014. This adjustment will be recalculated for subsequent years.

[566] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011

# Specialty CFL

Measure Number: IV-E-10-c (Efficient Products Program, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 76
Effective date: 1/1/12
End date: TBD

**Referenced Documents:**

1. Residential Lighting Markdown Impact Evaluation, Nexus Market Research, January 20, 2009
2. Residential Lighting Measure Life Study, Nexus Market Research, June 4, 2008
3. WasteHeatAdjustment.doc
4. "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993
5. 2012_DeltaWatts_MeasureCost
6. Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)

**Description**
An existing incandescent bulb is replaced with a lower wattage ENERGY STAR qualified specialty compact fluorescent bulb. Specialty CFL bulbs are defined as lamps for general illumination that use fluorescent light emitting technology and an integrated electronic ballast with or without a standard Edison screw-base. They can be dimmable, designed for special applications, have special color enhancement properties or have screw-bases that are not standard Edison bases, and include A-lamps, candelabras, G-lamps (globe), reflectors, torpedoes, dimmables, and 3-way bulbs.

**Algorithms**
**Demand Savings**

$\Delta kW = ((\Delta Watts) / 1000) \times ISR \times WHF_d$

$\Delta kW(\text{Res.} <=15W) = ((39.1) / 1000) \times 0.9 \times 1.0) = 0.0352$

$\Delta kW(\text{Res.} >15W) = ((65.6) / 1000) \times 0.9 \times 1.0) = 0.0590$

$\Delta kW(\text{Comm.} <=15W) = ((39.1) / 1000) \times 0.9 ) \times 1.082 = 0.0381$

$\Delta kW(\text{Comm.} >15W) = ((65.6) / 1000) \times 0.9 ) \times 1.082 = 0.0639$

**Energy Savings**

$\Delta kWh = ((\Delta Watts) / 1000) \times HOURS \times ISR \times WHF_e$

$\Delta kWh\ (\text{Res.} <=15W) = ((39.1) / 1000) \times 694 \times 0.9 \times 1.0 = 24.43$

$\Delta kWh\ (\text{Res.} >15W) = ((65.6) / 1000) \times 694 \times 0.9 \times 1.0 = 40.95$

$\Delta kWh\ (\text{Comm.} <=15W) = ((39.1) / 1000) \times 2,800 \times 0.9 \times 1.033 = 101.85$

$\Delta kWh\ (\text{Comm.} >15W) = ((65.6) / 1000) \times 2,800 \times 0.9 \times 1.033 = 170.82$

Where:

$\Delta Watts$ = Average delta watts between specialty CFL and incandescent $Watts_{BASE} - Watts_{EE}$[567]
$\Delta kW$ = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW
$Watts_{EE}$ = Energy efficient connected kW
$\Delta kWh$ = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units rebated that actually get used = 0.9 [568]

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[567] Assumed difference in wattage between installed CFL and the incandescent bulb it replaces. Based on EVT analysis of bulbs purchased through the Efficient Product program since 2009 and using an equivalent baseline based on the ENERGY STAR consumer guide. See 2012_DeltaWatts_MeasureCost for more information.
[568] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011

$WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.082 (calculated as 1 + (0.47*0.67*.808) / 3.1))[569]. The cooling savings are only added to the summer peak savings.

$WHF_e$ = Waste heat factor for energy to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.033 (calculated as 1 + ((0.47*0.29*.75) / 2.5))[570].

HOURS = average hours of use per year[571]

**Waste Heat Adjustment**

Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF). See above.

**Heating Increased Usage**

$\Delta MMBTU_{WH}$ = $(\Delta kWh / WHF_e) \times 0.003413 \times (1 - OA) \times AR \times HF \times DFH / HEff$

$\Delta MMBTU_{WH}$ (Res<=15W) = $(24.43 / 1) \times 0.003413 \times (1 - 0.25) \times 1.00 \times 0.00 / 0.75 = 0.0$

$\Delta MMBTU_{WH}$ (Res.>15W) = $(40.95 / 1) \times 0.003413 \times (1 - 0.25) \times 1.00 \times 0.00 / 0.75 = 0.0$

$\Delta MMBTU_{WH}$ (Comm<=15W) = $(101.85 / 1.033) \times 0.003413 \times (1 - 0.25) \times 0.70 \times 0.39 / 0.75 = 0.0919$

$\Delta MMBTU_{WH}$ (Comm.>15W) = $(170.82 / 1.033) \times 0.003413 \times (1 - 0.25) \times 0.70 \times 0.39 / 0.75 = 0.154$

Where:

$\Delta MMBTU_{WH}$ = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.

0.003413 = Conversion from kWh to MMBTU

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[572].

AR = Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of commercial buildings within 15 feet of exterior wall.

HF = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont for commercial lighting, assumed 0.0 for residential lighting [573]

DFH = Percent of lighting in heated spaces, assumed to be 95%

HEff = Average heating system efficiency, assumed to be 79%[574]

Oil heating is assumed typical for commercial buildings.

**Baseline Efficiencies – New or Replacement**

The baseline condition is an incandescent specialty light bulb.

**High Efficiency**

High efficiency is an ENERGY STAR qualified specialty compact fluorescent lamp.

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[569] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 33% average outside air; and 80.8% coincidence of cooling with the summer peak period. See WasteHeatAdjustment.doc for additional discussion.

[570] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 25% average outside air; and 29% of annual lighting energy contributes to cooling load. See "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993 and WasteHeatAdjustment.doc for additional discussion.

[571] Hours of usage differs for residential and commercial applications. See table below for HOURS at each application.

[572] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

[573] From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993. Efficiency Vermont does not calculate interactive effects for residential lighting.

[574] Based on average efficiency for furnaces and boilers of varied sizes in ASHRAE 90.1.1999, assumed to represent typical commercial building stock in Vermont.

**Operating Hours**
Residential: 694 hours / year[575]
Commercial: 2,800 hours / year[576]

**Loadshape**
Residential: Loadshape #1: Residential Indoor Lighting
Commercial: Loadshape #101: Commercial EP Lighting[577]

**Freeridership/Spillover Factors**

| **Measure Category** | | **Light Bulbs/Lamps** | | | | | |
|---|---|---|---|---|---|---|---|
| **Measure Code** | | **LBLCFSPC** | | | | | |
| **Product Description** | | **Compact Fluorescent – Specialty Bulb** | | | | | |
| | | **2012** | | **2013** | | **2014** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** | **Freerider** | **Spillover** | **Freerider** | **Spillover** |
| Efficient Products | 6032EPEP | 0.80 | 1.0 | 0.8 | 1.0 | 0.6 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
Lifetime is a function of the average hours of use for the lamp. Most CFLs have a *rated* lifetime of 10,000 hours. However, units that are turned on and off more frequently have shorter lifetimes, and those that stay on continuously for longer periods of time have longer lifetimes. CFLs rebated through this program for commercial applications are assumed to have a life of 10,000 hours (assumed annual use of 2800). That translates to 3.57 years for commercial applications. Nexus Market Research recently analyzed and report measure life for residential applications in the Residential Lighting Measure Life Study dated June 4, 2008. Measure life for residential markdown CFL's is 6.8[578] yr. Analysis period is the same as the lifetime.

**Measure Cost[579]**
Incremental Cost (Watts <=15) = $5.45
Incremental Cost (Watts >15) = $4.55

**O&M Cost Adjustments**
O& M cost adjustments are based on component costs provided in the reference table below.

**Fossil Fuel Descriptions**
See Heating Increased Usage above.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

575 Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011.
576 Based on agreement made during Savings Verification 2009.
577 Based on Commercial "Other" Lighting coincidence factors from RLW Analytics; "Development of Common Demand Impacts Standards for Energy Efficiency Measures/Programs for the ISO Forward Capacity Market (FCM)". Agreement made during Savings Verification 2009.
578 Residential Lighting Measure Life Study, Nexus Market Research, June 4, 2008
579 EVT has applied the ratio of incremental cost difference between the two size classifications as was found by EVT when the original TRM was developed based on a review of available product, to the NEEP RLS, 2011 proposed incremental cost (which was a single value, not split in to size classifications) to give separate incremental costs. See 2012_DeltaWatts_MeasureCost for more information.

**Hours of Use, In Use Rates, and Waste Heat Factors by Customer Type**

| | Average Annual Hours of Use | Average In Service Rate | $WHF_d$ | $WHF_e$ | AR | HF |
|---|---|---|---|---|---|---|
| Residential | 694 | 0.9[580] | 1.0 | 1.0 | 1.0 | 0.0 |
| Commercial | 2,800 | 0.9[581] | 1.082 | 1.033 | 0.7 | 0.39 |

**Component Costs and Lifetimes Used in Computing O&M Savings**

**Residential**

| | Baseline Measures | | |
|---|---|---|---|
| Component | Cost | Residential Life[582] | Commercial Life |
| Lamp<=15W | $2.71 | 1.44 | 0.36 |
| Lamp>15W | $4.29 | 1.44 | 0.36 |

[580] 2011 TAG agreement
[581] 2005 TAG agreement
[582] Based on standard assumption of 1000 hours lamp life for baseline bulb.

# Hard to Reach Standard CFL

Measure Number: IV-E-11-a (Efficient Products Program, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 76
Effective date: 1/1/2012
End date: 12/31/2014

**Referenced Documents:**

1 Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)
2) 2012 EISA Adjustment Calculations.xls

**Description**
This TRM describes the savings estimates for residential standard CFL's over the 3 year contract period 2012– 2014 that are provided to those customers that have not been able to take advantage of the Retail EP program (Hard to Reach) for economic, cultural or age-related reasons. These bulbs will be provided through VT Foodbanks and other potential outlets serving disadvantaged populations. Note the only difference between this and the standard Efficient Product Residential Standard CFL measure is the freerider rate. An existing incandescent screw-in bulb is replaced with a lower wattage ENERGY STAR qualified standard compact fluorescent screw-in bulb. Standard bulb is defined as a medium screw base, one-way, non-dimmable, bare tube compact fluorescent lamp within a color temperature range of 2700-3000 K.

**Algorithms**
**Demand Savings**
$\Delta kW$ = $((\Delta Watts) / 1000) \times ISR$

| | Year | Algorithm | ΔkW |
|---|---|---|---|
| ΔkW | 2012 | = (49.0 / 1000) x 0.77 x 1.0 | 0.0377 |
| | 2013 | = (43.6 / 1000) x 0.77x 1.0 | 0.0336 |
| | 2014 | = (37.0 / 1000) x 0.77 x 1.0 | 0.0285 |

**Energy Savings**
$\Delta kWh$ = $((\Delta Watts) / 1000) \times HOURS \times ISR \times WHF_e$

| | Year | Algorithm | ΔkWh |
|---|---|---|---|
| ΔkWh | 2012 | = (49.0 / 1000) x 694 x 0.77 x 1.0 | 26.2 |
| | 2013 | = (43.6 / 1000) x 694 x 0.77 x 1.0 | 23.3 |
| | 2014 | = (37.0 / 1000) x 694 x 0.77 x 1.0 | 19.8 |

Where:

$\Delta Watts$ = $Watts_{BASE} - Watts_{EE}$[583]
$\Delta kW$ = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW
$Watts_{EE}$ = Energy efficient connected kW
$\Delta kWh$ = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units rebated that actually get used = 0.77[584]
$WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.082 (calculated as 1 +

[583] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011
[584] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011

$(0.47*0.67*.808) / 3.1))$[585]. The cooling savings are only added to the summer peak savings.

= 1.0 for Residential

$WHF_e$ = Waste heat factor for energy to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.033 (calculated as 1 + $((0.47*0.29*.75) / 2.5))$[586].

= 1.0 for Residential

HOURS = average hours of use per year

= 694[587]

**Waste Heat Adjustment**

Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF). See above.

**Heating Increased Usage**

$\Delta MMBTU_{WH}$ = $(\Delta kWh / WHF_e) \times 0.003413 \times (1 – OA) \times AR \times HF \times DFH / HEff$

| | | |
|---|---|---|
| $\Delta MMBTU_{WH}$ | 2009 | $= (26.2 / 1) \times 0.003413 \times (1 – 0.25) \times 1.00 \times 0.00 / 0.75 = 0.0$ |
| | 2010 | $= (23.3 / 1) \times 0.003413 \times (1 – 0.25) \times 1.00 \times 0.00 / 0.75 = 0.0$ |
| | 2011 | $= (19.8 / 1) \times 0.003413 \times (1 – 0.25) \times 1.00 \times 0.00 / 0.75 = 0.0$ |

Where:

$\Delta MMBTU_{WH}$ = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.

0.003413 = Conversion from kWh to MMBTU

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[588].

AR = Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of commercial buildings within 15 feet of exterior wall.

HF = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont for commercial lighting, assumed 0.0 for residential lighting [589]

DFH = Percent of lighting in heated spaces, assumed to be 95%

HEff = Average heating system efficiency, assumed to be 79%[590]

Oil heating is assumed typical for commercial buildings.

**Baseline Efficiencies – New or Replacement**

The baseline condition is based on the "NEEP Residential Lighting Survey", 2011 and incorporates changes due to the Energy Independence and Security Act, 2007.

**Baseline Adjustment**

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585 Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 33% average outside air; and 80.8% coincidence of cooling with the summer peak period. See WasteHeatAdjustment.doc for additional discussion.

586 Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 25% average outside air; and 29% of annual lighting energy contributes to cooling load. See "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993 and WasteHeatAdjustment.doc for additional discussion.

587 Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011

588 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

589 From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993. Efficiency Vermont does not calculate interactive effects for residential lighting.

590 Based on average efficiency for furnaces and boilers of varied sizes in ASHRAE 90.1.1999, assumed to represent typical commercial building stock in Vermont.

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become EISA qualified incandescent or Halogen bulbs.

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012, 2013 or 2014 depending on the assumed baseline wattage (note if a mix of bulbs is assumed, the adjustment always occurs in 2012).

The appropriate adjustments are provided below (see 2012 EISA Adjustment Calculations.xls for details):

| Measure | Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|---|
| Commercial EP Standard CFL | 2012 | 0.66 | 2 |
| | 2013 | 0.77 | 1 |
| | 2014 | 0.88 | 1 |

**High Efficiency**
High efficiency is an ENERGY STAR qualified compact fluorescent lamp.

**Operating Hours**
694 hours per year[591]

**Loadshape**
Residential: Loadshape #1: Residential Indoor Lighting
Source: Vermont State Cost-Effectiveness Screening Tool.

**Freeridership/Spillover Factors**

| **Measure Category** | | **Light Bulbs/Lamps** | | | | | |
|---|---|---|---|---|---|---|---|
| **Measure Code** | | **LBLCFBLH** | | | | | |
| **Product Description** | | **Compact Fluorescent screw-base bulbs – Residential Hard to Reach** | | | | | |
| | | **2012** | | **2013** | | **2014** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** | **Freerider** | **Spillover** | **Freerider** | **Spill over** |
| Efficient Products | 6032EPEP | 0.90 | 1.0 | 0.8 | 1.0 | 0.7 | 1.0 |

Note the freerider rate is the only difference between this and the standard Efficient Product Residential Standard CFL measure. We do not have evaluation data to base the freerider rate on but estimate a starting point of 10% freeriders (compared to 40% in retail), and increasing at the same rate as the EP measure over the three years.

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
Lifetime is a function of the average hours of use for the lamp. Most CFL's have a *rated* lifetime of 10,000 hours. However, units that are turned on and off more frequently have shorter lives and those that stay on for longer periods of time have longer lives. CFLs rebated through this program are assumed to have a life of 8,500 hours. Based on an annual run hours of 694, the measure life is 8500/694 = 12.2 years. However a provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore the analysis period (i.e. the life of the savings) is reduced to the number of years remaining to 2020. So for installations in 2012, the measure life is 8 years, for 2013 7 years.

[591] Based on TAG 2011 agreement to use recommendation from RLS, 2011

**Measure Cost**[592]

The incremental cost for this measure is as follows

| Year | Measure Cost |
|---|---|
| 2012 | $1.90 |
| 2013 | $1.80 |
| 2014 | $1.50 |

**O&M Cost Adjustments**

O& M cost adjustments are based on component costs provided in the reference table below.

**Fossil Fuel Descriptions**

See Heating Increased Usage above.

**Water Descriptions**

There are no water algorithms or default values for this measure.

**Reference Tables**

**Methodology for Computing O&M Savings**

In order to account for the shift in baseline due to the Federal Legislation, the levelized baseline replacement cost over the lifetime of the CFL was calculated (see CFL baseline savings shift.xls). The key assumptions used in this calculation are documented below:

| | Incandescent | Halogen |
|---|---|---|
| Replacement Cost | $0.50 | $1.50 |
| Component Life (hours) | 1000 | 1000 |
| Baseline % in 2009-2011 | 100% | 0% |
| Baseline % in 2012 | 67% | 33% |
| Baseline % in 2013 | 33% | 67% |
| Baseline % in 2014 onward | 0% | 100% |

The calculation results in a levelized assumption of $0.98 baseline replacement cost every 1 year for CFL installations in 2012, $1.02 for installations in 2013 and $1.04 for installations in 2014. This adjustment will be recalculated for subsequent years.

[592] Based on TAG 2011 agreement to use recommendation from RLS, 2011

# Residential Standard CFL

Measure Number: IV-E-12-b (Efficient Products Program, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 76
Effective date: 1/1/2012
End date: 12/31/2014

**Referenced Documents:**
1) Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)
2) 2012 EISA Adjustment Calculations.xls

**Description**
This TRM describes the savings estimates for residential standard CFL's over the 3 year contract period 2009 – 2011. An existing incandescent screw-in bulb is replaced with a lower wattage ENERGY STAR qualified standard compact fluorescent screw-in bulb. Standard bulb is defined as a medium screw base, one-way, non-dimmable, bare tube compact fluorescent lamp within a color temperature range of 2700-3000 K.

**Algorithms**
**Demand Savings**
$\Delta kW = ((\Delta Watts) / 1000) \times ISR$

| | Year | Algorithm | ΔkW |
|---|---|---|---|
| ΔkW | 2012 | = (49.0 / 1000) x 0.77 x 1.0 | 0.0377 |
| | 2013 | = (43.6 / 1000) x 0.77x 1.0 | 0.0336 |
| | 2014 | = (37.0 / 1000) x 0.77 x 1.0 | 0.0285 |

**Energy Savings**
$\Delta kWh = ((\Delta Watts) / 1000) \times HOURS \times ISR \times WHF_e$

| | Year | Algorithm | ΔkWh |
|---|---|---|---|
| ΔkWh | 2012 | = (49.0 / 1000) x 694 x 0.77 x 1.0 | 26.2 |
| | 2013 | = (43.6 / 1000) x 694 x 0.77 x 1.0 | 23.3 |
| | 2014 | = (37.0 / 1000) x 694 x 0.77 x 1.0 | 19.8 |

Where:

$\Delta Watts$ = $Watts_{BASE} - Watts_{EE}$[593]
$\Delta kW$ = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW
$Watts_{EE}$ = Energy efficient connected kW
$\Delta kWh$ = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units rebated that actually get used
= 0.77[594]
$WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting.
= 1.0 for Residential
$WHF_e$ = Waste heat factor for energy to account for cooling savings from efficient lighting.
= 1.0 for Residential
HOURS = average hours of use per year

593 Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011
594 Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011

$= 694$[595]

**Waste Heat Adjustment**

Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF). See above.

**Heating Increased Usage**

$\Delta MMBTU_{WH} = (\Delta kWh / WHF_e) \times 0.003413 \times (1 - OA) \times AR \times HF \times DFH / HEff$

| | | |
|---|---|---|
| $\Delta MMBTU_{WH}$ | 2009 | $= (26.2 / 1) \times 0.003413 \times (1 - 0.25) \times 1.00 \times 0.00 / 0.75 = 0.0$ |
| | 2010 | $= (23.3 / 1) \times 0.003413 \times (1 - 0.25) \times 1.00 \times 0.00 / 0.75 = 0.0$ |
| | 2011 | $= (19.8 / 1) \times 0.003413 \times (1 - 0.25) \times 1.00 \times 0.00 / 0.75 = 0.0$ |

Where:

$\Delta MMBTU_{WH}$ = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.

0.003413 = Conversion from kWh to MMBTU

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[596].

AR = Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of commercial buildings within 15 feet of exterior wall.

HF = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont for commercial lighting, assumed 0.0 for residential lighting [597]

DFH = Percent of lighting in heated spaces, assumed to be 95%

HEff = Average heating system efficiency, assumed to be 79%[598]

**Baseline Efficiencies – New or Replacement**

The baseline condition is based on the "NEEP Residential Lighting Survey", 2011 and incorporates changes due to the Energy Independence and Security Act, 2007.

**Baseline Adjustment**

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become EISA qualified incandescent or Halogen bulbs.

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012, 2013 or 2014 depending on the assumed baseline wattage (note if a mix of bulbs is assumed, the adjustment always occurs in 2012).

The appropriate adjustments are provided below (see 2012 EISA Adjustment Calculations.xls for details):

| Measure | Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|---|
| Commercial EP | 2012 | 0.66 | 2 |

595 Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011

596 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

597 From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993. Efficiency Vermont does not calculate interactive effects for residential lighting.

598 Based on average efficiency for furnaces and boilers of varied sizes in ASHRAE 90.1.1999, assumed to represent typical commercial building stock in Vermont.

| | | | |
|---|---|---|---|
| Standard CFL | 2013 | 0.77 | 1 |
| | 2014 | 0.88 | 1 |

**High Efficiency**
High efficiency is an ENERGY STAR qualified compact fluorescent lamp.

**Operating Hours**
694 hours per year[599]

**Loadshape**
Residential: Loadshape #1: Residential Indoor Lighting
Source: Vermont State Cost-Effectiveness Screening Tool.

**Freeridership/Spillover Factors**

| Measure Category | | Light Bulbs/Lamps | | | | | |
|---|---|---|---|---|---|---|---|
| Measure Code | | LBLCFBLB | | | | | |
| Product Description | | Compact Fluorescent screw-base bulbs - Residential | | | | | |
| | | 2012 | | 2013 | | 2014 | |
| Track Name | Track No. | Freerider | Spillover | Freerider | Spillover | Freerider | Spillover |
| Efficient Products | 6032EPEP | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
Lifetime is a function of the average hours of use for the lamp. Most CFL's have a *rated* lifetime of 10,000 hours. However, units that are turned on and off more frequently have shorter lives and those that stay on for longer periods of time have longer lives. CFLs rebated through this program are assumed to have a life of 8,500 hours. Based on an annual run hours of 694, the measure life is 8500/694 = 12.2 years. However a provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore the analysis period (i.e. the life of the savings) is reduced to the number of years remaining to 2020. So for installations in 2012, the measure life is 8 years, for 2013 7 years.

**Measure Cost[600]**
The incremental cost for this measure is as follows

| Year | Measure Cost |
|---|---|
| 2012 | $1.90 |
| 2013 | $1.80 |
| 2014 | $1.50 |

**O&M Cost Adjustments**
O& M cost adjustments are based on component costs provided in the reference table below.

**Fossil Fuel Descriptions**
See Heating Increased Usage above.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

[599] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011
[600] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011

**Methodology for Computing O&M Savings**

In order to account for the shift in baseline due to the Federal Legislation, the levelized baseline replacement cost over the lifetime of the CFL was calculated (see CFL baseline savings shift.xls). The key assumptions used in this calculation are documented below:

| | Incandescent | Halogen |
|---|---|---|
| Replacement Cost | $0.50 | $1.50 |
| Component Life (hours) | 1000 | 1000 |
| Baseline % in 2009-2011 | 100% | 0% |
| Baseline % in 2012 | 67% | 33% |
| Baseline % in 2013 | 33% | 67% |
| Baseline % in 2014 onward | 0% | 100% |

The calculation results in a levelized assumption of $0.98 baseline replacement cost every 1 year for CFL installations in 2012, $1.02 for installations in 2013 and $1.04 for installations in 2014. This adjustment will be recalculated for subsequent years.

# ENERGY STAR Integrated Screw Based SSL (LED) Lamps

Measure Number: IV-E-13-d (Efficient Products Program, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 84
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**
1) LED ESTAR specs_NewCats.xls
2) 2013 EISA Adjustment Calculations.xls
3) IntegralLamps.pdf
4) 2013 LED Sales Review.xlsx

**Description**
An ENERGY STAR Integrated Screw Based SSL (LED) Lamp (specification effective August 2010) is purchased in place of an incandescent lamp. This measure is broken down in to Omnidirectional (e.g. A-Type lamps), Decorative (e.g. Globes and Torpedoes) and Directional (PAR Lamps, Reflectors, MR16). Further, the Omnidirectional are broken down in to <10W and >=10W and Directional Lamps in to <15W and >=15W categories to best reflect the delta wattage in each range. The ENERGY STAR specification can be viewed here: http://www.energystar.gov/ia/partners/manuf_res/downloads/IntegralLampsFINAL.pdf

**Algorithms**
**Demand Savings**
$\Delta kW = ((Watts_{BASE} - Watts_{EE}) /1000) \times ISR \times WHF_d$

**Energy Savings**
$\Delta kWh = ((Watts_{BASE} - Watts_{EE}) /1000) \times ISR \times HOURS \times WHF_e$

Where:

| | |
|---|---|
| $\Delta kW$ | = gross customer connected load kW savings for the measure |
| $Watts_{BASE}$ | = Baseline connected kW. |
| $Watts_{EE}$ | = Energy efficient connected kW. |
| $\Delta kWh$ | = gross customer annual kWh savings for the measure |
| ISR | = in service rate or the percentage of units rebated that actually get used |
| $WHF_d$ | = Waste heat factor for demand to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.082 (calculated as 1 + (0.47*0. 67*.808) / 3.1))[601]. The cooling savings are only added to the summer peak savings. The value for Residential lighting is assumed to be 1.0. |
| $WHF_e$ | = Waste heat factor for energy to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.033 (calculated as 1 + ((0.47*0.29*.75) / 2.5))[602]. The value for Residential lighting is assumed to be 1.0. |
| HOURS | = average hours of use per year |

Values used in algorithm[603] and results:

[601] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 25% average outside air; and 80.8% coincidence of cooling with the summer peak period. See WasteHeatAdjustment.doc for additional discussion.
[602] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 25% average outside air; and 29% of annual lighting energy contributes to cooling load. See “Calculating lighting and HVAC interactions”, Table 1, ASHRAE Journal November 1993 and WasteHeatAdjustment.doc for additional discussion.

| | | | | | | | 2013 | | 2014 | | 2020 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | LED Wattage | Base 2013 | Base 2014 | Base 2020 | LED | ΔkW | ΔkWh | ΔkW | ΔkWh | ΔkW | ΔkWh |
| Residential | Omnidirectional | <10W | 39.4 | 28.8 | 11.8 | 8.4 | 0.0270 | 33.5 | 0.0177 | 22.0 | 0.0030 | 3.7 |
| | | >=10W | 59.9 | 43.2 | 18.1 | 12.1 | 0.0416 | 51.6 | 0.0271 | 33.6 | 0.0052 | 6.5 |
| | Decorative | All | 21.9 | | | 3.6 | 0.0159 | 19.8 | 0.0159 | 19.8 | 0.0159 | 19.8 |
| | Directional | <15W | 44.3 | | | 9.7 | 0.0301 | 37.4 | 0.0301 | 37.4 | 0.0301 | 37.4 |
| | | >=15W | 46.3 | | | 16.7 | 0.0258 | 32.0 | 0.0258 | 32.0 | 0.0258 | 32.0 |
| Commercial | Omnidirectional | <10W | 39.5 | 28.8 | 11.8 | 8.4 | 0.0302 | 101.0 | 0.0198 | 66.2 | 0.0033 | 11.0 |
| | | >10W | 59.9 | 43.2 | 18.1 | 12.1 | 0.0464 | 155.2 | 0.0302 | 101.0 | 0.0058 | 19.5 |
| | Decorative | All | 21.9 | | | 3.6 | 0.0178 | 59.4 | 0.0178 | 59.4 | 0.0178 | 59.4 |
| | Directional | <15W | 44.3 | | | 9.7 | 0.0336 | 112.3 | 0.0336 | 112.3 | 0.0336 | 112.3 |
| | | >=15W | 46.3 | | | 16.7 | 0.0288 | 96.1 | 0.0288 | 96.1 | 0.0288 | 96.1 |

| | Residential | Commercial |
|---|---|---|
| ISR | 0.870[604] | 0.898[605] |
| Hours | 1241 | 3500 |
| WHFd | 1 | 1.082 |
| WHFe | 1 | 1.033 |

[603] See 2013 LED Sales Review.xls for details on how the baseline was determined based on a year's worth of LED sales data from a cross section of product brands and Vermont geography.
[604] See SMARTLIGHT QA 2012.docx for LED in service rate.
[605] Ibid

**Baseline Efficiencies – New or Replacement**
The baseline wattage is assumed to be an equivalent baseline bulb (standard or EISA qualified incandescent up until 2020 when it becomes a CFL) installed in a screw-base socket. See 2013 LED Sales Review.xls for details on how the baseline was determined based on a year's worth of LED sales data from a cross section of product brands and Vermont geography.

**High Efficiency**
The high efficiency wattage is assumed to be an ENERGY STAR qualified Integrated Screw Based SSL (LED) Lamp. See 2013 LED Sales Review.xls for details.

**Baseline Adjustment**
Federal legislation stemming from the Energy Independence and Security Act of 2007 began the phasing out of omnidirectional incandescent bulbs. From 2012 100W incandescents can no longer be manufactured, followed by restrictions on 75W in 2013 and 60W/40W in 2014. The baseline for this measure will become EISA compliant incandescent and halogen bulbs. Further in 2020, the baseline becomes a bulb with 45 Lumens per watt efficacy.
To account for these new standards, the savings for this measure will be reduced to account for the higher baselines starting in 2012 and 2020. The following table shows the calculated adjustments for each measure type. Note that while there are two baseline shifts during the lifetime of the LED lamp, Efficiency Vermont is only able to incorporate one adjustment factor. Therefore, both shifts are included in the calculation of a single adjustment factor (see 2013 EISA Adjustment Calculations.xls for details on how adjustment is calculated):

| | | | | Bulb Wattages Assumed in Calculation | | | Mid Measure Life Savings Adjustments | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **LED Wattage Range** | **LED Wattage** | **2013** | **2014** | **2020 EISA Compliant (45lu/W)** | **2013 Adjustment** | **After # of years** | **2014 Adjustment** | **After # of years** | **2015 Adjustment** | **After # of years** |
| **Residential** | **Omnidirectional** | <10W | 8.4 | 39.5 | 28.8 | 11.8 | 8.0% | 5 | 16.7% | 6 | 16.7% | 5 |
| | | >=10W | 12.1 | 59.9 | 43.2 | 18.1 | 10.0% | 5 | 19.3% | 6 | 19.3% | 5 |
| | **Decorative** | All | 3.6 | 21.9 | | | n/a | | n/a | | | |
| | **Directional** | <15W | 9.7 | 44.3 | | | n/a | | n/a | | | |
| | | >=15W | 16.7 | 46.3 | | | n/a | | n/a | | | |
| **Commercial** | **Omnidirectional** | <10W | 8.4 | 39.5 | 28.8 | 11.8 | 65.6% | 1 | 100.0% | 1 | 16.7% | 5 |
| | | >=10W | 12.1 | 59.9 | 43.2 | 18.1 | 64.0% | 1 | 19.3% | 6 | 19.3% | 5 |
| | **Decorative** | All | 3.6 | 21.9 | | | n/a | | n/a | | | |
| | **Directional** | <15W | 9.7 | 44.3 | | | n/a | | n/a | | | |
| | | >=15W | 16.7 | 46.3 | | | n/a | | n/a | | | |

For example for Residential Omnidirectional bulbs <10W measures installed in 2013, the full savings (as calculated above in the Algorithm section) will be claimed for the first five years, and the adjusted savings (full * adjustment factor) will be claimed for the remainder of the measure life (note this adjustment factor applies to both electric and fuel savings).
This adjustment will be recalculated for subsequent years.

**Heating Increased Usage**

$\Delta MMBTU_{WH}$ = $(\Delta kWh / WHF_e) \times 0.003413 \times (1 - OA) \times AR \times HF \times DFH / HEff$

Where:

$\Delta MMBTU_{WH}$ = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.

0.003413= Conversion from kWh to MMBTU

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[606].

AR = Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of commercial buildings within 15 feet of exterior wall. The assumed aspect ratio for residential buildings is 100%.

HF = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont for commercial lighting, assumed 0.0 for residential lighting[607]

DFH = Percent of lighting in heated spaces, assumed to be 95%

HEff = Average heating system efficiency, assumed to be 79%[608]

Oil heating is assumed typical for commercial buildings.

$\Delta MMBTU_{WH}$ (Residential) $= (\Delta kWh / 1) \times 0.003413 \times 1.00 \times 0.00 \times 0.95 / 0.79 = 0.0$

$\Delta MMBTU_{WH}$ (Commercial) $= (\Delta kWh / 1.033) \times 0.003413 \times 0.75 \times 0.70 \times 0.39 \times 0.95 / 0.79$

| | | LED Wattage | ΔMMBTUWH | | |
|---|---|---|---|---|---|
| | | | 2013 | 2014-2019 | 2020 |
| Commercial | Omnidirectional | <10W | 0.08 | 0.05 | 0.01 |
| | | >=10W | 0.13 | 0.08 | 0.02 |
| | Decorative | All | 0.04 | | |
| | Directional | <15W | 0.09 | | |
| | | >=15W | 0.07 | | |

**Operating Hours**

Residential: 1,241 hours / year[609]

Commercial: 3,500 hours / year[610]

**Loadshape**

Residential: Loadshape #1: Residential Indoor Lighting

Commercial: Loadshape #101: Commercial EP Lighting[611] and Loadshape #15 (Commercial A/C) for cooling bonus energy savings.

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[606] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

[607] From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993. Efficiency Vermont does not calculate interactive effects for residential lighting.

[608] Based on average efficiency for furnaces and boilers of varied sizes in ASHRAE 90.1.1999, assumed to represent typical commercial building stock in Vermont.

[609] The hours of use for this measure are based on the assumption that these will be installed in the highest use locations due to their high cost. Therefore prior assumptions for CFLs, when that same assumption was true are used for these lamps. Residential hours of use are based on average daily hours of use of 3.4 from Xenergy, Process and Impact Evaluation of Joint Utilities Starlights Residential Lighting Program, prepared for Boston Edison, Commonwealth Electric, Eastern Utilities, and New England Power Service Company, July 23, 2000.

[610] Commercial hours of use based on standard hours of use for commercial indoor lighting from Vermont State Cost Effectiveness Screening Tool.

**Freeridership/Spillover Factors**

| Measure Category | | Light Bulbs/Lamps | |
|---|---|---|---|
| Measure Code | | LBLLEDSC | |
| Product Description | | LED – Integral Screw Based Lamp | |
| Track Name | Track No. | Freerider | Spillover |
| Efficient Products | 6032EPEP | 0.94 | 1.25 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
Lifetime is a function of the average hours of use of the luminaire. A year's worth of LED sales data was reviewed and the rated life averaged (see 2013 LED Sales Review.xls). The assumed measure life is 20,000 hours for Omnidirectional <10W, 25,000 for Omnidirectional >=10W, 20,000 for Decorative lamps and 28,000 for Directional <15W lamps and 44,000 for Directional >=15W lamps . Lamps rebated through this program are therefore expected to have the following lifetime, based on the rated life in hours divided by the assumed average hours of use:

| | | Residential[612] | Commercial |
|---|---|---|---|
| Omnidirectional | <10W | 15 | 5.7 |
| | >=10W | 15 | 7.1 |
| Decorative | All | 15 | 5.7 |
| Directional | <15W | 15 | 8.0 |
| | >=15W | 15 | 12.6 |

Analysis period is equal to measure life.

**Measure Cost**
The efficient, baseline (incandescent, halogen and CFL) and incremental costs for these measures are provided below[613]:

| | | Lamp Costs | | | | Incremental Cost | | |
|---|---|---|---|---|---|---|---|---|
| | | Efficient | Baseline | | | | | |
| | LED Wattage | LED | Incandescent | EISA 2012-2014 Compliant | EISA 2020 Compliant | Incandescent | EISA 2012-2014 Compliant | EISA 2020 Compliant |
| Omnidirectional | <10W | $12.00 | $0.50 | $1.50 | $2.50 | $11.50 | $10.50 | $9.50 |
| | >=10W | $26.00 | $0.50 | $1.50 | $2.50 | $25.50 | $24.50 | $23.50 |
| Decorative | All | $21.00 | $1.00 | n/a | n/a | $20.00 | n/a | n/a |
| Directional | <15W | $41.00 | $5.00 | n/a | n/a | $36.00 | n/a | n/a |
| | >=15W | $57.00 | $5.00 | n/a | n/a | $52.00 | n/a | n/a |

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611 Based on Commercial "Other" Lighting coincidence factors from RLW Analytics; "Development of Common Demand Impacts Standards for Energy Efficiency Measures/Programs for the ISO Forward Capacity Market (FCM)". Agreement made during Savings Verification 2009.
612 Note all lifetimes are capped at 15 years (although their rated life/hours is higher).
613 All costs are based on review of a year's worth of LED sales data and the retail cost averaged (see 2013 LED Sales Review.xls)

**Methodology for Computing O&M Savings**

For Decorative and Directional bulbs, without a baseline shift, the following component costs and lifetimes will be used to calculate O&M savings:

| | | Baseline Measures | |
|---|---|---|---|
| | **Lamp Type** | Cost | Life[614] |
| **Residential** | Decorative | $1.00 | 0.8 |
| | Directional <15W | $5.00 | 0.8 |
| | Directional >=15W | $5.00 | 0.8 |
| **Commercial** | Decorative | $1.00 | 0.29 |
| | Directional <15W | $5.00 | 0.29 |
| | Directional >=15W | $5.00 | 0.29 |

For Omni-directional bulbs, to account for the shift in baseline due to the Federal Legislation, the levelized baseline replacement cost over the lifetime of the LED is calculated (see 2013 EISA Adjustment Calculations.xls). The key assumptions used in this calculation are documented below:

| | **Incandescent** | **EISA 2012-2014 Compliant** | **EISA 2020 Compliant** |
|---|---|---|---|
| Replacement Cost | As presented above | | |
| Component Life (hours) | 1000 | 1000 | 8,000 (Res)<br>10,000 (C&I) |
| Omnidirectional <10W | Until 2014 | 2014 – 2019 | 2020 on |
| Omnidirectional >=10W | 50% in 2013 | 50% in 2013, 100% 2014 – 2019 | 2020 on |

The calculation results in the following assumptions of equivalent annual baseline replacement cost[615]:

| | | | **Annual baseline O&M assumption for bulbs installed in** | | |
|---|---|---|---|---|---|
| | | **LED Wattage** | **2013** | **2014** | **2015** |
| **Residential** | **Omnidirectional** | <10W | $1.21 | $1.24 | $1.16 |
| | | >=10W | $1.19 | $1.17 | $1.01 |
| **Commercial** | **Omnidirectional** | <10W | $4.88 | $5.56 | $4.98 |
| | | >=10W | $4.98 | $4.79 | $4.32 |

**Fossil Fuel Descriptions**

See Heating Increased Usage above.

**Water Descriptions**

There are no water algorithms or default values for this measure.

614 Assumes incandescent baseline lamp life of 1000 hours.

615 See '2013 EISA Adjustment Calculations.xlsx' for details.

# Hard to Reach Specialty CFL

Measure Number: IV-E-14-a (Efficient Products Program, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 80
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**

1. Residential Lighting Markdown Impact Evaluation, Nexus Market Research, January 20, 2009
2. Residential Lighting Measure Life Study, Nexus Market Research, June 4, 2008
3. WasteHeatAdjustment.doc
4. "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993
5. 2012_DeltaWatts_MeasureCost
6. Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)

**Description**
An existing incandescent bulb is replaced with a lower wattage ENERGY STAR qualified specialty compact fluorescent bulb. Specialty CFL bulbs are defined as lamps for general illumination that use fluorescent light emitting technology and an integrated electronic ballast with or without a standard Edison screw-base. They can be dimmable, designed for special applications, have special color enhancement properties or have screw-bases that are not standard Edison bases, and include A-lamps, candelabras, G-lamps (globe), reflectors, torpedoes, dimmables, and 3-way bulbs. This particular measure characterizes those bulbs that are provided to customers that have not been able to take advantage of the Retail EP program for economic, cultural or age-related reasons (so called 'Hard to Reach'). These bulbs will be provided through VT Foodbanks and other potential outlets serving disadvantaged populations. Note the only difference between this and the standard Efficient Product Residential Specialty CFL measure is the freerider rate.

**Algorithms**
**Demand Savings**
$\Delta kW = ((\Delta Watts) / 1000) \times ISR \times WHF_d$
$\Delta kW(Res. <=15W) = ((39.1) / 1000) \times 0.7 \times 1.0) = 0.0274$
$\Delta kW(Res. >15W) = ((65.6) / 1000) \times 0.7 \times 1.0) = 0.0459$

**Energy Savings**
$\Delta kWh = ((\Delta Watts) / 1000) \times HOURS \times ISR \times WHF_e$
$\Delta kWh\ (Res. <=15W) = ((39.1) / 1000) \times 694 \times 0.7 \times 1.0 = 18.99$
$\Delta kWh\ (Res. >15W) = ((65.6) / 1000) \times 694 \times 0.7 \times 1.0 = 31.87$

Where:
$\Delta Watts$ = Average delta watts between specialty CFL and incandescent $Watts_{BASE} - Watts_{EE}$[616]
$\Delta kW$ = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW
$Watts_{EE}$ = Energy efficient connected kW
$\Delta kWh$ = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units rebated that actually get used = 0.7 [617]

[616] Assumed difference in wattage between installed CFL and the incandescent bulb it replaces. Based on EVT analysis of bulbs purchased through the Efficient Product program since 2009 and using an equivalent baseline based on the ENERGY STAR consumer guide. See 2012_DeltaWatts_MeasureCost for more information.

| | | |
|---|---|---|
| $WHF_d$ | = | Waste heat factor for demand to account for cooling savings from efficient lighting. |
| $WHF_e$ | = | Waste heat factor for energy to account for cooling savings from efficient lighting |
| HOURS | = | average hours of use per year[618] |

**Waste Heat Adjustment**

Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF). See above.

**Heating Increased Usage**

$\Delta MMBTU_{WH}$ = $(\Delta kWh / WHF_e) \times 0.003413 \times (1 - OA) \times AR \times HF \times DFH / HEff$

$\Delta MMBTU_{WH}$ (Res<=15W) = $(24.43 / 1) \times 0.003413 \times (1 - 0.25) \times 1.00 \times 0.00 / 0.75 = 0.0$

$\Delta MMBTU_{WH}$ (Res.>15W) = $(40.95 / 1) \times 0.003413 \times (1 - 0.25) \times 1.00 \times 0.00 / 0.75 = 0.0$

Where:

| | | |
|---|---|---|
| $\Delta MMBTU_{WH}$ | = | Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat. |
| 0.003413 | = | Conversion from kWh to MMBTU |
| OA | = | Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[619]. |
| AR | = | Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of commercial buildings within 15 feet of exterior wall. |
| HF | = | ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont for commercial lighting, assumed 0.0 for residential lighting [620] |
| DFH | = | Percent of lighting in heated spaces |
| HEff | = | Average heating system efficiency |

Oil heating is assumed typical for commercial buildings.

**Baseline Efficiencies – New or Replacement**

The baseline condition is an incandescent specialty light bulb.

**High Efficiency**

High efficiency is an ENERGY STAR qualified specialty compact fluorescent lamp.

**Operating Hours**

Residential: 694 hours / year[621]

**Loadshape**

Residential: Loadshape #1: Residential Indoor Lighting

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[617] Based on agreement with DPS to use half way point between general retail measure (0.9) and "free CFL" assumption (0.5).

[618] Hours of usage differs for residential and commercial applications. See table below for HOURS at each application.

[619] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

[620] From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993. Efficiency Vermont does not calculate interactive effects for residential lighting.

[621] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011.

**Freeridership/Spillover Factors**

| **Measure Category** | | **Light Bulbs/Lamps** | | | | | |
|---|---|---|---|---|---|---|---|
| **Measure Code** | | **LBLCFSPH** | | | | | |
| **Product Description** | | **Hard to Reach Compact Fluorescent – Specialty Bulb** | | | | | |
| | | **2012** | | **2013** | | **2014** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** | **Freerider** | **Spillover** | **Freerider** | **Spillover** |
| Efficient Products | 6032EPEP | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |

We do not have evaluation data to base the freerider rate on but to be consistent with all other lighting measures targeting low income populations, a net to gross rate of 1.0 is assumed. Since these bulbs are not subject to EISA regulations, there is no reason to believe this will decrease over the years.

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
Lifetime is a function of the average hours of use for the lamp. Most CFLs have a *rated* lifetime of 10,000 hours. However, units that are turned on and off more frequently have shorter lifetimes, and those that stay on continuously for longer periods of time have longer lifetimes. CFLs rebated through this program for commercial applications are assumed to have a life of 10,000 hours (assumed annual use of 2800). That translates to 3.57 years for commercial applications. Nexus Market Research recently analyzed and report measure life for residential applications in the Residential Lighting Measure Life Study dated June 4, 2008. Measure life for residential markdown CFL's is 6.8[622] yr. Analysis period is the same as the lifetime.

**Measure Cost[623]**
Incremental Cost (Watts <=15) = $5.45
Incremental Cost (Watts >15) = $4.55

**O&M Cost Adjustments**
O& M cost adjustments are based on component costs provided in the reference table below.

**Fossil Fuel Descriptions**
See Heating Increased Usage above.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

**Hours of Use, In Use Rates, and Waste Heat Factors by Customer Type**

| | Average Annual Hours of Use | Average In Service Rate | $WHF_d$ | $WHF_e$ | AR | HF |
|---|---|---|---|---|---|---|
| Residential | 694 | 0.7[624] | 1.0 | 1.0 | 1.0 | 0.0 |

**Component Costs and Lifetimes Used in Computing O&M Savings**

| | Baseline Measures |
|---|---|

622 Residential Lighting Measure Life Study, Nexus Market Research, June 4, 2008
623 EVT has applied the ratio of incremental cost difference between the two size classifications as was found by EVT when the original TRM was developed based on a review of available product, to the NEEP RLS, 2011 proposed incremental cost (which was a single value, not split in to size classifications) to give separate incremental costs. See 2012_DeltaWatts_MeasureCost for more information.
624 Based on agreement with DPS to use half way point between general retail measure (0.9) and "free CFL" assumption (0.5).

| Component | Cost | Residential Life[625] | Commercial Life |
|---|---|---|---|
| Lamp<=15W | $2.71 | 1.44 | 0.36 |
| Lamp>15W | $4.29 | 1.44 | 0.36 |

[625] Based on standard assumption of 1000 hours lamp life for baseline bulb.

# Solid State (LED) Fixtures

Measure Number: IV-E-15-a (Efficient Products Program, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 84
Effective date: 1/1/2014
End date: TBD

**Referenced Documents:**
1) WasteHeatAdjustment.doc;
2) "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993
3) ENERGY_STAR_Certified_Light_Fixtures.xls
4) 2013 EISA Adjustment Calculations'
5) NMR, RLW Analytics "Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs"

**Description**
An ENERGY STAR qualifying LED Fixture is purchased in place of an incandescent fixture. This measure is broken in to three categories – Indoor Fixtures (including track lighting, wall-wash, sconces, ceiling and fan lights), Task and Under Cabinet Fixtures and Outdoor Fixtures (including flood light, hanging lights, security/path lights, outdoor sconces).

**Algorithms**
**Demand Savings**
$\Delta kW = ((Watts_{BASE} - Watts_{EE}) / 1000) \times ISR \times WHF_d$

**Energy Savings**
$\Delta kWh = ((Watts_{BASE} - Watts_{EE}) / 1000) \times HOURS \times ISR \times WHF_e$

Where:
$\Delta kW$ = gross customer connected load kW savings for the measure
$Watts_{BASE}$[626] = Baseline connected kW.

| Fixture Type | 2013 $Watts_{BASE}$ | 2014 $Watts_{BASE}$ |
|---|---|---|
| Indoor Fixture | 64.2 | 64.1 |
| Task/Under cabinet Fixture | 39.9 | 29.0 |
| Outdoor Fixture | 61.8 | 58.0 |

$Watts_{EE}$[627] = Energy efficient connected kW.

| Fixture Type | $Watts_{EE}$ |
|---|---|
| Indoor Fixture | 22.8 |
| Task/Under cabinet Fixture | 8.0 |
| Outdoor Fixture | 17.2 |

$\Delta kWh$ = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units rebated that actually get used[628]

[626] Baseline wattages are determined by finding the average lumen equivalent baseline bulb (as defined by EISA regulations) of LED fixtures available on the ENERGY STAR qualifying list as of 08/2013 (see ENERGY_STAR_Certified_Light_Fixtures.xls for more details).
[627] Efficient wattages are determined by finding the average wattage of fixtures available on the ENERGY STAR qualifying list as of 08/2013.

| Customer Type | ISR |
|---|---|
| Residential | 0.95 |
| Commercial | 0.9 |

$WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.082 (calculated as 1 + (0.47*0.67*.808) / 3.1))[629]. The cooling savings are only added to the summer peak savings.

$WHF_e$ = Waste heat factor for energy to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.033 (calculated as 1 + ((0.47*0.29*.75) / 2.5))[630].

HOURS = average hours of use per year

| Fixture Type | Average Annual Hours of Use | |
|---|---|---|
| | Residential | Commercial |
| Indoor Fixture | 1,241[631] | 2,800[632] |
| Task/ Under cabinet Fixture | 730[633] | |
| Outdoor Fixture | 1642.5[634] | |

Using the defaults above, the kW and kWh savings for each fixture type and customer class are provided below:

| Fixture Type | Residential | | | | Commercial | | | |
|---|---|---|---|---|---|---|---|---|
| | 2013 | | 2014 | | 2013 | | 2014 | |
| | ΔkW | ΔkWh | ΔkW | ΔkWh | ΔkW | ΔkWh | ΔkW | ΔkWh |
| Indoor Fixture | 0.039 | 48.8 | 0.039 | 48.7 | 0.040 | 107.7 | 0.040 | 107.5 |
| Task/ Under cabinet Fixture | 0.030 | 22.1 | 0.020 | 14.6 | 0.031 | 82.9 | 0.020 | 54.5 |
| Outdoor Fixture | 0.042 | 69.6 | 0.039 | 63.7 | 0.040 | 112.5 | 0.037 | 102.8 |

**Baseline Adjustment**

Federal legislation stemming from the Energy Independence and Security Act of 2007 requires all general-purpose light bulbs between 40 and 100W to be approximately 30% more energy efficient than current incandescent bulbs, in essence beginning the phase out of standard incandescent bulbs. From 2012, 100W incandescents could no longer be manufactured, 75W incandescent are restricted from 2013 followed by restrictions on 60W and 40W in 2014. The baseline for LED fixtures will therefore become bulbs

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628 ISR is consistent with the CFL fixture measures.

629 Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 33% average outside air; and 80.8% coincidence of cooling with the summer peak period. See WasteHeatAdjustment.doc for additional discussion.

630 Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 25% average outside air; and 29% of annual lighting energy contributes to cooling load. See "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993 and WasteHeatAdjustment.doc for additional discussion.

631 The hours of use for this measure are consistent with the ENERGY STAR Integrated Screw Based SSL Lamp TRM and are based on the assumption that these will be installed in the highest use locations due to their high cost. Therefore prior assumptions for CFLs, when that same assumption was true are used for these lamps. Residential hours of use are based on average daily hours of use of 3.4 from Xenergy, Process and Impact Evaluation of Joint Utilities Starlights Residential Lighting Program, prepared for Boston Edison, Commonwealth Electric, Eastern Utilities, and New England Power Service Company, July 23, 2000.

632 Based on agreement made during Savings Verification 2009.

633 Estimated at 2 hours per day.

634 2005 RLW memo following on from NMR, RLW Analytics "Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs"

(improved incandescent or halogen, and CFL in 2020) that meet the new standard. To account for these new standards, the savings for this measure will be reduced to account for the higher baselines. The appropriate adjustments as a percentage of the base year savings for each Standard and Decorative Screw and Pin-based LED range are provided below (see '2013 EISA Adjustment Calculations' for details on calculation):

| | | | Bulb Wattages Assumed in Calculation | | | Mid Measure Life Savings Adjustments | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **LED Wattage** | **2013** | **2014** | **2020** | **2013 Adjust-ment** | **After # of years** | **2014 Adjust-ment** | **After # of years** | **2015 Adjust-ment** | **After # of years** |
| **Residential** | **Indoor** | 22.8 | 64.2 | 64.1 | 36.7 | 33.7% | 7 | 33.7% | 6 | 33.7% | 5 |
| | **Task / Undercabinet** | 8.0 | 39.9 | 29.0 | 9.1 | 11.0% | 4 | 5.2% | 6 | 5.2% | 5 |
| | **Outdoor** | 17.2 | 61.8 | 58.0 | 28.6 | 28.0% | 6 | 27.9% | 6 | 27.9% | 5 |
| **Commercial** | **Indoor** | 22.8 | 64.2 | 64.1 | 36.7 | 33.7% | 7 | 33.7% | 6 | 33.7% | 5 |
| | **Task / Undercabinet** | 8.0 | 39.9 | 29.0 | 9.1 | 18.0% | 4 | 5.2% | 6 | 5.2% | 5 |
| | **Outdoor** | 17.2 | 61.8 | 58.0 | 28.6 | 37.0% | 5 | 27.9% | 6 | 27.9% | 5 |

**Heating Increased Usage**

$\Delta MMBTU_{WH}$ = $(\Delta kWh / WHF_e) \times 0.003413 \times (1 - OA) \times AR \times HF \times DFH / HEff$

Where:

$\Delta MMBTU_{WH}$ = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.

0.003413 = Conversion from kWh to MMBTU

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[635].

AR = Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of commercial buildings within 15 feet of exterior wall.

HF = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont[636]. Assumed to be 0.0 for residential lighting

DFH = Percent of lighting in heated spaces. For prescriptive lighting, assumed to be 95%

HEff = Average heating system efficiency. For prescriptive lighting, assumed to be 79% in existing buildings and 83 % in new Construction[637].

| Fixture Type | Commercial | |
|---|---|---|
| | **2013 $\Delta MMBTU_{WH}$** | **2014 $\Delta MMBTU_{WH}$** |
| Indoor Fixture | 0.09 | 0.09 |
| Task/ Under cabinet | 0.07 | 0.04 |

[635] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."
[636] From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993.
[637] See WasteHeatAdjustment.doc.

| | | |
|---|---|---|
| Fixture | | |
| Outdoor Fixture | n/a | n/a |

Oil heating is assumed typical for commercial.

**Baseline Efficiencies – New or Replacement**
The baseline condition is an incandescent fixture.

**High Efficiency**
High Efficiency is an ENERGY STAR qualified LED fixture.

**Loadshape**
Residential: Loadshape, #1 – Residential Indoor Lighting;
Commercial: Loadshape; #101: Commercial EP Lighting for demand and lighting energy savings and #15 (Commercial A/C) for cooling energy savings.

**Freeridership/Spillover Factors**

| Measure Category | | LED Fixture | |
|---|---|---|---|
| Measure Code | | LFHLEDIN, LFHLEDOU, LFHLEDTU | |
| Product Description | | LED Indoor Fixture, LED Outdoor Fixture, LED Task/Undercabinet Fixture | |
| Track Name | Track No. | Freerider | Spillover |
| Efficient Products | 6032EPEP | 0.95 | 1.05 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
Lifetime is a function of the average hours of use of the luminaire[638].

| Fixture Type | Rated Life (hours)[639] | Residential Life (years) | Commercial Life (years) |
|---|---|---|---|
| Indoor Fixture | 45,000 | 15 | 15 |
| Task/Under cabinet Fixture | 35,000 | 15 | 12.5 |
| Outdoor Fixture | 48,000 | 15 | 15 |

**Measure Cost**
The incremental cost for this measure is provided in the table below[640]:

| Fixture Type | Incremental Cost |
|---|---|
| Indoor Fixture | $75 |
| Task/Under cabinet Fixture | $25 |
| Outdoor Fixture | $75 |

[638] Lifetimes are capped at 15 years even when the rated life/hours of use are higher.
[639] Average rated lives are determined by finding the average of fixtures available on the ENERGY STAR qualifying list as of 08/2013.
[640] Based on the online pricing of the limited available products on the market as of 08/2013.

**O&M Cost Adjustments**
To account for the shift in baseline due to the Federal Legislation, the levelized baseline replacement cost over the lifetime of the LED is calculated (see '2013 EISA Adjustment Calculations'). The key assumptions used in this calculation are documented below:

| | Incandescent | EISA 2012-2014 Compliant | EISA 2020 Compliant |
|---|---|---|---|
| **Replacement Cost** | $0.5 | $1.50 | $2.50 |
| **Component Life (hours)** | 1000 | 1000 | 8000 (Residential)<br>10,000 (Commercial) |
| **Years** | Until 2014 | 2014 – 2019 | 2020 on |

The calculation results in the following assumptions of equivalent annual baseline replacement cost:

| | | Annual baseline O&M assumption | | |
|---|---|---|---|---|
| | | 2013 | 2014 | 2015 |
| **Residential** | **All** | $1.05 | $0.96 | $0.86 |
| **Commercial** | **Indoor** | $2.52 | $2.51 | $2.23 |
| | **Task / Under cabinet** | $2.85 | $2.83 | $2.48 |
| | **Outdoor** | $2.33 | $2.32 | $2.05 |

**Water Descriptions**
There are no water algorithms or default values for this measure.

### Ceiling Fan End Use
# Ceiling Fan with ENERGY STAR Light Fixture

Measure Number: IV-F-1-d (Efficient Products Program, Ceiling Fan End Use)

**Version Date & Revision History**
Draft date: Portfolio 76
Effective date: 1/1/12
End date: TBD

**Referenced Documents:**

1) ceilingfans.xls;
2) Calwell and Horwitz (2001). "Ceiling Fans: Fulfilling the Energy Efficiency Promise". *Home Energy*. Jan/Feb. c) Caldwell and Horowitz. Unpublished memo circulated through CEE.
3) Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)
4) 2012 EISA Adjustment Calculations.xls

**Description**
This measure described energy savings associated with the use of integrated or attachable ENERGY STAR lighting fixture to an interior residential ceiling fan. If equipped with a light kit, then either fitted with an ENERGY STAR rated fixture or included with ENERGY STAR bulbs equal to the number of light sockets, as well as have separate fan and light switching. Energy savings are claimed only for the kWh savings attributable to lighting.

**Algorithms**
**Demand Savings**
From lighting:
$\Delta$kW = (BaseWatts - EffWatts) /1000)

| Year | Algorithm | $\Delta$kW |
|---|---|---|
| 2012 | = ((4*58) - 60)/1000)) | 0.172 |
| 2013 | = ((4*55) - 60)/1000)) | 0.16 |
| 2014 | = ((4*48) - 60)/1000)) | 0.132 |

**Energy Savings**
From lighting:
$\Delta$kWh = (BaseWatts - EffWatts) /1000) * HOURS

| Year | Algorithm | $\Delta$kW |
|---|---|---|
| 2012 | = ((4*58) - 60)/1000)) * 694 | 119 |
| 2013 | = ((4*55) - 60)/1000)) * 694 | 111 |
| 2014 | = ((4*48) - 60)/1000)) * 694 | 91.6 |

Where:

$\Delta$kWh = gross customer annual kWh savings for the measure
$\Delta$kW = gross customer connected load kW savings for the measure
BaseWatts = Wattage of baseline bulbs
EffWatts = Wattage of efficient bulb
HOURS = Run hours of light fixture

**Baseline Efficiencies – New or Replacement**
The baseline condition for fans with light kits assumes four sockets fitted with 60 watt incandescent bulbs. Based on information from manufacturer data and the Horowitz/Calwell article in the Jan/Feb 2001 issue of

Home Energy magazine. Based on the NEEP Residential Lighting Survey, 2001 study, the impact of the EISA legislation makes the baseline 58W in 2012, 55W in 2013 and 48W in 2014.

**Baseline Adjustment**

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become EISA qualified incandescent or Halogen bulbs.

The appropriate adjustments are provided below (see 2012 EISA Adjustment Calculations.xls for details):

| Measure | Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|---|
| Ceiling Fan with ENERGY STAR light fixture | 2012 | 0.66 | 2 |
| | 2013 | 0.72 | 1 |
| | 2014 | 0.85 | 1 |

**High Efficiency**

Energy Star fans with light kits assumes 2-D or circline Energy Star lamp totaling 60 watts. Conditions are based on information from manufacturer data and the Horowitz/Calwell article in the Jan/Feb 2001 issue of Home Energy magazine.

**Operating Hours**

694 hours per year[641]

**Loadshape**

Residential: Loadshape, #1 - Residential Indoor Lighting

**Freeridership/Spillover Factors**

| Measure Category | | Lighting Hardwired Fixture | | | | | |
|---|---|---|---|---|---|---|---|
| **Measure Code** | | LFHCNFFX | | | | | |
| **Product Description** | | **Ceiling fan with compact fluorescent interior fixture** | | | | | |
| | | **2012** | | **2013** | | **2014** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** | **Freerider** | **Spillover** | **Freerider** | **Spillover** |
| Efficient Products | 6032EPEP | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |

**Persistence**

The persistence factor is assumed to be one.

**Lifetimes**

20 years, equivalent to the EVT estimate for lifetime of interior fluorescent fixture.
Note: a provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore the analysis period (i.e. the life of the savings) is reduced to the number of years remaining to 2020. So for installations in 2012, the measure life is 8 years, for 2013 7 years.

**Measure Cost**

The incremental cost for this measure is $50[642].

[641] Based on TAG 2011 agreement to use recommendation from NEEP Residential Lighting Survey, 2011
[642] Estimate based on Horowitz and Calwell (unpublished memo).

**Annual Operations and Maintenance Savings**

Because compact fluorescent lamps last much longer than incandescent bulbs, CFLs offer significant operation and maintenance (O&M) savings over the life of the fixture for avoided incandescent lamps and the labor to install them. The following assumptions are used to calculate the O&M savings:

Incandescent bulb cost: $0.50 per bulb
Life of incandescent bulb: 1000 hours
EISA qualified bulb cost: $1.50 per bulb
Life of EISA qualified bulb: 1000 hours
CFL lamp cost: $2.50 per lamp
Life of CFL lamp: 8,500 hours (RES)

The O&M calculation results in a levelized annual baseline replacement cost as presented below (see EISA Adjustment Calculations.xls for details)[643]:

| Measure | Year Installed | Annual baseline replacement cost | Annual efficient replacement cost |
|---|---|---|---|
| Ceiling Fan with ENERGY STAR light fixture | 2012 | $8.03 | $2.11 |
| | 2013 | $8.05 | $2.11 |
| | 2014 | $7.47 | $2.11 |

This adjustment will be recalculated for subsequent years

**Fossil Fuel Descriptions**

There are no fossil-fuel algorithms or default values for this measure.

**Water Descriptions**

There are no water algorithms or default values for this measure.

[643] Note: As described above, the measure life is reduced to the number of years remaining until 2020 when the EISA legislation makes the CFL the baseline. The O&M calculation takes the entire stream of replacements for both the baseline and efficient cases over the actual expected lifetime (20 years) and converts to a levelized annual cost over the reduced measure 'savings' lifetime.

**Electronic Technology End Use**

# Internal Power Supplies

Measure Number: IV-G-1-c (Efficient Products Program, Electronic Technology End Use)

**Version Date & Revision History**
Draft date: Portfolio 56
Effective date: 01/01/09
End date: TBD

**<u>Referenced Documents:</u>** *80+ and Energy Star Work Paper May07.pdf,* *<Internal Power Supply Load Profile.x*ls>, <Internal Power Supplies Saving Calc.xls>, <80 Plus Datacenter Savings.xls>.

**Description:**
Power supplies convert high voltage ac to low voltage dc for use by the computer. Although sized to provide a maximum of 200–400 watts of dc output, conventional power supplies often require up to 300–650 watts of maximum ac input converting the rest to heat. They typically waste 30%–45% of all the electricity that passes through them, or about 125–150 kWh annually. Advanced new power supply designs offer more than 80% efficiency across a wide range of load conditions and often need no cooling fan.

**Algorithms**

The following ΔkW and ΔkWh is per computer.

**Demand Savings**

**80 PLUS DESKTOP:**
ΔkW (Residential) Desktop = $(Watts_{BASE} - Watts_{EE})/1000$
ΔkW (Residential) Desktop = (116– 93)/1000 = 0.023

ΔkW (Commercial) Desktop = $(Watts_{BASE} - Watts_{EE})/1000$
ΔkW (Commercial) Desktop = (74– 58)/1000 = 0.016

**ENERGY STAR DESKTOP:**
Average Demand Savings over all on hours based on 80PLUS savings during all on hours and increased idle savings during idle hours[644].
ΔkW (Residential) Desktop = 0.0376

ΔkW (Commercial) Desktop = 0.0284

**DESKTOP DERIVED SERVER:**
ΔkW Server = $(Watts_{BASE} - Watts_{EE})/1000$
ΔkW Server = (172 – 140.0)/1000 = 0.032

**DATACENTER SERVER:[645]**
ΔkW Server = $(Watts_{BASE} - Watts_{EE})/1000$
ΔkW Server = (664 – 604)/1000 = 0.060

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[644] See <Internal Power Supplies Saving Calc.xls>. Idle hours are assumed to be 3,000 hours for residential applications and 4,000 hours for commercial applications.
[645] See <80 Plus Datacenter Savings.xls>. Assumes mid-range performance for business workload for middle grade (Silver) efficiency. This basis may be revised based on program data from 2009.

**Energy Savings**

$\Delta kWh = \Delta kW \times HOURS$

**80 PLUS DESKTOP:**

$\Delta kWh$ (Residential) $= (0.023 \times 3{,}506) = 80.6$

$\Delta kWh$ (Commercial) $= (0.016 \times 5{,}523) = 88.4$

**ENERGY STAR DESKTOP:**

$\Delta kWh$ (Residential) $= (0.0376 \times 3{,}506) = 131.9$

$\Delta kWh$ (Commercial) $= (0.0284 \times 5{,}523) = 156.8$

**DESKTOP DERIVED SERVER:**

$\Delta kWh$ (Commercial) $= (0.032 \times 8{,}760) = 280.3$

**DATACENTER SERVER:**

$\Delta kWh$ (Commercial) $= (0.060 \times 8{,}760) = 525.6$

Where:

- $\Delta kW$ = gross customer connected load kW savings for the measure
- $\Delta Watts$ = $Watts_{BASE} - Watts_{EE}$
- $Watts_{BASE}$ = Baseline connected Watts
- $Watts_{EE}$ = Energy efficient connected Watts
- $\Delta kWh$ = gross customer annual kWh savings for the measure
- HOURS = average hours of use per year

**Baseline Efficiencies – New or Replacement**

Baseline is Intel 2004 required efficiency levels for internal power supplies.

**High Efficiency**

Efficiency is the 80 Plus internal power supply (converting AC power to DC power at 80% efficiency or greater, and a power factor correction of 0.9 or higher), or the ENERGY STAR Tier 1 Version 4.0 specifications (as 80 PLUS with additional idle state power requirements – see reference table).

**Operating Hours**[646]

Residential: 3,506 hours / year
Commercial: 5,523 hours / year
Server: 8,760 hours/year

**Loadshape**[647]

Desktop and Datacenter Server: Load Shape #25: Flat (8,760 hours)
Internal Power Supply, Commercial Desktop: Load Shape #74
Internal Power Supply, Residential Desktop: Load Shape #75

**Freeridership/Spillover Factors**

| | |
|---|---|
| Measure Category | Electronic Technology |
| Measure Code | EQPCMPTR |

[646] From *80 PLUS and ENERGY STAR Program Work Paper,*
[647] See < *Internal Power Supply Load Profile.x*ls>

| Product Description | | Internal Power Supplies | |
|---|---|---|---|
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Prescriptive | 6013FRMP | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | 1 | 1.1 |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| Customer Credit | 6015 CC | n/a | n/a |
| EDirect | 6021 DIRI | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Measure Life**
Measure life is based on an estimated PC life of 4 years.
Measure life is based on an estimated server life of 4 years.

**Measure Cost**
The incremental cost for the 80 Plus desktop PC power supply is $5.
The incremental cost for the ENERGY STAR desktop PC power supply is $8.
The incremental cost for the efficient desktop-derived server power supply is $15.
The incremental cost for the efficient datacenter server power supply is $70.[648]

**Incentive Level**
The incentive level for the 80 Plus desktop PC power supply is $5.
The incentive level for the ENERGY STAR desktop PC power supply is $8.
The incentive level for the efficient desktop-derived server power supply is $10.
The incentive level for the efficient datacenter server power supply is $70.

**O&M Cost Adjustments**
$0

**Fossil Fuel Descriptions**
n/a

**Water Descriptions**
n/a

[648] See <80 Plus Datacenter Savings.xls>. This cost is based upon redundant power supplies for the mid-range Silver performance assumed for savings calculations.

**Reference Table**

**ENERGY STAR Tier 1 Version 4.0 Idle State Power Requirements**

| Category | Tier 1 Requirement |
|---|---|
| **Standby (Off Mode)** | **≤ 2.0 W** |
| **Sleep Mode** | **≤ 4.0 W** |
| **Idle State** | |
| **Category A** (single-core, single processor desktop with < 1GB memory) | **≤ 50.0 W** |
| **Category B** (multiple-core or multiple processor desktop with > 1GB memory, < 128MB dedicated video memory) | **≤ 65.0 W** |
| **(Category C not included in EVT program)** | |

# Ultra Efficient LCD Monitors

Measure Number: IV-G-2-a (Efficient Products Program, Electronic Technology End Use)

**Version Date & Revision History**
Draft date: Portfolio 55
Effective date: 1/01/09
End date: TBD

**<u>Referenced Documents:</u>** *Submission to the California Energy Commission by PGE, Docket 07-AAER-3; Work Paper High Efficiency LCD Computer Monitor Program For the Mass Market Channel; Energy Star Program Requirements for Computer Monitors (Version 4.1); Internal Power Supply Load Profile.x*ls

**Description:**
With rapid advancements in LCD (Liquid Crystal Display) technology, LCD monitors are quickly replacing older CRT technologies in both residential and commercial applications. This program will provide an incentive with the purchase of a LCD monitor that meets or exceeds the Energy Star Tier 2 specification by 25% in place of one of a less efficient monitor available in the market. Initially, this will be an upstream incentive directed towards manufacturer business to business transactions, but may move towards a mid-stream approach in the future to influence retailers to stock, promote, and sell higher efficiency monitors.

**Algorithms**
The following ΔkW and ΔkWh are per monitor.

**Demand Savings**
Demand savings are a weighted representation of monitors in historical Energy Star monitor lists (2005 to 2008a) and from 2006 Energy Star market share. Additionally, the savings are based on active mode values for both the baseline and energy efficient monitors.[649]

$$\Delta kW\ \text{LCD Monitor} = (Watts_{BASE} - Watts_{EE}) / 1000 = (40.2 - 25.9)/1000 = 0.0143\ kW_{Active}$$

**Energy Savings**
Average Energy Savings over all hours based on efficiency savings during active, standby and idle operational modes.[650]

$$\Delta kWh_{Residential} = \Delta kWh_{Active} + \Delta kWh_{Sleep} + \Delta kWh_{Off} = 26.7 + 0.6 + 2.8 = 30.0\ kWh$$

$$\Delta kWh_{Commercial} = \Delta kWh_{Active} + \Delta kWh_{Sleep} + \Delta kWh_{Off} = 46.9 + 2.8 + 0.6 = 50.2\ kWh$$

Where:

ΔkW = gross customer connected load kW savings for the measure

$Watts_{BASE}$ = Baseline connected Watts as a weighted average of non-Energy Star and Energy Star (Below the + 25% threshold) LCD monitors

[649] Submission to the California Energy Commission by PGE, *Docket 07-AAER-3* pp. 17,18. (http://www.energy.ca.gov/appliances/2008rulemaking/documents/2008-02-01_documents/templates/PG&E_Computer_Monitors_and_other_Video_Displays_Template.pdf)

[650] Ibid p.18

| | |
|---|---|
| $Watts_{EE}$ | = Connected watts of high efficiency LCD monitors exceeding Energy Star Tier 2 by 25% |
| $\Delta kWh$ | = gross customer annual kWh savings for the measure |
| $\Delta kWh_{Active}$ | = Average savings over baseline for the high efficiency LCD monitor in its active state |
| $\Delta kWh_{Sleep}$ | = Average savings over baseline for the high efficiency LCD monitor in its sleep state |
| $\Delta kWh_{Off}$ | = Average savings over baseline for the high efficiency LCD monitor in its off (Standby) state |
| HOURS | = average hours of use per year |

**Baseline Efficiencies – New or Replacement**

Baseline is a weighted average based upon non-Energy Star LCD and Energy Star forecasted shipment data for 2007-2008.

**High Efficiency**

High efficiency is an LCD Monitor exceeding the Energy Star Tier 2 requirements by 25%.[651]

**Operating Hours**

Operating hours vary according to usage patterns for both residential and commercial LCD monitors. [652]

$\text{Annual Hours}_{Active - Res}$ = 1865 Hrs

$\text{Annual Hours}_{Active - Com}$ = 3278 Hrs

**Loadshape[653]**

Internal Power Supply, Commercial Desktop: Load Shape #74

Internal Power Supply, Residential Desktop: Load Shape #75

**Freeridership/Spillover Factors**

| Measure Category | | Electronic Technology | |
|---|---|---|---|
| Measure Code | | EQPCMPTR | |
| Product Description | | Ultra Efficient LCD Monitors | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Prescriptive | 6013FRMP | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | 0.7[654] | 1 |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |

[651] *ENERGY STAR Program Requirements for Computer Monitors (Version 4.1)*
[652] *CEC Docket 07-AAER-3*, op. cit., p. 7
[653] Assumed load profile from 80 Plus computer program < *Internal Power Supply Load Profile*.xls>
[654] *Work Paper: High Efficiency LCD Computer Monitor Program For the Mass Market Channel, p. 3*

| | | | |
|---|---|---|---|
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| Customer Credit | 6015 CC | n/a | n/a |
| EDirect | 6021 DIRI | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Measure Life**
Measure life is based on an estimated monitor life of 4 years.

**Measure Cost**
The incremental cost for the Ultra Efficient LCD Monitor is $1.80[655].

**Incentive Level**
The incentive level for the Ultra Efficient LCD Monitor is $6.

**O&M Cost Adjustments**
$0

**Fossil Fuel Descriptions**
n/a

**Water Descriptions**
n/a

**Reference Table**

**Ultra Efficient LCD Monitor Power Requirements[656]**

| Category | ES Tier 2 + 25% Requirement |
|---|---|
| **Standby (Off Mode)** | **≤ 1.0 W** |
| **Sleep Mode** | **≤ 2.0 W** |
| **Active State** | |
| **< 1 Megapixel** | **≤ 17.0 W** |
| **> 1 Megapixel** | **≤ 21W * # of Megapixels** |

[655] *Work Paper*, op. cit., p. 3. Weighted average incremental cost.
[656] *Energy Star*, op. cit.,

# Efficient Televisions

Measure Number: IV-G-3-b (Efficient Products Program, Electronic Technology End Use)

**Version Date & Revision History**
Draft date: Portfolio 82
Effective date: 4/1/2013
End date: TBD

**Referenced Documents:**

1. Savings Calculations for ES6_0_CEE_Electronics_Center_August_Monthly_Report.xls;
2. Efficient Televisions Measure Assumptions 01042013.xls
3. ENERGY STAR Program Requirements Product Specification for Televisions: Eligibility Criteria Version 6_0.pdf
4. ENERGY STAR Televisions Final Most Efficient 2013 Recognition Criteria.pdf

**Description:**
This program is designed to provide a midstream incentive to retailers to stock, promote, and sell televisions which meet or exceed ENERGY STAR 6.0, 20% higher than ENERGY STAR 6.0 and the 2013 ENERGY STAR Most Efficient specification.

**Algorithms**

The following ΔkW and ΔkWh is per television.

**Demand Savings**[657]

$\Delta kW = (Watts_{BASE} - Watts_{EE}) / 1000$
$\Delta kW_{ES}$ (10-35'') $= (47.5 – 28.1) / 1000 = 0.0194$
$\Delta kW_{ES}$ (36-50'') $= (85.3 – 50.5) / 1000 = 0.0348$
$\Delta kW_{ES}$ (>50'') $= (98.7 – 67.3) / 1000 = 0.0314$

$\Delta kW_{ES + 20\%}$ (10-35'') $= (47.5 – 28.2) / 1000 = 0.0192$
$\Delta kW_{ES + 20\%}$ (36-50'') $= (85.3 – 47.2) / 1000 = 0.0381$
$\Delta kW_{ES + 20\%}$ (>50'') $= (98.7 – 62.9) / 1000 = 0.0358$

$\Delta kW_{ME2013}$ (10-35'') $= (47.5 – 27.9) / 1000 = 0.0195$
$\Delta kW_{ME2013}$ (36-50'') $= (85.3 – 41.4) / 1000 = 0.0439$
$\Delta kW_{ME2013}$ (>50'') $= (98.7 – 55.3) / 1000 = 0.0434$

**Energy Savings** [658,659]

$\Delta kWh = \Delta kW \times HOURS_{Active}$

$\Delta kWh_{ES}$ (10-35'') $= (0.0194 \times 2009) = 38.9$ kWh
$\Delta kWh_{ES}$ (36-50'') $= (0.0348 \times 2009) = 69.9$ kWh
$\Delta kWh_{ES}$ (>50'') $= (0.0314 \times 2009) = 63.0$ kWh

$\Delta kWh_{ES + 20\%}$ (10-35'') $= (0.0192 \times 2009) = 38.6$ kWh
$\Delta kWh_{ES + 20\%}$ (36-50'') $= (0.0381 \times 2009) = 76.5$ kWh
$\Delta kWh_{ES + 20\%}$ (>50'') $= (0.0358 \times 2009) = 71.9$ kWh

[657] Savings Calculations for ES 6_0_CEE_Electronics_Center_August_Monthly_Report.xls
[658] Savings Calculations for ES 6_0_CEE_Electronics_Center_August_Monthly_Report.xls
[659] Standby energy savings not included due to high penetration of televisions in the market qualified under previous ENERGY STAR specifications requiring < 1 Watt in standby mode.

$\Delta kWh_{ME2013}$ (10-35'') = $(0.0195 \times 2009) = 39.2$ kWh
$\Delta kWh_{ME2013}$ (36-50'') = $(0.0439 \times 2009) = 88.2$ kWh
$\Delta kWh_{ME2013}$ (>50'') = $(0.0434 \times 2009) = 87.0$ kWh

Where:

$\Delta kW$ = gross customer connected load kW savings (active) for the measure
$\Delta Watts$ = $Watts_{BASE} - Watts_{EE}$
$Watts_{BASE}$ = Baseline connected Watts (active)
$Watts_{EE}$ = Energy efficient connected Watts (active)
$\Delta kWh$ = gross customer annual kWh savings in Active Mode
$HOURS_{Active}$ = average hours of use per year in Active Mode

**Baseline Efficiency**[660]
Baseline is the August 2012 weighted average for all television technologies below ENERGY STAR 6.0 specification based on the CEE Consumer Electronics Program Center – Monthly Television Data Report provided by NPD.

**High Efficiency**[661]
The High Efficiency Television is based on a weighted average for all products meeting ENERGY STAR 6.0 specification, 20% higher than ENERGY STAR 6.0 and the 2013 ENERGY STAR Most Efficient specification. The market for televisions is evolving fast, and Efficiency Vermont will revisit its program requirements annually as new efficient specifications and technologies emerge.

**Operating Hours**[662]
Active Mode: 2,009 hours / year

**Loadshape**[663]
Loadshape #94, Residential Efficient Televisions
Television: Custom Load Shape based on 5 hrs/day in active mode and 19 hours in standby mode.

| Measure Category | | Electronic Technology | |
|---|---|---|---|
| Measure Code | | EQPTLVSN | |
| Product Description | | Efficient Television | |
| Track Name | Track No. | Freerider | Spillover |
| Efficient Products | 6032EPEP | 0.9 | 1.1 |

The August 2012 CEE Monthly Report on Televisions shows a 29% market penetration of ENERGY STAR 6.0 televisions, 20% for ENERGY STAR 6.0 + 20% and 9% products in the market for Most Efficient 2013. This market penetration reflects the ongoing impact of efficiency program midstream promotions on retailer promotion and future buying patterns for high efficiency televisions.

**Persistence**
The persistence factor is assumed to be one.

660 Savings Calculations for ES 6_0_CEE_Electronics_Center_August_Monthly_Report.xls
661 Savings Calculations for ES 6_0_CEE_Electronics_Center_August_Monthly_Report.xls
US EPA, 'ENERGY STAR Program Requirements Product Specification for Televisions: Eligibility Criteria Version 6_0'
US EPA, 'ENERGY STAR Televisions Final Most Efficient 2013 Recognition Criteria.pdf'
662 Television Usage Analysis: Energy Efficiency Program For Consumer Products.pdf , March 2012
663 'Efficient Televisions Measure Assumptions 01042013.xls

**Lifetimes**[664]
Measure life is 6 years.

An LCD may have a life of up to 60,000 hours which is over 30 years at the assumed viewing rates. However, the replacement cycle on new televisions is about 6 years. Plasma televisions do not have as long a lifetime as LCDs, but do have a similar replacement cycle.

**Measure Cost**[665]
$0

Based on anecdotal information provided by manufacturers during development of the V3.0 TV specification, qualified TVs won't have any differential in price when compared to non-qualified TVs due to efficiency improvements alone. Rather, price differentials will occur due to additional features/functionality that as a side-benefit, may lead to efficiency improvements, e.g., LED backlighting, etc. Price differentials will also occur between technologies, e.g., a similarly sized LCD will likely cost more than a plasma, irrespective of which model is ENERGY STAR qualified. However, models that utilize the same screen technology and incorporate similar features should not differ in price if one is ENERGY STAR qualified and the other is non-qualified.

**O&M Cost Adjustments**
$0

**Fossil Fuel Descriptions**
n/a

**Water Descriptions**
n/a

[664] Appliance Magazine, 2006, 29th Annual Portrait of the US Appliance Industry.
[665] Mehernaz Polad, ICF International. Email from Robin Clark (ICF International) on April 10, 2008. This incremental cost correspondence was verified by Ecova on a conference call on 9/25/2012.

# Controlled Power Strip

Measure Number: IV-G-4-a (Efficient Products, Electronic Technology End Use)

**Version Date & Revision History**
Draft: Portfolio # 56
Effective date: 7/1/2009
End date: TBD

**Referenced Documents:**
1. ECOS Consulting, Preliminary Findings from Emerging Technology Scoping Study on Smart Plug Strips
2. BC Hydro report: Smart Strip electrical savings and usability, October 2008;
3. Loadshape_smart_revB.xls

**Description**
Controlled Power Strips (Smart Strips) are multi-plug power strips with the ability to automatically disconnect specific loads that are plugged into it depending upon the power draw of a control load, also plugged into the strip. Power is disconnected from the switched (controlled) outlets when the control load power draw is reduced below a certain adjustable threshold, thus turning off the appliances plugged into the switched outlets. By disconnecting, the standby load of the controlled devices, the overall load of a centralized group of equipment (ie. Entertainment centers and home office) can be reduced. Unswitched (uncontrolled) outlets are also provided that are not affected by the control device and so are always providing power to any device plugged into it.

**Note:** EVT and the VT DPS are reviewing more recent savings protocols from similar programs in other jurisdictions and are not in agreement on the savings assumptions for this measure.

**Algorithms**

**Demand Savings**
$\Delta$kW (Residential entertainment center) = ($\Delta$kWh /Hours)
= (79/6,935) = 0.011 kW

$\Delta$kW (Residential office) = ($\Delta$kWh /Hours)
= (38.4/5254) = 0.007 kW

**Energy Savings[666],[667]**
$\Delta$kWh = $\Delta$kW × HOURS
$\Delta$kWh (Residential entertainment center) = 79 kWh
$\Delta$kWh (Residential office) = 38.4 kWh

Where:
$\Delta$kW = gross customer connected load kW savings for the measure (kW)
$\Delta$kWh = gross customer annual kWh savings for the measure (kWh)
$Watts_{BASE}$ = Baseline connected Watts
$Watts_{EE}$ = Energy efficient connected Watts
HOURS = average hours of use per year in efficient (controlled off) mode

[666] Customer input on coupons will provide a basis for end use type.
[667] Savings estimates for residential applications were obtained from *Preliminary Findings from Emerging Technology Scoping Study on Smart Plug Strips*.

**Baseline Efficiency**
Baseline assumes a mix of typical home office equipment (computer and peripherals), or residential entertainment center equipment (TV, DVD player, set top box, etc), each with uncontrolled standby load.

**High Efficiency**
The efficient condition assumes peripherals are plugged into controlled Smart Strip outlets yielding a reduction in standby load. No savings are associated with the control load, or loads plugged into the uncontrolled outlets.

**Operating Hours**[668, 669]
Operating hours are defined as those hours during which the controlled standby loads are turned off by the Smart Strip.
Residential Entertainment Center: 6935 hours
Residential Office: 5254 hours

**Loadshapes**[670]
Loadshape # 96 : Standby Losses - Entertainment Center
Loadshape # 97 : Standby Losses - Home Office

**Freeridership/Spillover Factors**

| Measure Category | | Electronic Technology | |
|---|---|---|---|
| Measure Code | | EQPPWREC, EQPPWRHO, | |
| Product Description | | Controlled Power Strip | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| Pres Equip Rpl | 6013PRES | 1.0 | 1.0 |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6012MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | 1.0 | 1.0 |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |

**Persistence**
The persistence factor is assumed to be 1.

[668] Computer off hours are consistent with assumptions made in the Internal Power Supply measure characterization for desktop computers, using 80 PLUS and ENERGY STAR Program Work Paper. Distribution of hours are an EVT estimate based on assumptions about percentage of units on through a weekday and weekend (see loadshape_smart.xls).
[669] Typical on hours for a television is 5hrs per day, therefore off hours are (8760-(5*365) = 6935hours. Source: US EPA , 'FinalV3.0_TV Program Requirements.pdf'
[670] See Loadshape_smart_revB.xls

**Lifetimes**
The expected lifetime of the measure is 4 years[671].

**Measure Cost**
The installation cost of the measure is $15[672].

**Incentive Level**
The proposed Efficiency Vermont incentive amount is $5

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

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[671] BC Hydro report: Smart Strip electrical savings and usability, October 2008 (unit can only take one surge, then needs to be replaced)

[672] Incremental cost over standard power strip with surge protection based on *Preliminary Findings from Emerging Technology Scoping Study on Smart Plug Strips* with average market price of $35 for controlled power strip and $20 for baseline plug strip with surge protection

## Motors End Use
# Efficient Pool Pumps

Measure Number: IV-H-2-b (Efficient Products Program, Motors End Use)

**Version Date & Revision History**

| | |
|---|---|
| Draft date: | Portfolio 82 |
| Effective date: | 1/1/2013 |
| End date: | TBD |

**Referenced Documents:**

1. CEE Efficient Residential Swimming Pool Initiative; http://www.ceeforum.org/system/files/private/4114/cee_res_swimmingpoolinitiative_07dec2012_pdf_12958.pdf

2. CEE Draft Pool Pump Energy Savings Calculator; http://www.ceeforum.org/content/cee-draft-pool-pump-energy-savings-calculator

**Description**

A residential pool with a single speed pool pump motor can be replaced or retrofitted with a more efficient ENERGY STAR two-speed or variable speed model of equivalent or lesser horsepower. Measure assumes that both the baseline and the efficient motor have a timer.

**Algorithms**

**Energy Savings**[673]

$\Delta kWh_{TwoSpeed}$ = ((Hrs/Day$_{Base}$ * GPM$_{Base}$ * 60)/EF$_{Base}$)) – (((Hrs/Day$_{TwoSpeedHigh}$* GPM$_{TwoSpeedHigh}$ * 60)/EF$_{TwoSpeedHigh}$)) + ((Hrs/Day$_{TwoSpeedLow}$* GPM$_{TwoSpeedLow}$ * 60)/EF$_{TwoSpeedLow}$))) / 1000 * Days

$\Delta kWh_{VariableSpeed}$ = ((Hrs/Day$_{Base}$ * GPM$_{Base}$ * 60)/EF$_{Base}$)) – (((Hrs/Day$_{VarSpeedHigh}$* GPM$_{VarSpeedHigh}$ * 60)/EF$_{VarSpeedHigh}$)) + ((Hrs/Day$_{VarSpeedLow}$* GPM$_{VarSpeedLow}$ * 60)/EF$_{VarSpeedLow}$)) + ((Hrs/Day$_{VarSpeedLower}$* GPM$_{VarSpeedLower}$ * 60)/EF$_{VarSpeedLower}$))) / 1000 * Days

Where:

$\Delta kWh_{TwoSpeed}$ = gross customer annual kWh savings for the two speed measure
$\Delta kWh_{VariableSpeed}$ = gross customer annual kWh savings for the variable speed measure
Hrs/Day$_{Base}$ = Run hours of single speed pump
= 12
GPM$_{Base}$ = Gallons per minute flow of single speed pump
= 62[674]
EF$_{Base}$ = Energy Factor of baseline single speed pump (gal/Wh)
= 2.0
Hrs/Day$_{TwoSpeedHigh}$ = Run hours of two speed pump at high speed
= 2
GPM$_{TwoSpeedHigh}$ = Gallons per minute flow of two speed pump at high speed
= 62[675]
EF$_{TwoSpeedHigh}$ = Energy Factor of two speed pump at High Speed (gal/Wh)
= 2.0

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673 The methodology and all assumptions are taken from the CEE Pool Pump Energy Savings Calculator unless otherwise noted; http://www.ceeforum.org/content/cee-draft-pool-pump-energy-savings-calculator. See “cee_resapp_poolpumpsavingscalc_07dec2012_EVT.xlsx” for complete calculation.
674 Average GPM from single speed 1HP motors in CEC database.
675 Average GPM from 1HP two speed motors at high speed in CEC database.

$Hrs/Day_{TwoSpeedLow}$ = Run hours of two speed pump at low speed
= 8

$GPM_{TwoSpeedLow}$ = Gallons per minute flow of two speed pump at low speed
= 33.2[676]

$EF_{TwoSpeedLow}$ = Energy Factor of two speed pump at Low Speed (gal/Wh)
= 5.0

$Hrs/Day_{VarSpeedHigh}$ = Run hours of variable speed pump at high speed
= 1

$GPM_{VarSpeedHigh}$ = Gallons per minute flow of variable speed pump at high speed
= 50[677]

$EF_{VarSpeedHigh}$ = Energy Factor of variable speed pump at High Speed (gal/Wh)
= 3.0

$Hrs/Day_{VarSpeedLow}$ = Run hours of variable speed pump at low speed
= 1

$GPM_{VarSpeedLow}$ = Gallons per minute flow of variable speed pump at low speed
= 33[678]

$EF_{VariableSpeedLow}$ = Energy Factor of two speed pump at Low Speed (gal/Wh)
= 5.0

$Hrs/Day_{VarSpeedLower}$ = Run hours of variable speed pump at lower speed
= 12

$GPM_{VarSpeedLower}$ = Gallons per minute flow of variable speed pump at lower speed
= 20[679]

$EF_{VariableSpeedLower}$ = Energy Factor of two speed pump at Lower Speed (gal/Wh)
= 12.0

Days = Number of days swimming pool is operational
=107[680]

$\Delta kWh_{TwoSpeed}$ = ((12 * 62 * 60)/ 2.0) – (((2 * 62 * 60)/2.0 + ((8 * 33.2 * 60)/5.0))) / 1000 * 107
= 1649 kWh

$kWh_{VariableSpeed}$ = ((12 * 62 * 60)/ 2.0) – (((1 * 50 * 60)/3.0) + ((1 * 33 * 60)/5.0)) + ((12 * 20 * 60)/12.0))) / 1,000 * 107
= 2111 kWh

**Demand Savings**[681]

$\Delta kW_{TwoSpeed}$ = $kWh/day_{Base}$ / $Hrs/day_{Base}$ – $kWh/day_{TwoSpeed}$ / $Hrs/day_{TwoSpeed}$

$\Delta kW_{VariableSpeed}$ = $kWh/day_{Base}$ / $Hrs/day_{Base}$ – $kWh/day_{VariableSpeed}$ / $Hrs/day_{VariableSpeed}$

Where:

$\Delta kW_{TwoSpeed}$ = gross customer annual kW savings for the two speed measure

$\Delta kW_{VariableSpeed}$ = gross customer annual kW savings for the variable speed measure

$kWh/day_{Base}$ = Daily energy consumption of baseline pump(calculated using algorithm and variables above)
= 22.3 kWh

$Hrs/day_{Base}$ = 12 hours

$kWh/day_{TwoSpeed}$ = Daily energy consumption of two speed pump(calculated using algorithm and variables above)

676 Average GPM from 1HP two speed motors at low speed in CEC database.
677 Average GPM from 1HP variable speed motors at high speed in CEC database.
678 Average GPM from 1HP variable speed motors at low speed in CEC database.
679 Average GPM from 1HP variable speed motors at lower speed in CEC database.
680 Assumes pool operational between June 1st and September 15th.
681 The methodology and all assumptions are taken from the CEE Pool Pump Energy Savings Calculator unless otherwise noted; http://www.ceeforum.org/content/cee-draft-pool-pump-energy-savings-calculator. See “cee_resapp_poolpumpsavingscalc_07dec2012_EVT.xlsx” for complete calculation.

$= 6.9$ kWh
$Hrs/day_{TwoSpeed}$ = 10 hours
$kWh/day_{VariableSpeed}$ = Daily energy consumption of variable speed pump(calculated using algorithm and variables above)
$= 2.6$ kWh
$Hrs/day_{VariableSpeed}$ = 14 hours

$\Delta kW_{TwoSpeed} = 22.3/12 – 6.9/10$
$= 1.17kW$

$\Delta kW_{VariableSpeed} = 22.3/12 – 2.6/12$
$= 1.64$ kW

**Baseline Efficiencies – New or Replacement**
Baseline efficiency is a single speed pool pump with a timer.

**High Efficiency**
The high efficiency level is an ENERGY STAR[682] two-speed or variable speed pool pump with a timer.

**Loadshape**
Loadshape #100, Residential Efficient Pool Pump

**Freeridership/Spillover Factors**

| Measure Category | | Motors | |
|---|---|---|---|
| Measure Code | | MTRPLPMP | |
| Product Description | | Efficient Pool Pump | |
| Track Name | Track No. | Freerider | Spillover |
| Efficient Products | 6032EPEP | 1.0 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
The life of the equipment is 10 years[683].

**Measure Cost**
The incremental cost for this measure is \$100 for two speed pool pumps and \$846 for variable speed pool pumps[684].

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

682 See http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=PP.
683 The CEE Efficient Residential Swimming Pool Initiative, p18, indicates that the average motor life for pools in use year round is 5-7 years. For pools in use for under a third of a year, you would expect the lifetime to be higher so 10 years is selected as an assumption.
684 CEE Efficient Residential Swimming Pool Initiative, p34; http://www.ceeforum.org/system/files/private/4114/cee_res_swimmingpoolinitiative_07dec2012_pdf_12958.pdf

## DHW End-Use

# ENERGY STAR Heat Pump Water Heater

**Measure Number:** IV-I-1-a (Efficient Products Program, DHW End-Use)

**Version Date & Revision History**

Draft date: 7/9/2014
Effective date: 1/1/2014
End date: TBD

**Referenced Documents**:

NMR Group, Inc. "Vermont Single-Family Existing Homes Onsite Report FINAL." 2013.
Steven Winter Associates. "Heat Pump Water Heaters Evaluation of Field Installed Performance." Norwalk, CT, 2012.
U.S. Department of Energy. "Residential Heating Products Final Rule Technical Support Document." 2010.
U.S. Environmental Protection Agency. n.d. http://www.epa.gov/burnwise/woodstoves.html (accessed March 7, 2014).

**Analysis Documents:**

1) HPWH_TRM_Analysis.xlsx

**Description**

This measure claims savings for the installation of an ENERGY STAR heat pump water heater (HPWH) in place of a baseline water heater in a residential application. The measure is characterized for both market opportunity and retrofit applications. Savings are presented dependent on the existing water heater fuel type and HPWH storage volume. HPWH efficiency has been reduced to account for differences in field performance versus rated efficiency due to ambient conditions, hot water demand, and other factors, and a heating penalty is assessed to account for the impact of the heat pump water heater on the home’s heating load.

Homes with existing natural gas water heaters are not eligible for savings under this measure.

**Baseline Efficiency**

The baseline condition is assumed to be a new water heater that uses the same fuel as the home’s existing water heater with efficiency equal to the average energy factor of water heaters in existing Vermont homes for the corresponding fuel type.

**High Efficiency**

To qualify for this measure the installed equipment must be an ENERGY STAR heat pump water heater.

**Algorithms**

**Energy Savings**

For cases where this measure is installed in a home with an existing electric resistance water heater or in a new construction project, electric savings account for the improvement in performance of a HPWH over a baseline electric resistance water heater. For homes with existing fossil fuel water heaters, the installation of a HPWH results in an electric penalty equal to the annual electricity use of the water heater to rerpresent the added electric load. In both caseas a penalty is taken to account for the heating load placed on a home’s heating system by the HPWH, apportioned based on the percentage of homes in Vermont with electric heat.

For prescriptive purposes, savings and penalties will be assigned using deemed values, outlined in **Table 4**.

$\Delta kWh = \Delta EF_{Elec} * Q_{DHW} * (1 - PF\_ElecHeat)$

Where:

$\Delta EF_{Elec}$ = $(1/EF_{ElecBASE} – 1/EF_{HPWH})$ for homes with existing electric water heaters and new homes
= $– 1/EF_{HPWH}$ for homes with existing fossil fuel fired water heaters

Where:

$EF_{ElecBASE}$ = Energy Factor (efficiency) of baseline electric water heater
= 0.91[685]

$EF_{HPWH}$ = Energy Factor of heat pump water heater – prescriptive value based on rated EF and a de-rating factor to account for periods where the HPWH uses its electric resistance element to heat water in response to lower space temperature or increased hot water demand
= Rated EF (prescriptive value from **Table 4**) * De-rating Factor

**Table 1 – De-rating Factors[686]**

| Tank Volume | De-rating Factor |
|---|---|
| < 60 gallons | 26% |
| $\geq$ 60 gallons | 10% |

$Q_{DHW}$ = Heat delivered to water in HPWH tank annually
= 2,618 kWh[687]

PF_ElecHeat = Heating penalty factor from conversion of electric heat in home to water heat
= WHHF * %HeatSource / COP * ExistDHWElec

Where:

WHHF = Portion of reduced waste heat that results in increased heating
= 0.558[688]

%Heat Source[689] = portion of homes with electric space heat
= 5%

$COP_{HEAT}$ = Coefficient of Performance of electric space heating system
= 1.5[690]

ExistDHWElec[691] = 1 if the home has an existing electric water heater
= –1 if the home has an existing fossil fuel fired water heater

**Demand Savings**

The reduction (or increase) in electric demand due to the installation of a HPWH is derived below based on prescriptive energy savings found in **Table 4**.

$\Delta kW = \Delta kWh / Hours$

Where:

Hours = Full load hours of water heater

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685 Average efficiency of electric water heaters from VT SF Existing Homes Onsite Report Table 6-9 (NMR Group, Inc. 2013)

686 Based on a 2012 field study conducted by Steven Winter Associates in Massachusetts and Rhode Island, which found field measured COP for HPWHs fell 26% below rated COP for 50 gallons units, 10% below rated COP for 60 gallon units, and 11% below rated COP for 80 gallon units (Steven Winter Associates 2012).

687 Average annual DHW heat input for Vermont homes, derived from metered data for homes on CVPS Rate 3: Off-Peak Water Heating rate. See $Q_{DHW}$ in HPWH_TRM_Analysis.xlsx

688 Based on bin analysis of annual heating hours for Burlington, VT using TMY3 data: 4885 / 8760 = 55.8%. See Heating Penalty in HPWH_TRM_Analysis.xlsx

689 Split of primary heating fuels from the VT SF Existing Homes Onsite Report Table 5-1 after removing homes with natural gas space heat (NMR Group, Inc. 2013).

690 The COP used here is an assumption based upon a 50/50 split between resistance COP 1.0 and average Heat Pump effective COP of 2.0.

691 This factor ensures proper accounting of the heating penalty dependent on the fuel type of the home's existing water heater.

= 2533[692]

**Operating Hours**
2533 full load hours per year[693]

**Loadshape**
Loadshape #8 Residential DHW Fuel Switch

**Table 2 – Freeridership/Spillover Factors**

| | | | |
|---|---|---|---|
| **Measure Category** | | **Water Heating** | |
| **Product Description** | | **Heat Pump Water Heater** | |
| **Measure Code** | | **HWEHWHTP** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** |
| Efficient Products | 6032EPEP | 1.0 | 1.1 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
The expected measure life is assumed to be 13 years[694]. For retrofit measures, it is assumed that the existing water heating equipment has five years of remaining life and would be replaced with baseline equipment with the associated installed cost at end of life. Analysis period is the same as the lifetime.

**Measure Cost**
For measures installed in a market opportunity situation, the measure cost is the incremental cost for the installation of a HPWH versus baseline equipment based on the existing water heater fuel type. For retrofit measures, the measure cost is the full cost for the installation of a HPWH.[695]

**Table 3 – Measure Costs**

| Installation | HPWH EF | Baseline EF | HPWH Installed Cost | Baseline Installed Cost | Incremental Cost |
|---|---|---|---|---|---|
| Existing electric DHW | < 2.35 | 0.91 | $1,575 | $602 | $973 |
| Existing electric DHW | $\geq$ 2.35 | 0.91 | $1,703 | $602 | $1,101 |
| Existing propane DHW | < 2.35 | 0.59 | $1,575 | $1,079 | $496 |
| Existing propane DHW | $\geq$ 2.35 | 0.59 | $1,703 | $1,079 | $624 |
| Existing fuel oil DHW | < 2.35 | 0.51 | $1,575 | $1,974 | $(399) |
| Existing fuel oil fired | $\geq$ 2.35 | 0.51 | $1,703 | $1,974 | $(271) |

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
For homes with existing fossil fuel water heaters, fuel switching results in fuel savings equal to the annual fuel use that would have resulted if a baseline fossil fuel fired water heater had been installed in the home. For upstream measures where fossil fuel type may be unknown, savings are apportioned based on the breakdown of water heating fuels in Vermont homes, excluding natural gas. A fossil fuel penalty is taken to account for the heating load placed

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[692] Full load hours assumption based on Efficiency Vermont analysis of Itron eShapes.
[693] Ibid.
[694] Residential Heating Products Final Rule Technical Support Document, Page 8-52, this is the accepted lifetime for standard efficiency electric and gas storage water heaters. Manufacturer warranty and ENERGY STAR criteria for 10-year warranties for heat pump water heaters support assuming baseline lifetime for this measure (U.S. Department of Energy 2010).
[695] Residential Heating Products Final Rule Technical Support Document pages 8-27 to 8-28 (U.S. Department of Energy 2010)

on a home's heating system by the HPWH. For prescriptive purposes, this increased heating usage is allocated by fuel type based on the breakdown of primary heating fuel types in Vermont homes, excluding natural gas.

Savings and penalties will be assigned using deemed values, outlined in **Table 4**.

$\Delta$MMBtu = (SF_FF_DHW – PF_FF_Heating)

Where:

SF_FF_DHW = Savings from fuel switching, accounts for replacement of baseline fossil fuel fired water heater by HPWH
= $1/EF_{FFBASE} * Q_{DHW} *$ ExistDHWFF * %DHWFuel

Where:

$EF_{FFBase}$ = Energy Factor (efficiency) of baseline fossil fuel water heater
= 0.62 for propane water heaters[696]
= 0.65 for fuel oil water heaters[697]
= 0.64 for fossil fuel water heaters with unknown fuel type[698]

$Q_{DHW}$ = Heat delivered to water in HPWH tank annually
= 8.93 MMBtu[699]

ExistDHWFF = 1 if the home has an existing fossil fuel fired water heater
= 0 if the home has an existing electric water heater

%DHWFuel[700] = 1 if the existing water heater fuel type is known, all savings attributed to that fuel type
=76% for fuel oil, if fuel type is unknown
=24% for propane, if fuel type is unknown

PF_FF_Heating = Heating penalty factor from conversion of noneletric heat in home to water heat
= $\Delta EF_{Elec} * Q_{DHW} *$ WHHF * %HeatSource / $\eta$Heat * ExistDHWElec[701]

Where:

%HeatSource[702] = 61% for fuel oil
= 17% for propane
= 17% for Wood/Other

$\eta$Heat[703] = 84.2% for fuel oil
= 87.4% for propane
= 65% for Wood/Other

**Water Descriptions**

N/A

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[696] Average efficiency of electric water heaters from VT SF Existing Homes Onsite Report Table 6-7 (NMR Group, Inc. 2013)
[697] Ibid.
[698] Weighted average efficiency of propane and fuel oil water heaters from VT SF Existing Homes Onsite Report Tables 6-2 and 6-7 (NMR Group, Inc. 2013), excludes natural gas water heaters
[699] Average annual DHW heat input for Vermont homes, derived from metered data for homes on CVPS Rate 3: Off-Peak Water Heating rate. See $Q_{DHW}$ in HPWH_TRM_Analysis.xlsx
[700] This factor apportions fuel savings for homes with unknown fuel types, a prescreening is conducted to exclude homes with existing natural gas water heaters.
[701] This factor ensures proper accounting of the heating penalty dependent on the fuel type of the home's existing water heater.
[702] Split of primary heating fuels from the VT SF Existing Homes Onsite Report Table 5-1 after removing homes with natural gas space heat. (NMR Group, Inc. 2013).
[703] Weighted efficiencies based on VT SF Existing Homes Onsite Report Table 5-8 and 5-9. (NMR Group, Inc. 2013). Efficiency for homes using wood or pellet stoves based on review of EPA-Certified wood stoves (U.S. Environmental Protection Agency n.d.)

**Prescriptive Savings**
For prescriptive purposes this measure has been binned based on HPWH energy factor and existing water heater fuel type as follows:

### Table 4 – Prescriptive Savings Values[704]

| Existing DHW Fuel | Electric | | | Fuel Oil | | | Propane | | | Unknown Fossil Fuel | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Storage Volume | < 60 gallons | | | | | | | | | | | |
| Rated EF | EF<2.35 | 2.35<EF<2.7 | 2.7<EF | EF<2.35 | 2.35<EF<2.7 | 2.7<EF | EF<2.35 | 2.35<EF<2.7 | 2.7<EF | EF<2.35 | 2.35<EF<2.7 | 2.7<EF |
| Average EF | 2.31 | 2.41 | 2.75 | 2.31 | 2.41 | 2.75 | 2.31 | 2.41 | 2.75 | 2.31 | 2.41 | 2.75 |
| ΔkWh | 1321 | 1384 | 1561 | -1559 | -1495 | -1311 | -1559 | -1495 | -1311 | -1559 | -1495 | -1311 |
| ΔkW | 0.52 | 0.55 | 0.62 | -0.62 | -0.59 | -0.52 | -0.62 | -0.59 | -0.52 | -0.62 | -0.59 | -0.52 |
| ΔMMBtu Fuel Oil | -1.86 | -1.94 | -2.19 | 12.30 | 12.39 | 12.63 | -2.11 | -2.02 | -1.77 | 8.33 | 8.42 | 8.67 |
| ΔMMBtu Propane | -0.50 | -0.52 | -0.59 | -0.57 | -0.54 | -0.48 | 13.18 | 13.20 | 13.27 | 2.73 | 2.76 | 2.82 |
| ΔMMBtu Wood | -0.67 | -0.70 | -0.79 | -0.76 | -0.73 | -0.64 | -0.76 | -0.73 | -0.64 | -0.76 | -0.73 | -0.64 |
| Measure life (yrs) | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 |
| Incremental cost ($) | 973 | 1101 | 1101 | 404 | 532 | 532 | -570 | -442 | -442 | -403 | -275 | -275 |
| Retrofit cost ($) | 1575 | 1703 | 1703 | 1575 | 1703 | 1703 | 1575 | 1703 | 1703 | 1575 | 1703 | 1703 |
| Retrofit remaining life (yrs) | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Retrofit Baseline Cost ($) | 602 | 602 | 602 | 1171 | 1171 | 1171 | 2145 | 2145 | 2145 | 1978 | 1978 | 1978 |
| Item Code | EPHPWH1 | EPHPWH2 | EPHPWH3 | EPHPWH4 | EPHPWH5 | EPHPWH6 | EPHPWH7 | EPHPWH8 | EPHPWH9 | EPHPWH10 | EPHPWH11 | EPHPWH12 |
| Retrofit Item Code | EPHPWH25 | EPHPWH26 | EPHPWH27 | EPHPWH28 | EPHPWH29 | EPHPWH30 | EPHPWH31 | EPHPWH32 | EPHPWH33 | EPHPWH34 | EPHPWH35 | EPHPWH36 |

[704] See HPWH_TRM_Analysis.xlsx for derivation of savings. Prescriptive EF for each bin based on average EF of ENERGY STAR certified water heaters for each EF range.

| Existing DHW Fuel | Electric | | | Fuel Oil | | | Propane | | | Unknown Fossil Fuel | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Storage Volume | $\geq$ 60 gallons | | | | | | | | | | | |
| Rated EF | EF<2.35 | 2.35<EF<2.7 | 2.7<EF | EF<2.35 | 2.35<EF<2.7 | 2.7<EF | EF<2.35 | 2.35<EF<2.7 | 2.7<EF | EF<2.35 | 2.35<EF<2.7 | 2.7<EF |
| Average EF | 2.31 | 2.41 | 2.75 | 2.31 | 2.41 | 2.75 | 2.31 | 2.41 | 2.75 | 2.31 | 2.41 | 2.75 |
| ΔkWh | 1589 | 1640 | 1786 | -1282 | -1229 | -1078 | -1282 | -1229 | -1078 | -1282 | -1229 | -1078 |
| ΔkW | 0.63 | 0.65 | 0.70 | -0.51 | -0.48 | -0.42 | -0.50 | -0.48 | -0.42 | -0.50 | -0.48 | -0.42 |
| ΔMMBtu Fuel Oil | -2.23 | -2.30 | -2.51 | 12.67 | 12.75 | 12.95 | -1.74 | -1.66 | -1.46 | 8.71 | 8.78 | 8.99 |
| ΔMMBtu Propane | -0.60 | -0.62 | -0.67 | -0.47 | -0.45 | -0.39 | 13.28 | 13.30 | 13.35 | 2.83 | 2.85 | 2.91 |
| ΔMMBtu Wood | -0.81 | -0.83 | -0.91 | -0.63 | -0.60 | -0.53 | -0.63 | -0.60 | -0.53 | -0.63 | -0.60 | -0.53 |
| Measure life (yrs) | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 |
| Incremental cost ($) | 973 | 1101 | 1101 | 404 | 532 | 532 | -570 | -442 | -442 | -403 | -275 | -275 |
| Retrofit cost ($) | 1575 | 1703 | 1703 | 1575 | 1703 | 1703 | 1575 | 1703 | 1703 | 1575 | 1703 | 1703 |
| Retrofit remaining life (yrs) | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Retrofit Baseline Cost ($) | 602 | 602 | 602 | 1171 | 1171 | 1171 | 2145 | 2145 | 2145 | 1978 | 1978 | 1978 |
| Market Opp. Item Code | EPHPWH13 | EPHPWH14 | EPHPWH15 | EPHPWH16 | EPHPWH17 | EPHPWH18 | EPHPWH19 | EPHPWH20 | EPHPWH21 | EPHPWH22 | EPHPWH23 | EPHPWH24 |
| Retrofit Item Code | EPHPWH37 | EPHPWH38 | EPHPWH39 | EPHPWH40 | EPHPWH41 | EPHPWH42 | EPHPWH43 | EPHPWH44 | EPHPWH45 | EPHPWH46 | EPHPWH47 | EPHPWH48 |

# Low Income Single-Family Program

## Hot Water End Use

# Tank Wrap

Measure Number: V-A-1-e (Low Income Single Family Program, Hot Water End Use)

**Version Date & Revision History**

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**Referenced Documents:**

1. Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM)
2. NREL, National Residential Efficiency Measures Database
3. Efficiency Vermont Program Documentation
4. DOE, “Residential Heating Products Final Rule Technical Support Document”

**Description**

Insulation “blanket” is wrapped around the outside of an existing electric hot water tank to reduce stand-by losses.

**Algorithms**

**Energy Savings**

For electric DHW systems only:

$$\Delta kWh = ((U_{base}A_{base} – U_{insul}A_{insul}) * \Delta T * Hours) / (3412 * \eta DHW)$$

Where:

$\Delta kWh$ = gross customer annual kWh savings for the measure
$U_{base}$ = Overall heat transfer coefficient prior to adding tank wrap (Btu/Hr-F-ft$^2$)
= 1/12 [705]
$U_{insul}$ = Overall heat transfer coefficient after addition of tank wrap (Btu/Hr-F-ft$^2$)
= 1/22 [706]
$A_{base}$ = Surface area of storage tank prior to adding tank wrap (square feet)
= 23.18 [707]
$A_{insul}$ = Surface area of storage tank after addition of tank wrap (square feet)
= 25.31 [708]
$\Delta T$ = Average temperature difference between tank water and outside air temperature (°F)
= 55°F [709]
Hours = Number of hours in a year (since savings are assumed to be constant over year).
= 8760
3412 = Conversion from BTU to kWh
$\eta DHW$ = Recovery efficiency of electric hot water heater
= 0.98 [710]

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[705] Conservative baseline assumption
[706] Efficiency Vermont program documentation specifies R-10 tank wrap
[707] Assumptions from PA TRM. Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation. Area includes tank sides and top to account for typical wrap coverage.
[708] Ibid.
[709] Assumes 120°F water in the hot water tank and average temperature of basement of 65°F.
[710] NREL, National Residential Efficiency Measures Database,

For the prescriptive assumption, 40 gallons is selected as an average tank[711], and the savings are derived from adding R-10 to an R-12 tank. The prescriptive savings are therefore:

$$\Delta kWh = ((23.18/12 – 25.31/22) * 55 * 8760) / (3412 * 0.98)$$

$$= 113 \text{ kWh}$$

**Demand Savings**

$$\Delta kW = \Delta kWh / 8766$$

Where:

| | |
|---|---|
| ΔkW | = gross customer connected load kW savings for the measure |
| ΔkWh | = kWh savings from tank wrap installation, calcualted below |
| 8760 | = Number of hours in a year (savings are from reduced standby loss and are therefore assumed to be constant over the year). |

For the prescriptive assumption, the assumed savings is:

$$\Delta kW = 113 / 8760$$

$$= 0.0128 \text{ kW}$$

**Baseline Efficiencies – New or Replacement**

The baseline condition is a hot water tank that is not already well insulated. Newer, rigid, foam insulated tanks are considered to be effectively insulated while older tanks with fiberglass insulation that gives to gentle pressure are not.

**High Efficiency**

High efficiency is a hot water tank with a tank wrap of R-10.

**Operating Hours**

8766, savings are from reduced standby loss and are therefore assumed to be constant over the year.

**Loadshape**

Loadshape #25, Flat (8760 hours)

**Freeridership/Spillover Factors**

| Measure Category | | Hot Water | |
|---|---|---|---|
| Measure Code | | HWEINSUL | |
| Product Description | | Insulate hot water tank | |
| Track Name | Track No. | Freerider | Spillover |
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |

**Persistence**

The persistence factor is assumed to be one.

**Lifetimes**

6 years (same as in DPS screening of Efficiency Utility Core programs).
Analysis period is the same as the lifetime.

**Incremental Cost**

$35 average retrofit cost[712]

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http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

[711] DOE, "Residential Heating Products Final Rule Technical Support Document," Table 3.2.13, http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch3.pdf

[712] Based on EVT online product review.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure

**Fossil Fuel Descriptions**
n/a

# Pipe Wrap

Measure Number: V-A-2-f (Low Income Single Family Program, Hot Water End Use)

**Version Date & Revision History**
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**Referenced Documents:**

1. Navigant Consulting Inc., April 2009; "Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets"
2. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007
3. DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com)
4. NREL, National Residential Efficiency Measures Database

**Description**
Insulation is added to both the hot and cold pipes from the hot water tank to the first elbow. This is the most cost effective section to insulate since the water pipes act as an extension of the hot water tank up to the first elbow which acts as a heat trap. Insulating this length therefore helps reduce standby losses.

**Algorithms**

**Energy Savings**

For electric DHW systems:

$$\Delta kWh = ((C_{exist} / R_{exist} - C_{new} / R_{new}) * L * \Delta T * 8{,}760) / \eta DHW / 3412$$

Where:

| | |
|---|---|
| $R_{exist}$ | = Pipe heat loss coefficient of uninsulated pipe (existing) [(hr-°F-ft)/Btu]<br>= 1.0[713] |
| $C_{exist}$ | = Circumference of pipe before insulation added (ft) (Diameter (in) * π/12): (0.5" pipe = 0.131ft, 0.75" pipe = 0.196ft)<br>Assuming ½" pipe<br>= 0.131 |
| $R_{new}$ | = Pipe heat loss coefficient of insulated pipe (new) [(hr-°F-ft)/Btu]<br>= Actual (1.0 + R value of insulation)<br>Assuming R-2.4 (3/8" foam) insulation is added |
| = 3.4$C_{new}$ | = Circumference of pipe after insulation added (ft) (Diameter (in) * π/12):<br>Assuming ½" pipe and 3/8" foam ((0.5 + 3/8 + 3/8) * π/12)<br>= 0.327 |
| L | =Length of pipe from water heating source covered by pipe wrap (ft)<br>Assuming 3 feet of both the hot and cold pipes<br>= 6 |
| C | = Circumference of pipe (ft) (Diameter (in) * π/12): (0.5" pipe = 0.131ft, 0.75" pipe = 0.196ft)<br>Assuming ½" pipe<br>= 0.131 |
| $\Delta T$ | = Average temperature difference between supplied water and outside air temperature (°F)<br>= 55°F [714] |

[713] Navigant Consulting Inc., April 2009; "Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets", p77.

| | |
|---|---|
| 8,760 | = Hours per year |
| ηDHW | = Recovery efficiency of electric water heater<br>= 0.98 [715] |
| 3412 | = Conversion from Btu to kWh |

Assuming defaults provided above:

$$\Delta kWh = (((0.131 / 1) – (0.327 / 3.4)) * 6 * 55 * 8,760) / 0.98 / 3412$$

$$= 30.0 \text{ kWh}$$

**Demand Savings**

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

Where:

| | |
|---|---|
| ΔkW | = gross customer connected load kW savings for the measure |
| ΔkWh | = kWh savings from tank wrap installation, calcualted below |
| 8760 | = Number of hours in a year (savings are from reduced standby loss and are therefore assumed to be constant over the year). |

Assuming defaults provided above:

$$\Delta kW = 30.0 / 8760$$
$$= 0.0034 \text{ kW}$$

**Baseline Efficiencies – New or Replacement**
The baseline condition is a hot water system without pipe wrap.

**High Efficiency**
High efficiency is a hot water system with insulation on the hot and cold water pipes up to the first elbow.

**Loadshape**
Loadshape #25, Flat (8760 hours)

**Freeridership/Spillover Factors**

| Measure Category | | Hot Water End Use | |
|---|---|---|---|
| Measure Code | | HWEPIPES | |
| Product Description | | Insulating Water Pipes | |
| Track Name | Track No. | Freerider | Spillover |
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetime**
15 years[716].
Analysis period is the same as the lifetime.

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[714] Assumes 120°F water leaving the hot water tank and average temperature of basement of 65°F.
[715] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40
[716] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

**Incremental Cost**
The measure cost is assumed to be \$3 per linear foot[717], or \$18 for a 6 foot length, including installation labor

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure

**Fossil Fuel Descriptions**
For fossil fuel DHW systems:

$$\Delta MMbtu = ((C_{exist} / R_{exist}) - (C_{new} / R_{new})) * L * \Delta T * 8{,}760) / \eta DHW / 1{,}000{,}000$$

Where:

| | |
|---|---|
| $\eta DHW$ | = Recovery efficiency of fossil fuel water heater |
| | = 0.76 [718] |
| 1,000,000 | = Conversion from Btu to MMBtu |

Other variables as defined above

$$\Delta MMbtu = ((0.131 / 1) - (0.327 / 3.4)) * 6 * 55 * 8{,}760) / 0.76 / 1{,}000{,}000$$

$$= 0.132 \text{ MMBtu}$$

[717] Consistent with DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com)
[718] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

# Tank Temperature Turn-down

Measure Number: V-A-3-f (Low Income Single Family Program, Hot Water End Use)

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**Referenced Documents:**

1. Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM).
2. NREL, National Residential Efficiency Measures Database
3. DOE, "Residential Heating Products Final Rule Technical Support Document," Table 3.2.13, http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch3.pdf

**Description**
The domestic hot water tank thermostat is lowered to reduce standby losses.

**Algorithms**

**Energy Savings**

For electric DHW systems:

$\Delta kWh = ((U_{base}A_{base}) * \Delta T * Hours) / (3412 * \eta DHW)$

Where:

| | |
|---|---|
| $\Delta kWh$ | = Gross customer annual kWh savings for the measure |
| $U_{base}$ | = Overall heat transfer coefficient (Btu/Hr-F-ft$^2$) |
| | = 1/20 [719] |
| $A_{base}$ | = Surface area of storage tank (square feet) |
| | = 23.18[720] |
| $\Delta T$ | = Temperature difference between before and after turn down |
| | = 15°F [721] |
| Hours | = Number of hours in a year (savings are assumed to be constant over year) |
| | = 8760 |
| 3412 | = Conversion from BTU to kWh |
| $\eta DHW$ | = Recovery efficiency of electric water heater |
| | = 0.98 [722] |

$\Delta kWh = ((1/20 * 23.18) * 15 * 8760) / (3412 * 0.98)$

$= 45.5$ kWh

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[719] Assumes an existing well insulated tank, or that tank wrap is added at that same time as the turn-down. Assumptions from Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM).
[720] Area includes tank sides and top, for a 40 gallon tank. Assumptions from Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM). Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation. Area includes tank sides and top to account for typical wrap coverage.
[721] Assumes 135°F tank turned down to 120°F.
[722] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

**Demand Savings**

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

Where:

$\Delta kW$ = Gross customer connected load kW savings for the measure
$\Delta kWh$ = kWh savings, calculated above
8766 = Number of hours in a year (savings are from reduced standby loss and are therefore assumed to be constant over the year).

$\Delta kW$ = 45.5 / 8760

= 0.00519 kW

**Baseline Efficiencies – New or Replacement**
The baseline condition is a hot water tank with a thermostat setting that is higher than 125°F, typically 130°F or higher.

**High Efficiency**
High efficiency is a hot water tank with the thermostat set at 120°F or less.

**Operating Hours**
8766, savings are from reduced standby loss and are therefore assumed to be constant over the year.

**Loadshape**
Loadshape #25, Flat (8760 hours)

**Freeridership/Spillover Factors**

| | | | |
|---|---|---|---|
| Measure Category | | Hot Water End Use | |
| Measure Code | | HWETEMPS | |
| Product Description | | Hot Water Temperature Set back | |
| Track Name | Track No. | Freerider | Spillover |
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
2 years.
Analysis period is the same as the lifetime.

**Incremental Cost**
$5 for contractor time.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure

**Fossil Fuel Descriptions**
For fossil fuel DHW systems:

$\Delta MMBtu$ = $((U_{base}A_{base}) * \Delta T * Hours) / (1{,}000{,}000 * \eta DHW)$

Where:

$\Delta MMBtu$ = Gross customer annual MMBtu savings for the measure
$U_{base}$ = Overall heat transfer coefficient ($Btu/Hr\text{-}F\text{-}ft^2$)

| | |
|---|---|
| | = 1/20 [723] |
| $A_{base}$ | = Surface area of storage tank (square feet)[724] |
| | = 23.18 |
| $\Delta T$ | = 15°F [725] |
| Hours | = Number of hours in a year (savings are assumed to be constant over year) |
| | = 8760 |
| 1,000,000 | = Conversion from BTU to MMBtu |
| $\eta DHW$ | = Recovery efficiency of fossil fuel water heater |
| | = 0.76 [726] |

ΔMMBtu = ((1/20 * 23.18) * 15 * 8760) / (1,000,000 * 0.76)

= 0.20 MMBtu

[723] Assumes an existing well insulated tank, or that tank wrap is added at that same time as the turn-down. Assumptions from Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM).
[724] Area includes tank sides and top to account for typical wrap coverage, for a 40 gallon tank. Number from Tank Wrap measure and PA TRM.
[725] Assumes 135°F tank turned down to 120°F.
[726] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

# Low Flow Shower Head

Measure Number: V-A-4-e (Low Income Single Family Program, Hot Water End Use)

**Version Date & Revision History**
Draft date: Portfolio
Effective date: 1/1/2013
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**Referenced Documents**:

1. Energy Policy Act of 1992
2. 2010 Census
3. NREL, National Residential Efficiency Measures Database
4. AWWA, Residential End Uses of Water, 1999, http://www.allianceforwaterefficiency.org/residential-end-uses-of-water-study-1999.aspx
5. CADMUS and Opinion Dynamics, "Showerhead and Faucet Aerator Meter Study," prepared for the Michigan Evaluation Working Group, 2013.
6. Pacific Northwest Laboratory; "Energy Savings from Energy-Efficient Showerheads: REMP Case Study Results, Proposed Evaluation Algorithm, and Program Design Implications" http://www.osti.gov/bridge/purl.cover.jsp;jsessionid=80456EF00AAB94DB204E848BAE65F199?purl=/10185385-CEkZMk/native/
7. East Bay Municipal Utility District; "Water Conservation Market Penetration Study" http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf
8. SBW Consulting, Evaluation for the Bonneville Power Authority, 1994, http://www.bpa.gov/energy/n/reports/evaluation/residential/faucet_aerator.cfm
9. Champlain Water District, 2010 Water Quality Report, http://www.cwd-h2o.org/vertical/Sites/%7B0A660058-838C-4456-B2E9-CCDA30420B07%7D/uploads/2011_Water_Quality_Report1.pdf

**Description**
An existing shower head with a high flow rate is replaced with new unit that has a low flow rate. This is a retrofit measure.

**Algorithms**

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

$\Delta kWh$[727] $= (((GPM_{base} \times min/person/day_{base} - GPM_{efficient} \times min/person/day_{efficient}) \times \#\ people \times days/year\ ) / SH/home\ ) \times 8.3 \times (TEMP_{sh} - TEMP_{in}) / DHW\ Recovery\ Efficiency / 3412 \times ISR$

$GPM_{base}$ = Gallons Per Minute of baseline shower head
= 2.02 [728]

$GPM_{efficient}$ = Gallons Per Minute of low flow shower head
= 1.5 [729]

$min/person/day_{base}$ = Average minutes in the shower per person per day with baseline showerhead
= 4.7 [730]

[727] Note, the algorithm and variables are provided as documentation for the deemed savings result provided which should be claimed for all shower head installations.
[728] Median from AWWA, Residential End Uses of Water, 1999, http://www.allianceforwaterefficiency.org/residential-end-uses-of-water-study-1999.aspx
[729] EVT program documentation as of November 2012
[730] Based on 7.8 minutes per shower and 0.6 showers per person per day (7.8 × 0.6 = 4.7 minutes per person per day); CADMUS and Opinion Dynamics, "Showerhead and Faucet Aerator Meter Study," prepared for the Michigan Evaluation Working Group, 2013.

$min/person/day_{efficient}$ = Average minutes in the shower per person per day with low flow showerhead

= 4.7 [731]

\# people = Average number of people per household

= 2.34 [732]

days/y = Days shower used per year

= 365

SH/home = Average number of showers in the home

= 1.7 [733]

8.3 = Constant to convert gallons to lbs

$TEMP_{sh}$ = Assumed temperature of water used by shower head

= 101F[734]

$TEMP_{in}$ = Assumed temperature of water entering house

= 54 F[735]

DHW Recovery Efficiency = Recovery efficiency of electric water heater

= 0.98 [736]

3412 = Constant to converts BTU to kWh

ISR = In Service Rate

= 0.95 [737]

$$\Delta kWh = [((2.02 \times 4.7 - 1.5 \times 4.7) \times 2.34 \times 365) / 1.7] \times 8.3 \times (101\text{-}54) / 0.98 / 3412 \times 0.95$$

= 136 kWh

**Demand Savings**

$\Delta kW$ = $\Delta kWh$ / hours

Where:

Hours = Operating hours from Residential DHW Conservation Loadshape[738]

= 3427

$\Delta kW$ = 136 kWh / 3427

= 0.0395 kW

**Baseline Efficiencies – New or Replacement**

The baseline condition is an existing shower head with a high flow.

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[731] Ibid.

[732] Average people per household in Vermont single family buildings, 2010 Census

[733] Estimate based on review of a number of studies:

a. Pacific Northwest Laboratory; "Energy Savings from Energy-Efficient Showerheads: REMP Case Study Results, Proposed Evaluation Algorithm, and Program Design Implications" http://www.osti.gov/bridge/purl.cover.jsp;jsessionid=80456EF00AAB94DB204E848BAE65F199?purl=/10185385-CEkZMk/native/
b. East Bay Municipal Utility District; "Water Conservation Market Penetration Study" http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf
c. AWWA, Residential End Uses of Water, 1999, http://www.allianceforwaterefficiency.org/residential-end-uses-of-water-study-1999.aspx

[734] CADMUS and Opinion Dynamics, “Showerhead and Faucet Aerator Meter Study,” prepared for the Michigan Evaluation Working Group, 2013.

[735] Champlain Water District, 2010 Water Quality Report, http://www.cwd-h2o.org/vertical/Sites/%7B0A660058-838C-4456-B2E9-CCDA30420B07%7D/uploads/2011_Water_Quality_Report1.pdf

[736] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

[737] Navigant, 2013, Draft Evaluation of Multi-Family Home Energy Savings Program for ComEd PY4 and Nicor Gas PY1

[738] Based on Itron eShapes (8760 data) and adjusted for diversity within the hour

**High Efficiency**
High efficiency is a low flow shower head.

**Loadshape**
For DHW systems not on Utility Controlled DHW program (Default):
Loadshape #8, Residential DHW Conservation

For DHW systems on Utility Controlled DHW program:
Loadshape #54, Controlled DHW Conservation

**Freeridership/Spillover Factors**

| Measure Category | | Hot Water | |
|---|---|---|---|
| Measure Code | | HWESHOWR | |
| Product Description | | Low Flow Shower Head | |
| Track Name | Track No. | Freerider | Spillover |
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
9 years (same as in DPS screening of Efficiency Utility Core programs).
Analysis period is the same as the lifetime.

**Measure Cost**
The incremental cost for low-flow shower heads is presumed to be zero for new construction or major rehab projects, and $15 for retrofit applications.[739]

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure

**Fossil Fuel Descriptions**[740]
If fossil fuel water heating:
$\Delta MMBtu = ((\Delta kWh \times \eta WH_{electric}) / \eta WH_{combustion}) \times 0.003412$

Where:

$\eta WH_{electric}$ = Recovery efficiency of electric water heater
= 0.98 [741]

$\eta WH_{combustion}$ = Recovery efficiency of fossil fuel water heater
= 0.76 [742]

Other factors as defined above

$$\Delta MMBtu = ((136 \times 0.98) / 0.76) \times 0.003412$$

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[739] Includes showerhead cost of $2.5 for a regular, $2.97 for chrome and $7.26 for handheld, plus labor installation costs.
[740] Fossil fuel savings based on efficiency factors of .62 for oil, natural gas, and liquid propane high efficiency stand alone DHW heaters as approved by the VT- DPS and used by Efficiency Vermont. Efficiency factor of .88 is used for electric DHW heater.
[741] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40
[742] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

$= 0.60$ MMBtu

**Water Descriptions**

$\Delta CCF = ((GPM_{base} \times min/person/day_{base} - GPM_{efficient} \times min/person/day_{efficient}) \times \#\ people \times days/year\ ) / (SH/home \times 748)$

Where:

$\Delta$CCF = customer water savings in hundreds of cubic feet for the measure

748 = Conversion from gallons to CCF

Other factors are as defined above

$$\Delta CCF = ((2.02 \times 4.7 - 1.5 \times 4.7) \times 2.34 \times 365)/ (1.7 \times 748)$$

$$= 1.64\ CCF$$

# Low Flow Faucet Aerator

Measure Number: V-A-5-e (Low Income Single Family Program, Hot Water End Use)

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**Referenced Documents**:

1. DOE, “Energy and Water Conservation Standards,” Federal Register Vol. 63, No. 52, March 18, 1998, 13307
2. AWWA, Residential End Uses of Water, 1999, http://www.allianceforwaterefficiency.org/residential-end-uses-of-water-study-1999.aspx
3. Ontario Energy Board, "Measures and Assumptions for Demand Side Management Planning."
4. East Bay Municipal Utility District; "Water Conservation Market Penetration Study" http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf
5. CADMUS and Opinion Dynamics, “Showerhead and Faucet Aerator Meter Study,” prepared for the Michigan Evaluation Working Group, 2013.
6. Champlain Water District, 2010 Water Quality Report, http://www.cwd-h2o.org/vertical/Sites/%7B0A660058-838C-4456-B2E9-CCDA30420B07%7D/uploads/2011_Water_Quality_Report1.pdf
7. NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40
8. 2010 Census

**Description**
An existing faucet aerator with a high flow rate is replaced with new unit that has a low flow rate. This is a retrofit measure.

**Algorithms**

**Energy Savings**

If electric domestic water heater:

$\Delta$kWh[743] = $(((GPM_{base} - GPM_{efficient}) / GPM_{base} \times \# \text{ people} \times gpcd \times days/year \times DR) / (F/home)) \times 8.3 \times (TEMP_{ft} - TEMP_{in})$ / DHW Recovery Efficiency / 3412

Where:

| | |
|---|---|
| $GPM_{base}$ | = Gallons Per Minute of baseline faucet<br>= 2.2 [744] |
| $GPM_{efficient}$ | = Gallons Per Minute of low flow faucet<br>= 1.5 or<br>= 1.0 |
| # people | = Average number of people per household<br>= 2.34 [745] |
| gpcd | = Average gallons per person per day using faucets<br>= 10.9 [746] |

[743] Note, the algorithm and variables are provided as documentation for the deemed savings result provided which should be claimed for all faucet aerator installations.
[744] In 1998, the Department of Energy adopted a maximum flow rate standard of 2.2 GPM at 60 psi for all faucets: DOE, “Energy and Water Conservation Standards,” Federal Register Vol. 63, No. 52, March 18, 1998, 13307
[745] Average people per household in Vermont single family buildings, 2010 Census
[746] AWWA, Residential End Uses of Water, 1999, http://www.allianceforwaterefficiency.org/residential-end-uses-of-water-study-1999.aspx

days/y = Days faucet used per year
= 365

DR = Percentage of water flowing down drain (if water is collected in a sink, a faucet aerator will not result in any saved water)
= 50% [747]

F/home = Average number of faucets in the home
= 3.5 [748]

8.3 = Constant to convert gallons to lbs

$TEMP_{ft}$ = Assumed temperature of water used by faucet
= 88 F[749]

$TEMP_{in}$ = Assumed temperature of water entering house
= 54 F[750]

DHW Recovery Efficiency = Recovery efficiency of electric water heater
= 0.98 [751]

3412 = Constant to converts BTU to kWh

Aerator at 1.5 gpm

$$\Delta kWh = ((2.2 - 1.5) / 2.2 \times 2.34 \times 10.9 \times 365 \times 0.5) / 3.5 \times 8.3 \times (88 - 54) / 0.98 / 3412$$

$$= 35.7 \text{ kWh}$$

Aerator at 1.0 gpm

$$\Delta kWh = ((2.2 - 1.0) / 2.2 \times 2.34 \times 10.9 \times 365 \times 0.5) / 3.5 \times 8.3 \times (88 - 54) / 0.98 / 3412$$

$$= 61.2 \text{ kWh}$$

**Demand Savings**

$$\Delta kW = \Delta kWh / hours$$

Where:

Hours = Operating hours from Residential DHW Conservation Loadshape[752]
= 3427

Aerator at 1.5 gpm

$$\Delta kW = 35.7 \text{ kWh} / 3427 = 0.0104 \text{ kW}$$

Aerator at 1.0 gpm

$$\Delta kW = 61.2 \text{ kWh} / 3427 = 0.0179 \text{ kW}$$

**Baseline Efficiencies – New or Replacement**

The baseline condition is an existing faucet aerator using 2.2 gpm.

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[747] Estimate consistent with Ontario Energy Board, "Measures and Assumptions for Demand Side Management Planning."

[748] Estimate based on East Bay Municipal Utility District; "Water Conservation Market Penetration Study" http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf

[749] Weighted average of kitchen (93F) and bathroom (86F) faucet use temperatures, CADMUS and Opinion Dynamics, "Showerhead and Faucet Aerator Meter Study," prepared for the Michigan Evaluation Working Group, 2013.

[750] Champlain Water District, 2010 Water Quality Report, http://www.cwd-h2o.org/vertical/Sites/%7B0A660058-838C-4456-B2E9-CCDA30420B07%7D/uploads/2011_Water_Quality_Report1.pdf

[751] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

[752] Based on Itron eShapes (8760 data) and adjusted for diversity within the hour

**High Efficiency**
High efficiency is a low flow aerator, 1.5 or 1.0 gpm.

**Loadshape**
For DHW systems not on Utility Controlled DHW program (Default):
Loadshape #8, Residential DHW Conservation

For DHW systems on Utility Controlled DHW program:
Loadshape #54, Controlled DHW Conservation

**Freeridership/Spillover Factors**

| Measure Category | | Hot Water | |
|---|---|---|---|
| Measure Code | | HWEFAUCT | |
| Product Description | | Low Flow Faucet Aerator | |
| Track Name | Track No. | Freerider | Spillover |
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
The expected lifetime of the measure is 9 years (same as in DPS screening of Efficiency Utility Core programs). Analysis period is the same as the lifetime.

**Measure Cost**
The incremental cost for low-flow faucet aerators is presumed to be zero for new construction or major rehab projects, and $10 for retrofit applications.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure

**Fossil Fuel Descriptions**[753]
If fossil fuel water heating:
$\Delta MMBtu = ((\Delta kWh \times \eta WH_{electric}) / \eta WH_{combustion}) \times 0.003412$

Where:

$\eta WH_{electric}$ = Recovery efficiency of electric water heater
= 0.98 [754]

$\eta WH_{combustion}$ = Recovery efficiency of fossil fuel water heater
= 0.76 [755]

Other factors as defined above

Aerator at 1.5 gpm

$\Delta MMBtu = ((35.7 \times 0.98) / 0.76) \times 0.003412$

= 0.157 MMBtu

Aerator at 1.0 gpm

[753] Fossil fuel savings based on efficiency factors of .62 for oil, natural gas, and liquid propane high efficiency stand-alone DHW heaters as approved by the VT- DPS and used by Efficiency Vermont. Efficiency factor of .88 is used for electric DHW heater.
[754] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40
[755] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

$$\Delta MMBtu = ((61.2 \times 0.98) / 0.76) \times 0.003412$$

$$= 0.269 \text{ MMBtu}$$

**Water Descriptions**

$$\Delta CCF = ((GPM_{base} - GPM_{efficient}) / GPM_{base} \times \# \text{ people} \times gpcd \times days/year \times DR) / (F/home \times 748)$$

Where:

$\Delta CCF$ = customer water savings in hundreds of cubic feet for the measure

748 = Conversion from gallons to CCF

Other factors are as defined above

Aerator at 1.5 gpm

$$\Delta CCF = ((2.2 - 1.5) / 2.2 \times 2.34 \times 10.9 \times 365 \times 0.5) / (3.5 \times 748)$$

$$= 0.566 \text{ CCF}$$

Aerator at 1.0 gpm

$$\Delta CCF = ((2.2 - 1.0) / 2.2 \times 2.34 \times 10.9 \times 365 \times 0.5) / (3.5 \times 748)$$

$$= 0.970 \text{ CCF}$$

## Lighting End Use
# Standard CFL Direct Install

Measure Number: V-C-5-c (Low Income Single-Family Program, Lighting End Use)

**Version Date & Revision History**:
Draft date: Portfolio 76
Effective date: 1/1/2012
End date: 12/31/2014

**Referenced Documents:**

1. DI Cost Query.xls, Direct Install Prescriptive Lighting TAG.doc
2. Residential Lighting Markdown Impact Evaluation, Nexus Market Research, RLW Analytics, and GDS Associated, January 20, 2009
3. Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)
4. 2012 EISA Adjustment Calculations.xls

**Description**
A compact fluorescent lamp replaces an incandescent bulb in an interior lighting fixture in a low income single-family homes direct install application.

**Algorithms**
**Demand Savings**
$\Delta$kW = (($\Delta$Watts) /1000)* ISR

| Year | Algorithm | $\Delta$kW |
|---|---|---|
| 2012 | = (49.0 / 1000) * 0.8 | 0.0392 |
| 2013 | = (43.6 / 1000) * 0.8 | 0.0349 |
| 2014 | = (37.0 / 1000) * 0.8 | 0.0296 |

**Energy Savings**
$\Delta$kWh = (($\Delta$Watts) /1000) * ISR * HOURS

| Year | Algorithm | $\Delta$kWh |
|---|---|---|
| 2012 | = (49.0 / 1000) * 0.8 * 694 | 27.2 |
| 2013 | = (43.6 / 1000) * 0.8 * 694 | 24.2 |
| 2014 | = (37.0 / 1000) * 0.8 * 694 | 20.5 |

Where:

$\Delta$kW = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW
$Watts_{EE}$ = Energy efficient connected kW
$\Delta$kWh = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units rebated that actually get used
= 0.8[756]
HOURS = average hours of use per year
= 694[757]

[756] 0.8 ISR based on TAG 2009 agreement.
[757] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011.

**Baseline Efficiencies – New or Replacement**
The baseline is an incandescent bulb.

**Baseline Adjustment**
In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become Halogen bulbs (see percentages in O&M table below).

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012.
The appropriate adjustments are provided below (see CFL baseline savings shift.xls for details on how adjustment is calculated):

| Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|
| 2012 | 0.66 | 2 |
| 2013 | 0.77 | 1 |
| 2014 | 0.88 | 1 |

**High Efficiency**
High efficiency is an ENERGY STAR compact fluorescent bulb.
Delta watts based on NEEP Residential Lighting Survey, 2011.

**Operating Hours**
Operating hours will be assumed as 1.9 hours per day or 694 hours per year[758].

**Loadshape**
If Indoor, Loadshape #1 - Residential Indoor Lighting
If Outdoor, Loadshape #2 - Residential Outdoor Lighting

**Freeridership/Spillover Factors**

| Measure Category | | Light Bulbs/Lamps | |
|---|---|---|---|
| Measure Code | | LBLCFBLB | |
| Product Description | | Compact Fluorescent Screw-base bulb | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | 1 | 1 |
| LIMF NC | 6018LINC | 1 | 1 |
| LIMF Rehab | 6018LIRH | 1 | 1 |

[758] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011.

| | | | |
|---|---|---|---|
| MF Mkt NC | 6019MFNC | 1 | 1 |
| MF Mkt Retro | 6020MFMR | 0.9 | 1.05 |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | 1 | 1 |
| RES Retrofit | 6036RETR | 0.9 | 1 |
| RNC VESH | 6038VESH | 1 | 1 |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be 90% as agreed to by EVT and the DPS (TAG 2007).

**Lifetimes**
Bulb life is assumed to be 8500 hours, based on agreement between EVT and the DPS (TAG 2009). At 694 hours per year and including the 90% persistence factor this equates to 11 years. A provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore the measure life will reduce each year and be equal to the number of years remaining to 2020; so for 2012 this will be 8 years, 2013 7 years.

Analysis period is the same as the lifetime.

**Measure Cost**[759]
The average installed cost is assumed to be $6.09 ($2.50 for the bulb and $3.59 for labor)[760].

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Methodology for Computing O&M Savings**
In order to account for the shift in baseline due to the Federal Legislation, the levelized baseline replacement cost over the lifetime of the CFL was calculated (see 2012 EISA Adjustments.xls). The key assumptions used in this calculation are documented below:

| | Incandescent | Halogen | CFL |
|---|---|---|---|
| Replacement Cost | $0.50 | $1.50 | $2.50 |
| Component Life (hours) | 1000 | 1000 | 8500 |

[759] 2009 cost represents full, installed cost and is computed with a weighted average of all direct install interior CFLs installed under the Efficiency Vermont Existing Homes and Low Income Program between 1/1/2006 and 12/1/2007. 2010 and 2011 costs decline at same rate as the assumption for CFL bulbs.
[760] $2.50 for CFL is based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011. Labor rate consistent with other measures.

| | | | |
|---|---|---|---|
| Baseline % in 2009-2011 | 100% | 0% | 0% |
| Baseline % in 2012 | 67% | 33% | 0% |
| Baseline % in 2013 | 33% | 67% | 0% |
| Baseline % in 2014 onward | 0% | 100% | 0% |
| Baseline % in 2020 onward | 0% | 0% | 100% |

The calculation results in a levelized assumption of $0.93 baseline replacement cost every 1 year for CFL installations in 2012, $0.96 every year for installations in 2013, and $0.98 for installations in 2014. This adjustment will be recalculated for subsequent years.

# Specialty CFL Direct Install

Measure Number: V-C-7-a (Low Income Single-Family Program, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 75
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**
1. 2009 to 2011 bulbs installed.xlsx
2. Xenergy, 1998; "Process and Impact Evaluation of Joint Utilities Starlights Residential Lighting Program".

**Description**
An existing incandescent bulb is replaced with a lower wattage ENERGY STAR qualified specialty compact fluorescent bulb through a Direct Install program. Specialty CFL bulbs are defined as lamps for general illumination that use fluorescent light emitting technology and an integrated electronic ballast with or without a standard Edison screw-base. They can be dimmable, designed for special applications, have special color enhancement properties or have screw-bases that are not standard Edison bases, and include A-lamps, candelabras, G-lamps (globe), reflectors, torpedoes, dimmables, and 3-way bulbs. This TRM should be used for both interior and exterior installations, the only difference being the loadshape. Note specialty bulbs are currently exempt from EISA regulations.

**Algorithms**

**Demand Savings**
$\Delta kW = ((\Delta Watts) / 1000) \times ISR$
$\Delta kW(Res. <=15W) = ((43.9) / 1000) \times 0.8 = 0.0351$
$\Delta kW(Res. >15W) = ((62.6) / 1000) \times 0.8 = 0.0501$

**Energy Savings**
$\Delta kWh = \Delta kW \times HOURS$
$\Delta kWh\ (Res. <=15W) = (0.0351 \times 694) = 24.4$
$\Delta kWh\ (Res. >15W) = (0.0501 \times 694) = 34.8$

Where:

| | |
|---|---|
| $\Delta kW$ | = gross customer connected load kW savings for the measure |
| $\Delta Watts$ | = Average delta watts between specialty CFL and incandescent $Watts_{BASE} - Watts_{EE}$[761] |
| ISR | = in service rate or the percentage of units rebated that actually get used[762] |
| $\Delta kWh$ | = gross customer annual kWh savings for the measure |
| HOURS | = average hours of use per year |

**Baseline Efficiencies – New or Replacement**
The baseline condition is an incandescent specialty light bulb.

**High Efficiency**
High efficiency is an ENERGY STAR qualified specialty compact fluorescent lamp.

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[761] The delta watts is calculated by finding the weighted average wattage of specialty bulbs installed in Existing Homes, Low Income and RNC from 01/2009-04/2011. The equivalent incandescent wattage was used to calculate delta watts. See 2009 to 2011 bulbs installed.xlsx
[762] ISR is assumed to be equal to standard CFL Direct Install measure, and is based on a 2009 TAG agreement.

**Operating Hours**
Assumed to be 1.9 hours a day or 694 hours per year [763].

**Loadshape**
Loadshape #1: Residential Indoor Lighting
Loadshape #2: Residential Outdoor Lighting

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Freeridership/Spillover Factors**

| Measure Category | | Light Bulbs/Lamps | |
|---|---|---|---|
| Measure Code | | LBLCFSPD | |
| Product Description | | Compact Fluorescent – Specialty Bulb Direct Install | |
| Track Name | Track No. | Freerider | Spillover |
| LIMF Retrofit | 6017RETR | 1 | 1 |
| LIMF NC | 6018LINC | 1 | 1 |
| LIMF Rehab | 6018LIRH | 1 | 1 |
| MF Mkt NC | 6019MFNC | 1 | 1 |
| MF Mkt Retro | 6020MFMR | 1 | 1 |
| LISF Retrofit | 6034LISF | 1 | 1 |
| RES Retrofit | 6036RETR | 0.9 | 1 |
| RNC VESH | 6038VESH | 1 | 1 |

**Persistence**
The persistence factor is assumed to be 90% as agreed to by EVT and the DPS (TAG 2007).

**Lifetimes**
Bulb life is assumed to be 8500 hours, based on agreement between EVT and the DPS (TAG 2009). The measure life, including the 90% persistence factor is therefore assumed to be 8500/694 * 0.9 = 11 years. Analysis period is the same as the lifetime.

**Measure Cost[764]**

| | | |
|---|---|---|
| Cost (Watts <=15) | = \$8.16 + \$3.59 (labor) | = \$11.75 |
| Cost (Watts >15) | = \$8.84 + \$3.59 (labor) | = \$12.43 |

**Incentive Level**
The incentive level is equal to the measure cost (these bulbs are free to the customer).

**O&M Cost Adjustments**
O& M cost adjustments are based on component costs provided in the reference table below.

**Water Descriptions**
There are no water algorithms or default values for this measure.

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[763] Hours of use are based on TAG 2011 agreement to use the NEEP Residential Lighting Survey, 2011 proposed values.
[764] Incremental cost of bulb is consistent with the assumptions from the NEEP Residential Lighting Survey, 2011. This evaluation did not provide the <=15W and >15W categories and so the costs from EVT's analysis of incremental costs are adjusted such that the average matches the values from the NEEP study. Labor cost is consistent with the standard bulb direct install measures.

**Reference Tables**
**Component Costs and Lifetimes Used in Computing O&M Savings**

**Residential**

| | Baseline Measures | |
|---|---|---|
| Component | Cost[765] | Life[766] |
| Lamp<=15W | $2.71 | 1.4 |
| Lamp>15W | $4.29 | 1.4 |

[765] Baseline cost is consistent with the assumptions from the NEEP Residential Lighting Survey, 2011. This evaluation did not provide the <=15W and >15W categories and so the costs from EVT's analysis of baseline costs are adjusted such that the average matches the values from the NEEP study
[766] Based on the assumption that the incandescent bulb rated life is 1000 hours. 1000/694 = 1.4years.

**Refrigeration End Use**

# Refrigerator Early Replacement

Measure Number: V-E-1-d (Low Income Single Family, Refrigeration End Use)

**Version Date & Revision History**

Draft date: Portfolio 80
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**

1) 2012 Refrigerator Retrofit Savings.xls
2) http://www.energystar.gov/ia/partners/product_specs/program_reqs/refrig_prog_req.pdf
3) http://www1.eere.energy.gov/buildings/appliance_standards/downloads/nia_refrig-frzr_final.zip
4) http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrigerator_report_1.pdf
5) http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf
6) Refrigerator kW Calculations.xls

**Description**

This is an early replacement measure of an existing pre-2001 inefficient refrigerator with a new refrigerator exceeding minimum qualifying efficiency standards established as ENERGY STAR or optionally CEE Tier 2 or CEE Tier 3. Savings are calculated between the average energy usage of an existing unit and that of a higher efficiency unit for the remaining life of the existing unit, plus the savings between an average baseline unit and that of a higher efficiency unit for the remainder of the measure life. Prior to 2012, eligibility was restricted to pre-1993 refrigerators. Efficiency Vermont has decided to expand eligibility to the next refrigerator standard change (2001). The estimated decrease in consumption of a post-1993 / pre-2001 unit over a pre-1993 unit is 35%. EVT has assumed that 30% of the future replacements will fall in to the 1993-2001 category[767] and have adjusted the savings accordingly (see '2012 Refrigerator Retrofit Savings.xls' for more details). We will review this assumption after a year and adjust as necessary.

**Algorithms**

**Energy Savings[768]**

ΔkWh – Energy Star for remaining life of existing unit (3 years) = 592 kWh
ΔkWh – CEE Tier 2 for remaining life of existing unit (3 years) = 620 kWh
ΔkWh – CEE Tier 3 for remaining life of existing unit (3 years) = 647 kWh

ΔkWh – Energy Star for remaining measure life (9 years) = 113 kWh
ΔkWh – CEE Tier 2 for remaining measure life (9 years) = 141 kWh
ΔkWh – CEE Tier 3 for remaining measure life (9 years) = 169 kWh

**Demand Savings**

ΔkW = ΔkWh/Hours
ΔkW – Energy Star for remaining life of existing unit (3 years) = 592/8477 = 0.070 kW
ΔkW – CEE Tier 2 for remaining life of existing unit (3 years) = 620/8477 = 0.073 kW
ΔkW – CEE Tier 3 for remaining life of existing unit (3 years) = 647/8477 = 0.076 kW

ΔkW – Energy Star for remaining measure life (9 years) = 113/8477 = 0.013 kW
ΔkW – CEE Tier 2 for remaining measure life (9 years) = 141/8477 = 0.017 kW

[767] Based upon conversations with the weatherization agencies.
[768] Based on analysis of 2008-2009 rebated units, see 2012 Refrigerator Retrofit Savings.xls. The estimate of the consumption of 1993-2001 units is based upon Figure 3.2.3 from http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf). Based upon conversations with the weatherization agencies the weighted average assumes 30% of future replacements will fall in this category.

$\Delta$kW – CEE Tier 3 for remaining measure life (9 years) = 169/8477 = 0.020 kW

Where:

$\Delta$kWh = gross customer annual kWh savings for the measure

HOURS = Equivalent Full Load Hours

= 8477[769]

$\Delta$kW = gross customer connected load kW savings for the measure

**Baseline Efficiencies – New or Replacement**

The existing pre-2001 refrigerator baseline efficiency is estimated according to a combination of Association of Home Appliance Manufacturers (AHAM) estimated usage data and actual meter measurements from replacements installed thru EVT from 2006-2008[770]. For the purpose of this measure it is assumed that the remaining life of the existing refrigerator is 3 years. For the remaining 14 years of the new refrigerator, the 2001 federal minimum standard is set as the baseline efficiency. See 2012 Refrigerator Retrofit Savings.xls for more details.

**High Efficiency**

High efficiency is defined as any model meeting or exceeding 2007 Energy Star standard – currently set to 20% over the 2001 federal minimum standard or optionally 25% or 30% to meet CEE Tier 2 or Tier 3. EVT's energy savings estimates are based on the weighted average test measurements for qualifying models based on the models rebated during 2006-2008.

**Loadshape**

Loadshape #4, Residential Refrigerator

**Freeridership/Spillover Factors**

| Measure Category | | Refrigeration | |
|---|---|---|---|
| Measure Code | | RFRESRER, RFRT2RER, RFRT3RER | |
| Product Description | | Energy Star Refrigerator | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| MF Mkt Retro | 6020MFMR | n/a | n/a |

[769] The Summer and Winter Coincident kW are calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. To calculate an Equivalent Full Load Hours the UEC (* PartUse) is divided by the summer coincident kW (956 * .779)/0.088 = 8477 hours. The summer coincidence factor is therefore assumed to be 1.0 and a winter coincidence factor calculated as the relative winter to summer kW result from the algorithm. For the calculation see "Refrigerator kW Calculations.xls".

[770] Note that in 2009 this measure became prescriptive and so individual unit consumption values were no longer tracked.

| | | | |
|---|---|---|---|
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |
| RES Retrofit | 6036RETR | 0.9 | 1.0 |
| RNC VESH | 6038VESH | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
12 Years[771]
Analysis period is the same as the lifetime.

**Measure Cost**
The initial measure cost for an Energy Star refrigerator is $740 and Tier 2 is $850 and Tier 3 is $930. The avoided replacement cost (after 3 years) of a baseline refrigerator is $700.[772]

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**
N/A

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[771] From ENERGY STAR calculator: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?e678-f5e6&e678-f5e6

[772] Measure costs are based on review of data from the Northeast Regional ENERGY STAR Consumer Products Initiative; "2009 ENERGY STAR Appliances Practices Report", submitted by Lockheed Martin, December 2009. See 2009 VT Appliance Data_TRMCostAnalysis.xls for data. ESTAR incremental cost reduced to $40 based on ENERGY STAR Calculator; http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?e678-f5e6&e678-f5e6

[772] Based upon conversations with the weatherization agencies.

# Freezer Early Replacement

Measure Number: Measure Number: V-E-2-b (Low Income Single Family, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 80
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**
1) 2012 Freezer Retrofit Savings.xls;
2) 2009 VT Appliance Data_TRMCostAnalysis.xls
3) Refrigerator kW Calculations.xls

**Description**
This is an early replacement measure of an existing pre-2001 inefficient freezer with a new freezer exceeding minimum qualifying efficiency standards established as ENERGY STAR. Savings are calculated between the average energy usage of an existing unit and that of a higher efficiency unit for the remaining life of the existing unit, plus the savings between an average baseline unit and that of a higher efficiency unit for the remainder of the measure life.

Prior to 2012, eligibility was restricted to pre-1993 refrigerators. Efficiency Vermont has decided to expand eligibility to the next freezer standard change (2001). The estimated decrease in consumption of a post-1993 / pre-2001 unit over a pre-1993 unit is 25%. EVT has assumed that 30% of the future replacements will fall in to the 1993-2001 category[773] and have adjusted the savings accordingly (see '2012 Freezer Retrofit Savings.xls' for more details). We will review this assumption after a year and adjust as necessary.

**Algorithms**

**Energy Savings**
ΔkWh – ENERGY STAR for remaining life of existing unit (3 years) = 269 kWh
ΔkWh – ENERGY STAR for remaining measure life (9 years) = 52.5 kWh

**Demand Savings**
ΔkW = ΔkWh/Hours

ΔkW – ENERGY STAR for remaining life of existing unit (3 years) = 269/8477 = 0.032 kW
ΔkW – ENERGY STAR for remaining measure life (9 years) = 52.5/8477 = 0.006 kW

Where:
ΔkWh = gross customer annual kWh savings for the measure
HOURS = Equivalent Full Load Hours
= 8477[774]

ΔkW = gross customer connected load kW savings for the measure

**Baseline Efficiencies – New or Replacement**

[773] Based upon conversations with the weatherization agencies.
[774] The Summer and Winter Coincident kW are calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. To calculate an Equivalent Full Load Hours the UEC (* PartUse) is divided by the summer coincident kW (956 * .779)/0.088 = 8477 hours. The summer coincidence factor is therefore assumed to be 1.0 and a winter coincidence factor calculated as the relative winter to summer kW result from the algorithm. For the calculation see "Refrigerator kW Calculations.xls".

The existing pre-2001 freezer baseline efficiency is estimated by calculating the estimated kWh for an equivalent unit at the Federal Standard prior in 1990 and 1993 for all units incentivized through the Efficient Product program in 2009-2010[775].For the purpose of this measure it is assumed that the remaining life of the existing freezer is 3 years. For the remaining 14 years of the new freezer, the 2001 Federal minimum standard is set as the baseline efficiency. See Freezer Retrofit Savings.xls for more details.

**High Efficiency**
High efficiency is defined as any model meeting or exceeding 2007 ENERGY STAR standard – currently set to 10% over the 2001 Federal minimum standard .

**Loadshape**
Loadshape #4, Residential Refrigerator

**Freeridership/Spillover Factors**

| Measure Category | | Refrigeration | |
|---|---|---|---|
| Measure Code | | RFRESFZR | |
| Product Description | | Energy Star Freezer Early Replacement | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| MF Mkt Retro | 6020MFMR | 0.9 | 1.0 |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |
| RES Retrofit | 6036RETR | 0.9 | 1.0 |
| RNC VESH | 6038VESH | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

[775] Note that in 2010 this measure became prescriptive and so individual unit consumption values were no longer tracked.

**Lifetimes**
12 Years[776]
Analysis period is the same as the lifetime.

**Measure Cost**
The full cost for an ENERGY STAR unit is $500. The cost of a baseline replacement freezer is $465. [777]

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**
N/A

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776 From ENERGY STAR calculator: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?e678-f5e6&e678-f5e6

777 Based on review of data from the Northeast Regional ENERGY STAR Consumer Products Initiative; "2009 ENERGY STAR Appliances Practices Report", submitted by Lockheed Martin, December 2009. See 2009 VT Appliance Data_TRMCostAnalysis.xlsfor data.

# Refrigerator Early Removal

Measure Number: V-E-3-a (Low Income Single Family, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 80
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**

1. ADM Evaluation Study of the 2004-05 Statewide Residential Appliance Recycling Program;
2. KEMA Residential Refrigerator Recycling Ninth Year Retention Study;
3. Opinion Dynamics; "Fridge & Freezer Recycle Rewards Program PY4 Metering Study: DRAFT Savings Results"
4. The Cadmus Group et al., "Residential Retrofit High Impact Measure Evaluation Report", prepared for the California Public Utilities Commission, February 8, 2010
5. Appliance Recycling data2008-2012_V2.xls
6. Refrigerator kW Calculations.xls

**Description**
This is an early retirement measure for the removal of an existing inefficient secondary refrigerator from service observed during a site visit by a weatherization agency, Home Performance contractor or Efficiency Vermont staff member. The contractor has signed an agreement that the unit will be rendered permanently inoperable and properly recycled or disposed of. The program will target refrigerators with an age greater than 10 years, although data from the Efficient Product program suggests the average age of retired units is over 30 years. Savings are calculated for the estimated energy consumption during the remaining life of the existing unit.

**Algorithms**

**Energy Savings**
$\Delta kWh = UEC * PartUse * LI_{size\ factor}$
$= 956 * 0.779 * 0.84$
$= 626\ kWh$

**Demand Savings**
$\Delta kW = \Delta kWh/Hours$
$= 626/8477$
$= 0.074\ kW$

Where:

$\Delta kWh$ = gross customer annual kWh savings for the measure
UEC = Unit Energy Consumption
= 956kWh[778]
PartUse = adjustment factor for weighted partial use of appliance
= 0.779[779]

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[778] Unit Energy Consumption is based upon review of the data collected by Jaco from units retired in the program from 2009-2012. To estimate the consumption of the retired units EVT used a regression equation with multiple attributes from a recent Illinois evaluation (Opinion Dynamics; "Fridge & Freezer Recycle Rewards Program PY4 Metering Study: DRAFT Savings Results"). For information see "Appliance Recycling data2008-2012_V2.xls".

| | |
|---|---|
| $LI_{size\ factor}$ | = Factor applied to the savings derived from Efficient Products Program to account for smaller units being installed in Low Income households.<br>= 0.84[780] |
| HOURS | = Equivalent Full Load Hours<br>= 8477[781] |
| $\Delta$kW | = gross customer connected load kW savings for the measure |

**Baseline Efficiencies – New or Replacement**
The existing refrigerator baseline consumption is based upon data collected by Jaco from units retired in the Efficient Products program from 2009-2012 and adjusted for part use consumption.

**High Efficiency**
N/A

**Loadshape**
Loadshape #4, Residential Refrigerator

**Freeridership/Spillover Factors**

| Measure Category | | Refrigeration | |
|---|---|---|---|
| Measure Code | | RFRRERPS | |
| Product Description | | Low Income Refrigerator Early Retirement | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6012MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

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[779] Based on analysis of Jaco data. Participants were asked how much the refrigerator was run through the year. The data was weighted assuming the response “All months” equaled 12 months, “Summer” or “Winter” equaled 3 months and “Spring/Fall” equaled 6 months.

[780] Size Factor is calculated by comparing the average Low Income retrofitted energy savings per unit (592kwh for ENERGY STAR and 620 for CEE T2) to the average single family residential retrofitted energy savings (709kWh for ENERGY STAR and 737 for CEE T2) indicating a 84% savings factor..

[781] The Summer and Winter Coincident kW are calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. To calculate an Equivalent Full Load Hours the UEC (* PartUse) is divided by the summer coincident kW (956 * .779)/0.088 = 8477 hours. The summer coincidence factor is therefore assumed to be 1.0 and a winter coincidence factor calculated as the relative winter to summer kW result from the algorithm. For the calculation see “Refrigerator kW Calculations.xls”.

**Lifetimes**
8 years [782]
Analysis period is the same as the lifetime.

**Measure Cost**
The cost of pickup and recycling of the refrigerator is $50 based upon agreement with contractors or vendors who will collect secondary units when replacing the primary unit. Contractors have signed an agreement that the units will be recycled and not placed on the secondary market.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel savings for this measure.

**Water Descriptions**
There are no water savings for this measure.

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[782] KEMA "Residential refrigerator recycling ninth year retention study", 2004

# Freezer Early Removal

Measure Number: V-E-4-a (Low Income Single Family, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 80
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**

1. ADM Evaluation Study of the 2004-05 Statewide Residential Appliance Recycling Program;
2. KEMA Residential Refrigerator Recycling Ninth Year Retention Study;
3. Opinion Dynamics; "Fridge & Freezer Recycle Rewards Program PY4 Metering Study: DRAFT Savings Results"
4. The Cadmus Group et al., "Residential Retrofit High Impact Measure Evaluation Report", prepared for the California Public Utilities Commission, February 8, 2010
5. Appliance Recycling data2008-2012_v2.xls
6. Refrigerator kW Calculations.xls

**Description**
This is an early retirement measure for the removal of an existing inefficient freezer from service observed during a site visit by a weatherization agency, Home Performance contractor or Efficiency Vermont staff member. The contractor has signed an agreement that the unit will be rendered permanently inoperable and properly recycled or disposed of. The program will target freezers with an age greater than 10 years, although data from the Efficient Product program suggests the average age of retired units is over 30 years. Savings are calculated for the estimated energy consumption during the remaining life of the existing unit.

**Algorithms**
**Energy Savings**
ΔkWh = UEC * PartUse
= 1231 * 0.777
= 956 kWh

**Demand Savings**
ΔkW = ΔkWh/Hours
= 956 /8477
= 0.113 kW

Where:
ΔkWh = gross customer annual kWh savings for the measure
UEC = Unit Energy Consumption
= 1231 kWh[783]
PartUse = adjustment factor for weighted partial use of appliance
= 0.777[784]
HOURS = Equivalent Full Load Hours
= 8477[785]

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[783] Unit Energy Consumption is based upon review of the data collected by Jaco from units retired in the program from 2009-2012. To estimate the consumption of the retired units EVT used a regression equation with multiple attributes from a recent Illinois evaluation (Opinion Dynamics; "Fridge & Freezer Recycle Rewards Program PY4 Metering Study: DRAFT Savings Results"). For information see "Appliance Recycling data2008-2012_V2.xls".
[784] Based on analysis of Jaco data. Participants were asked how much the freezer was run through the year. The data was weighted assuming the response "All months" equaled 12 months, "Summer" or "Winter" equaled 3 months and "Spring/Fall" equaled 6 months.

$\Delta kW$ = gross customer connected load kW savings for the measure

**Baseline Efficiencies – New or Replacement**

The existing freezer baseline consumption is based upon data collected by Jaco from units retired in the Efficient Products program from 2009-2012 and adjusted for part use consumption.

**High Efficiency**

N/A

**Loadshape**

Loadshape #4, Residential Refrigerator

**Freeridership/Spillover Factors**

| Measure Category | | Refrigeration | |
|---|---|---|---|
| Measure Code | | RFRFERPS | |
| Product Description | | Freezer Early Retirement | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6012MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |

**Persistence**

The persistence factor is assumed to be one.

**Lifetimes**

8 years [786] Analysis period is the same as the lifetime.

**Measure Cost**

The cost of pickup and recycling of the refrigerator is $50 based upon agreement with contractors or vendors who will collect secondary units when replacing the primary unit. Contractors have signed an agreement that the units will be recycled and not placed on the secondary market.

[785] The Summer and Winter Coincident kW are calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. To calculate an Equivalent Full Load Hours the UEC (* PartUse) is divided by the summer coincident kW (956 * .779)/0.088 = 8477 hours. The summer coincidence factor is therefore assumed to be 1.0 and a winter coincidence factor calculated as the relative winter to summer kW result from the algorithm. For the calculation see “Refrigerator kW Calculations.xls”.

[786] KEMA “Residential refrigerator recycling ninth year retention study”, 2004

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel savings for this measure.

**Water Descriptions**
There are no water savings for this measure.

## Clothes Washing End Use
# Clothes Washer Retrofit

Measure Number: V-F-1-c (Low Income Single Family, Clothes Washing End Use)

**Version Date & Revision History**
Draft date: Portfolio 81
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**
1) LISF 2013 Clothes Washer Retrofit Savings.xls
2) http://www.eia.gov/consumption/residential/data/2009/
3) http://www1.eere.energy.gov/buildings/appliance_standards/residential/clothes_washers_support_stakeholder_negotiations.html

**Description**
This is an early retrofit measure of an existing inefficient clothes washer with a new clothes washer exceeding minimum qualifying efficiency standards established as ENERGY STAR, CEE Tier 2 or CEE Tier 3, Most Efficient or Top Ten (as defined below). Savings are calculated between the average energy usage of an existing unit and that of an efficient new unit for the remaining life of the existing unit, plus the savings between an average baseline unit and that of a efficient unit for the remainder of the measure life. Qualification criteria for this measure are customers with a clothes washer that is over eight years old and pre-2004, has Electric DHW and an Electric Dryer.

**Algorithms**

**Energy Savings**[787]

| Efficiency Level | ΔkWh for remaining life of existing unit (first 3 years) | ΔkWh for remaining measure life (Next 11 years) |
|---|---|---|
| ENERGY STAR | 336 | 162 |
| CEE TIER 2 | 534 | 277 |
| CEE TIER 3 | 587 | 348 |
| ENERGY STAR Most Efficient (as of 1/1/2013) | 695 | 446 |
| Top Ten | 746 | 484 |

**Demand Savings**
ΔkW = ΔkWh/Hours

Where:

ΔkWh = gross customer annual kWh savings for the measure
ΔkW = gross customer connected load kW savings for the measure
Hours = Operating hours of clothes washer unit
= 322

| Efficiency Level | ΔkW for remaining life of existing unit (first 3 years) | ΔkW for remaining measure life (Next 11 years) |
|---|---|---|
| ENERGY STAR | 1.05 | 0.50 |
| CEE TIER 2 | 1.66 | 0.86 |
| CEE TIER 3 | 1.82 | 1.08 |

[787] The calculations are based on analysis of previous year's rebated units through Efficient Products (see Efficient Product measure for write up of savings methodology).,See LISF 2013 Clothes Washer Retrofit Savings.xls

| | | |
|---|---|---|
| ENERGY STAR Most Efficient (as of 1/1/2013) | 2.16 | 1.38 |
| Top Ten | 2.32 | 1.50 |

**Baseline Efficiencies – New or Replacement**
The baseline efficiency is determined according to the modified energy factor (MEF) that takes into account the energy and water required per clothes washer cycle, including energy required by the clothes dryer per clothes washer cycle. For the purpose of this measure it is assumed that the remaining life of the existing clothes washer is 3 years (i.e. it is 11 years in to its 14 year life). The federal baseline for clothes washers prior to 2004 was 0.817 MEF[788], and the average value of units tested in a 2001 DOE market assessment was 1.164.. For the remaining 11 years of the new clothes washer, the current federal baseline MEF of 1.26 is inflated by 20% to 1.51 to account for a transforming market. See LISF 2013 Clothes Washer Retrofit Savings.xls for more details.

**High Efficiency**
High efficiency is defined as any model meeting or exceeding ENERGY STAR, CEE Tier 2 or Tier 3 standards as of 1/1/2011, ENERGY STAR Most Efficient of Top Ten as defined in table below..

| Efficiency Level | Modified Energy Factor (MEF) | Water Factor (WF) |
|---|---|---|
| ENERGY STAR | >= 2.0 | <= 6.0 |
| CEE TIER 2 | >= 2.20 | <= 4.5 |
| CEE TIER 3 | >= 2.40 | <= 4.0 |
| ENERGY STAR Most Efficient (as of 1/1/2013) | >= 2.4 (for units <=2.5 ft3)<br>>= 3.2 (for units >2.5 ft3) | <= 4.5 (for units <=2.5 ft3)<br><= 3.0 (for units >2.5 ft3) |
| Top Ten | Defined as the ten most efficient units available. | |

Energy and water savings estimates are based on the weighted average MEF factor for qualifying models based on the models rebated during the previous calendar year, except Top Ten which is based upon averaging the units provided on the website (http://www.toptenusa.org/Top-Ten-Clothes-Washers) as of September 2012.

Qualification criteria for this measure are customers with Electric DHW and Electric Dryers.

**Operating Cycles**
322 clothes washer cycles / year [789]

**Operating Hours**
322 operating hours / year [790]

**Loadshape**
Loadshape #9, Residential Clothes Washing

**Freeridership/Spillover Factors**

| | |
|---|---|
| Measure Category | Cooking and Laundry |
| Measure Code | CKLESWER, CKLT2WER, CKLT3WER, CKLMEWER, CKLTTWER |
| Product Description | Energy Star Clothes Washer |

788 http://www.cee1.org/resid/seha/rwsh/press-rel.php3
789 Weighted average of 322 clothes washer cycles per year. 2009 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section: http://www.eia.gov/consumption/residential/data/2009/
790 Based on assumption of average one hour per cycle.

| Track Name | Track No. | Freerider | Spillover |
|---|---|---|---|
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |
| RES Retrofit | 6036RETR | 0.9 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
14 years.[791] Analysis period is the same as the lifetime.

**Measure Cost**
The full measure cost assumption is provided below:

| Efficiency Level | Full Measure Cost |
|---|---|
| ENERGY STAR | $825 |
| CEE Tier 2 | $850 |
| CEE Tier 3 | $950 |
| ENERGY STAR Most Efficient | $1100 |
| Top Ten | $1110 |

The deferred (for 3 years) baseline replacement clothes washer cost is assumed to be $600.[792]

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
Since only customers with electric DWH and dryers are eligible for this measure, there are no fossil fuel impacts.

**Water Descriptions**

$\Delta$CCF = customer water savings in hundreds of cubic feet for the measure

The water savings for each efficiency level are presented below:

| Efficiency Level | WF | ΔWater (CCF per year) | | |
|---|---|---|---|---|
| | | Remaining life of | Remaining measure | Weighted average for |

[791] Based on DOE Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_standard.xlsm.
[792] Based on weighted average of top loading and front loading units (based on available product from the CEC Appliance database) and cost data from Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_standard.xlsm. See '2013 MF In unit Clothes Washer Savings_Retrofit.xls' for details.

| | | existing unit (first 3 years) | life (Next 11 years) | use in screening[793] |
|---|---|---|---|---|
| Existing unit | 12.87[794] | n/a | n/a | |
| Federal Standard | 7.93 | n/a | n/a | |
| ENERGY STAR | 5.41 | 8.8 | 3.0 | 4.2 |
| CEE Tier 2 | 3.61 | 16.1 | 7.5 | 9.4 |
| CEE Tier 3 | 3.51 | 15.1 | 7.1 | 8.8 |
| ENERGY STAR Most Efficient | 2.90 | 16.8 | 8.5 | 10.3 |
| Top Ten | 3.54 | 16.5 | 7.8 | 9.6 |

[793] Efficiency Vermont's screening tool does not allow for mid-life savings adjustments for water, thus a single value is required.

[794] US DOE, Life Cycle Cost Model, spreadsheet dated December 1999 (http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/lcc_spreadsheet.xls), indicates 38.61 gallons of water per cycle. Assume average size of 3 cu ft gives 12.87 WF assumption. http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/lcc_spreadsheet.xls

**Ventilation End Use**

# Residential Fan—Quiet, Exhaust-Only Continuous Ventilation

Measure Number: V-G-1-a (Low Income Single Family, Ventilation End Use)

**Version Date & Revision History**

Draft date: Portfolio 73
Effective date: 1/1/2011
End date: TBD

**Referenced Documents:**

1. Residential Vent Fan Assessment.xls
2. GDS Associates Measure Life Report "Residential and C&I Lighting and HVAC measures"
3. ASHRAE 62.2 Section 4.1 Whole House Ventilation

**Description**

This market opportunity is defined by the need for continuous mechanical ventilation due to reduced air-infiltration from a tighter building shell. In retrofit projects, existing fans may be too loud, or insufficient in other ways, to be operated as required for proper ventilation. This measure assumes a fan capacity of 50 CFM rated at less than 2.0 sones at 0.1 inches of water column static pressure. This measure may be applied to larger capacity, up to 130 CFM, efficient fans with bi-level controls because the savings and incremental costs are very similar. All eligible installations shall be sized to provide the mechanical ventilation rate indicated by ASHRAE 62.2.

**Algorithms**

**Demand Savings**

$\Delta kW = CFM * (1/Fan_{Efficiency,\ Baseline} - 1/Fan_{Efficiency,\ Effcient})/1000$
$= 50 * (1/3.1 – 1/8.3)/1000$
$= 0.01$ kW

Where:

CFM = Nominal Capacity of the exhaust fan, 50 CFM[795]
$Fan_{Efficiency,\ Baseline}$ = Average efficacy for baseline fan, 3.1 CFM/Watt[796]
$Fan_{Efficiency,\ Effcient}$ = Average efficacy for efficient fan, 8.3 CFM/Watt[797]

**Energy Savings**

$\Delta kWh$ = Hours * $\Delta kW$
= 8760 * 0.01
= 87.6 kWh

Where:

$\Delta kW$ = connected load kW savings per qualified ventilation fan and controls.
Hours = assumed annual run hours, 8760 for continuous ventilation.

**Baseline Efficiencies – New or Replacement**

New standard efficiency (average CFM/Watt of 3.1[798]) exhaust-only ventilation fan, quiet (< 2.0 sones[799]) operating in accordance with recommended ventilation rate indicated by ASHRAE 62.2[800]

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[795] 50CFM is the closest available fan size to ASHRAE 62.2 Section 4.1 Whole House Ventilation rates based upon typical square footage and bedrooms.
[796] Average of CFM/Watt values at two static pressures of 0.1 and 0.25 inches of water column for quiet fans rated for 50 CFM. Based on fan information gathered and referenced in the spreadsheet, "Residential Vent Fan Assessment.xls"
[797] Average of CFM/Watt values at two static pressures of 0.1 and 0.25 inches of water column for quiet fans rated for 50 CFM. Based on fan information gathered and referenced in the spreadsheet, "Residential Vent Fan Assessment.xls"
[798] Average of efficacies at static pressures of 0.1 and 0.25 inches of water column.
[799] Rated fan sound level at a static pressure of 0.1 inches of water column.

**High Efficiency**
New efficient (average CFM/watt of 8.3 ) exhaust-only ventilation fan, quiet (< 2.0 sones) Continuous operation in accordance with recommended ventilation rate indicated by ASHRAE 62.2[801]

**Operating Hours**
Continuous, 8760.

**Loadshape**
Loadshape # 25: Flat (8760 hours)

**Freeridership/Spillover Factors**

| Measure Category | | Ventilation | |
|---|---|---|---|
| Measure Code | | VNTXCEIL, | |
| Product Description | | Exhaust fan, ceiling, | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | 1.0 | 1.0 |
| LIMF NC | 6018LINC | 1.0 | 1.0 |
| LIMF Rehab | 6018LIRH | 0.95 | 1.1 |
| MF Mkt NC | 6019MFNC | 0.9 | 1.0 |
| MF Mkt Retro | 6020MFMR | 1.0 | 1.0 |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | 1.0 | 1.0 |
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |
| RES Retrofit | 6036RETR | 0.9 | 1.0 |
| RNC VESH | 6038VESH | 0.95 | 1.1 |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetime**

[800] On/off cycling controls may be required of baseline fans larger than 50CFM.
[801] Bi-level controls may be used by efficient fans larger than 50 CFM

19 years[802]
Analysis period is the same as the lifetime.

**Incremental Cost per Unit**
Incremental cost per installed fan is $43.50 for quiet, efficient fans.[803]

**Reference Tables**
None

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[802] Conservative estimate based upon GDS Associates Measure Life Report “Residential and C&I Lighting and HVAC measures” 25 years for whole-house fans, and 19 for thermostatically-controlled attic fans.
[803] See the Fan Info worksheet of the spreadsheet “Residential Vent Fan Assessment.xls”

# Residential New Construction Program

## Refrigeration End Use

# ENERGY STAR Refrigerator

Measure Number: VI-B-1-i (Residential New Construction Program, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 81
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**
1) 2013 RF Savings Analysis.xls;
2) 2009 VT Appliance Data w doc_CostAnalysisTRM
3) Refrigerator kW Calculations.xls

**Description**
An Energy Star, CEE Tier 2 or Tier 3 qualifying refrigerator is installed in place of a refrigerator of baseline efficiency.

**Algorithms**

**Energy Savings**[804]

**ENERGY STAR:**

$\Delta kWh = kWh_{base} - kWh_{ES}$
$= 600.4 – 480.3$
$= 120.1$

**CEE Tier 2:**

$\Delta kWh = kWh_{base} - kWh_{CT2}$
$\Delta kWh = 600.4 – 450.3$
$= 150.1$

**CEE Tier 3:**

$\Delta kWh_{CT3} = kWh_{base} - kWh_{CT3}$
$\Delta kWh_{CT3} = 600.4 – 420.3$
$= 180.1$

**Demand Savings**[805]

$\Delta kW_{ES} = \Delta kWh_{ES} / Hours$
$\Delta kW = 120.1 / 8477$
$= 0.014$

**CEE Tier 2:**

$\Delta kW = \Delta kWh_{CT2} / Hours$
$\Delta kW = 150.1 / 8477$
$= 0.018$

**CEE Tier 3:**

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[804] Based on analysis of previous year's rebated units, see 2013 RF Savings Analysis.xls.
[805] Based on analysis of previous year's rebated units, see 2013 RF Savings Analysis.xls.

$\Delta kW_{CT3} = \Delta kWh_{CT3} / Hours$

$\Delta kW_{CT3} = 180.1 / 8477$

$= 0.021$

Where:

| | |
|---|---|
| $\Delta kW$ | = gross customer connected load kW savings for the measure |
| $kWh_{base}$ | = Baseline unit consumption |
| $kWh_{ES}$ | = Energy-Star unit consumption |
| $kWh_{CT2}$ | = CEE Tier 2 unit consumption |
| $kWh_{CT3}$ | = CEE Tier 3 unit consumption |
| $\Delta kWh$ | = gross customer annual kWh savings for the measure |
| HOURS | = Equivalent Full Load Hours |
| | = 8477[806] |

**Baseline Efficiencies – New or Replacement**

Baseline efficiency is a refrigerator meeting the minimum Federal efficiency standard for refrigerator efficiency.

**High Efficiency**

The high efficiency level is a refrigerator meeting ENERGY STAR, CEE Tier 2 or CEE Tier 3 specifications for energy efficiency as of April 28th, 2008 (20%, 25% or 30% above Federal Standard respectively),

**Loadshape**

Loadshape #4, Residential Refrigeration, Vermont State Cost-Effectiveness Screening Tool.

**Freeridership/Spillover Factors**

| Measure Category | | Refrigeration | |
|---|---|---|---|
| Measure Codes | | RFRESRRP. RFRESRT2, RFRESRT3 | |
| Product Description | | Energy Star refrigerator, CEE Tier 2, CEE Tier 3 | |
| Track Name | Track No. | Freerider | Spillover |
| RNC VESH | 6038VESH | 1 | 1.0 |

**Persistence**

The persistence factor is assumed to be one.

**Lifetimes**

12 Years[807]

**Measure Cost**

The assumed incremental cost to the ENERGY STAR level is $40[808], to CEE Tier 2 level is $150 and to CEE Tier 3 is $230[809].

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806 The Summer and Winter Coincident kW are calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. To calculate an Equivalent Full Load Hours the UEC (* PartUse) is divided by the summer coincident kW (956 * .779)/0.088 = 8477 hours. The summer coincidence factor is therefore assumed to be 1.0 and a winter coincidence factor calculated as the relative winter to summer kW result from the algorithm. For the calculation see "Refrigerator kW Calculations.xls".

807 From ENERGY STAR calculator: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?e678-f5e6&e678-f5e6

808 From ENERGY STAR Calculator; based on Appliance Magazine, Market Research Report, January 2011; http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?e678-f5e6&e678-f5e6

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

[809] Based on review of data from the Northeast Regional ENERGY STAR Consumer Products Initiative; "2009 ENERGY STAR Appliances Practices Report", submitted by Lockheed Martin, December 2009. See 2009 VT Appliance Data_TRMCostAnalysis.xlsfor data.

### Lighting End Use
# Standard CFL Direct Install

Measure Number: VI-C-7-f (Residential New Construction Program, Lighting End Use)

**Version Date & Revision History**:
Draft date: Portfolio 76
Effective date: 01/01/12
End date: 12/31/14

**Referenced Documents:**

1. DI Cost Query.xls, Direct Install Prescriptive Lighting TAG.doc
2. Residential Lighting Markdown Impact Evaluation, Nexus Market Research, RLW Analytics, and GDS Associated, January 20, 2009
3. Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)
4. 2012 EISA Adjustment Calculations.xls

**Description**
A compact fluorescent lamp replaces an incandescent bulb in an interior lighting fixture in a low income single-family homes direct install application.

**Algorithms**
**Demand Savings**
$\Delta$kW = (($\Delta$Watts) /1000)* ISR

| Year | Algorithm | $\Delta$kW |
|---|---|---|
| 2012 | = (49.0 / 1000) * 0.8 | 0.0392 |
| 2013 | = (43.6 / 1000) * 0.8 | 0.0349 |
| 2014 | = (37.0 / 1000) * 0.8 | 0.0296 |

**Energy Savings**
$\Delta$kWh = (($\Delta$Watts) /1000) * ISR * HOURS

| Year | Algorithm | $\Delta$kWh |
|---|---|---|
| 2012 | = (49.0 / 1000) * 0.8 * 694 | 27.2 |
| 2013 | = (43.6 / 1000) * 0.8 * 694 | 24.2 |
| 2014 | = (37.0 / 1000) * 0.8 * 694 | 20.5 |

Where:
$\Delta$kW = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW
$Watts_{EE}$ = Energy efficient connected kW
$\Delta$kWh = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units rebated that actually get used
= 0.8[810]
HOURS = average hours of use per year
= 694[811]

**Baseline Efficiencies – New or Replacement**
The baseline is an incandescent bulb.

[810] 0.8 ISR based on TAG 2009 agreement.
[811] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011.

**Baseline Adjustment**
In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become Halogen bulbs (see percentages in O&M table below).

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012.
The appropriate adjustments are provided below (see CFL baseline savings shift.xls for details on how adjustment is calculated):

| Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|
| 2012 | 0.66 | 2 |
| 2013 | 0.77 | 1 |
| 2014 | 0.88 | 1 |

**High Efficiency**
High efficiency is an ENERGY STAR compact fluorescent bulb.
Delta watts based on NEEP Residential Lighting Survey, 2011.

**Operating Hours**
Operating hours will be assumed as 1.9 hours per day or 694 hours per year[812].

**Loadshape**
If Indoor, Loadshape #1 - Residential Indoor Lighting
If Outdoor, Loadshape #2 - Residential Outdoor Lighting

**Freeridership/Spillover Factors**

| Measure Category | | Light Bulbs/Lamps | |
|---|---|---|---|
| Measure Code | | LBLCFBLB | |
| Product Description | | Compact Fluorescent Screw-base bulb | |
| Track Name | Track No. | Freerider | Spillover |
| LIMF Retrofit | 6017RETR | 1 | 1 |
| LIMF NC | 6018LINC | 1 | 1 |
| LIMF Rehab | 6018LIRH | 1 | 1 |
| MF Mkt NC | 6019MFNC | 1 | 1 |
| MF Mkt Retro | 6020MFMR | 0.9 | 1.05 |
| LISF Retrofit | 6034LISF | 1 | 1 |
| RES Retrofit | 6036RETR | 0.9 | 1 |
| RNC VESH | 6038VESH | 1 | 1 |

**Persistence**
The persistence factor is assumed to be 90% as agreed to by EVT and the DPS (TAG 2007).

**Lifetimes**
Bulb life is assumed to be 8500 hours, based on agreement between EVT and the DPS (TAG 2009). At 694 hours per year and including the 90% persistence factor this equates to 11 years. A provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria

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[812] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011.

of at least 45 lumens per watt, in essence making the CFL baseline. Therefore the measure life will reduce each year and be equal to the number of years remaining to 2020; so for 2012 this will be 8 years, 2013 7 years.

Analysis period is the same as the lifetime.

**Measure Cost**[813]
The average installed cost is assumed to be $6.09 ($2.50 for the bulb and $3.59 for labor)[814].

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Methodology for Computing O&M Savings**
In order to account for the shift in baseline due to the Federal Legislation, the levelized baseline replacement cost over the lifetime of the CFL was calculated (see 2012 EISA Adjustments.xls). The key assumptions used in this calculation are documented below:

| | Incandescent | Halogen | CFL |
|---|---|---|---|
| Replacement Cost | $0.50 | $1.50 | $2.50 |
| Component Life (hours) | 1000 | 1000 | 8500 |
| Baseline % in 2009-2011 | 100% | 0% | 0% |
| Baseline % in 2012 | 67% | 33% | 0% |
| Baseline % in 2013 | 33% | 67% | 0% |
| Baseline % in 2014 onward | 0% | 100% | 0% |
| Baseline % in 2020 onward | 0% | 0% | 100% |

The calculation results in a levelized assumption of $0.93 baseline replacement cost every 1 year for CFL installations in 2012, $0.96 every year for installations in 2013, and $0.98 for installations in 2014. This adjustment will be recalculated for subsequent years.

[813] 2009 cost represents full, installed cost and is computed with a weighted average of all direct install interior CFLs installed under the Efficiency Vermont Existing Homes and Low Income Program between 1/1/2006 and 12/1/2007. 2010 and 2011 costs decline at same rate as the assumption for CFL bulbs.
[814] $2.50 for CFL is based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011. Labor rate consistent with other measures.

# Specialty CFL Direct Install

Measure Number: VI-C-16-a (Residential New Construction Program, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 75
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**

1. 2009 to 2011 bulbs installed.xlsx
2. Xenergy, 1998; "Process and Impact Evaluation of Joint Utilities Starlights Residential Lighting Program".

**Description**
An existing incandescent bulb is replaced with a lower wattage ENERGY STAR qualified specialty compact fluorescent bulb through a Direct Install program. Specialty CFL bulbs are defined as lamps for general illumination that use fluorescent light emitting technology and an integrated electronic ballast with or without a standard Edison screw-base. They can be dimmable, designed for special applications, have special color enhancement properties or have screw-bases that are not standard Edison bases, and include A-lamps, candelabras, G-lamps (globe), reflectors, torpedoes, dimmables, and 3-way bulbs. This TRM should be used for both interior and exterior installations, the only difference being the loadshape. Note specialty bulbs are currently exempt from EISA regulations.

**Algorithms**

**Demand Savings**
$\Delta kW = ((\Delta Watts) / 1000) \times ISR$
$\Delta kW(Res. <=15W) = ((43.9) / 1000) \times 0.8 = 0.0351$
$\Delta kW(Res. >15W) = ((62.6) / 1000) \times 0.8 = 0.0501$

**Energy Savings**
$\Delta kWh = \Delta kW \times HOURS$
$\Delta kWh\ (Res. <=15W) = (0.0351 \times 694) = 24.4$
$\Delta kWh\ (Res. >15W) = (0.0501 \times 694) = 34.8$

Where:

| | |
|---|---|
| $\Delta kW$ | = gross customer connected load kW savings for the measure |
| $\Delta Watts$ | = Average delta watts between specialty CFL and incandescent $Watts_{BASE} - Watts_{EE}$[815] |
| ISR | = in service rate or the percentage of units rebated that actually get used[816] |
| $\Delta kWh$ | = gross customer annual kWh savings for the measure |
| HOURS | = average hours of use per year |

**Baseline Efficiencies – New or Replacement**
The baseline condition is an incandescent specialty light bulb.

**High Efficiency**
High efficiency is an ENERGY STAR qualified specialty compact fluorescent lamp.

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[815] The delta watts is calculated by finding the weighted average wattage of specialty bulbs installed in Existing Homes, Low Income and RNC from 01/2009-04/2011. The equivalent incandescent wattage was used to calculate delta watts. See 2009 to 2011 bulbs installed.xlsx
[816] ISR is assumed to be equal to standard CFL Direct Install measure, and is based on a 2009 TAG agreement.

**Operating Hours**
Assumed to be 1.9 hours a day or 694 hours per year [817].

**Loadshape**
Loadshape #1: Residential Indoor Lighting
Loadshape #2: Residential Outdoor Lighting

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Freeridership/Spillover Factors**

| Measure Category | | Light Bulbs/Lamps | |
|---|---|---|---|
| Measure Code | | LBLCFSPD | |
| Product Description | | Compact Fluorescent – Specialty Bulb Direct Install | |
| Track Name | Track No. | Freerider | Spillover |
| LIMF Retrofit | 6017RETR | 1 | 1 |
| LIMF NC | 6018LINC | 1 | 1 |
| LIMF Rehab | 6018LIRH | 1 | 1 |
| MF Mkt NC | 6019MFNC | 1 | 1 |
| MF Mkt Retro | 6020MFMR | 1 | 1 |
| LISF Retrofit | 6034LISF | 1 | 1 |
| RES Retrofit | 6036RETR | 0.9 | 1 |
| RNC VESH | 6038VESH | 1 | 1 |

**Persistence**
The persistence factor is assumed to be 90% as agreed to by EVT and the DPS (TAG 2007).

**Lifetimes**
Bulb life is assumed to be 8500 hours, based on agreement between EVT and the DPS (TAG 2009). The measure life, including the 90% persistence factor is therefore assumed to be 8500/694 * 0.9 = 11 years. Analysis period is the same as the lifetime.

**Measure Cost**[818]
Cost (Watts <=15) = \$8.16 + \$3.59 (labor) = \$11.75
Cost (Watts >15) = \$8.84 + \$3.59 (labor) = \$12.43

**Incentive Level**
The incentive level is equal to the measure cost (these bulbs are free to the customer).

**O&M Cost Adjustments**
O& M cost adjustments are based on component costs provided in the reference table below.

**Water Descriptions**
There are no water algorithms or default values for this measure.

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[817] Hours of use are based on TAG 2011 agreement to use the NEEP Residential Lighting Survey, 2011 proposed values.
[818] Incremental cost of bulb is consistent with the assumptions from the NEEP Residential Lighting Survey, 2011. This evaluation did not provide the <=15W and >15W categories and so the costs from EVT's analysis of incremental costs are adjusted such that the average matches the values from the NEEP study. Labor cost is consistent with the standard bulb direct install measures.

**Reference Tables**
**Component Costs and Lifetimes Used in Computing O&M Savings**

**Residential**

| | Baseline Measures | |
|---|---|---|
| Component | Cost[819] | Life[820] |
| Lamp<=15W | $2.71 | 1.4 |
| Lamp>15W | $4.29 | 1.4 |

[819] Baseline cost is consistent with the assumptions from the NEEP Residential Lighting Survey, 2011. This evaluation did not provide the <=15W and >15W categories and so the costs from EVT's analysis of baseline costs are adjusted such that the average matches the values from the NEEP study
[820] Based on the assumption that the incandescent bulb rated life is 1000 hours. 1000/694 = 1.4years.

# Solid State (LED) Recessed Downlight

Measure Number: VI-C-15-a (Residential New Construction Program, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio No. 52
Effective date: 01/01/08
End date: TBD

Referenced Documents: 1) 2005_lighting_wattage_EPP.xls

**Description**
An LED Downlight is used in place of an incandescent downlight. The downlight must be tested by the DOE Caliper Testing Program or Independent 3rd party testing with results shown to meet the upcoming Energy Star Specification for Solid State Luminaires. This Specification will take effect September 31st, 2008, and can be downloaded from www.netl.doe.gov . See Reference Table of Energy Star requirements for recessed downlights.

**Algorithms**

**Demand Savings**[821]
$\Delta kW = ((Watts_{BASE} - Watts_{EE}) / 1000) \times ISR$
$\Delta kW = ((65 - 12) / 1000) \times 0.73) = 0.0387$

**Energy Savings**
$\Delta kWh = \Delta kW \times HOURS$
$\Delta kWh = (0.0387 \times 1241) = 48.0$

Where:

| | |
|---|---|
| $\Delta kW$ | = gross customer connected load kW savings for the measure |
| $Watts_{BASE}$ | = Baseline connected kW.[822] |
| $Watts_{EE}$ | = Energy efficient connected kW.[823] |
| $\Delta kWh$ | = gross customer annual kWh savings for the measure |
| ISR | = in service rate or the percentage of units rebated that actually get used[824] |
| HOURS | = average hours of use per year[825] |

**Waste Heat Adjustment**
Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF). See above.

**Baseline Efficiencies – New or Replacement**
The baseline condition is a 65 watt BR30 incandescent fixture installed in a screw-base socket.

**High Efficiency**
High Efficiency is a downlight that has been tested by the DOE Caliper Testing Program or Independent 3rd party testing with results shown to meet the upcoming Energy Star Specification for Solid State Luminaires. This Specification will take effect September 31st, 2008, and can be downloaded from www.netl.doe.gov . See Reference Table of Energy Star requirements for recessed downlights.

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821 Assumed difference in wattage between installed CFL and the incandescent bulb it replaces. Based on EVT analysis of CFLs rebated through Efficient Products Program.
822 Baseline wattage based on 65 Watt BR30 incandescent bulb.
823 Energy Efficient wattage based on 12 Watt LR6 Downlight from LLF Inc.
824 ISR differs for residential and commercial applications. See table below for ISR in each application.
825 Hours of usage differs for residential and commercial applications. See table below for HOURS at each application.

**Operating Hours**
Residential: 1,241 hours / year

**Loadshape**
Residential: Loadshape #1: Residential Indoor Lighting
Source: Vermont State Cost-Effectiveness Screening Tool.

**Freeridership/Spillover Factors**

| Measure Category | | LED | |
|---|---|---|---|
| Measure Code | | LFHRDLED | |
| Product Description | | Solid State Recessed Downlight | |
| Track Name | Track No. | Freerider | Spillover |
| Efficient Products | 6032EPEP | 0.94 | 1.25 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
Lifetime is a function of the average hours of use of the lumenaire. The Energy Star Specification for Solid State Recessed Downlights requires luminaires to maintain at least 70% initial light output for 25,000 hrs in a residential application and 35,000 hours in a commercial application. Based on these lifetimes, LED Recessed Downlights rebated through this program are expected to have a life of 20.1 years for residential applications (assumed average daily usage of 3.4 hours) and 10.0 years for commercial applications (assumed daily usage of 9.6 hours).

Analysis period is 20 years for residential installations, 10 years for commercial installations.

**Measure Cost**
The incremental cost for this measure is $80

**Incentive Level**
The incentive level for this measure is $40

**O&M Cost Adjustments**

| | Annual O&M Savings[826] |
|---|---|
| Residential | $2.64 |

**Fossil Fuel Descriptions**
See Heating Increased Usage above.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

**Hours of Use, In Use Rates, and Waste Heat Factors by Customer Type**

| | Average Annual Hours of Use | Average In Service Rate | $WHF_d$ | $WHF_e$ | AR | HF |
|---|---|---|---|---|---|---|
| Residential | 1,241 | 0.73 | 1.0 | 1.0 | 1.0 | 0.0 |

[826] From VT State screening tool

**Component Costs and Lifetimes Used in Computing O&M Savings**
**Residential**

| | Efficient Measures | | Baseline Measures | |
|---|---|---|---|---|
| Component | Cost | Life[827] | Cost | Life |
| Lamp | 0 | 20 | $3.17 | 1.2 |

**Commercial**

| | Efficient Measures | | Baseline Measures | |
|---|---|---|---|---|
| Component | Cost | Life[828] | Cost | Life |
| Lamp | 0 | 10 | $3.17 | 0.40 |

**Partial List of Energy Star Requirements for Solid State Recessed Downlights**

| | |
|---|---|
| Lumen Depreciation / Lifetime | LED shall deliver at least 70% of initial lumens for the minimum number of hours specified below:<br>• >= 25,000 hrs Residential Indoor<br>• >= 35,000 hrs Commercial |
| Minimum CRI | 75 |
| Minimum Light Output | <= 4.5" Aperture: 345 lumens (initial)<br>> 4.5" Aperture: 575 lumens (initial) |
| Zonal Lumen Density Requirement | Luminaire shall deliver a total of 75% lumens (initial) within the 0-60 zone (bilaterally symmetrical) |
| Minimum Luminaire Efficacy | 35 lm/w |
| Allowable CCTs | • 2700K, 3000K, and 3500K for residential products<br>• No restrictions for commercial |
| Reduced Air Leakage | Recessed downlights intended for installation in insulated ceilings shall be IC rated and be leak tested per ASTM E283 to demonstrate no more than 2.0 cfm at 75 Pascals pressure difference. The luminaire must include a label certifying "sirtight" or similar designation to show accordance with ASTM E283. |
| Minimum Warranty | 3 years |

- Eligible Products must meet the full requirements of the Energy Star specification. The complete Energy Star Specification for Solid State Luminaires can be obtained at www.netl.doe.gov

[827] Life of components based on use patterns of specific application.
[828] Life of components based on use patterns of specific application.

# Interior Recessed Fluorescent Fixture

Measure Number: VI-C-11-c (Residential New Construction Program, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 76
Effective date: 1/1/12
End date: 12/31/2012

Referenced Documents:
1) RNC Lighting Fixture Reference 2012.xlsx
2) 2012 EISA Adjustment Calculations.xls
3) ) Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)
4) NMR, RLW Analytics "Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs"

**Description**
An ENERGY STAR qualified interior recessed lighting fixture wired for exclusive use with pin-based compact fluorescent lamps or other interior recessed lighting fixture with ENERGY STAR qualified screw-based compact fluorescent lamps replaces an interior recessed lighting fixture with incandescent lamp(s) in a residential new construction application

**Algorithms**[829]
**Demand Savings**
$\Delta$kW = ((Watts$_{BASE}$ – Watts$_{EE}$) /1000) * ISR* SA$_{code}$

$\Delta$kW 2012 = (( 72.0 – 21.9 / 1000) * 1.0 * 0.70) = 0.0351
2013 = (( 64.0 – 21.9 / 1000) * 1.0 * 0.65) = 0.0274
2014 = (( 57.0 – 21.9 / 1000) * 1.0 * 0.60) = 0.0211

**Energy Savings**
$\Delta$kWh = ((Watts$_{BASE}$ – Watts$_{EE}$) /1000) * HOURS * ISR * SA$_{code}$

$\Delta$kWh 2012 = (( 72.0 – 21.9 / 1000) * 912 * 1.0 * 0.70) = 32.0
2013 = (( 64.0 – 21.9 / 1000) * 912 * 1.0 * 0.65) = 25.0
2014 = (( 57.0 – 21.9 / 1000) * 912 * 1.0 * 0.60) = 19.2

Where:
$\Delta$kW = gross customer connected load kW savings for the measure
Watts$_{BASE}$ = Baseline connected kW
Watts$_{EE}$ = Energy efficient connected kW
$\Delta$kWh = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units rebated that actually get used
HOURS = average hours of use per year
SA$_{code}$ = Savings adjustment to account for code required efficient lighting

| Year | SAcode |
|---|---|
| 2012 | 30% |
| 2013 | 35% |
| 2014 | 40% |

[829] Baseline and efficient wattages derived from EVT fixture data installed in new residential homes between 2003 and 2007. After 2007 EVT stopped collecting detailed fixture data. Baseline wattages have been adjusted for years 2012, 2013 and 2014 based on new federal regulations (EISA) for incandescent bulbs (see reference docs).

**Savings Adjustment**
The 2011 RBES requires a minimum of 50% of lamps in permanently installed fixtures to be high efficacy lamps. The savings for these efficient lamps needs to be subtracted from the total lighting savings calculated for each home. In 2012, the savings adjustment for code required efficient lighting shall be based on the assumption that 30% of installed lighting is efficient due to code (the 2008 NMR baseline study reported 22% efficient lighting in new non-ENERGY STAR qualified homes). This accounts for the time lag in market transformation, and for the fact that the residential building energy code is not currently consistently enforced. This will increase by 5% each year and may be updated when new baseline study results are known.

**Baseline Efficiencies – New or Replacement**
An interior recessed lighting fixture with incandescent lamp(s).

**Baseline Mid-Life Adjustment**
In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become EISA qualified incandescent or Halogen bulbs.

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012, 2013 or 2014 depending on the assumed baseline wattage (note if a mix of bulbs is assumed, the adjustment always occurs in 2012).

The appropriate adjustments are provided below (see 2012 EISA Adjustment Calculations.xls for details):

| Measure | Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|---|
| Interior Recessed Fluorescent Fixture | 2012 | 0.61 | 2 |
| | 2013 | 0.76 | 1 |
| | 2014 | 0.88 | 1 |

**High Efficiency**
An ENERGY STAR qualified interior recessed lighting fixture wired for exclusive use with pin-based compact fluorescent lamps or other interior recessed lighting fixture with ENERGY STAR qualified screw-based compact fluorescent lamps.

**Operating Hours**
912 hours / year (2.5 hrs per day)[830]

**Loadshape**
Residential Indoor Lighting, #1
Source: Vermont State Cost-Effectiveness Screening Tool.

**Freeridership/Spillover Factors**

| Measure Category | | Residential Lighting Hardwired Fixture | | | | | |
|---|---|---|---|---|---|---|---|
| Measure Code | | LFHCNREC | | | | | |
| Product Description | | Compact fluorescent interior recessed fixture | | | | | |
| | | 2012 | | 2013 | | 2014 | |
| Track Name | Track No. | Freerider | Spillover | Freerider | Spillover | Freerider | Spillover |
| RNC VESH | 6038VESH | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |

[830] Based upon 2005 results from RLW Metering study (2005 RLW memo following on from "Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs")

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
20 years[831].
Note: a provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore the analysis period (i.e. the life of the savings) is reduced to the number of years remaining to 2020. So for installations in 2012, the measure life is 8 years, for 2013 7 years.

**Measure Cost**
The incremental cost for this measure is $32[832]

**Annual Operations and Maintenance Savings**
Because compact fluorescent lamps last much longer than incandescent bulbs, CFLs offer significant operation and maintenance (O&M) savings over the life of the fixture for avoided incandescent lamps and the labor to install them. The following assumptions are used to calculate the O&M savings:
Incandescent bulb cost: $0.50 per bulb
Life of incandescent bulb: 1000 hours
EISA qualified bulb cost: $1.50 per bulb
Life of EISA qualified bulb: 1000 hours
CFL lamp cost: $2.50 per lamp
Life of CFL lamp: 8,500 hours (RES),
CFL ballast replacement cost: n/a

The O&M calculation results in a levelized annual baseline replacement cost as presented below (see 2012 EISA Adjustment Calculations.xls for details) [833]:

| Measure | Year Installed | Annual baseline replacement cost | Annual efficient replacement cost |
|---|---|---|---|
| Interior Recessed Fluorescent Fixture | 2012 | $1.95 | $0.63 |
| | 2013 | $2.10 | $0.71 |
| | 2014 | $2.29 | $0.81 |

This adjustment will be recalculated for subsequent years

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

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831 "Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures", GDS Associates, June 2007 (http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf).

832 ENERGY STAR Qualified Lighting Savings Calculator default incremental cost input

833 Note: As described above, the measure life is reduced to the number of years remaining until 2020 when the EISA legislation makes the CFL the baseline. The O&M calculation takes the entire stream of replacements for both the baseline and efficient cases over the actual expected lifetime (20 years) and converts to a levelized annual cost over the reduced measure 'savings' lifetime.

# Interior Surface Fluorescent Fixture

Measure Number: VI-C-10-c (Residential New Construction Program, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 76
Effective date: 1/1/12
End date: 12/31/2014

**Referenced Documents:**

1) RNC Lighting Fixture Reference 2012.xlsx
2) 2012 EISA Adjustment Calculations.xls
3) Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)
4) NMR, RLW Analytics "Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs"

**Description**
An ENERGY STAR qualified interior surface lighting fixture wired for exclusive use with pin-based compact fluorescent lamps or other interior surface lighting fixture with ENERGY STAR qualified screw-based compact fluorescent lamps replaces an interior surface lighting fixture with incandescent lamp(s) in a residential new construction application. This category includes surface ceiling and surface wall fixtures.

**Algorithms**[834]

**Demand Savings**
$\Delta kW = ((Watts_{BASE} – Watts_{EE}) /1000) * ISR * SA_{code}$

$\Delta kW$ 2012 = (( 116.0 - 27.8 / 1000) * 1.0 *0.70) = 0.0617
2013 = (( 110.0- 27.8 / 1000) * 1.0 *0.65) = 0.0534
2014 = (( 96 - 27.8 / 1000) * 1.0 *0.60) = 0.0409

**Energy Savings**
$\Delta kWh = ((Watts_{BASE} – Watts_{EE}) /1000) * HOURS * ISR * SA_{code}$

$\Delta kWh$ 2012 = (( 116.0 - 27.8 / 1000) * 912 * 1.0 *0.70) = 56.3
2013 = (( 110.0- 27.8 / 1000) * 912 * 1.0 *0.65) = 48.7
2014 = (( 96 - 27.8 / 1000) * 912 * 1.0 *0.60) = 37.3

Where:

$\Delta kW$ = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW
$Watts_{EE}$ = Energy efficient connected kW
$\Delta kWh$ = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units rebated that actually get used
HOURS = average hours of use per year
$SA_{code}$ = Savings adjustment to account for code required efficient lighting.

| Year | SAcode |
|---|---|
| 2012 | 30% |
| 2013 | 35% |
| 2014 | 40% |

[834] Baseline and efficient wattages derived from EVT fixture data installed in new residential homes between 2003 and 2007. After 2007 EVT stopped collecting detailed fixture data. Baseline wattages have been adjusted for years 2012, 2013 and 2014 based on new federal regulations (EISA) for incandescent bulbs (see reference docs).

**Savings Adjustment**
The 2011 RBES requires a minimum of 50% of lamps in permanently installed fixtures to be high efficacy lamps. The savings for these efficient lamps needs to be subtracted from the total lighting savings calculated for each home. In 2012, the savings adjustment for code required efficient lighting shall be based on the assumption that 30% of installed lighting is efficient due to code (the 2008 NMR baseline study reported 22% efficient lighting in new non-ENERGY STAR qualified homes). This accounts for the time lag in market transformation, and for the fact that the residential building energy code is not currently consistently enforced. This will increase by 5% each year and may be updated when new baseline study results are known.

**Baseline Efficiencies – New or Replacement**
The baseline condition is an interior surface lighting fixture with incandescent lamp(s).

**Baseline Mid-Life Adjustment**
In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become EISA qualified incandescent or Halogen bulbs.

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012, 2013 or 2014 depending on the assumed baseline wattage (note if a mix of bulbs is assumed, the adjustment always occurs in 2012).

The appropriate adjustments are provided below (see 2012 EISA Adjustment Calculations.xls for details):

| Measure | Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|---|
| Interior Surface Fluorescent Fixture | 2012 | 0.67 | 2 |
| | 2013 | 0.73 | 1 |
| | 2014 | 0.85 | 1 |

**High Efficiency**
An ENERGY STAR qualified interior surface lighting fixture wired for exclusive use with pin-based compact fluorescent lamps or other interior surface lighting fixture with ENERGY STAR qualified screw-based compact fluorescent lamps.

**Operating Hours**
912 hours / year (2.5 hrs per day)[835]

**Loadshape**
Residential Indoor Lighting, #1
Source: Vermont State Cost-Effectiveness Screening Tool.

**Freeridership/Spillover Factors**

| **Measure Category** | | **Residential Lighting Hardwired Fixture** | | | | | |
|---|---|---|---|---|---|---|---|
| **Measure Code** | | **LFHCNSUR** | | | | | |
| **Product Description** | | **Compact fluorescent interior surface fixture** | | | | | |
| | | **2012** | | **2013** | | **2014** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** | **Freerider** | **Spillover** | **Freerider** | **Spillover** |
| RNC VESH | 6038VESH | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |

[835] Based upon 2005 results from RLW Metering study (2005 RLW memo following on from "Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs")

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
20 years[836].
Note: a provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore the analysis period (i.e. the life of the savings) is reduced to the number of years remaining to 2020. So for installations in 2012, the measure life is 8 years, for 2013 7 years.

**Measure Cost**
The incremental cost for this measure is $32[837]

**Annual Operations and Maintenance Savings**
Because compact fluorescent lamps last much longer than incandescent bulbs, CFLs offer significant operation and maintenance (O&M) savings over the life of the fixture for avoided incandescent lamps and the labor to install them. The following assumptions are used to calculate the O&M savings:
Incandescent bulb cost: $0.50 per bulb
Life of incandescent bulb: 1000 hours
EISA qualified bulb cost: $1.50 per bulb
Life of EISA qualified bulb: 1000 hours
CFL lamp cost: $2.50 per lamp
Life of CFL lamp: 8,500 hours (RES),
CFL ballast replacement cost: n/a

The O&M calculation results in a levelized annual baseline replacement cost as presented below (see 2012 EISA Adjustment Calculations.xls for details) [838]:

| Measure | Year Installed | Annual baseline replacement cost | Annual efficient replacement cost |
|---|---|---|---|
| Interior Surface Fluorescent Fixture | 2012 | $2.95 | $0.63 |
| | 2013 | $3.30 | $0.71 |
| | 2014 | $3.46 | $0.81 |

This adjustment will be recalculated for subsequent years

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

[836] "Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures", GDS Associates, June 2007 (http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf).
[837] ENERGY STAR Qualified Lighting Savings Calculator default incremental cost input for interior fixture.
[838] Note: As described above, the measure life is reduced to the number of years remaining until 2020 when the EISA legislation makes the CFL the baseline. The O&M calculation takes the entire stream of replacements for both the baseline and efficient cases over the actual expected lifetime (20 years) and converts to a levelized annual cost over the reduced measure 'savings' lifetime.

# Exterior Fluorescent Fixture

Measure Number: VI-C-3-g (Residential New Construction, Lighting End Use)

Version Date & Revision History
Draft date: Portfolio 76
Effective date: 1/1/12
End date: 12/31/14

**Referenced Documents:**

1) RNC Lighting Fixture Reference 2012.xlsx
2) NMR, RLW Analytics "Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs"
3) 2012 EISA Adjustment Calculations.xls
4) Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)

**Description**

An ENERGY STAR qualified exterior lighting fixture wired for exclusive use with pin-based compact fluorescent lamp(s) or other exterior lighting fixture with ENERGY STAR qualified screw-based compact fluorescent lamps replaces an exterior lighting fixture with incandescent lamp(s) in a residential new construction application. This measure characterization applies to exterior fluorescent fixtures in the following exterior locations: post lamp, recessed ceiling, surface ceiling, and surface wall.

**Algorithms**[839]

**Demand Savings**

$\Delta kW = ((Watts_{BASE} – Watts_{EE}) /1000) * ISR * SA_{code}$

$\Delta kW$ 2012 = (( 72.0 - 21.7 / 1000) * 1.0 *0.70) = 0.0352
2013 = (( 64.0 - 21.7 / 1000) * 1.0 *0.65) = 0.0275
2014 = (( 57.0 - 21.7 / 1000) * 1.0 *0.60) = 0.0212

**Energy Savings**

$\Delta kWh = ((Watts_{BASE} – Watts_{EE}) /1000) * HOURS * ISR * SA_{code}$

$\Delta kWh$ 2012 =(( 72.0 - 21.7 / 1000) * 1,642.5 * 1.0 *0.70) = 57.8
2013 = (( 64.0 - 21.7 / 1000) * 1,642.5 * 1.0 *0.65) = 45.2
2014 = (( 57.0 - 21.7 / 1000) * 1,642.5 * 1.0 *0.60) = 34.8

Where:

$\Delta kW$ = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW
$Watts_{EE}$ = Energy efficient connected kW
$\Delta kWh$ = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units rebated that actually get used
HOURS = average hours of use per year
$SA_{code}$ = Savings adjustment to account for code required efficient lighting.

| Year | SAcode |
|---|---|

[839] Baseline and efficient wattages derived from EVT fixture data installed in new residential homes between 2003 and 2007. After 2007 EVT stopped collecting detailed fixture data. Baseline wattages have been adjusted for years 2012, 2013 and 2014 based on federal regulations (EISA) for incandescent bulbs consistent with bulb wattages proposed by NEEP RLS, 2011 (see reference docs).

| | |
|---|---|
| 2012 | 30% |
| 2013 | 35% |
| 2014 | 40% |

**Savings Adjustment**

The 2011 RBES requires a minimum of 50% of lamps in permanently installed fixtures to be high efficacy lamps. The savings for these efficient lamps needs to be subtracted from the total lighting savings calculated for each home. In 2012, the savings adjustment for code required efficient lighting shall be based on the assumption that 30% of installed lighting is efficient due to code (the 2008 NMR baseline study reported 22% efficient lighting in new non-ENERGY STAR qualified homes). This accounts for the time lag in market transformation, and for the fact that the residential building energy code is not currently consistently enforced. This will increase by 5% each year and may be updated when new baseline study results are known.

**Baseline Efficiencies – New or Replacement**

An exterior lighting fixture with incandescent lamp(s).

**Baseline Mid-Life Adjustment**

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become EISA qualified incandescent or Halogen bulbs.

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012, 2013 or 2014 depending on the assumed baseline wattage (note if a mix of bulbs is assumed, the adjustment always occurs in 2012).
The appropriate adjustments are provided below (see 2012 EISA Adjustment Calculations.xls for details):

| Measure | Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|---|
| Exterior Fluorescent Fixture | 2012 | 0.61 | 2 |
| | 2013 | 0.76 | 1 |
| | 2014 | 0.89 | 1 |

**High Efficiency**

An ENERGY STAR qualified exterior lighting fixture wired for exclusive use with pin-based fluorescent lamp(s) or other exterior lighting fixture with ENERGY STAR qualified screw-based compact fluorescent lamps.

**Operating Hours**

1,642.5 hours / year[840]

**Loadshape**

Residential Outdoor Lighting, #2. Vermont State Cost-Effectiveness Screening Tool.

**Freeridership/Spillover Factors**

| **Measure Category** | | **Residential Lighting Hardwired Fixture** | | | | | |
|---|---|---|---|---|---|---|---|
| **Measure Code** | | **LFHCEFIX** | | | | | |
| **Product Description** | | **Exterior Fluorescent Fixture** | | | | | |
| | | **2012** | | **2013** | | **2014** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** | **Freerider** | **Spillover** | **Freerider** | **Spillover** |
| RNC VESH | 6038VESH | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |

[840] NMR, RLW Analytics "Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs"

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
Lifetime for a fluorescent fixture is 15 years[841].
Note: a provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore the analysis period (i.e. the life of the savings) is reduced to the number of years remaining to 2020. So for installations in 2012, the measure life is 8 years, for 2013 7 years.

**Measure Cost**
The average installed cost is $17[842]

**Annual Operations and Maintenance Savings**
Because compact fluorescent lamps last much longer than incandescent bulbs, CFLs offer significant operation and maintenance (O&M) savings over the life of the fixture for avoided incandescent lamps and the labor to install them. The following assumptions are used to calculate the O&M savings:
Incandescent bulb cost: $0.50 per bulb
Life of incandescent bulb: 1000 hours
EISA qualified bulb cost: $1.50 per bulb
Life of EISA qualified bulb: 1000 hours
CFL lamp cost: $2.50 per lamp
Life of CFL lamp: 8,500 hours (RES),
CFL ballast replacement cost: $14 (RES)
Life of CFL ballast: 24,959 hours (RES)

The O&M calculation results in a levelized annual baseline replacement cost as presented below (see 2012 EISA Adjustment Calculations.xls for details) [843]:

| Measure | Year Installed | Annual baseline replacement cost | Annual efficient replacement cost |
|---|---|---|---|
| Exterior Fixture (RES) | 2012 | $2.67 | $0.56 |
| | 2013 | $2.85 | $0.63 |
| | 2014 | $2.97 | $0.73 |

This adjustment will be recalculated for subsequent years

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

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[841] "Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures", GDS Associates, June 2007 (http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf).

[842] ENERGY STAR Qualified Lighting Savings Calculator default incremental cost input for exterior fixtures.
[843] Note: As described above, the measure life is reduced to the number of years remaining until 2020 when the EISA legislation makes the CFL the baseline. The O&M calculation takes the entire stream of replacements for both the baseline and efficient cases over the actual expected lifetime (20 years) and converts to a levelized annual cost over the reduced measure 'savings' lifetime.

# Generic Linear Fluorescent Tube Fixture

Measure Number: VI-C-9-e (Residential New Construction Program, Lighting End Use)

**Version Date & Revision History**
Draft Date: Portfolio 76
Effective: 1/1/12
End: 12/31/2014

**Referenced Documents:**

1) RNC Lighting Fixture Reference 2012.xlsx
2) 2012 EISA Adjustment Calculations.xls
3) Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)
4) NMR, RLW Analytics "Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs"

**Description**
Generic linear fluorescent tube fixture(s) replaces an interior lighting fixture in a residential new construction application. This category includes surface ceiling and surface wall fixtures using a linear fluorescent tube.

**Algorithms**[844]
**Demand Savings**
$\Delta kW = ((Watts_{BASE} – Watts_{EE}) /1000)* ISR * SA_{code}$

$\Delta kW$ 2012 = ((247.5– 58.0 / 1000) * 1.0 * 0.70) = 0.133
2013 = ((220.0– 58.0 / 1000) * 1.0 * 0.65) = 0.105
2014 = ((209.0– 58.0 / 1000) * 1.0 * 0.60) = 0.091

**Energy Savings**
$\Delta kWh = ((Watts_{BASE} – Watts_{EE}) /1000) * HOURS * ISR * SA_{code}$

$\Delta kWh$ 2012 = ((247.5– 58.0 / 1000) * 912* 1.0 * 0.70) = 121.0
2013 = ((220.0– 58.0 / 1000) * 912* 1.0 * 0.65) = 96.0
2014 = ((209.0– 58.0 / 1000) * 912* 1.0 * 0.60) = 82.6

Where:

$\Delta kW$ = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW
$Watts_{EE}$ = Energy efficient connected kW
$\Delta kWh$ = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units rebated that actually get used
HOURS = average hours of use per year
$SA_{code}$ = Savings adjustment to account for code required efficient lighting

| Year | SAcode |
|---|---|
| 2012 | 30% |
| 2013 | 35% |
| 2014 | 40% |

[844] Baseline and efficient wattages derived from EVT fixture data installed in new residential homes between 2003 and 2007. After 2007 EVT stopped collecting detailed fixture data. Baseline wattages have been adjusted for years 2012, 2013 and 2014 based on new federal regulations (EISA) for incandescent bulbs (see reference docs).

**Savings Adjustment**

The 2011 RBES requires a minimum of 50% of lamps in permanently installed fixtures to be high efficacy lamps. The savings for these efficient lamps needs to be subtracted from the total lighting savings calculated for each home. In 2012, the savings adjustment for code required efficient lighting shall be based on the assumption that 30% of installed lighting is efficient due to code (the 2008 NMR baseline study reported 22% efficient lighting in new non-ENERGY STAR qualified homes). This accounts for the time lag in market transformation, and for the fact that the residential building energy code is not currently consistently enforced. This will increase by 5% each year and may be updated when new baseline study results are known.

**Baseline Efficiencies – New or Replacement**

The baseline is an interior incandescent lighting fixture.

**Baseline Mid-Life Adjustment**

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become EISA qualified incandescent or Halogen bulbs.

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012, 2013 or 2014 depending on the assumed baseline wattage (note if a mix of bulbs is assumed, the adjustment always occurs in 2012).

The appropriate adjustments are provided below (see 2012 EISA Adjustment Calculations.xls for details):

| Measure | Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|---|
| Generic Linear Fluorescent Fixture | 2012 | 0.76 | 1 |
| | 2013 | 0.88 | 1 |
| | 2014 | 0.93 | 1 |

**High Efficiency**

An interior lighting fixture with one or more florescent tube lamps. Generic linear florescent tubes include, T-8s, T-5s, as well as U-tubes.

**Operating Hours**

912 hours / year (2.5 hrs per day)[845]

**Loadshape**

Residential Indoor Lighting, #1. Vermont State Cost-Effectiveness Screening Tool

**Freeridership/Spillover Factors**

| **Measure Category** | | **Residential Lighting Hardwired Fixture** | | | | | |
|---|---|---|---|---|---|---|---|
| **Measure Code** | | **LFHGENFT** | | | | | |
| **Product Description** | | **Generic Linear Fluorescent Tube Fixture** | | | | | |
| | | **2012** | | **2013** | | **2014** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** | **Freerider** | **Spillover** | **Freerider** | **Spillover** |
| RNC VESH | 6038VESH | 0.60 | 1.0 | 0.5 | 1.0 | 0.4 | 1.0 |

**Persistence**

The persistence factor is assumed to be one.

845 Based upon 2005 results from RLW Metering study (2005 RLW memo following on from "Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs")

**Lifetimes**
20 years[846].
Note: a provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore the analysis period (i.e. the life of the savings) is reduced to the number of years remaining to 2020. So for installations in 2012, the measure life is 8 years, for 2013 7 years[847].

**Measure Cost**
The incremental cost for this measure is $32[848].

**Annual Operations and Maintenance Savings**
Because compact fluorescent lamps last much longer than incandescent bulbs, CFLs offer significant operation and maintenance (O&M) savings over the life of the fixture for avoided incandescent lamps and the labor to install them. The following assumptions are used to calculate the O&M savings:
Incandescent bulb cost: $0.50 per bulb
Life of incandescent bulb: 1000 hours
EISA qualified bulb cost: $1.50 per bulb
Life of EISA qualified bulb: 1000 hours
T8 lamp cost: $3.00 per lamp
Life of T8 lamp: 8,500 hours (RES),
CFL ballast replacement cost: n/a (ballast life exceeds measure life)

The O&M calculation results in a levelized annual baseline replacement cost as presented below (see 2012 EISA Adjustment Calculations.xls for details) [849]:

| Measure | Year Installed | Annual baseline replacement cost | Annual efficient replacement cost |
|---|---|---|---|
| Generic Linear Fluorescent Fixture | 2012 | $4.58 | $1.03 |
| | 2013 | $4.78 | $1.16 |
| | 2014 | $5.06 | $1.34 |

This adjustment will be recalculated for subsequent years

**Fossil Fuel Descriptions**
There are no fossil-fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

[846] "Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures", GDS Associates, June 2007 (http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf).

[847] T8s are more efficient than CFLs so there is savings after 2020, however since the baseline could be a standard incandescent bulb or a linear fluorescent, this is ignored for simplicity.
[848] ENERGY STAR Qualified Lighting Savings Calculator default incremental cost input
[849] Note: As described above, the measure life is reduced to the number of years remaining until 2020 when the EISA legislation makes the CFL the baseline. The O&M calculation takes the entire stream of replacements for both the baseline and efficient cases over the actual expected lifetime (20 years) and converts to a levelized annual cost over the reduced measure 'savings' lifetime.

### Ventilation End Use

# Residential Fan—Quiet, Exhaust-Only Continuous Ventilation

Measure Number: VI-D-1-e (Residential New Construction, Ventilation End Use)

**Version Date & Revision History**

Draft date: Portfolio 73
Effective date: 1/1/2011
End date: TBD

**Referenced Documents:**

1. Residential Vent Fan Assessment.xls
2. GDS Associates Measure Life Report "Residential and C&I Lighting and HVAC measures"
3. ASHRAE 62.2 Section 4.1 Whole House Ventilation

**Description**

This market opportunity is defined by the need for continuous mechanical ventilation due to reduced air-infiltration from a tighter building shell. Standard baseline fans may be too loud, or insufficient in other ways, to be operated as required for proper ventilation. This measure assumes a fan capacity of 50 CFM rated at less than 2.0 sones at 0.1 inches of water column static pressure. This measure may be applied to larger capacity, up to 130 CFM, efficient fans with bi-level controls because the savings and incremental costs are very similar. All eligible installations shall be sized to provide the mechanical ventilation rate indicated by ASHRAE 62.2 and the 2011 Vermont Residential Buildings Energy Code, Section 402

**Algorithms**

**Demand Savings**

$\Delta kW = CFM * (1/Fan_{Efficiency, Baseline} - 1/Fan_{Efficiency, Effcient})/1000$
$= 50 * (1/3.1 – 1/8.3)/1000$
$= 0.01$ kW

Where:

CFM = Nominal Capacity of the exhaust fan, 50 CFM[850]
$Fan_{Efficiency, Baseline}$ = Average efficacy for baseline fan, 3.1 CFM/Watt[851]
$Fan_{Efficiency, Effcient}$ = Average efficacy for efficient fan, 8.3 CFM/Watt [852]

**Energy Savings**

$\Delta kWh$ = Hours * $\Delta kW$
= 8760 * 0.01
= 87.6 kWh

Where:

$\Delta kW$ = connected load kW savings per qualified ventilation fan and controls.
Hours = assumed annual run hours, 8760 for continuous ventilation.

**Baseline Efficiencies – New or Replacement**

New standard efficiency (average CFM/Watt of 3.1[853]) exhaust-only ventilation fan, quiet (< 2.0 sones[854]) operating in accordance with recommended ventilation rate indicated by ASHRAE 62.2[855]

[850] 50CFM is the closest available fan size to ASHRAE 62.2 Section 4.1 Whole House Ventilation rates based upon typical square footage and bedrooms.
[851] Average of CFM/Watt values at two static pressures of 0.1 and 0.25 inches of water column for quiet fans rated for 50 CFM. Based on fan information gathered and referenced in the spreadsheet, "Residential Vent Fan Assessment.xls"
[852] Average of CFM/Watt values at two static pressures of 0.1 and 0.25 inches of water column for quiet fans rated for 50 CFM. Based on fan information gathered and referenced in the spreadsheet, "Residential Vent Fan Assessment.xls"

**High Efficiency**
New efficient (average CFM/watt of 8.3) exhaust-only ventilation fan, quiet (< 2.0 sones) Continuous operation in accordance with recommended ventilation rate indicated by ASHRAE 62.2[856]

**Operating Hours**
Continuous, 8760.

**Loadshape**
Loadshape # 25: Flat (8760 hours)

**Freeridership/Spillover Factors**

| Measure Category | | Ventilation | |
|---|---|---|---|
| Measure Code | | VNTXCEIL, | |
| Product Description | | Exhaust fan, ceiling, | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | 1.0 | 1.0 |
| LIMF NC | 6018LINC | 1.0 | 1.0 |
| LIMF Rehab | 6018LIRH | 0.95 | 1.1 |
| MF Mkt NC | 6019MFNC | 0.9 | 1.0 |
| MF Mkt Retro | 6020MFMR | 1.0 | 1.0 |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | 1.0 | 1.0 |
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |
| RES Retrofit | 6036RETR | 0.9 | 1.0 |
| RNC VESH | 6038VESH | 0.95 | 1.1 |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

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[853] Average of efficacies at static pressures of 0.1 and 0.25 inches of water column.
[854] Rated fan sound level at a static pressure of 0.1 inches of water column.
[855] On/off cycling controls may be required of baseline fans larger than 50CFM.
[856] Bi-level controls may be used by efficient fans larger than 50 CFM

**Lifetime**
19 years[857]
Analysis period is the same as the lifetime.

**Incremental Cost per Unit**
Incremental cost per installed fan is $43.50 for quiet, efficient fans.[858]

**Reference Tables**
None

[857] Conservative estimate based upon GDS Associates Measure Life Report "Residential and C&I Lighting and HVAC measures" 25 years for whole-house fans, and 19 for thermostatically-controlled attic fans.
[858] See the Fan Info worksheet of the spreadsheet "Residential Vent Fan Assessment.xls"

**Dishwashing End Use**

# ENERGY STAR Dishwasher

Measure Number: VI-H-1-g (Residential New Construction, Dishwashing End Use)

**Version Date & Revision History**

Draft date: Portfolio 65
Effective date: 01/01/2011
End date: TBD

Referenced Documents: 1) RNC_ES.DW.kWh.2011.xls; 2) 2009 VT Appliance Data w doc_CostAnalysisTRM; 3) tablehc11.10.pdf; 4) CalculatorConsumerDishwasher.xls.

**Description**

A dishwasher meeting the efficiency specifications of ENERGY STAR, CEE TIER 1 (for compact dishwashers) or CEE TIER 2 (for standard dishwashers) is installed in place of a model meeting the federal standard..

**Algorithms**

**Energy Savings**

Energy savings are presented for each dishwasher type and efficiency standard in the Reference Table section below .

**Demand Savings**

Demand savings are presented for each dishwasher type and efficiency standard in the Reference Table section below.

**Baseline Efficiencies – New or Replacement**

The Baseline reflects the minimum federal efficiency standards for dishwashers effective January 1, 2010 as presented in the tables below.

**High Efficiency**

The high efficiency standard is presented in the table below:

| Dishwasher Type | Efficiency Standard | Minimum Energy Factor | Maximum kWh/year | Maximum gallons/cycle |
|---|---|---|---|---|
| Standard | Federal Standard | No requirement | 355 | 6.5 |
| | ENERGY STAR | No requirement | 324 | 5.8 |
| | CEE TIER 1 | 0.72 | 307 | 5.0 |
| | CEE TIER 2 | 0.75 | 295 | 4.25 |
| Compact | Federal Standard | No requirement | 260 | 4.5 |
| | ENERGY STAR | No requirement | 234 | 4.0 |
| | CEE TIER 1 | 1.0 | 222 | 3.5 |

**Operating Hours**

Assuming one and a half hours per cycle and 177 cycles per[859] year therefore 266 operating hours per year.

**Loadshape**

*Residential DHW Conservation, #8. Vermont State Cost-Effectiveness Screening Tool*

[859] 177 cycles per year is based on a weighted average of dishwasher usage in New England derived from the 2005 RECs data; http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc10homeappliaceindicators/pdf/tablehc11.10.pdf

**Freeridership/Spillover Factors**

| Measure Category | | Cooking and Laundry | |
|---|---|---|---|
| Measure Codes | | CKLSEDRP, CKLS1DRP, CKLS2DRP, CKLCEDRP, CKLC1DRP, | |
| Product Description | | Energy Star Dishwasher | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6012MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | 0.90 | 1.1 |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| Customer Credit | 6015CC | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
13 years.[860]
Analysis period is the same as the lifetime.

**Measure Cost**
The incremental costs for these measures are provided below:

| Dishwasher Type | Efficiency Standard | Incremental Cost[861] |
|---|---|---|
| Standard | ENERGY STAR | $12 |
| | CEE TIER 1 | $25 |
| | CEE TIER 2 | $100 |
| Compact | ENERGY STAR | $12 |
| | CEE TIER 1 | $25 |

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

[860] Koomey, Jonathan et al. (Lawrence Berkeley National Lab), Projected Regional Impacts of Appliance Efficiency Standards for the U.S. Residential Sector, February 1998.
[861] ENERGY STAR cost based on ENERGY STAR Dishwasher Calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerDishwasher.xls) .Other costs estimated based on review of data from the Northeast Regional ENERGY STAR Consumer Products Initiative; “2009 ENERGY STAR Appliances Practices Report”, submitted by Lockheed Martin, December 2009. See 2009 VT Appliance Data_TRMCostAnalysis.xlsfor data.

**Fossil Fuel Descriptions**
Fossil fuel savings are presented for each dishwasher type and efficiency standard in the Reference Table section below.

**Water Descriptions**
Water savings are presented for each dishwasher type and efficiency standard in the Reference Table section below.

**Reference Tables**
Customer Energy Savings by dishwasher type and efficiency standard in RNC Homes[862]

| | Standard | | | Compact | |
|---|---|---|---|---|---|
| | ENERGY STAR | TIER 1 | TIER 2 | ENERGY STAR | TIER 1 |
| **kWh Savings** | 19.8 | 25.78 | 42.84 | 18.38 | 33.75 |
| **kW savings** | 0.07 | 0.1 | 0.16 | 0.07 | 0.13 |
| **MMBtu oil savings** | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| **MMBtu gas savings** | 0.03 | 0.04 | 0.06 | 0.03 | 0.05 |
| **MMBtu propane savings** | 0.06 | 0.08 | 0.14 | 0.06 | 0.11 |
| **Water Savings CCF** | 0.39 | 0.61 | 0.74 | 0.16 | 0.42 |

[862] Source: RNC_ES.DW.kWh.2011.xls

### Clothes Dryer End Use
# Electric Clothes Dryer Fuel Switch

Measure Number: VI-J-1-a (Residential New Construction, Clothes Washing End Use)

**Version Date & Revision History**
Draft date: Portfolio 42
Effective date: 7/1/06

Referenced Documents: 1) Dryer usage.xls

**Description**
An electric clothes dryer is replaced with a fossil fuel based clothes dryer meeting specified efficiency criteria. The measure characterization and savings estimates are based on average usage per person and average number of people per Vermont household., Therefore, this is a prescriptive measure, with identical savings applied to all installation instances, applicable across all housing types.

**Algorithms**
**Energy Savings**[863]
ΔkWh = 977 kWh (supporting documentation in Dryer Usage.xls)
ΔMMBtu = -3.33 MMBtu (negative indicates increase in fuel consumption) (977 *.003413 = 3.33) it is assumed that gas and electric dryers have similar efficiencies. All heated air passes through the clothes and contributes to drying.

**Demand Savings**
ΔkW = 4.8 kW electric dryer = 5kW heating element. Gas dryer may have 200 watt glow coil. Motor wattage assumed to be equal.

Where:

| | |
|---|---|
| ΔkWh | = weighted average annual kWh savings per dryer per residential unit |
| ΔMMBtu | = weighted average fossil fuel energy savings per dryer per residential unit in MMBtu (million Btu) |
| ΔkW | = weighted average connected load kW savings per dryer |

**Baseline Efficiencies – New or Replacement**
Baseline efficiency is an electric dryer used in conjunction with a mix of standard top-loading clothes washers (80%) and Energy Star qualified washers (20%) (supporting documentation in Dryer Usage.xls).

**Non-Electric**
A propane or natural gas dryer used in conjunction with a mix of standard top-loading clothes washers (80%) and Energy Star qualified washers (20%) (supporting documentation in Dryer Usage.xls).

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
14 years (same as for clothes washers in DPS screening of Efficiency Utility Core programs).
Remaining life = 4 years

**Analysis Period**
30 years

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[863] Average annual dryer kWh per Vermont household using EIA data for kwh/year/household for nationwide household and using census data for Vermont residents/household. Assumes an average 2.44 people per home in Vermont. Estimates for usage for homes of other sizes is based on MMBtu consumption for DHW by number of bedrooms from RECS 2001 data and scaled proportionally from the per person consumption estimate. Estimated kWh savings detailed above are net of auxiliary electricity use by the new fossil fuel based equipment.

**Operating Hours**
n/a

**Loadshape**
Loadshape #9, Residential Clothes Washer, Vermont State Cost-Effectiveness Screening Tool

**Freeridership/Spillover Factors**

| Measure Category | | Hot Water Fuel Switch | |
|---|---|---|---|
| Measure Codes | | OTFYPROP; OTFYNGAS | |
| Product Description | | Clothes Dryer fuel switch (various fossil fuel systems) | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6012MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | 0.30[864] | 1 |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| Customer Credit | 6015CC | n/a | n/a |

**Measure Costs**
Full retrofit costs for the efficient fossil fuel based clothes dryer are detailed below. Note, we estimate the electric clothes dryer being replaced was on average 9 years old with 4 years of working life remaining. This is taken into account in measure screening.

| Equipment Type | Est. Full Installed Cost for Baseline Electric Equipment | Est. First Time Full Installed Cost for Efficient Equipment |
|---|---|---|
| Clothes Dryer | $320 | $580 |

**Source:** Survey of local retailers.

**Incentive Level**

| Track Name | Track No. | Incentive |
|---|---|---|
| LISF Retrofit | 6034LISF | 75% of full installed cost |
| RES Retrofit | 6036RETR | $200 |

[864] The freerider rate for both natural gas and propane fired units will be 30%.

| | | |
|---|---|---|
| RNC VESH | 6038VESH | $100 |

**O&M Cost Adjustments**

| | Baseline (Electric Clothes Dryer) | Fossil Fuel Clothes Clothes Dryer | O&M Cost Adjustments |
|---|---|---|---|
| **Equipment Annual Maintenance Costs** | $15 | $35 | ($20) |

Source: EVT estimate.

**Water Descriptions**
There are no water algorithms or default values for this measure.

# Clothes Washer

Measure Number: VI-K-1-b (Residential New Construction Program, Clothes Washing End Use)

**Version Date & Revision History**
Draft date: Portfolio 81
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**

1) 2013 RNC Clothes Washer Savings.xls;
2) 2009 RECS_HC3.8 Appliances in Northeast Region.xls

**Description**
Clothes washers exceeding minimum qualifying efficiency standards established as ENERGY STAR, CEE Tier 2 or Tier 3 as of 1/1/2011, Most Efficient or Top Ten as defined below:

| Efficiency Level | Modified Energy Factor (MEF) | Water Factor (WF) |
|---|---|---|
| Federal Standard | >= 1.26 | <= 9.5 |
| ENERGY STAR | >= 2.0 | <= 6.0 |
| CEE TIER 2 | >= 2.20 | <= 4.5 |
| CEE TIER 3 | >= 2.40 | <= 4.0 |
| ENERGY STAR Most Efficient (as of 1/1/2013) | >= 2.4 (for units <=2.5 ft3)<br>>= 3.2 (for units >2.5 ft3) | <= 4.5 (for units <=2.5 ft3)<br><= 3.0 (for units >2.5 ft3) |
| Top Ten (as of 09/2012) | Defined as the ten most efficient units available. | |

The modified energy factor (MEF) measures energy consumption of the total laundry cycle (unit operation, washing and drying); the higher the number, the greater the efficiency.
The Water Factor is the number of gallons needed for each cubic foot of laundry. A lower number indicates lower consumption and more efficient use of water.

Savings are provided for both specific DHW and Dryer fuel combinations and for if the fuel is unknown.

**Algorithms**

**Energy Savings**
Energy and Demand Savings are presented in the reference tables below, and are dependent on the fuel type of the DHW system and the dryer. The calculations are based on analysis of rebated units through Efficient Products (see Efficient Product measure for write up of savings methodology). The savings are presented for each efficiency level in the reference table “Customer Energy Savings by Water Heater and Dryer Fuel Type”, and 2013 RNC Clothes Washer Savings.xls. The savings for when fuel combination is unknown is also provided.

**Demand Savings**

$\Delta kW = \Delta kWh/Hours$

Where:

| | | |
|---|---|---|
| $\Delta$kWh | = | gross customer annual kWh savings for the measure |
| $\Delta$kW | = | gross customer connected load kW savings for the measure |
| Hours | = | assumed annual run hours of clothes washer |

See “Customer Energy Savings by Water Heater and Dryer Fuel Type”.

**Baseline Efficiencies – New or Replacement**

The baseline efficiency is determined according to the modified energy factor (MEF) that takes into account the energy and water required per clothes washer cycle, including energy required by the clothes dryer per clothes washer cycle. The federal baseline MEF of 1.26 is inflated by 20% to 1.51 for savings comparison to account for non-qualifying models that are higher then the federal baseline MEF.

**High Efficiency**
High efficiency is defined as any model meeting or exceeding ENERGY STAR, CEE Tier 2 or Tier 3 standards as of of 1/1/2011, ENERGY STAR Most Efficient of Top Ten as defined in the following table:

| Efficiency Level | Modified Energy Factor (MEF) | Water Factor (WF) |
|---|---|---|
| ENERGY STAR | >= 2.0 | <= 6.0 |
| CEE TIER 2 | >= 2.20 | <= 4.5 |
| CEE TIER 3 | >= 2.40 | <= 4.0 |
| ENERGY STAR Most Efficient (as of 1/1/2013) | >= 2.4 (for units <=2.5 ft3)<br>>= 3.2 (for units >2.5 ft3) | <= 4.5 (for units <=2.5 ft3)<br><= 3.0 (for units >2.5 ft3) |
| Top Ten | Defined as the ten most efficient units available. | |

Energy and water savings estimates are based on the weighted average MEF factor for qualifying models based on the models rebated during the previous calendar year, except Top Ten which is based upon averaging the units provided on the website (http://www.toptenusa.org/Top-Ten-Clothes-Washers) as of September 2012

**Operating Cycles**
322 clothes washer cycles / year [865]

**Operating Hours**
322operating hours / year [866]

**Loadshape**
Loadshape #9, Residential Clothes Washing, Vermont State Screening Tool.

**Freeridership/Spillover Factors**

| **Measure Category** | | **Cooking and Laundry** | | | | | |
|---|---|---|---|---|---|---|---|
| **Product Description** | | **Efficient Clothes Washer** | | | | | |
| **Measure Code** | | **CKLESWRP, CKLC2WRP** | | **CKLC3WRP** | | **CKLMEWRP, CKLTTWRP** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** | **Freerider** | **Spillover** | **Freerider** | **Spillover** |
| RNC VESH | 6038VESH | 0.5 | 1.0 | 0.75 | 1.0 | 0.95 | 1.2 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
14 years[867] (same as DPS screening of Efficiency Utility program).
Analysis period is the same as the lifetime.

**Measure Cost**
The incremental cost for this measure is provided in the table below[868]:

[865] Weighted average of 322 clothes washer cycles per year. 2009 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section: http://www.eia.gov/consumption/residential/data/2009/
[866] Assume one hour per cycle.
[867] Based on DOE Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_standard.xlsm.

| Efficiency Level | Incremental Cost |
|---|---|
| ENERGY STAR | $225 |
| CEE Tier 2 | $250 |
| CEE Tier 3 | $350 |
| ENERGY STAR Most Efficient | $500 |
| Top Ten | $510 |

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
Fossil Fuel savings are dependent on the DHW and Dryer fuel type and are presented in the tables below.

**Water Descriptions**[869]
The water savings for each efficiency level are presented below:

| Efficiency Level | WF | ΔWater (CCF per year) |
|---|---|---|
| Federal Standard | 7.93 | 0.0 |
| ENERGY STAR | 5.41 | 3.0 |
| CEE Tier 2 | 3.61 | 7.5 |
| CEE Tier 3 | 3.51 | 7.1 |
| ENERGY STAR Most Efficient | 2.90 | 8.5 |
| Top Ten | 3.54 | 7.8 |

**Reference Tables**

**Customer Energy Savings by Water Heater and Dryer Fuel Type**[870]
**ENERGY STAR:**

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 162 | 0.50 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 59 | 0.18 | 0 | 0.41 | 0 |
| Electric Dryer/Natural Gas DHW | 59 | 0.18 | 0 | 0 | 0.41 |
| Electric Dryer/Oil DHW | 59 | 0.18 | 0.41 | 0 | 0 |
| Propane Dryer/Electric DHW | 104 | 0.32 | 0 | 0.20 | 0 |
| Propane Dryer/Propane DHW | 2 | 0.01 | 0 | 0.61 | 0 |
| Propane Dryer/Oil DHW | 2 | 0.01 | 0.61 | 0 | 0 |
| Natural Gas Dryer/Electric DHW | 104 | 0.32 | 0 | 0 | 0.20 |
| Natural Gas Dryer/Natural Gas DHW | 2 | 0.01 | 0 | 0 | 0.61 |
| Natural Gas Dryer/Oil DHW | 2 | 0.01 | 0.61 | 0 | 0 |

[868] Based on weighted average of top loading and front loading units (based on available product from the CEC Appliance database) and cost data from Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_standard.xlsm. See '2013 In Unit Clothes Washer Savings.xls' for details.

[869] Based on analysis of previous year's rebated units, see 2013 RNC Clothes Washer Savings.xls

[870] Where dryer and DHW use different fossil fuels, savings are combined under the DHW fossil fuel because a single measure can only have one fuel type for screening purposes and the DHW savings are larger than the Dryer savings.

**Tier 2:**

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 277 | 0.86 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 108 | 0.34 | 0 | 0.67 | 0 |
| Electric Dryer/Natural Gas DHW | 108 | 0.34 | 0 | 0 | 0.67 |
| Electric Dryer/Oil DHW | 108 | 0.34 | 0.67 | 0 | 0 |
| Propane Dryer/Electric DHW | 175 | 0.54 | 0 | 0.35 | 0 |
| Propane Dryer/Propane DHW | 7 | 0.02 | 0 | 1.02 | 0 |
| Propane Dryer/Oil DHW | 7 | 0.02 | 1.02 | 0 | 0 |
| Natural Gas Dryer/Electric DHW | 175 | 0.54 | 0 | 0 | 0.35 |
| Natural Gas Dryer/Natural Gas DHW | 7 | 0.02 | 0 | 0 | 1.02 |
| Natural Gas Dryer/Oil DHW | 7 | 0.02 | 1.02 | 0 | 0 |

**Tier 3:**

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 348 | 1.08 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 124 | 0.39 | 0 | 0.89 | 0 |
| Electric Dryer/Natural Gas DHW | 124 | 0.39 | 0 | 0 | 0.89 |
| Electric Dryer/Oil DHW | 124 | 0.39 | 0.89 | 0 | 0 |
| Propane Dryer/Electric DHW | 229 | 0.71 | 0 | 0.40 | 0 |
| Propane Dryer/Propane DHW | 6 | 0.02 | 0 | 1.30 | 0 |
| Propane Dryer/Oil DHW | 6 | 0.02 | 1.30 | 0 | 0 |
| Natural Gas Dryer/Electric DHW | 229 | 0.71 | 0 | 0 | 0.40 |
| Natural Gas Dryer/Natural Gas DHW | 6 | 0.02 | 0 | 0 | 1.30 |
| Natural Gas Dryer/Oil DHW | 6 | 0.02 | 1.30 | 0 | 0 |

**Most Efficient:**

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 446 | 1.38 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 164 | 0.51 | 0 | 1.12 | 0 |
| Electric Dryer/Natural Gas DHW | 164 | 0.51 | 0 | 0 | 1.12 |
| Electric Dryer/Oil DHW | 164 | 0.51 | 1.12 | 0 | 0 |
| Propane Dryer/Electric DHW | 289 | 0.90 | 0 | 0.53 | 0 |
| Propane Dryer/Propane DHW | 8 | 0.02 | 0 | 1.66 | 0 |
| Propane Dryer/Oil DHW | 8 | 0.02 | 1.66 | 0 | 0 |
| Natural Gas Dryer/Electric DHW | 289 | 0.90 | 0 | 0 | 0.53 |
| Natural Gas Dryer/Natural Gas DHW | 8 | 0.02 | 0 | 0 | 1.66 |

| | | | | | |
|---|---|---|---|---|---|
| Natural Gas Dryer/Oil DHW | 8 | 0.02 | 1.66 | 0 | 0 |

**Top Ten:**

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 484 | 1.50 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 188 | 0.58 | 0 | 1.18 | 0 |
| Electric Dryer/Natural Gas DHW | 188 | 0.58 | 0 | 0 | 1.18 |
| Electric Dryer/Oil DHW | 188 | 0.58 | 1.18 | 0 | 0 |
| Propane Dryer/Electric DHW | 306 | 0.95 | 0 | 0.61 | 0 |
| Propane Dryer/Propane DHW | 10 | 0.03 | 0 | 1.79 | 0 |
| Propane Dryer/Oil DHW | 10 | 0.03 | 1.79 | 0 | 0 |
| Natural Gas Dryer/Electric DHW | 306 | 0.95 | 0 | 0 | 0.61 |
| Natural Gas Dryer/Natural Gas DHW | 10 | 0.03 | 0 | 0 | 1.79 |
| Natural Gas Dryer/Oil DHW | 10 | 0.03 | 1.79 | 0 | 0 |

**Savings if DHW and Dryer fuel is unknown:**

| | kWh | kW | MMBTU Oil | MMBTU Natural Gas | MMBTU Propane |
|---|---|---|---|---|---|
| Non-CEE Energy Star Units | 51.0 | 0.16 | 0.04 | 0.07 | 0.31 |
| CEE 2 | 93.1 | 0.29 | 0.07 | 0.12 | 0.51 |
| CEE 3 | 107.9 | 0.34 | 0.09 | 0.15 | 0.67 |
| Most Efficient | 142.1 | 0.44 | 0.11 | 0.19 | 0.85 |
| Top Ten | 161.2 | 0.50 | 0.12 | 0.21 | 0.90 |

## Multiple End Uses
# Comprehensive Shell Measure Savings

Measure Number: VI-L-1-b (Residential New Construction, Heating, Cooling and Hot Water End Uses)

**Version Date & Revision History**
Draft date: Portfolio 81a
Effective date: 1/1/2014
End date: TBD

**Referenced Documents:**
1) VT UDRH_Baseline2011_Input Data_MEDIAN-FINAL_121613.xlsx
2) VT UDRH_Baseline2011_REMv14.3_MEDIAN-FINAL_121613.udr
3) RNC UDRH 2013 Update_Memo to PSD_FINAL bm.docx

**Description**
This measure characterization documents the methodology and key assumptions for comprehensive residential new construction savings due to thermal shell and mechanical equipment improvements. This characterization includes savings for heating, cooling and hot water end uses[871].

**Algorithms**

**Energy and Demand Savings**
Energy and demand savings will be calculated using the User Defined Reference Home (UDRH) feature in REM/Rate™. All Residential New Construction Projects will be modeled in REM/Rate™ to estimate annual energy consumption and demand for heating, cooling and hot water. Each project will be modeled a second time to a baseline[872] specification. The difference in modeled energy consumption and demand between the AsBuilt project and UDRH baseline models will be the savings for that project.

**Energy Savings** = $Energy_{AsBuilt}$ - $Energy_{UDRH}$
**Demand Savings** = $Demand_{AsBuilt}$ - $Demand_{UDRH}$

Where:

$Energy_{AsBuilt}$ = REM/Rate modeled consumption (kWh and MMBtu) of the AsBuilt home
$Energy_{UDRHt}$ = REM/Rate modeled consumption (kWh and MMBtu) of the UDRH home
$Demand_{AsBuilt}$ = REM/Rate modeled demand (kW) of the AsBuilt home
$Demand_{UDRHt}$ = REM/Rate modeled demand (kW) of the UDRH home

**Baseline and Above-Baseline Efficiencies**
The following table provides an overview of the UDRH baseline specification[873]. The efficiencies listed below for the Energy Code Plus and ENERGY STAR program tiers are a mixture of prescriptive program guidelines and mandatory prescriptive requirements. Mandatory requirements are noted with an asterisk. Each program home will be unique and may fall above or below the efficiency guidelines listed below. All homes must meet a minimum performance (HERS) target[874].

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[871] This comprehensive measure characterization replaces the following Residential New Construction measures: Heating Savings, Efficient Furnace Fan Motor, Central Air Conditioner, Space Cooling Savings, ES Central Air Conditioner, and Fossil Fuel Water Heater
[872] Baseline specifications are derived from the Vermont Residential New Construction Baseline Study Analysis of On-Site Audits Final Report, February 13, 2013. A new UDRH baseline will be submitted to DPS for review within three months of final updates to a new Vermont RNC baseline study.
[873] See Reference document VT UDRH_Baseline2011_Input Data_MEDIAN-FINAL_121613.xlsx for the detailed specification.
[874] Efficiency Vermont Residential New Construction Requirements and Specifications
http://www.efficiencyvermont.com/docs/for_my_home/rnc/VESH_Requirements.pdf

| | | Baseline Efficiency | Above-Baseline Efficiency | |
|---|---|---|---|---|
| | | ***UDRH*** | ***Energy Code Plus*** | ***ENERGY STAR*** |
| **Heating** | Boiler, gas/prop | 94.1 AFUE | 85 AFUE* | |
| | Boiler, oil/kero | 86.9AFUE | | |
| | Furnace, gas/prop | 87.0 AFUE | 95 AFUE* | |
| | Furnace, oil/kero | 83.0 AFUE | 85 AFUE* | |
| **Cooling** | CAC | 13 SEER | 14.5 SEER* | |
| **Heat Pump** | ASHP | 7.7 HSPF / 13 SEER | ENERGY STAR qualified*[875] | |
| | GSHP | 3.1 COP / 11.24 EER | | |
| **Domestic Hot Water** | Tank, gas/prop | 0.62 EF | 0.59 EF | |
| | Tank, oil/kero | 0.49 EF | 0.51 EF | |
| | Instant, gas/prop | 0.82 EF | 0.82 EF | |
| | Indirect, gas/prop | 0.97 EF | | |
| | Indirect, oil/kero | 0.80 EF | N/A | |
| **Air Leakage** | Infiltration | 3.4 ACH50 | 4 ACH50* | 3 ACH50* |
| **Thermal Shell** | Insulation Grade[876] | 2 | 2 | 1 |
| | Ceiling | R-38 | R-49 | |
| | Above-grade walls | R-19 | R-20 | |
| | Foundation Wall | R-10 | R-15 | |
| | Slab-on-Grade | R-10 | R-15 | |
| | Frame floors | R-24 | R-30 | |
| | Windows | U - 0.34 | U - 0.32* | |

**Loadshapes**
Loadshape #5, Residential Space Heat
Loadshape #11, Residential A/C
Loadshape #7, Residential DHW Insulation

**Freeridership/Spillover Factors**

| Measure Category | | Comprehensive Thermal Measure REM/Rate Calculated Heating, Cooling, DHW | |
|---|---|---|---|
| Measure Codes | | TSHCOMPH, TSHCOMPC, HWECOMP1 | |
| Product Description | | Space Heating, Cooling and DHW Savings | |
| Track Name | Track No. | Freerider | Spillover |
| RNC VESH | 6038VESH | 0.95 | 1.1 |

**Persistence**
The persistence factor is assumed to be one.

[875] http://www.energystar.gov/index.cfm?c=products.pr_find_es_products
[876] Insulation grade refers to the quality of insulation installation. Research has shown insulation is typically installed poorly and not to manufacturer's specifications. This has a significant impact on energy performance of the insulation. Grade 1 (per manufacturer instructions) is required by ENERGY STAR Homes.

**Lifetimes**
25 years.
Analysis period is the same as the lifetime.

**Measure Cost**
$3,627[877]

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

[877] Incremental costs above IECC 2009 taken from ENERGY STAR Qualified Homes, Version 3 Savings & Cost Estimate Summary

# Residential Emerging Markets Program

## Hot Water End Use

# Tank Wrap

Measure Number: VII-A-1-c (Residential Existing Homes, Hot Water End Use)

**Version Date & Revision History**
Draft date: Portfolio 81
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**

1. Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM)
2. NREL, National Residential Efficiency Measures Database
3. Efficiency Vermont Program Documentation
4. DOE, "Residential Heating Products Final Rule Technical Support Document"

**Algorithms**

**Energy Savings**
For electric DHW systems only:

$$\Delta kWh = ((U_{base}A_{base} - U_{insul}A_{insul}) * \Delta T * Hours) / (3412 * \eta DHW)$$

Where:

| | |
|---|---|
| $\Delta kWh$ | = gross customer annual kWh savings for the measure |
| $U_{base}$ | = Overall heat transfer coefficient prior to adding tank wrap (Btu/Hr-F-ft$^2$)<br>= 1/12 [878] |
| $U_{insul}$ | = Overall heat transfer coefficient after addition of tank wrap (Btu/Hr-F-ft$^2$)<br>= 1/22 [879] |
| $A_{base}$ | = Surface area of storage tank prior to adding tank wrap (square feet)<br>= 23.18 [880] |
| $A_{insul}$ | = Surface area of storage tank after addition of tank wrap (square feet)<br>= 25.31 [881] |
| $\Delta T$ | = Average temperature difference between tank water and outside air temperature (°F)<br>= 55°F [882] |
| Hours | = Number of hours in a year (since savings are assumed to be constant over year).<br>= 8760 |
| 3412 | = Conversion from BTU to kWh |
| $\eta DHW$ | = Recovery efficiency of electric hot water heater<br>= 0.98 [883] |

For the prescriptive assumption, 40 gallons is selected as an average tank[884], and the savings are derived from adding R-10 to an R-12 tank. The prescriptive savings are therefore:

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[878] Conservative baseline assumption
[879] Efficiency Vermont program documentation specifies R-10 tank wrap
[880] Assumptions from PA TRM. Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation. Area includes tank sides and top to account for typical wrap coverage.
[881] Ibid.
[882] Assumes 120°F water in the hot water tank and average temperature of basement of 65°F.
[883] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40
[884] DOE, "Residential Heating Products Final Rule Technical Support Document," Table 3.2.13, http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch3.pdf

$\Delta kWh = ((23.18/12 – 25.31/22) * 55 * 8760) / (3412 * 0.98)$

$= 113$ kWh

**Demand Savings**

$\Delta kW$ = $\Delta kWh$ / 8766

Where:

$\Delta kW$ = gross customer connected load kW savings for the measure

$\Delta kWh$ = kWh savings from tank wrap installation, calcualted below

8760 = Number of hours in a year (savings are from reduced standby loss and are therefore assumed to be constant over the year).

For the prescriptive assumption, the assumed savings is:

$\Delta kW$ = 113 / 8760

= 0.0128 kW

**Baseline Efficiencies – New or Replacement**

The baseline condition is a hot water tank that is not already well insulated. Newer, rigid, foam insulated tanks are considered to be effectively insulated while older tanks with fiberglass insulation that gives to gentle pressure are not.

**High Efficiency**

High efficiency is a hot water tank with a tank wrap of R-10.

**Operating Hours**

8760, savings are from reduced standby loss and are therefore assumed to be constant over the year.

**Loadshape**

Loadshape #25, Flat (8760 hours)

**Freeridership/Spillover Factors**

| Measure Category | | Hot Water | |
|---|---|---|---|
| Measure Code | | HWEINSUL | |
| Product Description | | Insulate hot water tank | |
| Track Name | Track No. | Freerider | Spillover |
| RES Retrofit | 6036RETR | 1.0 | 1.0 |

**Persistence**

The persistence factor is assumed to be one.

**Lifetimes**

6 years (same as in DPS screening of Efficiency Utility Core programs).
Analysis period is the same as the lifetime.

**Incremental Cost**

$35 average retrofit cost[885]

**O&M Cost Adjustments**

There are no operation and maintenance cost adjustments for this measure

[885] Based on EVT online product review.

**Fossil Fuel Descriptions**
n/a

# Pipe Wrap

Measure Number: VII-A-2-c (Residential Existing Homes, Hot Water End Use)

**Version Date & Revision History**
Draft date: Portfolio 81
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**

1. Navigant Consulting Inc., April 2009; "Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets"
2. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007
3. DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com)
4. NREL, National Residential Efficiency Measures Database

**Description**
Insulation is added to both the hot and cold pipes from the hot water tank to the first elbow. This is the most cost effective section to insulate since the water pipes act as an extension of the hot water tank up to the first elbow which acts as a heat trap. Insulating this length therefore helps reduce standby losses.

**Algorithms**

**Energy Savings**

For electric DHW systems:

$$\Delta kWh = ((C_{exist} / R_{exist} - C_{new} / R_{new}) * L * \Delta T * 8{,}760) / \eta DHW / 3412$$

Where:

$R_{exist}$ = Pipe heat loss coefficient of uninsulated pipe (existing) [(hr-°F-ft)/Btu]
= 1.0[886]

$C_{exist}$ = Circumference of pipe before insulation added (ft) (Diameter (in) * π/12): (0.5" pipe = 0.131ft, 0.75" pipe = 0.196ft)
Assuming ½" pipe
= 0.131

$R_{new}$ = Pipe heat loss coefficient of insulated pipe (new) [(hr-°F-ft)/Btu]
= Actual (1.0 + R value of insulation)
Assuming R-2.4 (3/8" foam) insulation is added
= 3.4

$C_{new}$ = Circumference of pipe after insulation added (ft) (Diameter (in) * π/12):
Assuming ½" pipe and 3/8" foam ((0.5 + 3/8 + 3/8) * π/12)
= 0.327

L =Length of pipe from water heating source covered by pipe wrap (ft)
Assuming 3 feet of both the hot and cold pipes
= 6

C = Circumference of pipe (ft) (Diameter (in) * π/12): (0.5" pipe = 0.131ft, 0.75" pipe = 0.196ft)
Assuming ½" pipe
= 0.131

[886] Navigant Consulting Inc., April 2009; "Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets", p77.

| | | |
|---|---|---|
| $\Delta T$ | = Average temperature difference between supplied water and outside air temperature (°F)<br>= 55°F [887] |
| 8,760 | = Hours per year |
| $\eta DHW$ | = Recovery efficiency of electric water heater<br>= 0.98 [888] |
| 3412 | = Conversion from Btu to kWh |

Assuming defaults provided above:

$\Delta kWh = (((0.131 / 1) – (0.327 / 3.4)) * 6 * 55 * 8,760) / 0.98 / 3412$

$= 30.0$ kWh

**Demand Savings**

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

Where:

| | |
|---|---|
| $\Delta kW$ | = gross customer connected load kW savings for the measure |
| $\Delta kWh$ | = kWh savings from tank wrap installation, calcualted below |
| 8760 | = Number of hours in a year (savings are from reduced standby loss and are therefore assumed to be constant over the year). |

Assuming defaults provided above:

$\Delta kW = 30.0 / 8760$
$= 0.0034$ kW

**Baseline Efficiencies – New or Replacement**
The baseline condition is a hot water system without pipe wrap.

**High Efficiency**
High efficiency is a hot water system with insulation on the hot and cold water pipes up to the first elbow.

**Loadshape**
Loadshape #25, Flat (8760 hours)

**Freeridership/Spillover Factors**

| Measure Category | | Hot Water End Use | |
|---|---|---|---|
| Measure Code | | HWEPIPES | |
| Product Description | | Insulating Water Pipes | |
| Track Name | Track No. | Freerider | Spillover |
| RES Retrofit | 6036RETR | 0.90 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetime**
15 years[889].
Analysis period is the same as the lifetime.

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[887] Assumes 120°F water leaving the hot water tank and average temperature of basement of 65°F.
[888] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40
[889] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

**Incremental Cost**
The measure cost is assumed to be $3 per linear foot[890], or $18 for a 6 foot length, including installation labor

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure

**Fossil Fuel Descriptions**
For fossil fuel DHW systems:

$$\Delta MMbtu = ((C_{exist} / R_{exist} – C_{new} / R_{new}) * L * \Delta T * 8{,}760) / \eta DHW / 1{,}000{,}000$$

Where:

$\eta DHW$ = Recovery efficiency of fossil fuel water heater
= 0.76 [891]

1,000,000 = Conversion from Btu to MMBtu

Other variables as defined above

$$\Delta MMbtu = ((0.131 / 1) – (0.327 / 3.4)) * 6 * 55 * 8{,}760) / 0.76 / 1{,}000{,}000$$

$$= 0.132 \text{ MMBtu}$$

890 Consistent with DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com)
[891] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

# Tank Temperature Turn-down

Measure Number: VII-A-3-c (Residential Existing Homes, Hot Water End Use)

**Version Date & Revision History**
Draft date: Portfolio 81
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**
1. Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM).
2. NREL, National Residential Efficiency Measures Database
3. DOE, "Residential Heating Products Final Rule Technical Support Document," Table 3.2.13, http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch3.pdf

**Description**
The domestic hot water tank thermostat is lowered to reduce standby losses.

**Algorithms**

**Energy Savings**

For electric DHW systems:

$\Delta$kWh = $((U_{base}A_{base}) * \Delta T * Hours) / (3412 * \eta DHW)$

Where:

| | |
|---|---|
| $\Delta$kWh | = Gross customer annual kWh savings for the measure |
| $U_{base}$ | = Overall heat transfer coefficient (Btu/Hr-F-$ft^2$) |
| | = 1/20 [892] |
| $A_{base}$ | = Surface area of storage tank (square feet) |
| | = 23.18[893] |
| $\Delta T$ | = Temperature difference between before and after turn down |
| | = 15°F [894] |
| Hours | = Number of hours in a year (savings are assumed to be constant over year) |
| | = 8760 |
| 3412 | = Conversion from BTU to kWh |
| $\eta$DHW | = Recovery efficiency of electric water heater |
| | = 0.98 [895] |

$\Delta$kWh = $((1/20 * 23.18) * 15 * 8760) / (3412 * 0.98)$

= 45.5 kWh

**Demand Savings**

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[892] Assumes an existing well insulated tank, or that tank wrap is added at that same time as the turn-down. Assumptions from Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM).
[893] Area includes tank sides and top, for a 40 gallon tank. Assumptions from Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM). Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation. Area includes tank sides and top to account for typical wrap coverage.
[894] Assumes 135°F tank turned down to 120°F.
[895] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

$\Delta kW = \Delta kWh / 8760$

Where:

| | |
|---|---|
| $\Delta kW$ | = Gross customer connected load kW savings for the measure |
| $\Delta kWh$ | = kWh savings, calculated above |
| 8766 | = Number of hours in a year (savings are from reduced standby loss and are therefore assumed to be constant over the year). |

$\Delta kW = 45.5 / 8760$

$= 0.00519$ kW

**Baseline Efficiencies – New or Replacement**
The baseline condition is a hot water tank with a thermostat setting that is higher than 125°F, typically 130°F or higher.

**High Efficiency**
High efficiency is a hot water tank with the thermostat set at 120°F or less.

**Operating Hours**
8766, savings are from reduced standby loss and are therefore assumed to be constant over the year.

**Loadshape**
Loadshape #25, Flat (8760 hours)

**Freeridership/Spillover Factors**

| Measure Category | | Hot Water End Use | |
|---|---|---|---|
| Measure Code | | HWETEMPS | |
| Product Description | | Hot Water Temperature Set back | |
| Track Name | Track No. | Freerider | Spillover |
| RES Retrofit | 6036RETR | 1.0 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
2 years.
Analysis period is the same as the lifetime.

**Incremental Cost**
$5 for contractor time.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure

**Fossil Fuel Descriptions**
For fossil fuel DHW systems:

$\Delta MMBtu = ((U_{base}A_{base}) * \Delta T * Hours) / (1{,}000{,}000 * \eta DHW)$

Where:

| | |
|---|---|
| $\Delta MMBtu$ | = Gross customer annual MMBtu savings for the measure |
| $U_{base}$ | = Overall heat transfer coefficient (Btu/Hr-F-ft$^2$) |

= 1/20 [896]

$A_{base}$ = Surface area of storage tank (square feet)[897]

= 23.18

$\Delta T$ = 15°F [898]

Hours = Number of hours in a year (savings are assumed to be constant over year)

= 8760

1,000,000 = Conversion from BTU to MMBtu

$\eta DHW$ = Recovery efficiency of fossil fuel water heater

= 0.76 [899]

$\Delta$MMBtu = ((1/20 * 23.18) * 15 * 8760) / (1,000,000 * 0.76)

= 0.20 MMBtu

[896] Assumes an existing well insulated tank, or that tank wrap is added at that same time as the turn-down. Assumptions from Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM).

[897] Area includes tank sides and top to account for typical wrap coverage, for a 40 gallon tank. Number from Tank Wrap measure and PA TRM.

[898] Assumes 135°F tank turned down to 120°F.

[899] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

# Low Flow Shower Head

Measure Number: VII-A-4-c (Residential Existing Homes, Hot Water End Use)

**Version Date & Revision History**
Draft date: Portfolio 81
Effective date: 1/1/2013
End date: TBD

**Referenced Documents**:

1. Energy Policy Act of 1992
2. 2010 Census
3. NREL, National Residential Efficiency Measures Database
4. AWWA, Residential End Uses of Water, 1999, http://www.allianceforwaterefficiency.org/residential-end-uses-of-water-study-1999.aspx
5. CADMUS and Opinion Dynamics, "Showerhead and Faucet Aerator Meter Study," prepared for the Michigan Evaluation Working Group, 2013.
6. Pacific Northwest Laboratory; "Energy Savings from Energy-Efficient Showerheads: REMP Case Study Results, Proposed Evaluation Algorithm, and Program Design Implications" http://www.osti.gov/bridge/purl.cover.jsp;jsessionid=80456EF00AAB94DB204E848BAE65F199?purl=/10185385-CEkZMk/native/
7. East Bay Municipal Utility District; "Water Conservation Market Penetration Study" http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf
8. SBW Consulting, Evaluation for the Bonneville Power Authority, 1994, http://www.bpa.gov/energy/n/reports/evaluation/residential/faucet_aerator.cfm
9. Champlain Water District, 2010 Water Quality Report, http://www.cwd-h2o.org/vertical/Sites/%7B0A660058-838C-4456-B2E9-CCDA30420B07%7D/uploads/2011_Water_Quality_Report1.pdf

**Description**
An existing shower head with a high flow rate is replaced with new unit that has a low flow rate. This is a retrofit measure.

**Algorithms**

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

$\Delta kWh$[900] $= (((GPM_{base} \times min/person/day_{base} - GPM_{efficient} \times min/person/day_{efficient}) \times \#\ people \times days/year\ ) / SH/home\ ) \times 8.3 \times (TEMP_{sh} - TEMP_{in}) / DHW\ Recovery\ Efficiency / 3412 \times ISR$

$GPM_{base}$ = Gallons Per Minute of baseline shower head
= 2.02 [901]

$GPM_{efficient}$ = Gallons Per Minute of low flow shower head
= 1.5 [902]

$min/person/day_{base}$ = Average minutes in the shower per person per day with baseline showerhead
= 4.7 [903]

[900] Note, the algorithm and variables are provided as documentation for the deemed savings result provided which should be claimed for all shower head installations.
[901] Median from AWWA, Residential End Uses of Water, 1999, http://www.allianceforwaterefficiency.org/residential-end-uses-of-water-study-1999.aspx
[902] EVT program documentation as of November 2012

$min/person/day_{efficient}$ = Average minutes in the shower per person per day with low flow showerhead
= 4.7 [904]

| | |
|---|---|
| # people | = Average number of people per household<br>= 2.34 [905] |
| days/y | = Days shower used per year<br>= 365 |
| SH/home | = Average number of showers in the home<br>= 1.7 [906] |
| 8.3 | = Constant to convert gallons to lbs |
| $TEMP_{sh}$ | = Assumed temperature of water used by shower head<br>= 101F[907] |
| $TEMP_{in}$ | = Assumed temperature of water entering house<br>= 54 F[908] |
| DHW Recovery Efficiency | = Recovery efficiency of electric water heater<br>= 0.98 [909] |
| 3412 | = Constant to converts BTU to kWh |
| ISR | = In Service Rate<br>= 0.95 [910] |

$$\Delta kWh = [((2.02 \times 4.7 - 1.5 \times 4.7) \times 2.34 \times 365) / 1.7] \times 8.3 \times (101-54) / 0.98 / 3412 \times 0.95$$

$$= 136 \text{ kWh}$$

**Demand Savings**

$\Delta kW$ = $\Delta kWh$ / hours

Where:

Hours = Operating hours from Residential DHW Conservation Loadshape[911]
= 3427

$$\Delta kW = 136 \text{ kWh} / 3427$$
$$= 0.0395 \text{ kW}$$

**Baseline Efficiencies – New or Replacement**

The baseline condition is an existing shower head with a high flow.

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903 Based on 7.8 minutes per shower and 0.6 showers per person per day (7.8 × 0.6 = 4.7 minutes per person per day); CADMUS and Opinion Dynamics, "Showerhead and Faucet Aerator Meter Study," prepared for the Michigan Evaluation Working Group, 2013.

904 Ibid.

905 Average people per household in Vermont single family buildings, 2010 Census

906 Estimate based on review of a number of studies:

d. Pacific Northwest Laboratory; "Energy Savings from Energy-Efficient Showerheads: REMP Case Study Results, Proposed Evaluation Algorithm, and Program Design Implications" http://www.osti.gov/bridge/purl.cover.jsp;jsessionid=80456EF00AAB94DB204E848BAE65F199?purl=/10185385-CEkZMk/native/

e. East Bay Municipal Utility District; "Water Conservation Market Penetration Study" http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf

f. AWWA, Residential End Uses of Water, 1999, http://www.allianceforwaterefficiency.org/residential-end-uses-of-water-study-1999.aspx

907 CADMUS and Opinion Dynamics, "Showerhead and Faucet Aerator Meter Study," prepared for the Michigan Evaluation Working Group, 2013.

908 Champlain Water District, 2010 Water Quality Report, http://www.cwd-h2o.org/vertical/Sites/%7B0A660058-838C-4456-B2E9-CCDA30420B07%7D/uploads/2011_Water_Quality_Report1.pdf

909 NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

910 Navigant, 2013, Draft Evaluation of Multi-Family Home Energy Savings Program for ComEd PY4 and Nicor Gas PY1

911 Based on Itron eShapes (8760 data) and adjusted for diversity within the hour

**High Efficiency**
High efficiency is a low flow shower head.

**Loadshape**
For DHW systems not on Utility Controlled DHW program (Default):
Loadshape #8, Residential DHW Conservation

For DHW systems on Utility Controlled DHW program:
Loadshape #54, Controlled DHW Conservation

**Freeridership/Spillover Factors**

| Measure Category | | Hot Water | |
|---|---|---|---|
| Measure Code | | HWESHOWR | |
| Product Description | | Low Flow Shower Head | |
| Track Name | Track No. | Freerider | Spillover |
| RES Retrofit | 6036RETR | 0.90 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
9 years (same as in DPS screening of Efficiency Utility Core programs).
Analysis period is the same as the lifetime.

**Measure Cost**
The incremental cost for low-flow shower heads is presumed to be zero for new construction or major rehab projects, and $15 for retrofit applications.[912]

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure

**Fossil Fuel Descriptions[913]**
If fossil fuel water heating:
$\Delta MMBtu = ((\Delta kWh \times \eta WH_{electric}) / \eta WH_{combustion}) \times 0.003412$

Where:
$\eta WH_{electric}$ = Recovery efficiency of electric water heater
= 0.98 [914]
$\eta WH_{combustion}$ = Recovery efficiency of fossil fuel water heater
= 0.76 [915]
Other factors as defined above

$$\Delta MMBtu = ((136 \times 0.98) / 0.76) \times 0.003412$$

$$= 0.60\ MMBtu$$

[912] Includes showerhead cost of $2.5 for a regular, $2.97 for chrome and $7.26 for handheld, plus labor installation costs.
[913] Fossil fuel savings based on efficiency factors of .62 for oil, natural gas, and liquid propane high efficiency stand alone DHW heaters as approved by the VT- DPS and used by Efficiency Vermont. Efficiency factor of .88 is used for electric DHW heater.
[914] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40
[915] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

**Water Descriptions**

$\Delta CCF = ((GPM_{base} \times min/person/day_{base} - GPM_{efficient} \times min/person/day_{efficient}) \times \# \text{ people} \times days/year) / (SH/home \times 748)$

Where:

$\Delta CCF$ = customer water savings in hundreds of cubic feet for the measure

748 = Conversion from gallons to CCF

Other factors are as defined above

$$\Delta CCF = ((2.02 \times 4.7 - 1.5 \times 4.7) \times 2.34 \times 365) / (1.7 \times 748)$$

= 1.64 CCF

# Low Flow Faucet Aerator

Measure Number: VII-A-5-c (Residential Existing Homes, Hot Water End Use)

**Version Date & Revision History**
Draft date: Portfolio 81
Effective date: 1/1/2013
End date: TBD

**Referenced Documents**:

1. DOE, "Energy and Water Conservation Standards," Federal Register Vol. 63, No. 52, March 18, 1998, 13307
2. AWWA, Residential End Uses of Water, 1999, http://www.allianceforwaterefficiency.org/residential-end-uses-of-water-study-1999.aspx
3. Ontario Energy Board, "Measures and Assumptions for Demand Side Management Planning."
4. East Bay Municipal Utility District; "Water Conservation Market Penetration Study" http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf
5. CADMUS and Opinion Dynamics, "Showerhead and Faucet Aerator Meter Study," prepared for the Michigan Evaluation Working Group, 2013.
6. Champlain Water District, 2010 Water Quality Report, http://www.cwd-h2o.org/vertical/Sites/%7B0A660058-838C-4456-B2E9-CCDA30420B07%7D/uploads/2011_Water_Quality_Report1.pdf
7. NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40
8. 2010 Census

**Description**
An existing faucet aerator with a high flow rate is replaced with new unit that has a low flow rate. This is a retrofit measure.

**Algorithms**

**Energy Savings**

If electric domestic water heater:

$\Delta$kWh[916] $= (((GPM_{base} – GPM_{efficient}) / GPM_{base} \times \#\ people \times gpcd \times days/year \times DR) / (F/home)) \times 8.3 \times (TEMP_{ft} - TEMP_{in}) / DHW\ Recovery\ Efficiency / 3412$

Where:

$GPM_{base}$ = Gallons Per Minute of baseline faucet
= 2.2 [917]

$GPM_{efficient}$ = Gallons Per Minute of low flow faucet
= 1.5 or
= 1.0

# people = Average number of people per household
= 2.34 [918]

gpcd = Average gallons per person per day using faucets
= 10.9 [919]

[916] Note, the algorithm and variables are provided as documentation for the deemed savings result provided which should be claimed for all faucet aerator installations.
[917] In 1998, the Department of Energy adopted a maximum flow rate standard of 2.2 GPM at 60 psi for all faucets: DOE, "Energy and Water Conservation Standards," Federal Register Vol. 63, No. 52, March 18, 1998, 13307
[918] Average people per household in Vermont single family buildings, 2010 Census
[919] AWWA, Residential End Uses of Water, 1999, http://www.allianceforwaterefficiency.org/residential-end-uses-of-water-study-1999.aspx

days/y = Days faucet used per year
= 365

DR = Percentage of water flowing down drain (if water is collected in a sink, a faucet aerator will not result in any saved water)
= 50% [920]

F/home = Average number of faucets in the home
= 3.5 [921]

8.3 = Constant to convert gallons to lbs

$TEMP_{ft}$ = Assumed temperature of water used by faucet
= 88 F[922]

$TEMP_{in}$ = Assumed temperature of water entering house
= 54 F[923]

DHW Recovery Efficiency = Recovery efficiency of electric water heater
= 0.98 [924]

3412 = Constant to converts BTU to kWh

Aerator at 1.5 gpm

$$\Delta kWh = ((2.2 - 1.5) / 2.2 \times 2.34 \times 10.9 \times 365 \times 0.5) / 3.5 \times 8.3 \times (88 - 54) / 0.98 / 3412$$

$$= 35.7 \text{ kWh}$$

Aerator at 1.0 gpm

$$\Delta kWh = ((2.2 - 1.0) / 2.2 \times 2.34 \times 10.9 \times 365 \times 0.5) / 3.5 \times 8.3 \times (88 - 54) / 0.98 / 3412$$

$$= 61.2 \text{ kWh}$$

**Demand Savings**

$\Delta kW = \Delta kWh / hours$

Where:

Hours = Operating hours from Residential DHW Conservation Loadshape[925]
= 3427

Aerator at 1.5 gpm

$$\Delta kW = 35.7 \text{ kWh} / 3427 = 0.0104 \text{ kW}$$

Aerator at 1.0 gpm

$$\Delta kW = 61.2 \text{ kWh} / 3427 = 0.0179 \text{ kW}$$

**Baseline Efficiencies – New or Replacement**

The baseline condition is an existing faucet aerator using 2.2 gpm.

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920 Estimate consistent with Ontario Energy Board, "Measures and Assumptions for Demand Side Management Planning."

921 Estimate based on East Bay Municipal Utility District; "Water Conservation Market Penetration Study" http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf

922 Weighted average of kitchen (93F) and bathroom (86F) faucet use temperatures, CADMUS and Opinion Dynamics, "Showerhead and Faucet Aerator Meter Study," prepared for the Michigan Evaluation Working Group, 2013.

923 Champlain Water District, 2010 Water Quality Report, http://www.cwd-h2o.org/vertical/Sites/%7B0A660058-838C-4456-B2E9-CCDA30420B07%7D/uploads/2011_Water_Quality_Report1.pdf

924 NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

925 Based on Itron eShapes (8760 data) and adjusted for diversity within the hour

**High Efficiency**
High efficiency is a low flow aerator, 1.5 or 1.0 gpm.

**Loadshape**
For DHW systems not on Utility Controlled DHW program (Default):
Loadshape #8, Residential DHW Conservation

For DHW systems on Utility Controlled DHW program:
Loadshape #54, Controlled DHW Conservation

**Freeridership/Spillover Factors**

| | | | |
|---|---|---|---|
| Measure Category | | Hot Water | |
| Measure Code | | HWEFAUCT | |
| Product Description | | Low Flow Faucet Aerator | |
| Track Name | Track No. | Freerider | Spillover |
| RES Retrofit | 6036RETR | 0.90 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
The expected lifetime of the measure is 9 years (same as in DPS screening of Efficiency Utility Core programs). Analysis period is the same as the lifetime.

**Measure Cost**
The incremental cost for low-flow faucet aerators is presumed to be zero for new construction or major rehab projects, and $10 for retrofit applications.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure

**Fossil Fuel Descriptions**[926]
If fossil fuel water heating:
$\Delta MMBtu = ((\Delta kWh \times \eta WH_{electric}) / \eta WH_{combustion}) \times 0.003412$

Where:
$\eta WH_{electric}$ = Recovery efficiency of electric water heater
= 0.98 [927]
$\eta WH_{combustion}$ = Recovery efficiency of fossil fuel water heater
= 0.76 [928]
Other factors as defined above

Aerator at 1.5 gpm
$\Delta MMBtu = ((35.7 \times 0.98) / 0.76) \times 0.003412$

= 0.157 MMBtu

Aerator at 1.0 gpm

[926] Fossil fuel savings based on efficiency factors of .62 for oil, natural gas, and liquid propane high efficiency stand-alone DHW heaters as approved by the VT- DPS and used by Efficiency Vermont. Efficiency factor of .88 is used for electric DHW heater.
[927] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40
[928] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

$\Delta MMBtu = ((61.2 \times 0.98) / 0.76) \times 0.003412$

$= 0.269$ MMBtu

**Water Descriptions**

$\Delta CCF = ((GPM_{base} – GPM_{efficient}) / GPM_{base} \times \# \text{ people} \times \text{gpcd} \times \text{days/year} \times DR) / (F/home \times 748)$

Where:

$\Delta CCF$ = customer water savings in hundreds of cubic feet for the measure

748 = Conversion from gallons to CCF

Other factors are as defined above

Aerator at 1.5 gpm

$\Delta CCF = ((2.2 – 1.5) / 2.2 \times 2.34 \times 10.9 \times 365 \times 0.5) / (3.5 \times 748)$

$= 0.566$ CCF

Aerator at 1.0 gpm

$\Delta CCF = ((2.2 – 1.0) / 2.2 \times 2.34 \times 10.9 \times 365 \times 0.5) / (3.5 \times 748)$

$= 0.970$ CCF

### Hot Water End Use (with Electric Hot Water Fuel Switch)
# Electric Domestic Hot Water System Fuel Switch

Measure Number: VII-A-15-b Residential Existing Homes, Water Heating End Use)

**Version Date & Revision History**
Draft date: Portfolio 49
Effective date: 9/1/2007
End date: TBD

Referenced Documents: 1) 2007_Rx DHW Economics Tool.xls

**Description**
An electric domestic hot water heater is replaced with a fossil fuel based domestic hot water heater meeting specified efficiency criteria. This measure characterization and savings estimates are taken from averages, and, as such, is applicable across all house types.

**Algorithms**
**Energy Savings**

| Electric DHW Fuel Switch Prescriptive Saving Values | |
|---|---|
| **Bedrooms** | **kWh Savings** |
| 1 | 2,400 |
| 2 | 3,000 |
| 3 | 3,600 |
| 4 | 4,500 |
| 5+ | 5,400 |

**Source**: Negotiated Efficiency Vermont and DPS estimate based on an analysis of 1993 and 2001 RECS data and 2000 DOE Technical Support Document for DHW Efficiency Standards. Assumes the average 3 bedroom home consumes 3,600 kWh. Estimates for usage for homes of other sizes is based on MMBtu consumption for DHW by number of bedrooms from RECS 2001 data and scaled proportionally from the 3 bedroom consumption estimate. Estimated kWh savings detailed above are net of auxiliary electricity use by the new fossil fuel based equipment. For full reference, see “Rx EDHW Fuel Switch.xls”

**Baseline Efficiencies – New or Replacement**
Electric domestic hot water heating system installed prior to the new 2004 Federal efficiency standards with a 50 gallon storage tank and energy factor of 0.88.

**High Efficiency**
Cost-effective fossil fuel based domestic hot water heating system meeting the following minimum efficiency standards and installed in homes meeting the minimum number of bedrooms by system type and fuel.

**Minimum Bedrooms for Cost-Effective Fuel Switch Threshold Table**

| Fuel Type | Equipment Type | Average Efficient EF | Minimum Bedrooms Uncontrolled Electric Rate | Minimum Bedrooms Controlled Electric Rate |
|---|---|---|---|---|
| # 2 Heating Oil | Water Heater (stand-alone) | 64% | >=3 | >=4 |

| | | | | |
|---|---|---|---|---|
| | Storage Tank (indirect-fired) | 75% | >=1 | >=1 |
| | Instantaneous (continuous) | 88% | >=1 | >=2 |
| | | | | |
| Natural Gas | Water Heater (stand-alone) | 59% | >=1 | >=1 |
| | Storage Tank (indirect-fired) | 75% | >=1 | >=1 |
| | Instantaneous (continuous) | 80% | >=1 | >=1 |
| | | | | |
| Liquid Propane | Water Heater (stand-alone) | 61% | Not cost-effective | Not cost-effective |
| | Storage Tank (indirect-fired) | 75% | >=4 | Not cost-effective |
| | Instantaneous (continuous) | 80% | >=4 | Not cost-effective |
| | | | | |
| Kerosene | Instantaneous (continuous) | 88% | >=2 | >=2 |
| | | | | |

**Operating Hours**
n/a

**Loadshape**
Loadshape #6, Residential DHW Fuel Switch
Loadshape # 52, Controlled DHW Fuel Switch

**Freeridership/Spillover Factors**

| Measure Category | | Hot Water Fuel Switch | |
|---|---|---|---|
| Measure Code | | HWFCFOIL, HWFCKERO,HWFCNGAS, HWFCPROP, HWFNFOIL, HWFNNGAS, HWFNPROP, HWFNWOOD, HWFSFOIL, HWFSNGAS, HWFSPROP, | |
| Product Description | | Hot water fuel switch (various fossil fuel systems) | |
| Track Name | Track No. | Freerider | Spillover |
| LISF Retrofit | 6034LISF | 1 | 1 |
| RES Retrofit | 6036RETR | 0.80/0.50[929] | 1 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**

| Fuel Type | Equipment Type | Analysis Period | Measure Lifetime |
|---|---|---|---|
| # 2 Heating Oil | Water Heater (stand-alone) | 30 | 10 |
| | Storage Tank (indirect-fired) | 30 | 15 |
| | Instantaneous (continuous) | 30 | 15 |

[929] The freerider rate for stand-alone natural gas fired systems will be 0.50. All other systems will have a freerider rate of 0.80.

| | | | |
|---|---|---|---|
| | | | |
| Natural Gas | Water Heater (stand-alone) | 30 | 13 |
| | Storage Tank (indirect-fired) | 30 | 15 |
| | Instantaneous (continuous) | 30 | 15 |
| | | | |
| Liquid Propane | Water Heater (stand-alone) | 30 | 13 |
| | Storage Tank (indirect-fired) | 30 | 15 |
| | Instantaneous (continuous) | 30 | 15 |
| | | | |
| Kerosene | Instantaneous (continuous) | 30 | 15 |
| | | | |

Source: EVT estimate.

**Measure Costs**
Full retrofit costs for the efficient fossil fuel based DHW heating system are detailed below. Note, we estimate the electric DHW system being replaced was on average 12 years old, with only 3 years of working life remaining. This is taken into account in measure screening.

| Fuel Type | Equipment Type | Est. Full Installed Cost for Baseline Electric DHW Equipment | Est. First Time Full Installed Cost for Efficient Equipment | Replacement Costs for Efficient Equipment |
|---|---|---|---|---|
| # 2 Heating Oil | Water Heater (stand-alone) | $500 | $2,250 | $1,500 |
| | Storage Tank (indirect-fired) | $500 | $1,700 | $1,200 |
| | Instantaneous (continuous) | $500 | $2,500 | $1,925 |
| | | | | |
| Natural Gas | Water Heater (stand-alone) | $500 | $9,75 | $950 |
| | Storage Tank (indirect-fired) | $500 | $1,350 | $1,200 |
| | Instantaneous (continuous) | $500 | $1,500 | $1,400 |
| | | | | |
| Liquid Propane | Water Heater (stand-alone) | $500 | $1,300 | $950 |
| | Storage Tank (indirect-fired) | $500 | $1,650 | $1,200 |
| | Instantaneous (continuous) | $500 | $2,000 | $1,400 |
| | | | | |
| Kerosene | Instantaneous (continuous) | $500 | $2,600 | $2,200 |
| | | | | |

**Source:** Estimate from actual installed costs reported to Efficiency Vermont from custom DHW fuel switches during 2006-2007.

**O&M Cost Adjustments**

| Fuel Type | Equipment Type | Baseline Equipment Annual Maintenance Costs (Electric DHW Heater) | Efficient Fossil Fuel Equipment Annual Maintenance Costs | O&M Cost Adjustments |
|---|---|---|---|---|
| # 2 Heating Oil | Water Heater (stand-alone) | $10 | $35 | ($25) |
| | Storage Tank (indirect-fired) | $10 | $10 | $0 |
| | Instantaneous (continuous) | $10 | $35 | ($25) |
| | | | | |
| Natural Gas | Water Heater (stand-alone) | $10 | $17 | ($7) |
| | Storage Tank (indirect-fired) | $10 | $10 | $0 |
| | Instantaneous (continuous) | $10 | $17 | ($7) |
| | | | | |
| Liquid Propane | Water Heater (stand-alone) | $10 | $17 | ($7) |
| | Storage Tank (indirect-fired) | $10 | $10 | $0 |
| | Instantaneous (continuous) | $10 | $17 | ($7) |
| | | | | |
| Kerosene | Instantaneous (continuous) | $10 | $35 | ($25) |
| | | | | |

Source: EVT estimate.

**Fossil Fuel Descriptions**
Replacing an electric domestic hot water heater with a fossil fuel based heater results in an increase in fossil fuel consumption. The tables below details increased MMBTU consumption by system type and house size in terms of bedrooms. These consumption estimates were calculated based on a comparison of the former kWh consumption per bedroom for DHW and the electric hot water heater energy factor of 0.88 and the new energy factor of the specific fuel and system type.

**Controlled and Uncontrolled Rate Electric Fuel Switch: MMBtu Consumption per System Type by House Size (Bedrooms)**

| Fuel Type | Equipment Type | 1 Bedroom | 2 Bedroom | 3 Bedroom | 4 Bedroom | 5+ Bedroom |
|---|---|---|---|---|---|---|
| # 2 Heating Oil | Water Heater (stand-alone) | 11.26 | 14.08 | 16.89 | 21.12 | 25.34 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Storage Tank (indirect-fired) | 9.61 | 12.01 | 14.42 | 18.02 | 21.62 |
| | Instantaneous (continuous) | 8.19 | 10.24 | 12.29 | 15.36 | 18.43 |
| | | | | | | |
| Natural Gas | Water Heater (stand-alone) | 12.22 | 15.27 | 18.33 | 22.91 | 27.49 |
| | Storage Tank (indirect-fired) | 9.61 | 12.01 | 14.42 | 18.02 | 21.62 |
| | Instantaneous (continuous) | 9.01 | 11.26 | 13.52 | 16.89 | 20.27 |
| | | | | | | |
| Liquid Propane | Water Heater (stand-alone) | 11.82 | 14.77 | 17.73 | 22.16 | 26.59 |
| | Storage Tank (indirect-fired) | 9.61 | 12.01 | 14.42 | 18.02 | 21.62 |
| | Instantaneous (continuous) | 9.01 | 11.26 | 13.52 | 16.89 | 20.27 |
| | | | | | | |
| Kerosene | Instantaneous (continuous) | 8.19 | 10.24 | 12.29 | 15.36 | 18.43 |
| | | | | | | |

**Water Descriptions**
There are no water algorithms or default values for this measure.

## Clothes Dryer End Use

# Electric Clothes Dryer Fuel Switch

Measure Number: VII-A-16-a (Existing Homes, Clothes Washing End Use)

**Version Date & Revision History**
Draft date: Portfolio 42
Effective date: 1/1/07

Referenced Documents: 1) Dryer usage.xls

**Description**
An electric clothes dryer is replaced with a fossil fuel based clothes dryer meeting specified efficiency criteria. The measure characterization and savings estimates are based on average usage per person and average number of people per Vermont household., Therefore, this is a prescriptive measure, with identical savings applied to all installation instances, applicable across all housing types.

**Algorithms**

**Energy Savings**[930]

ΔkWh = 977 kWh (supporting documentation in Dryer Usage.xls)

ΔMMBtu = -3.33 MMBtu (negative indicates increase in fuel consumption) (977*.003413 = 3.33) it is assumed that gas and electric dryers have similar efficiencies. All heated air passes through the clothes ad contributes to drying.

**Demand Savings**
ΔkW = 4.8 kW electric dryer = 5kW heating element. Gas dryer may have 200 watt glow coil. Motor wattage assumed to be equal.

Where:

| | |
|---|---|
| ΔkWh | = weighted average annual kWh savings per dryer per residential unit |
| ΔMMBtu | = weighted average fossil fuel energy savings per dryer per residential unit in MMBtu (million Btu) |
| ΔkW | = weighted average connected load kW savings per dryer |

**Baseline Efficiencies – New or Replacement**
Baseline efficiency is an electric dryer used in conjunction with a mix of standard top-loading clothes washers (80%) and ENERGY STAR qualified washers (20%)[931] (supporting documentation in Dryer Usage.xls).

**Non-Electric**
A propane or natural gas dryer used in conjunction with a mix of standard top-loading clothes washers (80%) and ENERGY STAR qualified washers (20%) (supporting documentation in Dryer Usage.xls).

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
14 years (same as for clothes washers in DPS screening of Efficiency Utility Core programs).
Remaining life = 4 years

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930 Average annual dryer kWh per Vermont household using EIA data for kwh/year/household for nationwide household and using census data for Vermont residents/household. Assumes an average 2.44 people per home in Vermont. Estimates for usage for homes of other sizes is based on MMBtu consumption for DHW by number of bedrooms from RECS 2001 data and scaled proportionally from the per person consumption estimate. Estimated kWh savings detailed above are net of auxiliary electricity use by the new fossil fuel based equipment.

931 Vermont estimates saturation of ENERGY STAR washers to be 20%

**Analysis Period**
30 years

**Baseline Efficiencies – New or Replacement**
Efficiencies assumed to be the same for both baseline and new equipment.

**Operating Hours**
n/a

**Loadshape**
Loadshape #9, Residential Clothes Washer, Vermont State Cost Effectiveness Screening Tool

**Freeridership/Spillover Factors**

| Measure Category | | Hot Water Fuel Switch | |
|---|---|---|---|
| Measure Codes | | OTFYPROP; OTFYNGAS | |
| Product Description | | Clothes Dryer fuel switch (various fossil fuel systems) | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6012MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | 1 | 1 |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | 1.0/0.90[932] | 1 |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| Customer Credit | 6015CC | n/a | n/a |

**Measure Costs**
Full retrofit costs for the efficient fossil fuel based clothes dryer are detailed below. Note, we estimate the electric clothes dryer being replaced was on average 10 years old with 4 years of working life remaining. This is taken into account in measure screening.

| Equipment Type | Est. Full Installed Cost for Baseline Electric Equipment | Est. First Time Full Installed Cost for Efficient Equipment | Replacement Costs for Efficient Equipment |
|---|---|---|---|
| Clothes Dryer | $320 | $580 | $380 |

**Source:** Survey of local retailers.

[932] The freerider rate for natural gas fired units will be 10%, propane will have a freerider rate of 0%.

**Incentive Level**

| Track Name | Track No. | Incentive |
|---|---|---|
| LISF Retrofit | 6034LISF | 75% of full installed cost |
| RES Retrofit | 6036RETR | $200 |
| RNC VESH | 6038VESH | $100 |

**O&M Cost Adjustments**

| | Baseline (Electric Clothes Dryer) | Fossil Fuel Clothes Clothes Dryer | O&M Cost Adjustments |
|---|---|---|---|
| **Equipment Annual Maintenance Costs** | $15 | $35 | ($20) |

Source: EVT estimate.

**Water Descriptions**
There are no water algorithms or default values for this measure.

## Lighting End Use

# Standard CFL Direct Install

Measure Number: VII-B-2-c (Residential Emerging Markets Program, Lighting End Use)

**Version Date & Revision History**:
Draft date: Portfolio 76
Effective date: 01/01/12
End date: 12/31/14

**Referenced Documents:**

1. DI Cost Query.xls, Direct Install Prescriptive Lighting TAG.doc
2. Residential Lighting Markdown Impact Evaluation, Nexus Market Research, RLW Analytics, and GDS Associated, January 20, 2009
3. Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)
4. 2012 EISA Adjustment Calculations.xls

**Description**
A compact fluorescent lamp replaces an incandescent bulb in an interior lighting fixture in a low income single-family homes direct install application.

**Algorithms**
**Demand Savings**
$\Delta$kW = (($\Delta$Watts) /1000)* ISR

| Year | Algorithm | $\Delta$kW |
|---|---|---|
| 2012 | = (49.0 / 1000) * 0.8 | 0.0392 |
| 2013 | = (43.6 / 1000) * 0.8 | 0.0349 |
| 2014 | = (37.0 / 1000) * 0.8 | 0.0296 |

**Energy Savings**
$\Delta$kWh = (($\Delta$Watts) /1000) * ISR * HOURS

| Year | Algorithm | $\Delta$kWh |
|---|---|---|
| 2012 | = (49.0 / 1000) * 0.8 * 694 | 27.2 |
| 2013 | = (43.6 / 1000) * 0.8 * 694 | 24.2 |
| 2014 | = (37.0 / 1000) * 0.8 * 694 | 20.5 |

Where:

$\Delta$kW = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW
$Watts_{EE}$ = Energy efficient connected kW
$\Delta$kWh = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units rebated that actually get used = 0.8[933]
HOURS = average hours of use per year = 694[934]

[933] 0.8 ISR based on TAG 2009 agreement.
[934] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011.

**Baseline Efficiencies – New or Replacement**
The baseline is an incandescent bulb.

**Baseline Adjustment**
In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become Halogen bulbs (see percentages in O&M table below).

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012.
The appropriate adjustments are provided below (see CFL baseline savings shift.xls for details on how adjustment is calculated):

| Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|
| 2012 | 0.66 | 2 |
| 2013 | 0.77 | 1 |
| 2014 | 0.88 | 1 |

**High Efficiency**
High efficiency is an ENERGY STAR compact fluorescent bulb.
Delta watts based on NEEP Residential Lighting Survey, 2011.

**Operating Hours**
Operating hours will be assumed as 1.9 hours per day or 694 hours per year[935].

**Loadshape**
If Indoor, Loadshape #1 - Residential Indoor Lighting
If Outdoor, Loadshape #2 - Residential Outdoor Lighting

**Freeridership/Spillover Factors**

| | | | |
|---|---|---|---|
| Measure Category | | Light Bulbs/Lamps | |
| Measure Code | | LBLCFBLB | |
| Product Description | | Compact Fluorescent Screw-base bulb | |
| Track Name | Track No. | Freerider | Spillover |
| LIMF Retrofit | 6017RETR | 1 | 1 |
| LIMF NC | 6018LINC | 1 | 1 |
| LIMF Rehab | 6018LIRH | 1 | 1 |
| MF Mkt NC | 6019MFNC | 1 | 1 |
| MF Mkt Retro | 6020MFMR | 0.9 | 1.05 |
| LISF Retrofit | 6034LISF | 1 | 1 |
| RES Retrofit | 6036RETR | 0.9 | 1 |
| RNC VESH | 6038VESH | 1 | 1 |

**Persistence**
The persistence factor is assumed to be 90% as agreed to by EVT and the DPS (TAG 2007).

[935] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011.

**Lifetimes**
Bulb life is assumed to be 8500 hours, based on agreement between EVT and the DPS (TAG 2009). At 694 hours per year and including the 90% persistence factor this equates to 11 years. A provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore the measure life will reduce each year and be equal to the number of years remaining to 2020; so for 2012 this will be 8 years, 2013 7 years.

Analysis period is the same as the lifetime.

**Measure Cost**[936]
The average installed cost is assumed to be $6.09 ($2.50 for the bulb and $3.59 for labor)[937].

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Methodology for Computing O&M Savings**
In order to account for the shift in baseline due to the Federal Legislation, the levelized baseline replacement cost over the lifetime of the CFL was calculated (see 2012 EISA Adjustments.xls). The key assumptions used in this calculation are documented below:

| | Incandescent | Halogen | CFL |
|---|---|---|---|
| Replacement Cost | $0.50 | $1.50 | $2.50 |
| Component Life (hours) | 1000 | 1000 | 8500 |
| Baseline % in 2009-2011 | 100% | 0% | 0% |
| Baseline % in 2012 | 67% | 33% | 0% |
| Baseline % in 2013 | 33% | 67% | 0% |
| Baseline % in 2014 onward | 0% | 100% | 0% |
| Baseline % in 2020 onward | 0% | 0% | 100% |

The calculation results in a levelized assumption of $0.96 baseline replacement cost every 1 year for CFL installations in 2012, $1.14 every year for installations in 2013, and $1.19 for installations in 2014. This adjustment will be recalculated for subsequent years.

[936] 2009 cost represents full, installed cost and is computed with a weighted average of all direct install interior CFLs installed under the Efficiency Vermont Existing Homes and Low Income Program between 1/1/2006 and 12/1/2007. 2010 and 2011 costs decline at same rate as the assumption for CFL bulbs.
[937] $2.50 for CFL is based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011. Labor rate consistent with other measures.

# Solid State (LED) Recessed Downlight

Measure Number: VII-B-4-a (Residential Emerging Markets Program, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 77
Effective date: 1/1/2011
End date: TBD

**Referenced Documents:**
1) WasteHeatAdjustment.doc;
2) "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993

**Description**
An LED Downlight is used in place of an incandescent downlight. The downlight must be tested by the DOE Caliper Testing Program or Independent 3rd party testing with results shown to meet the upcoming Energy Star Specification for Solid State Luminaires. This Specification will take effect September 31st, 2008, and can be downloaded from http://www.netl.doe.gov/ssl/. See Reference Table of Energy Star requirements for recessed downlights.

**Algorithms**
**Demand Savings**

$\Delta kW = ((Watts_{BASE} - Watts_{EE}) / 1000) \times ISR \times WHF_d$

$\Delta kW(Residential) = ((65 - 12) / 1000) \times 0.95) \times 1.0 = 0.05035$

$\Delta kW(Commercial) = ((65 - 12) / 1000) \times 0.95 ) \times 1.082 = 0.054479$

**Energy Savings**

$\Delta kWh = ((Watts_{BASE} - Watts_{EE}) / 1000) \times HOURS \times ISR \times WHF_e$

$\Delta kWh\ (Residential) = ((65 - 12) / 1000) \times 1241 \times 0.95 \times 1.0 = 62.48$

$\Delta kWh\ (Commercial) = ((65 - 12) / 1000) \times 2800 \times 0.95 \times 1.033 = 145.63$

Where:

$\Delta kW$ = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW.[938]
$Watts_{EE}$ = Energy efficient connected kW.[939]
$\Delta kWh$ = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units rebated that actually get used[940]
$WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.082 (calculated as 1 + (0.47*0.67*.808) / 3.1))[941]. The cooling savings are only added to the summer peak savings.
$WHF_e$ = Waste heat factor for energy to account for cooling savings from efficient lighting. For commercial lighting, the value is 1.033 (calculated as 1 + ((0.47*0.29*.75) / 2.5))[942].
HOURS = average hours of use per year[943]

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938 Baseline wattage based on 65 Watt BR30 incandescent bulb.
939 Energy Efficient wattage based on 12 Watt LR6 Downlight from LLF Inc.
940 ISR differs for residential and commercial applications. See table below for ISR in each application.
941 Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 33% average outside air; and 80.8% coincidence of cooling with the summer peak period. See WasteHeatAdjustment.doc for additional discussion.
942 Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 25% average outside air; and 29% of annual lighting energy contributes to cooling load. See "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993 and WasteHeatAdjustment.doc for additional discussion.
943 Hours of usage differs for residential and commercial applications. See table below for HOURS at each application.

**Waste Heat Adjustment**
Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF). See above.

**Heating Increased Usage**
$\Delta MMBTU_{WH}$ = ($\Delta$kWh / $WHF_e$) × 0.003413 × AR × HF / 0.75
$\Delta MMBTU_{WH}$ (Residential) = (62.48 / 1.033) × 0.003413 × (1– 0.25) × 0.70 × 0.0 × 0.95 / 0.79 = 0.0
$\Delta MMBTU_{WH}$ (Commercial) = (145.63/ 1.033) × 0.003413 × (1– 0.25) × 0.70 × 0.39 × 0.95 / 0.79 = 0.11847

Where:

| | |
|---|---|
| $\Delta MMBTU_{WH}$ | = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat. |
| 0.003413 | = Conversion from kWh to MMBTU |
| OA | = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[944]. |
| AR | = Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of commercial buildings within 15 feet of exterior wall. The assumed aspect ratio for residential buildings is 100%. |
| HF | = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont for commercial lighting, assumed 0.0 for residential lighting [945] |
| DFH | = Percent of lighting in heated spaces, assumed to be 95% |
| HEff | = Average heating system efficiency, assumed to be 79%[946] |

Oil heating is assumed typical for commercial.

**Baseline Efficiencies – New or Replacement**
The baseline condition is a 65 watt BR30 incandescent fixture installed in a screw-base socket.

**High Efficiency**
High Efficiency is a downlight that has been tested by the DOE Caliper Testing Program or Independent 3rd party testing with results shown to meet the upcoming Energy Star Specification for Solid State Luminaires. This Specification will take effect September 31st, 2008, and can be downloaded from http://www.netl.doe.gov/ssl/ . See Reference Table of Energy Star requirements for recessed downlights.

**Operating Hours**
Residential: 1,241 hours / year
Commercial: 2,800 hours / year[947]

**Loadshape**
Residential: Loadshape, #1 - Residential Indoor Lighting; Commercial: Loadshape; #101: Commercial EP Lighting[948]

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944 Based on 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air." See WasteHeatAdjustment.doc
945 From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993. Efficiency Vermont does not calculate interactive effects for residential lighting.
946 Based on average efficiency for furnaces and boilers of varied sizes in ASHRAE 90.1.1999, assumed to represent typical commercial building stock in Vermont. See WasteHeatAdjustment.doc.
947 Based on agreement made during Savings Verification 2009.
948 Based on Commercial "Other" Lighting coincidence factors from RLW Analytics; "Development of Common Demand Impacts Standards for Energy Efficiency Measures/Programs for the ISO Forward Capacity Market (FCM)". Agreement made during Savings Verification 2009.

**Freeridership/Spillover Factors**

| Measure Category | | LED | |
|---|---|---|---|
| Measure Code | | LFHRDLED | |
| Product Description | | Solid State Recessed Downlight | |
| Track Name | Track No. | Freerider | Spillover |
| Efficient Products | 6032EPEP | 0.94 | 1.25 |
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |
| RES Retrofit | 6036RETR | 0.90 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
Lifetime is a function of the average hours of use of the lumenaire. The Energy Star Specification for Solid State Recessed Downlights requires luminaires to maintain at least 70% initial light output for 25,000 hrs in a residential application and 35,000 hours in a commercial application. Based on these lifetimes, LED Recessed Downlights rebated through this program are expected to have a life of 20.1 years for residential applications (assumed average daily usage of 3.4 hours) and 12.5 years for commercial applications (assumed annual usage of 2800 hours).
Analysis period is 20 years for residential installations, 12.5 years for commercial installations..

**Measure Cost**
The incremental cost for this measure is $44.35

**O&M Cost Adjustments**
O& M cost adjustments are based on component costs provided in the reference table below.

**Fossil Fuel Descriptions**
See Heating Increased Usage above.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

**Hours of Use, In Use Rates, and Waste Heat Factors by Customer Type**

| | Average Annual Hours of Use | Average In Service Rate | $WHF_d$ | $WHF_e$ | AR | HF |
|---|---|---|---|---|---|---|
| Residential | 1,241 | 0.95 | 1.0 | 1.0 | 1.0 | 0.0 |
| Commercial | 2,800[949] | 0.95 | 1.082 | 1.033 | 0.7 | 0.39 |

**Component Costs and Lifetimes Used in Computing O&M Savings Residential**

| Component | Market | Baseline Measures | |
|---|---|---|---|
| | | Cost | Life[950] |
| Lamp | Residential | $4.67 | 1.13 |
| | Commercial | $4.67 | 0.71 |

**Partial List of Energy Star Requirements for Solid State Recessed Downlights**

| | |
|---|---|
| Lumen Depreciation / Lifetime | LED shall deliver at least 70% of initial lumens for the minimum number of hours specified below: |

[949] Based on agreement made during Savings Verification 2009.
[950] Based on standard assumption of 2000 hours lamp life for baseline bulb 65 watt BR30 incandescent.

| | |
|---|---|
| | • >= 25,000 hrs Residential Indoor<br>• >= 35,000 hrs Commercial |
| Minimum CRI | 75 |
| Minimum Light Output | <= 4.5" Aperture: 345 lumens (initial)<br>> 4.5" Aperture: 575 lumens (initial) |
| Zonal Lumen Density Requirement | Luminaire shall deliver a total of 75% lumens (initial) within the 0-60 zone (bilaterally symmetrical) |
| Minimum Luminaire Efficacy | 35 lm/w |
| Allowable CCTs | • 2700K, 3000K, and 3500K for residential products<br>• No restrictions for commercial |
| Reduced Air Leakage | Recessed downlights intended for installation in insulated ceilings shall be IC rated and be leak tested per ASTM E283 to demonstrate no more than 2.0 cfm at 75 Pascals pressure difference. The luminaire must include a label certifying "sirtight" or similar designation to show accordance with ASTM E283. |
| Minimum Warranty | 3 years |
| • Eligible Products must meet the full requirements of the Energy Star specification. The complete Energy Star Specification for Solid State Luminaires can be obtained at www.netl.doe.gov | |

# Free CFL

Measure Number: VII-B-5-c (Residential Emerging Markets Program, Lighting End Use)

**Version Date & Revision History:**
Draft date: Portfolio 76
Effective date: 01/01/12
End date: 12/31/14

**Referenced Documents:**

1) EKOS Porchlight Report- December 2006.pdf
2) Residential Lighting Markdown Impact Evaluation, Nexus Market Research, RLW Analytics, and GDS Associated, January 20, 2009
3) Northeast Regional Residential Lighting Strategy, 2011 (NEEP RLS, 2011)
4) 2012 EISA Adjustment Calculations.xls

**Description**
An existing incandescent screw-in bulb is replaced with a lower wattage ENERGY STAR qualified compact fluorescent screw-in bulb that was received free of charge at a Efficiency Vermont event or as part of a targeted campaign, and is installed in a Residential fixture.

**Algorithms**
**Demand Savings**
$\Delta kW$ $= ((\Delta Watts) / 1000) \times ISR$

| Year | Algorithm | ΔkW |
|---|---|---|
| 2012 | (49.0 / 1000) * 0.5 | 0.0245 |
| 2013 | (43.6 / 1000) * 0.5 | 0.0218 |
| 2014 | (37.0 / 1000) * 0.5 | 0.0185 |

**Energy Savings**
$\Delta kWh$ $= ((\Delta Watts) / 1000) \times HOURS \times ISR$

| Year | Algorithm | ΔkWh |
|---|---|---|
| 2012 | (49.0 / 1000) * 694 * 0.5 | 17.0 |
| 2013 | (43.6 / 1000) * 694 * 0.5 | 15.1 |
| 2014 | (37.0 / 1000) * 694 * 0.5 | 12.8 |

Where:

$\Delta Watts$ $= Watts_{BASE} - Watts_{EE}$[951]
$\Delta kW$ = gross customer connected load kW savings for the measure
$Watts_{BASE}$ = Baseline connected kW
$Watts_{EE}$ = Energy efficient connected kW
$\Delta kWh$ = gross customer annual kWh savings for the measure
ISR = in service rate or the percentage of units given out that actually get used[952]
HOURS = average hours of use per year

**Waste Heat Adjustment**
N/A

**Heating Increased Usage**

[951] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011
[952] Efficiency Vermont will assume an In Service Rate for a Free CFL of 50%. An EKOS study of a free CFL campaign, 'Project Porchlight' in Ottawa, found an install rate of 70% of those who could recall receiving the bulb. A 50% ISR is considered a conservative assumption, especially when the bulbs will be accompanied by marketing material explaining the benefits. The state-wide CFL media campaign set to launch in January,2008 will also increase in-service rates by significantly raising awareness of the benefits of CFLs.

N/A

**Baseline Efficiencies – New or Replacement**
The baseline condition is an incandescent light bulb.

**Baseline Adjustment**
In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will begin phasing out incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will become Halogen bulbs (see percentages in O&M table below).

To account for these new standards, the savings for this measure will be reduced to account for the higher baseline starting in 2012, 2013 or 2014 depending on the assumed baseline wattage (note if a mix of bulbs is assumed, the adjustment always occurs in 2012).

The appropriate adjustments are provided below (see 2012 EISA Adjustment Calculations.xls for details)

| Year Installed | Savings Adjustment | Years of Full Savings Before Adjustment |
|---|---|---|
| 2012 | 0.66 | 2 |
| 2013 | 0.77 | 1 |
| 2014 | 0.88 | 1 |

**High Efficiency**
High efficiency is an ENERGY STAR qualified compact fluorescent lamp.

**Operating Hours**
Operating hours will be assumed as 1.9 hours per day or 694 hours per year[953].

**Loadshape**
Residential: Loadshape #1: Residential Indoor Lighting
Source: Vermont State Cost-Effectiveness Screening Tool.

**Freeridership/Spillover Factors**

| | | | |
|---|---|---|---|
| Measure Category | | Light Bulbs/Lamps | |
| Measure Code | | LBLCFFRE | |
| Product Description | | Free Compact Fluorescent screw-base bulbs | |
| Track Name | Track No. | Freerider | Spillover |
| Efficient Products | 6032EPEP | 1.0 | 1.0 |
| RES Retrofit | 6036RETR | 1.0 | 1.0 |

**Persistence**
The persistence factor is assumed to be 90%.

**Lifetimes**
CFLs rebated through this program are assumed to have a rated life of 8,500 hours.
Bulb life is assumed to be 8500 hours, based on agreement between EVT and the DPS (TAG 2009). At 694 hours per year and including the 90% persistence factor this equates to 11 years. A provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore the measure life will reduce each year and be equal to the number of years remaining to 2020; so for 2012 this will be 8 years, 2013 7 years.

953 Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011.

**Measure Cost**[954]

The incremental cost for this measure is as follows

| Year | Measure Cost |
|---|---|
| 2012 | $1.90 |
| 2013 | $1.80 |
| 2014 | $1.50 |

**Fossil Fuel Descriptions**

N/A

**Water Descriptions**

There are no water algorithms or default values for this measure.

**Reference Tables**

**Methodology for Computing O&M Savings**

In order to account for the shift in baseline due to the Federal Legislation, the levelized baseline replacement cost over the lifetime of the CFL was calculated (see 2012 EISA Adjustment Calculations.xls). The key assumptions used in this calculation are documented below:

| | Incandescent | Halogen |
|---|---|---|
| Replacement Cost | $0.50 | $1.50 |
| Component Life (hours) | 1000 | 1000 |
| Baseline % in 2012 | 67% | 33% |
| Baseline % in 2013 | 33% | 67% |
| Baseline % in 2014 onward | 0% | 100% |

The calculation results in a levelized assumption of $0.93 baseline replacement cost every 1 year for CFL installations in 2012, $0.96 every year for installations in 2013, and $0.97 for installations in 2014. This adjustment will be recalculated for subsequent years.

[954] Based on TAG 2011 agreement to use recommendation from NEEP RLS, 2011

# Specialty CFL Direct Install

Measure Number: VII-B-6-a (Residential Emerging Markets, Lighting End Use)

**Version Date & Revision History**
Draft date: Portfolio 75
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**
1. 2009 to 2011 bulbs installed.xlsx
2. Xenergy, 1998; "Process and Impact Evaluation of Joint Utilities Starlights Residential Lighting Program".

**Description**
An existing incandescent bulb is replaced with a lower wattage ENERGY STAR qualified specialty compact fluorescent bulb through a Direct Install program. Specialty CFL bulbs are defined as lamps for general illumination that use fluorescent light emitting technology and an integrated electronic ballast with or without a standard Edison screw-base. They can be dimmable, designed for special applications, have special color enhancement properties or have screw-bases that are not standard Edison bases, and include A-lamps, candelabras, G-lamps (globe), reflectors, torpedoes, dimmables, and 3-way bulbs. This TRM should be used for both interior and exterior installations, the only difference being the loadshape. Note specialty bulbs are currently exempt from EISA regulations.

**Algorithms**

**Demand Savings**
$\Delta kW = ((\Delta Watts) / 1000) \times ISR$
$\Delta kW(Res. <= 15W) = ((43.9) / 1000) \times 0.8 = 0.0351$
$\Delta kW(Res. > 15W) = ((62.6) / 1000) \times 0.8 = 0.0501$

**Energy Savings**
$\Delta kWh = \Delta kW \times HOURS$
$\Delta kWh\ (Res. <= 15W) = (0.0351 \times 694) = 24.4$
$\Delta kWh\ (Res. > 15W) = (0.0501 \times 694) = 34.8$

Where:
- $\Delta kW$ = gross customer connected load kW savings for the measure
- $\Delta Watts$ = Average delta watts between specialty CFL and incandescent $Watts_{BASE} - Watts_{EE}$[955]
- ISR = in service rate or the percentage of units rebated that actually get used[956]
- $\Delta kWh$ = gross customer annual kWh savings for the measure
- HOURS = average hours of use per year

**Baseline Efficiencies – New or Replacement**
The baseline condition is an incandescent specialty light bulb.

**High Efficiency**
High efficiency is an ENERGY STAR qualified specialty compact fluorescent lamp.

**Operating Hours**
Assumed to be 1.9 hours a day or 694 hours per year [957].

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[955] The delta watts is calculated by finding the weighted average wattage of specialty bulbs installed in Existing Homes, Low Income and RNC from 01/2009-04/2011. The equivalent incandescent wattage was used to calculate delta watts. See 2009 to 2011 bulbs installed.xlsx
[956] ISR is assumed to be equal to standard CFL Direct Install measure, and is based on a 2009 TAG agreement.

**Loadshape**
Loadshape #1: Residential Indoor Lighting
Loadshape #2: Residential Outdoor Lighting

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Freeridership/Spillover Factors**

| Measure Category | | Light Bulbs/Lamps | |
|---|---|---|---|
| Measure Code | | LBLCFSPD | |
| Product Description | | Compact Fluorescent – Specialty Bulb Direct Install | |
| Track Name | Track No. | Freerider | Spillover |
| LIMF Retrofit | 6017RETR | 1 | 1 |
| LIMF NC | 6018LINC | 1 | 1 |
| LIMF Rehab | 6018LIRH | 1 | 1 |
| MF Mkt NC | 6019MFNC | 1 | 1 |
| MF Mkt Retro | 6020MFMR | 1 | 1 |
| LISF Retrofit | 6034LISF | 1 | 1 |
| RES Retrofit | 6036RETR | 0.9 | 1 |
| RNC VESH | 6038VESH | 1 | 1 |

**Persistence**
The persistence factor is assumed to be 90% as agreed to by EVT and the DPS (TAG 2007).

**Lifetimes**
Bulb life is assumed to be 8500 hours, based on agreement between EVT and the DPS (TAG 2009). The measure life, including the 90% persistence factor is therefore assumed to be 8500/694 * 0.9 = 11 years.
Analysis period is the same as the lifetime.

**Measure Cost**[958]
Cost (Watts <=15) = $8.16 + $3.59 (labor) = $11.75
Cost (Watts >15) = $8.84 + $3.59 (labor) = $12.43

**Incentive Level**
The incentive level is equal to the measure cost (these bulbs are free to the customer).

**O&M Cost Adjustments**
O& M cost adjustments are based on component costs provided in the reference table below.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**
**Component Costs and Lifetimes Used in Computing O&M Savings**

[957] Hours of use are based on TAG 2011 agreement to use the NEEP Residential Lighting Survey, 2011 proposed values.
[958] Incremental cost of bulb is consistent with the assumptions from the NEEP Residential Lighting Survey, 2011. This evaluation did not provide the <=15W and >15W categories and so the costs from EVT's analysis of incremental costs are adjusted such that the average matches the values from the NEEP study. Labor cost is consistent with the standard bulb direct install measures.

**Residential**

| | Baseline Measures | |
|---|---|---|
| Component | Cost[959] | Life[960] |
| Lamp<=15W | $2.71 | 1.4 |
| Lamp>15W | $4.29 | 1.4 |

[959] Baseline cost is consistent with the assumptions from the NEEP Residential Lighting Survey, 2011. This evaluation did not provide the <=15W and >15W categories and so the costs from EVT's analysis of baseline costs are adjusted such that the average matches the values from the NEEP study

[960] Based on the assumption that the incandescent bulb rated life is 1000 hours. 1000/694 = 1.4years.

## HVAC End Use
# Efficient Furnace Fan Motor

Measure Number: VII-C-1-d

**Version Date & Revision History**
Draft date: Portfolio 77
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**
1) Pigg Furnace Fan Report 2003.pdf;
2) "Energy Savings from Efficient Furnace Fan Air Handlers in Massachusetts" ACEEE Sachs and Smith, 2003
3) 2009 - Focus on Energy - ECM Furnace Blower Motor Impact Assessment.pdf
4) FOE to VT Blower Savings.xls

**Description**
This measure will provide incentives for installing an ENERGY STAR qualified natural gas, or propane and an efficient oil fired furnace with a high efficiency brushless permanent magnet fan motor (BPM, also called ECM, ICM, and other terms), hereafter referred to as "efficient fan motor". This prescriptive measure will apply when retrofitting an existing unit or installing a new furnace. The incentive offer and savings estimation relate only to the efficiency gains associated with an upgrade to an efficient fan motor. For homes that install an efficient furnace fan and have central A/C, additional kWh savings are estimated due to the efficiency gains from the furnace fan which is used to circulate cooled air.

**Algorithms**
**Energy Savings**[961]
Heating Only Efficient Furnace Fan kWh Savings

$\Delta$kWh = (Heating + Shoulder $\Delta$kWh savings)
$\Delta$kWh = 418 + 145 + 79 = 642

Heating & Central A/C Efficient Furnace Fan kWh Savings

$\Delta$kWh = (Heating + Shoulder $\Delta$kWh savings) + (Cooling $\Delta$kWh savings)
$\Delta$kWh = 418 + 178+ 79 = 675

Where:

$\Delta$kWh = gross customer annual kWh savings for the measure
Heating + Shoulder $\Delta$kWh savings = kWh savings during heating and shoulder seasons
Cooling $\Delta$kWh savings = kWh savings during cooling season

**Demand Savings**[962]

[961] To estimate heating, cooling and shoulder season savings for Vermont, VEIC adapted results from a 2009 Focus on Energy study of BPM blower motor savings in Wisconsin. This study included effects of behavior change based on the efficiency of new motor greatly increasing the amount of people that run the fan continuously. The savings from the Wisconsin study were adjusted to account for different run hour assumptions (average values used) for Illinois. See: Reference Table, below and reference doc "FOE to VT Blower Savings.xlsx"
[962] This measure's peak savings occur in the heating season. Demand savings are accordingly unrelated to the presence of CAC, and are based upon heating savings and heating operating hours. The heating operating hours are based upon the kWh to max kW (1522) used by the loadshape

Efficient Furnace Fan kW Savings

$\Delta$kW = (Heating$\Delta$kWh savings) / Hours

$\Delta$kW = 405/(1522) = 0.27

Where:

$\Delta$kW = gross customer connected load kW savings for the measure

Hours = Fan Heating Operating Hours

**Baseline Efficiencies – New or Replacement**

A furnace meeting minimum Federal efficiency standards using a low-efficiency permanent split capacitor (PSC) fan motor.

**High Efficiency**

The installed natural gas or propane furnace must be ENERGY STAR qualified, residential sized, i.e. <=200,000 Btu/hr unit that meets the criteria for electricity consumption by the furnace fan motor[963], a calculation of of annual electricity used relative to total energy use. Version 3.0, effective 2/1/2012 requires this new metric to be less than or equal to 2.0%. Version 4.0, effective 2/1/2013 includes a new metric for case leakage with negligible energy impacts. Qualification criteria for oil fired furnaces are that they must be residential sized as described above and have an AFUE >=85 and an EaE <=600.

**Operating Hours**

Cooling Only: 375 hours/year[964]

**Loadshape**

Loadshape #5, Residential Space Heat.

Loadshape #71, Furnace Fan Heating and Cooling

**Freeridership/Spillover Factors[965]**

| Measure Category | | Space Heat Efficiency | |
|---|---|---|---|
| Measure Code | | SHEFNMTR | |
| Product Description | | Efficient Furnace Fan Motor | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | 1.0 | 1.0 |

[963] Complete Energy Star version criteria and the current methodology for calculating Furnace fan efficiency metric can be found here: http://www.energystar.gov/index.cfm?c=revisions.furnace_spec.

[964] ARI data indicates 500 full load hours for A/C use in Vermont. VEIC experience in other states suggests that ARI estimates for A/C use tend to be overstated. In an effort to compensate for this overstatement, Efficiency Vermont applied a .75 multiplier to the ARI estimate in determining residential A/C hours of use.

[965] EVT estimate for freerider and spillover rates

| | | | |
|---|---|---|---|
| LIMF NC | 6018LINC | 1.0 | 1.0 |
| LIMF Rehab | 6018LIRH | 1.0 | 1.0 |
| MF Mkt NC | 6019MFNC | 1.0 | 1.0 |
| MF Mkt Retro | 6020MFMR | 1.0 | 1.0 |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | 1.0 | 1.0 |
| LISF Retrofit | 6034LISF | n/a | n/a |
| RES Retrofit | 6036RETR | 0.95 | 1.0 |
| RNC VESH | 6038VESH | 0.95 | 1.0 |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
18 years.[966]
Analysis period is the same as the lifetime.

**Measure Cost**
$97[967]

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
No net increase in fossil fuel consumption occurs due to the comparative increase in average AFUEs of furnace models with efficient furnace fans compared to the lower AFUEs of condensing furnaces without efficient furnace fans. The increased AFUEs fully compensates for the lost waste heat from the inefficient furnace fan motors.[968]

$\Delta$MMBtu Oil = 0
$\Delta$MMBtu Nat Gas = 0
$\Delta$MMBtu Propane = 0

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Table**

**Efficient Furnace Fan Savings Estimates by Season and presence of Central A/C**

| | Total Savings (kWh) | |
|---|---|---|
| **Season** | **CAC** | **No CAC** |

966 "Energy Savings from Efficient Furnace Fan Air Handlers in Massachusetts" ACEEE Sachs and Smith, 2003.
967 Adapted from Federal Appliance Standard Life-Cycle and Payback Analysis, Tables 8.2.3 and 8.2.13 in http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/hvac_ch_08_lcc_2011-06-24.pdf
968 Pigg, 2003, Electricity Use By New Furnaces: A Wisconsin Field Study. Page 45 "Impact of ECM Furnaces on Gas Consumption"

| | | |
|---|---|---|
| Heating Season | 418 | 418 |
| Cooling Season | 178 | 145 |
| Shoulder Periods | 79 | 79 |
| ***Total Savings*** | ***675*** | ***642*** |
| Demand Savings | 0.27 kW | |

# Brushless Permanent Magnet (BLPM) Circulator Pump

Measure Number: VII-C-3-a

**Version Date & Revision History**
Draft Date: 3/3/2015
Effective date: 1/1/2014
End date: TBD

**Referenced Documents:**

1. 98 PIP High Perf Circ Pump_2015 Final.docx
2. Final Analyzed Data.xlsx
3. ISR CIRC PUMP_FINAL CALL LIST.xlsx

**Description**
This measure is for installing fractional horsepower circulator pumps with brushless permanent magnet pump (BLPM) motors. Typical applications include baseboard and radiant floor heating systems that utilize a primary/secondary loop system in single-family residences. Circulator pumps that use BLPMs are more efficient because they lack brushes that add friction to the motor, as well as the ability to modulate their speed to match the load. This is possible because the drive senses the difference between the magnetic field of the rotating rotor and the rotating magnetic field of the windings in the motor stator. As the system flow demand changes (zones open or close), the drive senses the torque difference at the impeller via the change in the magnetic field difference and adjusts its speed by altering the frequency to the motor. BLPMs are especially efficient in no-load/low-load applications.

The Efficiency Vermont High Performance Circulator Pump (HPCP) Program is a pilot program to promote the installation of efficient brushless permanent magnet motor (BLPM) circulator pumps with integrated variable speed controls in Vermont homes and businesses. The program is offered to HVAC distributors who sell/ship equipment in Vermont, and provides upstream financial incentives at the wholesale level for qualifying circulator pumps sold for installation in a commercial facility or residential home in Vermont.

**Demand Savings**
$\Delta kW = \Delta kWh / HOURS$

**Energy Savings**
$\Delta kWh = HOURS \times [(Watts_{Base} - Watts_{EE})/1000] \times ISR$

Where:

$\Delta kW$ = gross customer connected load kW savings for the measure (kW)
= 0.05864 kW

$\Delta kWh$ = gross customer annual kWh savings for the measure (kWh)
= 115.7 kWh

HOURS = 1973[969]

$Watts_{Base}$ = Baseline connected kW
= 87.7 Watts[970]

$Watts_{EE}$ = Energy efficient connected kW
= 14.4 Watts[971]

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[969] Efficiency Vermont performed a metering study to better understand run hours of high performance circulator pumps. Analysis can be found in Final Analyzed Data.xlsx.
[970] Efficiency Vermont performed a metering study to better understand watt draw. Analysis can be found in Final Analyzed Data.xlsx.
[971] Efficiency Vermont performed a metering study to better understand watt draw. Analysis can be found in Final Analyzed Data.xlsx.

ISR = In Service Rate, or the percentage of units rebated that actually get used
= 80%[972]

**Baseline Efficiencies – New or Replacement**
The baseline equipment is a circulator pump using a low-efficiency shaded pole motor. It is assumed that this pump is installed on the primary loop of a multi-loop system, and is running constantly when outside temperatures are 55°F or lower during the winter heating season (October – April).

**High Efficiency**
The efficient equipment is a circulator pump with brushless permanent magnet motor.

**Operating Hours**
The annual operating hours are assumed to be 1973[973].

**Loadshape**
Loadshape #5: Residential Space Heat

**Freeridership/Spillover Factors**

| Measure Category | | Space Heat Efficiency | |
|---|---|---|---|
| Measure Code | | MTRCIRCZ | |
| Product Description | | Efficient Circulator Pump Motor | |
| Track Name | Track No. | Freerider | Spillover |
| Efficient Products | 6032EPEP | 0.95 | 1.00 |

**Persistence**
The persistence factor is assumed to be 1.

**Lifetimes**
20 years – typical circulator pumps using shaded pole motors are expected to last around 15 years; circulator pump motors with ECMs typically operate at lower RPMs, thus producing less heat and extending the life of the motor.

**Measure Cost**
The estimated incremental cost for this measure is $100.

**O&M Cost Adjustments**
None.

**Fossil Fuel Descriptions**
None.

**Water Descriptions**
None.

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972 In-Service Rate Study performed by Efficiency Vermont found the ISR to be 80%. Calculation can be found in ISR CIRC PUMP_FINAL CALL LIST.xlsx
973 Efficiency Vermont performed a metering study to better understand run hours of high performance circulator pumps. Analysis can be found in Final Analyzed Data.xlsx.

# ENERGY STAR Central Air Conditioner

Measure Number: VII-C-4-e

**Version Date & Revision History**
Draft date: Portfolio 77
Effective date: 01/01/2012
End date: TBD

**Referenced Documents:**

1) CAC savings calc.xls, CAC Average size calc.xls
2) Central_ASHP_and_CAC_Program_Requirements.pdf ("Energy Star Version 4.1 for Central Air Conditioners"

**Description**
This measure is for upgrading the total system to a Consortium for Energy Efficiency (CEE) Tier 1 qualified central air conditioner (CAC) ducted split system when retrofitting an existing unit or installing a new system in existing homes. This will be a stand-alone prescriptive measure.

**Algorithms**

**Demand Savings**
$\Delta$kW = BtuH /1000 * ( $1/EER_{BASE}$ - $1/EER_{EE}$)
$\Delta$kW = 36000/1000 * (1/11 – 1/12) = 0.2727

**Energy Savings**
$\Delta$kWh = BtuH /1000 * ( $1/SEER_{BASE}$ - $1/SEER_{EE}$) * Hours
$\Delta$kWh = 36000/1000 * (1/13 – 1/14.5) * 375 = 107.4

Where:

| | |
|---|---|
| $\Delta$kW | = gross customer connected load kW savings for the measure |
| $EER_{EE}$ | = EER rating for efficient CAC unit |
| $EER_{BASE}$ | = EER rating for baseline CAC unit |
| BtuH | = CAC unit size in British thermal units per hour (36,000 or 3 tons is the average CAC unit size rebated by EVT between 2004 and 2008[974]) |
| $\Delta$kWh | = gross customer annual kWh savings for the measure |
| $SEER_{EE}$ | =SEER rating for efficient CAC unit |
| $SEER_{BASE}$ | = SEER rating for baseline CAC unit |
| HOURS | = average hours of use per year |

**Baseline Efficiencies – New or Replacement**
Meets minimum Federal standards for residential central air conditioner; SEER 13, EER 11.

**High Efficiency**
ENERGY STAR qualified, residential sized, i.e. <=65,000 Btu/hr, central air-conditioning units, split system.
The ENERGY STAR standard for split Central Air Conditioners as of January 1, 2009 is >= 14.5 SEER and >=12 EER.

**Operating Hours**
375 hours / Year[975]

[974] See CAC Average size calc.xls
[975] EVT applied 25% adjustment factor to U.S. Climate Cooling Region 2 Full Load Hours of 500 hours for 375 hours.

**Loadshape**
Loadshape #11, Residential A/C, Vermont State Cost Effectiveness Screening Tool

**Freeridership/Spillover Factors**

| Measure Category | | Air Conditioner | |
|---|---|---|---|
| Measure Code | | ACEESACP | |
| Product Description | | Energy Star Air Conditioner | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |
| RES Retrofit | 6036RETR | 0.90 | 1.0 |
| RNC VESH | 6038VESH | 0.90 | 1.0 |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
14 years.[976]
Analysis period is the same as the lifetime.

[976] ENERGY STAR assumption:
http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls

**Measure Cost**
$97.[977]

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

[977] Incremental cost from 13 to 14.5 SEER is based on an EPA review of 2007 Industry Data (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) finding incremental costs of $39-$104 for 2.5 to 5 ton units, and review of the Technical Support Document for Energy Efficiency Standards for Consumer Products: Residential Central Air Conditioners and Heat Pumps. Appendix J, Table J-1. U.S. Department of Energy, May, 2002, where interpolation of the data suggests an incremental cost of $137. See CAC savings calc.xls for more detail.

# Residential Fan—Quiet, Exhaust-Only Continuous Ventilation

Measure Number: VII-C-5-a

**Version Date & Revision History**
Draft date: Portfolio 73
Effective date: 1/1/2011
End date: TBD

**Referenced Documents:**
1. Residential Vent Fan Assessment.xls
2. GDS Associates Measure Life Report "Residential and C&I Lighting and HVAC measures"
3. ASHRAE 62.2 Section 4.1 Whole House Ventilation

**Description**
This market opportunity is defined by the need for continuous mechanical ventilation due to reduced air-infiltration from a tighter building shell. In retrofit projects, existing fans may be too loud, or insufficient in other ways, to be operated as required for proper ventilation. This measure assumes a fan capacity of 50 CFM rated at less than 2.0 sones at 0.1 inches of water column static pressure. This measure may be applied to larger capacity, up to 130 CFM, efficient fans with bi-level controls because the savings and incremental costs are very similar. All eligible installations shall be sized to provide the mechanical ventilation rate indicated by ASHRAE 62.2.

**Algorithms**
**Demand Savings**

$$\Delta kW = CFM * (1/Fan_{Efficiency,\ Baseline} - 1/Fan_{Efficiency,\ Effcient})/1000$$
$$= 50 * (1/3.1 - 1/8.3)/1000$$
$$= 0.01\ kW$$

Where:

CFM = Nominal Capacity of the exhaust fan, 50 CFM[978]
$Fan_{Efficiency,\ Baseline}$ = Average efficacy for baseline fan, 3.1 CFM/Watt[979]
$Fan_{Efficiency,\ Effcient}$ = Average efficacy for efficient fan, 8.3 CFM/Watt [980]

**Energy Savings**

$$\Delta kWh = Hours * \Delta kW$$
$$= 8760 * 0.01$$
$$= 87.6\ kWh$$

Where:

$\Delta kW$ = connected load kW savings per qualified ventilation fan and controls.
Hours = assumed annual run hours, 8760 for continuous ventilation.

**Baseline Efficiencies – New or Replacement**
New standard efficiency (average CFM/Watt of 3.1[981]) exhaust-only ventilation fan, quiet (< 2.0 sones[982]) operating in accordance with recommended ventilation rate indicated by ASHRAE 62.2[983]

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[978] 50CFM is the closest available fan size to ASHRAE 62.2 Section 4.1 Whole House Ventilation rates based upon typical square footage and bedrooms.
[979] Average of CFM/Watt values at two static pressures of 0.1 and 0.25 inches of water column for quiet fans rated for 50 CFM. Based on fan information gathered and referenced in the spreadsheet, "Residential Vent Fan Assessment.xls"
[980] Average of CFM/Watt values at two static pressures of 0.1 and 0.25 inches of water column for quiet fans rated for 50 CFM. Based on fan information gathered and referenced in the spreadsheet, "Residential Vent Fan Assessment.xls"
[981] Average of efficacies at static pressures of 0.1 and 0.25 inches of water column.
[982] Rated fan sound level at a static pressure of 0.1 inches of water column.
[983] On/off cycling controls may be required of baseline fans larger than 50CFM.

**High Efficiency**
New efficient (average CFM/watt of 8.3) exhaust-only ventilation fan, quiet (< 2.0 sones) Continuous operation in accordance with recommended ventilation rate indicated by ASHRAE 62.2[984]

**Operating Hours**
Continuous, 8760.

**Loadshape**
Loadshape # 25: Flat (8760 hours)

**Freeridership/Spillover Factors**

| Measure Category | | Ventilation | |
|---|---|---|---|
| Measure Code | | VNTXCEIL, | |
| Product Description | | Exhaust fan, ceiling, | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | 1.0 | 1.0 |
| LIMF NC | 6018LINC | 1.0 | 1.0 |
| LIMF Rehab | 6018LIRH | 0.95 | 1.1 |
| MF Mkt NC | 6019MFNC | 0.9 | 1.0 |
| MF Mkt Retro | 6020MFMR | 1.0 | 1.0 |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | 1.0 | 1.0 |
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |
| RES Retrofit | 6036RETR | 0.9 | 1.0 |
| RNC VESH | 6038VESH | 0.95 | 1.1 |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetime**
19 years[985]

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[984] Bi-level controls may be used by efficient fans larger than 50 CFM

Analysis period is the same as the lifetime.

**Incremental Cost per Unit**
Incremental cost per installed fan is $43.50 for quiet, efficient fans.[986]

**Reference Tables**
None

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[985] Conservative estimate based upon GDS Associates Measure Life Report "Residential and C&I Lighting and HVAC measures" 25 years for whole-house fans, and 19 for thermostatically-controlled attic fans.
[986] See the Fan Info worksheet of the spreadsheet "Residential Vent Fan Assessment.xls"

# Variable Speed Mini-Split Heat Pumps

**Measure Number:** VII-C-6-a

**Version Date & Revision History**
Draft date: 8/12/2014
Effective date: 12/1/2014
End date: TBD

**Referenced Documents**:
1. Energy & Resource Solutions. *Emerging Technology Program Primary Research – Ductless Heat Pumps.* Lexington, MA: NEEP Regional EM&V Forum, 2014.
2. GDS Associates, Inc. *Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures.* Manchester, NH: The New England State Program Working Group (SPWG), 2007.
3. Navigant Consulting Inc. *Incremental Cost Study Phase Two Final Report.* Burlington, MA: NEEP Evaluation, Measurement, and Verification Forum, 2013.
4. NMR Group, Inc. "Vermont Single-Family Existing Homes Onsite Report FINAL." 2013.
5. U.S. Environmental Protection Agency. n.d. http://www.epa.gov/burnwise/woodstoves.html (accessed March 7, 2014).
6. CCHPSavingsAnalysis.xlsx
7. DHP LoadProfileAverager.xlsx

**Description**
This measure claims savings for the installation of single head variable speed mini-split heat pumps in a residential application. The measure is characterized as a market opportunity claiming electric energy and demand savings for both heating and cooling versus the installation of a baseline heat pump.

**Baseline Efficiency**
The baseline condition is assumed to be a new heat pump that is capable of providing heat using the heat pump cycle down to 5°F and meets the following minimum efficiency criteria:

**Table 5 – Baseline Efficiency Criteria**[987]

| Equipment | HSPF | EER | SEER |
|---|---|---|---|
| Air-Source Heat Pump | 8.2 | 12 | 14.5 |

**High Efficiency**
To qualify for savings under this measure the installed equipment must be a new mini-split heat pump that has a variable speed inverter-driven compressor, COP at 5°F ≥ 1.75 (at maximum capacity operation), and be capable of providing heat using the heat pump cycle down to -5°F. It must also meet or exceed the following efficiency criteria, per AHRI Standard 210-240-2008 for Unitary Air-Conditioning and Air-Source Heat Pump equipment.

**Table 6 – High Efficiency Criteria**

| Equipment | HSPF | EER | SEER |
|---|---|---|---|
| Air-Source Heat Pump | 10.3 | 12 | 20 |

[987] Based on November 2014 TAG Agreement and ENERGY STAR Key Product Criteria for Air-Source Heat Pumps, effective date January 1, 2009

**Algorithms**

**Energy Savings**

Electric energy savings include reductions in heating and cooling consumption based on improved system efficiency. Seasonal efficiency values have been used to approximate varying system efficiencies due to changes in operating conditions.

Cooling savings are calculated using nominal system capacity and Full Load Cooling Hours for Vermont.

Heating savings are calculated using a weather bin analysis in order to account for the variable heating capacity of CCHPs at different outdoor temperatures. The analysis assumes that both efficient and baseline heating systems operate below 50°F, except in summer months (May to August), and that the heat pump provides heating based on its maximum capacity for each weather bin.[988] Below 5°F the baseline system cuts off and the efficient system continues to provide heating. The operation of the efficient system below 5°F is treated as an electric consumption and demand penalty taken against the previously mentioned savings. While this operation represents a penalty, it also represents a savings of fuel from the home's existing heating system, and the electric penalty is slightly reduced to account for homes with existing electric resistance heat.

$$\Delta kWh = \left[Q_{Cooling} \times FLH_{Cooling} \times \left(\frac{1}{SEER_{Baseline}} - \frac{1}{SEER_{Efficient}}\right) + \sum_{i=1}^{n}\left(Q_{Heating\geq 5°\mathrm{F},i}\right) \times \left(\frac{1}{HSPF_{Baseline} \times 90\%} - \frac{1}{HSPF_{Efficient} \times 90\%}\right) - \sum_{i=1}^{n}\left(Q_{Heating<5°\mathrm{F},i}\right) \times \left(\frac{1}{HSPF_{Efficient} \times 90\%}\right)\right] \times \frac{1\,kWh}{1{,}000\,Wh} + \sum_{i=1}^{n}\left(Q_{Heating<5°\mathrm{F},i}\right) \times \%ElecHeat \times \frac{1\,kWh}{3{,}412\,Btu}$$

Where:

| | |
|---|---|
| ΔkWh | = total net kWh savings for heating and cooling (deemed assumption for prescriptive savings, based on size category) |
| $Q_{Cooling}$ | = nominal cooling capacity, Btu/hr<br>= See Table 3 (deemed assumption for prescriptive savings, based on size category) |
| $FLH_{Cooling}$ | = full load cooling hours<br>= 375[989] (deemed assumption for prescriptive savings) |
| $SEER_{Baseline}$ | = 14.5[990], Btu/Wh (deemed assumption for prescriptive savings) |
| $SEER_{Efficient}$ | = See |

Table **7** (deemed assumption for prescriptive savings, based on size category)

| | |
|---|---|
| $Q_{Heating\geq 5°F,i}$ | = heating capacity in weather bin *i* at or above 5°F, MMBtu<br>= See |

Table **7** (deemed assumption for prescriptive savings, based on size category)

| | |
|---|---|
| $HSPF_{Baseline}$ | = 8.2[991], Btu/Wh (deemed assumption for prescriptive savings) |
| $HSPF_{Efficient}$ | = See |

Table **7** (deemed assumption for prescriptive savings, based on size category)

| | |
|---|---|
| 90% | = Climatic adjustment to HSPF[992] (deemed assumption for prescriptive savings) |
| $Q_{Heating<5°F,i}$ | = heating capacity in weather bin *i* below 5°F, MMBtu<br>= See |

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988 See CCHPSavingsAnalysis.xlsx for detailed analysis

989 ARI data indicates 500 full load hours for A/C use in Vermont. VEIC experience in other states suggests that ARI estimates for A/C use tend to be overstated. In an effort to compensate for this overstatement, Efficiency Vermont applied a .75 multiplier to the ARI estimate in determining residential A/C hours of use.

990 See Baseline Efficiency section

991 See Baseline Efficiency section

992 Energy & Resource Solutions. (2014). *Emerging Technology Program Primary Research – Ductless Heat Pumps.* Lexington, MA: NEEP Regional EM&V Forum. Table 1-2. Page 5.

Table **7** (deemed assumption for prescriptive savings, based on size category)
%ElecHeat[993] = portion of homes with electric space heat
= 1% (deemed assumption for prescriptive savings)

For prescriptive purposes, electric savings will be assigned using deemed values based on nominal system capacity, SEER, and HSPF as outlined in

Table **7**.

**Demand Savings**
Demand savings are calculated using a weather bin analysis based on the average demand savings during winter peak demand periods where maximum reductions are anticipated. Reduced power draw for the efficient system compared to the baseline system is treated as a demand savings for heating at or above 5°F. For heating below 5°F the full power draw of the efficient system is treated as a demand penalty.

$$\Delta kW = \frac{\left[\begin{array}{c}\sum_{i=1}^{n}\left[Q_{Heating\geq 5°\mathrm{F},i}\times\left(\frac{1}{HSPF_{Baseline}\times 90\%}-\frac{1}{HSPF_{Efficient}\times 90\%}\right)\right] \\ -\sum_{i=1}^{n}\left[Q_{Heating<5°\mathrm{F},i}\times\left(\frac{1}{HSPF_{Efficient}\times 90\%}\right)\right]\end{array}\right]}{n}\times\frac{1\ kWh}{1{,}000\ Wh}$$

ΔkW = total average winter coincident peak kW reduction (deemed assumption for prescriptive)

For prescriptive purposes, demand savings will be assigned using deemed values based on nominal system capacity, HSPF, and EER as outlined in

Table **7**.[994]

**Fossil Fuel Descriptions**
Fossil fuel savings are taken for operation of the efficient system below 5°F for offsetting fuel use from the home's existing heating system.

$$\Delta MMBtu = \sum_{i=1}^{n} Q_{Heating<5°\mathrm{F},i}\times \%HeatSource_j/\eta_{Heat\,j}$$

Where:

$\Delta MMBtu_j$ = MMbtu savings for each fuel type *j* (deemed assumption for prescriptive)
$\%HeatSource_j$[995] = Percent of existing heating systems using fuel type *j*
= 51% for fuel oil
= 15% for propane
= 12% for Wood/Other
= 21% for Natural Gas
$\eta_{Heat\,j}$[996] = Heating system efficiency for fuel type *j* (deemed assumption for prescriptive)
= 84.2% for fuel oil
= 87.4% for propane
= 65% for Wood/Other
= 88% for Natural Gas

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993 Split of primary heating fuels from the VT SF Existing Homes Onsite Report Table 5-1. (NMR Group, Inc. 2013)
994 See CCHPSavingsAnalysis.xlsx, Demand Savings, for detailed analysis
995 Split of primary heating fuels from the VT SF Existing Homes Onsite Report Table 5-1. (NMR Group, Inc. 2013).
996 Weighted efficiencies based on VT SF Existing Homes Onsite Report Table 5-8 and 5-9. (NMR Group, Inc. 2013). Efficiency for homes using wood or pellet stoves based on review of EPA-Certified wood stoves. (U.S. Environmental Protection Agency n.d.)

For prescriptive purposes, fossil fuel savings will be assigned using deemed values based on nominal system capacity, as outlined in Table 8.[997]

**Water Descriptions**
N/A

**Table 7 – Prescriptive Electric Savings Values**[998]

| Nominal Capacity | $SEER_{Avg}$ | $EER_{Avg}$ | $HSPF_{Avg}$ | $\Delta kWh_{cooling}$ | $Q_{\geq 5F}$ | $Q_{<5F}$ | $\Delta kWh_{heating}$ | $\Delta kWh_{total}$ | $\Delta kW$ |
|---|---|---|---|---|---|---|---|---|---|
| 9,000 | 26.37 | 15.7 | 12.8 | 105 | 35.8 | 1.5 | 1600 | 1705 | 0.22 |
| 12,000 | 23.05 | 13.1 | 11.8 | 115 | 38.4 | 1.6 | 1427 | 1542 | 0.24 |
| 15,000 | 21.10 | 12.9 | 11.5 | 121 | 37.3 | 1.7 | 1283 | 1404 | 0.27 |
| 18,000 | 20.25 | 13.5 | 10.7 | 132 | 50.0 | 1.6 | 1393 | 1525 | 0.33 |
| 24,000 | 20.00 | 12.5 | 10.6 | 171 | 54.3 | 1.9 | 1471 | 1642 | 0.37 |

**Table 8 – Prescriptive Fossil Fuel Savings Values**

| Nominal Capacity | $\Delta MMBtu_{oil}$ | $\Delta MMBtu_{propane}$ | $\Delta MMBtu_{wood}$ | $\Delta MMBtu_{natural\ gas}$ |
|---|---|---|---|---|
| 9,000 | 0.92 | 0.26 | 0.28 | 0.37 |
| 12,000 | 0.98 | 0.28 | 0.30 | 0.39 |
| 15,000 | 1.02 | 0.29 | 0.31 | 0.40 |
| 18,000 | 1.00 | 0.28 | 0.30 | 0.39 |
| 24,000 | 1.16 | 0.33 | 0.36 | 0.46 |

**Loadshape**
Loadshape #116, Residential Variable Speed Mini-Split and Multi-Split Heat Pumps

**Table 9 – Freeridership/Spillover Factors**

| **Measure Category** | | **HVAC** | |
|---|---|---|---|
| **Product Description** | | **Efficient ductless mini-split, heat pump baseline** | |
| **Measure Code** | | **SHRHPCVH** | |
| **Track Name** | **Track No.** | **Freerider** | **Spillover** |
| Efficient Products | 6032UPST | 0.81 | 1.07 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
The expected measure life is assumed to be 18 years.[999]

**Measure Cost**
Measure cost represents the incremental installed cost of an efficient versus a baseline CCHP.

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997 See CCHPSavingsAnalysis.xlsx, Fuel Offset, for detailed analysis
998 Efficiency values for each bin based on average values from AHRI rated equipment, see AHRI in CCHPSavingsAnalysis.xlsx
999 Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
Table 1 – Residential Measures. https://neep.org/Assets/uploads/files/emv/emv-library/measure_life_GDS%5B1%5D.pdf

**Table 10 – Measure Costs**[1000]

| Nominal Equipment Capacity (Btu/hr) | Incremental Costs |
|---:|---:|
| 9,000 | $493 |
| 12,000 | $591 |
| 15,000 | $588 |
| 18,000 | $611 |
| 24,000 | $693 |

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

[1000] Incremental Cost Study Phase Two Final Report, Navigant Consulting Inc., January 16, 2013. See excerpted data in CCHPSavingsAnalysis.xlsx

# Residential Efficient Space Heating System

Measure Number: VII-C-7-a

**Version Date & Revision History**
Draft date: Portfolio 87
Effective date: 1/1/2014
End date: TBD

**Referenced Documents:**
1. Table 8.3.3 The Technical support documents for federal residential appliance standards: http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/chapter_8.pdf
2. EVT estimated heating full load hours.doc
3. NEEP Incremental Cost Study, phase 1: http://www.neep.org/sites/default/files/resources/Incremental%20Cost_study_FINAL_REPORT_2011Sep23.pdf
   - NEEP Residential Boilers 2011_08_18.xlsx
   - NEEP Residential Furnace Analysis 2011_08_19.xlsx
4. DOE Technical Appliance Standards Technical Support Document: "Appendix E. Engineering Analysis Cost and Efficiency Tables"
5. NMR Group Inc "Vermont Single-Family Existing Homes Onsite Report. Final 2/15/2013"
6. VGS Usage Regression Work.xls

**Description**
This measure applies to the installation of primary oil- or propane-fired boiler or furnace heating systems in residential existing homes applications. Fossil fuel savings are realized due to the higher AFUE of the qualifying equipment. All systems must be installed per the VT Residential Building Energy Standards and all boiler installations must incorporate high performance Circulator Pumps (electric savings for this will be claimed based on existing measure characterizations).

This measure will provide a standard incentive through two channels. First through the existing Home Performance with ENERGY STAR (HPwES) program where this measure will continue to be treated as an Early Replacement since Efficiency Vermont's involvement results in replacements that would not likely have occurred otherwise. The savings from HPwES projects are generated through modeling software (not characterized here), and a mid life baseline shift will be incorporated to account for the hypothetical future baseline replacement at the AFUE level presented below, consistent with the Market Opportunity measure. The second channel is through the Energy Efficiency Network (EEN) whereby member HVAC contractors and fuel dealers will be able to offer an identical incentive for their customers to upsell to the higher efficiency levels. For measures installed this way (outside of Home Performance with ENERGY STAR) a market opportunity baseline will be used.

**Algorithms**

**Electrical Savings**
The electrical energy and demand savings associated with high performance Circulator Pump is provided in a standalone characterization.

**Fossil Fuel Savings**
For Market Opportunity measures provided through a rebate form:

$\Delta$MMBTU = (FLH * (Capacity / 1,000,000) * (1/$AFUE_{Base}$ – 1 /$AFUE_{Eff}$)

Where:
$\Delta$MMBTU = gross customer annual MMBtu fuel savings for the measure
FLH = estimated average full load heating hours

| | |
|---|---|
| | = 810 for boilers and 1024 for furnaces[1001] |
| Capacity | = capacity of equipment to be installed (Btuh)[1002] |

| Unit Type | Capacity (Btuh) |
|---|---|
| Boiler | 125,000 |
| Furnace | 73,000 |

| | |
|---|---|
| 1,000,000 | = Conversion from Btuh to MMBtu/hour |
| $AFUE_{Base}$ | = Efficiency of baseline equipment in AFUE; see table below[1003] |
| $AFUE_{Eff}$ | = Efficiency of new equipment in AFUE; see table below[1004] |

| Unit Type | $AFUE_{Base}$ | $AFUE_{Eff}$ |
|---|---|---|
| Oil Boiler | 85% | 87% |
| LP Boiler | 86.7% | 95% |
| Oil Furnace | 82.6% | 87% |
| LP Furnace | 88% | 95% |

Prescriptive savings are provided below:

| Unit Type | ΔMMBTU |
|---|---|
| Oil Boiler | 2.7 |
| LP Boiler | 10.2 |
| Oil Furnace | 4.6 |
| LP Furnace | 6.3 |

Note: Savings from Early Replacement measures provided through the Home Performance with ENERGY STAR program will be calculated using the modeling software and include a mid-life savings adjustment to account for the deferred baseline replacement.

**Baseline Efficiencies**

Baseline equipment is a new standard efficiency oil- or propane-fired furnace or boiler with an AFUE provided below.

For the Early Replacement measure the initial baseline is the existing unit efficiency. A mid life baseline adjustment will be incorporated to account for the hypothetical new baseline replacement at the same AFUEbase level provided below. It is assumed that this baseline shift will occur after a third of the measure life – so after 6.7 years for furnaces and 8.3 years for boilers.

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1001 Estimated by following a methodology outlined in the Uniform Methods Project using natural gas billing data provided by Vermont Gas Systems (VGS) for homes that participated in Efficiency Vermont's Residential New Construction (RNC) program. Since capacity has not been collected through the Home Performance with ENERGY STAR program it was not possible to perform the analysis with a more appropriate data set for this program. The RNC data was limited to only those homes with annual gas consumption greater than 75MMBtus in an attempt to remove the high performance/ low load homes in RNC. See "EVT estimated heating full load hours.doc" for greater explanation and 'VGS Usage Regression Work.xls' for analysis.

1002 Weighted average of capacity data from NEEP Incremental Cost Study Phase 1. See Workbook Volume 2 Market Characterization tab; http://neep.org/emv-forum/forum-products-and-guidelines/#Incremental. Includes data from Vermont, Massachusetts and New York. Analysis provided in 'NEEP Residential Boilers 2011_08-18.xls' and 'NEEP Residential Furnace Analysis 2011_08_19.xls'.

1003 Based on the average findings from p60, NMR Group Inc "Vermont Single-Family Existing Homes Onsite Report. Final 2/15/2013". Note these are significantly above the Federal Minimum Standard but represent an estimate of what people are purchasing without Efficiency Vermont intervention.

1004 The efficiency criteria were developed based on consideration of availability of product, incremental cost etc and with input from EEN representatives.

**High Efficiency**

The installed oil or propane furnace or boiler must have an AFUE greater than those shown below.

| Unit Type | $AFUE_{Base}$ | $AFUE_{Eff}$ |
|---|---|---|
| Oil Boiler | 85% | 87% |
| LP Boiler | 86.7% | 95% |
| Oil Furnace | 82.6% | 87% |
| LP Furnace | 88% | 95% |

**Loadshape**

N/A.

**Freeridership/Spillover Factors**

| Measure Category | | Space Heating Equipment | |
|---|---|---|---|
| Measure Codes | | SHRFFOIL, SHRFFOUF, SHRBFOIL, SHRBFOUF, SHRBPROP, SHRBPRUF, SHRFPROP | |
| Product Description | | Efficient Space Heating Equipment | |
| Track Name | Track No. | Freerider | Spillover |
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |
| RES Retrofit | 6036RETR | 1.0 | 1.0 |

**Persistence**

The persistence factor is assumed to be one.

**Lifetimes**

| Equipment Type | Measure Lifetime[1005] |
|---|---|
| Furnaces | 20 |
| Boilers | 25 |

**Measure Cost**

The incremental costs of more efficient equipment are detailed below[1006]:

| Unit Type | Baseline cost | Efficient Cost | Incremental Cost |
|---|---|---|---|
| Oil Boiler | $4,316 | $4,642 | $326 |
| LP Boiler | $5,212 | $7,242 | $2,030 |
| Oil Furnace | $2,906 | $3,574 | $668 |
| LP Furnace | $2,564 | $3,306 | $742 |

**O&M Cost Adjustments**

O&M cost estimates for baseline and efficient boilers and furnaces are provided below[1007]:

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[1005] Table 8.3.3 The Technical support documents for federal residential appliance standards: http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/chapter_8.pdf

[1006] Costs are derived based upon the NEEP Incremental Cost Study (http://neep.org/emv-forum/forum-products-and-guidelines/#Incremental) and also cross checking with the DOE Technical Appliance Standards Technical Support Document "Appendix E. Engineering Analysis Cost and Efficiency Tables". See 'CostsFurnacesBoilersNEW.xls'.

| Unit Type | Baseline Annual O&M Cost | Efficient Annual O&M Cost |
|---|---|---|
| Boilers | $90.82 | $111.50 |
| Furnaces | $80.13 | $103.01 |

**Water Descriptions**
There are no water algorithms or default values for this measure.

[1007] The DOE Technical Appliance Standards Technical Support Document "Appendix E. Engineering Analysis Cost and Efficiency Tables**"** provides a slight increase in annual O&M assumption for gas boilers and furnaces. The same values are assumed for oil units. See 'CostsFurnacesBoilersNEW.xls'.

**Refrigeration End Use**
# Refrigerator Early Replacement

Measure Number: VII-G-1-c (Residential Emerging Markets, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 80
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**

1) 2012 Refrigerator Retrofit Savings.xls
2) http://www.energystar.gov/ia/partners/product_specs/program_reqs/refrig_prog_req.pdf
3) http://www1.eere.energy.gov/buildings/appliance_standards/downloads/nia_refrig-frzr_final.zip
4) http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrigerator_report_1.pdf
5) Refrigerator kW Calculations.xls

**Description**
This is an early replacement measure of an existing pre-2001 inefficient refrigerator with a new refrigerator exceeding minimum qualifying efficiency standards established as Energy Star or optionally CEE Tier 2 or CEE Tier 3. Savings are calculated between the average energy usage of an existing unit and that of a higher efficiency unit for the remaining life of the existing unit, plus the savings between an average baseline unit and that of a higher efficiency unit for the remainder of the measure life. This measure will be reviewed on a 3 year basis to gauge the accuracy of savings and review cost-effectiveness of the program. Prior to 2012, eligibility was restricted to pre-1993 refrigerators. Efficiency Vermont has decided to expand eligibility to the next refrigerator standard change (2001). The estimated decrease in consumption of a post-1993 / pre-2001 unit over a pre-1993 unit is 43%. EVT has assumed that 30% of the future replacements will fall in to the 1993-2001 category[1008] and have adjusted the savings accordingly (see '2012 Refrigerator Retrofit Savings.xls' for more details). We will review this assumption after a year and adjust as necessary.

**Algorithms**
**Energy Savings**

$\Delta$kWh – Energy Star for remaining life of existing unit (3 years) = 709 kWh
$\Delta$kWh – CEE Tier 2 for remaining life of existing unit (3 years) = 737 kWh
$\Delta$kWh – CEE Tier 3 for remaining life of existing unit (3 years) = 764 kWh

$\Delta$kWh – Energy Star for remaining measure life (9 years) = 113 kWh
$\Delta$kWh – CEE Tier 2 for remaining measure life (9 years) = 141 kWh
$\Delta$kWh – CEE Tier 3 for remaining measure life (9 years) = 169 kWh

**Demand Savings**

$\Delta kW = \Delta kWh/Hours$

$\Delta$kW – Energy Star for remaining life of existing unit (3 years) = 709/8477 = 0. 084kW
$\Delta$kW – CEE Tier 2 for remaining life of existing unit (3 years) = 737/8477 = 0.087 kW
$\Delta$kW – CEE Tier 3 for remaining life of existing unit (3 years) = 764/8477 = 0.090 kW

$\Delta$kW – Energy Star for remaining measure life (9 years) = 113/8477 = 0.013 kW
$\Delta$kW – CEE Tier 2 for remaining measure life (9 years) = 141/8477 = 0.017 kW
$\Delta$kW – CEE Tier 3 for remaining measure life (9 years) = 169/8477 = 0.020 kW

[1008] Based upon conversations with the weatherization agencies.

Where:

ΔkWh = gross customer annual kWh savings for the measure
HOURS = Equivalent Full Load Hours
= 8477[1009]
ΔkW = gross customer connected load kW savings for the measure

**Baseline Efficiencies – New or Replacement**

The existing pre-2001 refrigerator baseline efficiency is estimated according to a combination of Association of Home Appliance Manufacturers (AHAM) estimated usage data and actual meter measurements from replacements installed thru EVT from 2006-2008[1010]. For the purpose of this measure it is assumed that the remaining life of the existing refrigerator is 3 years. For the remaining 14 years of the new refrigerator, the 2001 federal minimum standard is set as the baseline efficiency. See 2012 Refrigerator Retrofit Savings.xls for more details.

**High Efficiency**

High efficiency is defined as any model meeting or exceeding 2007 Energy Star standard – currently set to 20% over the 2001 federal minimum standard or optionally 25% or 30% to meet CEE Tier 2 or Tier 3. EVT's energy savings estimates are based on the weighted average test measurements for qualifying models based on the models rebated during 2006-2008.

**Loadshape**

Loadshape #4, Residential Refrigerator

**Freeridership/Spillover Factors**

| Measure Category | | Refrigeration | |
|---|---|---|---|
| Measure Code | | RFRESRER, RFRT2RER, RFRT3RER | |
| Product Description | | Energy Star Refrigerator | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| MF Mkt Retro | 6020MFMR | n/a | n/a |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |

[1009] The Summer and Winter Coincident kW are calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. To calculate an Equivalent Full Load Hours the UEC (* PartUse) is divided by the summer coincident kW (956 * .779)/0.088 = 8477 hours. The summer coincidence factor is therefore assumed to be 1.0 and a winter coincidence factor calculated as the relative winter to summer kW result from the algorithm. For the calculation see "Refrigerator kW Calculations.xls".

[1010] Note that in 2009 this measure became prescriptive and so individual unit consumption values were no longer tracked.

| | | | |
|---|---|---|---|
| RES Retrofit | 6036RETR | 0.9 | 1.0 |
| RNC VESH | 6038VESH | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
12 Years[1011]
Analysis period is the same as the lifetime.

**Measure Cost**
The initial measure cost for an Energy Star refrigerator is $740, Tier 2 is $850 and Tier 3 is $930. The avoided replacement cost (after 3 years) of a baseline replacement refrigerator is $700.[1012]

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel savings for this measure.

**Water Descriptions**
There are no water savings for this measure.

**Reference Tables**
N/A

1011 From ENERGY STAR calculator:
http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?e678-f5e6&e678-f5e6

1012 Measure costs are based on review of data from the Northeast Regional ENERGY STAR Consumer Products Initiative; "2009 ENERGY STAR Appliances Practices Report", submitted by Lockheed Martin, December 2009. See 2009 VT Appliance Data_TRMCostAnalysis.xlsfor data. ESTAR incremental cost reduced to $40 based on ENERGY STAR Calculator; http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?e678-f5e6&e678-f5e6

# Freezer Early Replacement

Measure Number: VII-G-2-b (Existing Homes, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 80
Effective date: 1/1/2012
End date: TBD

**Referenced Documents:**
1) 2012 Freezer Retrofit Savings.xls;
2) 2009 VT Appliance Data_TRMCostAnalysis.xls

**Description**
This is early replacement measure of an existing pre-2001 inefficient freezer with a new freezer exceeding minimum qualifying efficiency standards established as ENERGY STAR. Savings are calculated between the average energy usage of an existing unit and that of a higher efficiency unit for the remaining life of the existing unit, plus the savings between an average baseline unit and that of a higher efficiency unit for the remainder of the measure life. Prior to 2012, eligibility was restricted to pre-1993 refrigerators. Efficiency Vermont has decided to expand eligibility to the next freezer standard change (2001). The estimated decrease in consumption of a post-1993 / pre-2001 unit over a pre-1993 unit is 25%. EVT has assumed that 30% of the future replacements will fall in to the 1993-2001 category[1013] and have adjusted the savings accordingly (see '2012 Freezer Retrofit Savings.xls' for more details). We will review this assumption after a year and adjust as necessary.

**Algorithms**

**Energy Savings**
ΔkWh – ENERGY STAR for remaining life of existing unit (3 years) = 269 kWh
ΔkWh – ENERGY STAR for remaining measure life (9 years) = 52.5 kWh

**Demand Savings**
ΔkW = ΔkWh/Hours

ΔkW – ENERGY STAR for remaining life of existing unit (3 years) = 269/8477 = 0.032 kW
ΔkW – ENERGY STAR for remaining measure life (9 years) = 52.5/8477 = 0.006 kW

Where:
ΔkWh = gross customer annual kWh savings for the measure
HOURS = Equivalent Full Load Hours
= 8477[1014]
ΔkW = gross customer connected load kW savings for the measure

**Baseline Efficiencies – New or Replacement**
The existing pre-2001 freezer baseline efficiency is estimated by calculating the estimated kWh for an equivalent unit at the Federal Standard in 1990 and 1993 for all units incentivized through the Efficient Product program in 2009-2010[1015]. For the purpose of this measure it is assumed that the remaining life of the existing freezer is 3 years.

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[1013] Based upon conversations with the weatherization agencies.
[1014] The Summer and Winter Coincident kW are calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. To calculate an Equivalent Full Load Hours the UEC (* PartUse) is divided by the summer coincident kW (956 * .779)/0.088 = 8477 hours. The summer coincidence factor is therefore assumed to be 1.0 and a winter coincidence factor calculated as the relative winter to summer kW result from the algorithm. For the calculation see "Refrigerator kW Calculations.xls".
[1015] Energy usage algorithms taken from: http://eec.ucdavis.edu/ACEEE/1994-96/1996/VOL09/207.PDF and http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf. Note that in 2010 this measure became prescriptive and so individual unit consumption values were no longer tracked.

For the remaining 14 years of the new freezer, the 2001 Federal minimum standard is set as the baseline efficiency. See Freezer Retrofit Savings.xls for more details.

**High Efficiency**
High efficiency is defined as any model meeting or exceeding 2007 ENERGY STAR standard – currently set to 10% over the 2001 Federal minimum standard .

**Loadshape**
Loadshape #4, Residential Refrigerator

**Freeridership/Spillover Factors**

| Measure Category | | Refrigeration | |
|---|---|---|---|
| Measure Code | | RFRESFZR | |
| Product Description | | Energy Star Freezer Early Replacement | |
| Track Name | Track No. | Freerider | Spillover |
| C&I Retrofit | 6012CNIR | n/a | n/a |
| Farm Retrofit | 6012FARM | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Farm Rx | 6013FRMP | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Upstream | 6013UPST | n/a | n/a |
| Act250 NC | 6014A250 | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |
| MF Mkt Retro | 6020MFMR | 0.9 | 1.0 |
| C&I Lplus | 6021LPLU | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |
| RES Retrofit | 6036RETR | 0.9 | 1.0 |
| RNC VESH | 6038VESH | n/a | n/a |
| EP GMP Blueline | 6042EPEP | n/a | n/a |
| GMP Furnace | 6042EPEP | n/a | n/a |
| GMP HP | 6046RETR | n/a | n/a |
| VEEP GMP | 6048VEEP | n/a | n/a |
| LIMF Lplus | 6052LPLU | n/a | n/a |
| MFMR Lplus | 6053LPLU | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
12 Years[1016]

[1016] From ENERGY STAR calculator: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?e678-f5e6&e678-f5e6

Analysis period is the same as the lifetime.

**Measure Cost**
The full cost for an ENERGY STAR unit is $500. The cost of a baseline replacement freezer is $465.[1017]

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel algorithms or default values for this measure.

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**
N/A

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[1017] Based on review of data from the Northeast Regional ENERGY STAR Consumer Products Initiative; “2009 ENERGY STAR Appliances Practices Report”, submitted by Lockheed Martin, December 2009. See 2009 VT Appliance Data_TRMCostAnalysis.xlsfor data.

# Refrigerator Early Removal

Measure Number: VII-G-3-a (Residential Emerging Markets, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 80
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**

1. ADM Evaluation Study of the 2004-05 Statewide Residential Appliance Recycling Program;
2. KEMA Residential Refrigerator Recycling Ninth Year Retention Study;
3. Opinion Dynamics; "Fridge & Freezer Recycle Rewards Program PY4 Metering Study: DRAFT Savings Results"
4. The Cadmus Group et al., "Residential Retrofit High Impact Measure Evaluation Report", prepared for the California Public Utilities Commission, February 8, 2010
5. Appliance Recycling data2008-2012_V2.xls
6. Refrigerator kW Calculations.xls

**Description**
This is an early retirement measure for the removal of an existing inefficient secondary refrigerator from service observed during a site visit by a weatherization agency, Home Performance contractor or Efficiency Vermont staff member. The contractor has signed an agreement that the unit will be rendered permanently inoperable and properly recycled or disposed of. The program will target refrigerators with an age greater than 10 years, although data from the Efficient Product program suggests the average age of retired units is over 30 years. Savings are calculated for the estimated energy consumption during the remaining life of the existing unit.

**Algorithms**

**Energy Savings**
$\Delta$kWh = UEC * PartUse
= 956 * 0.779
= 745 kWh

**Demand Savings**
$\Delta$kW = $\Delta$kWh/Hours
= 745/8477
= 0.088 kW

Where:

$\Delta$kWh = gross customer annual kWh savings for the measure
UEC = Unit Energy Consumption
= 745kWh[1018]
PartUse = adjustment factor for weighted partial use of appliance
= 0.779[1019]

[1018] Unit Energy Consumption is based upon review of the data collected by Jaco from units retired in the program from 2009-2012. To estimate the consumption of the retired units EVT used a regression equation with multiple attributes from a recent Illinois evaluation (Opinion Dynamics; "Fridge & Freezer Recycle Rewards Program PY4 Metering Study: DRAFT Savings Results"). For information see "Appliance Recycling data2008-2012_V2.xls".

HOURS = Equivalent Full Load Hours
= 8477[1020]
ΔkW = gross customer connected load kW savings for the measure

**Baseline Efficiencies – New or Replacement**
The existing refrigerator baseline consumption is based upon data collected by Jaco from units retired in the Efficient Products program from 2009-2012 and adjusted for part use consumption.

**High Efficiency**
N/A

**Loadshape**
Loadshape #4, Residential Refrigerator

**Freeridership/Spillover Factors**

| Measure Category | | Refrigeration | |
|---|---|---|---|
| Measure Code | | RFRRERPS | |
| Product Description | | Refrigerator Early Retirement | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6012MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | 1.0 | 1.0 |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
8 years [1021]
Analysis period is the same as the lifetime.

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[1019] Based on analysis of Jaco data. Participants were asked how much the refrigerator was run through the year. The data was weighted assuming the response "All months" equaled 12 months, "Summer" or "Winter" equaled 3 months and "Spring/Fall" equaled 6 months.
[1020] The Summer and Winter Coincident kW are calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. To calculate an Equivalent Full Load Hours the UEC (* PartUse) is divided by the summer coincident kW (956 * .779)/0.088 = 8477 hours. The summer coincidence factor is therefore assumed to be 1.0 and a winter coincidence factor calculated as the relative winter to summer kW result from the algorithm. For the calculation see "Refrigerator kW Calculations.xls".
[1021] KEMA "Residential refrigerator recycling ninth year retention study", 2004

**Measure Cost**
The cost of pickup and recycling of the refrigerator is $50 based upon agreement with contractors or vendors who will collect secondary units when replacing the primary unit. Contractors have signed an agreement that the units will be recycled and not placed on the secondary market.

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel savings for this measure.

**Water Descriptions**
There are no water savings for this measure.

# Freezer Early Removal

Measure Number: VII-G-4-a (Residential Emerging Markets, Refrigeration End Use)

**Version Date & Revision History**
Draft date: Portfolio 80
Effective date: 1/1/2013
End date: TBD

**Referenced Documents:**

1. ADM Evaluation Study of the 2004-05 Statewide Residential Appliance Recycling Program;
2. KEMA Residential Refrigerator Recycling Ninth Year Retention Study;
3. Opinion Dynamics; “Fridge & Freezer Recycle Rewards Program PY4 Metering Study: DRAFT Savings Results”
4. The Cadmus Group et al., “Residential Retrofit High Impact Measure Evaluation Report”, prepared for the California Public Utilities Commission, February 8, 2010
5. Appliance Recycling data2008-2012_V2.xls
6. Refrigerator kW Calculations.xls

**Description**
This is an early retirement measure for the removal of an existing inefficient freezer from service observed during a site visit by a weatherization agency, Home Performance contractor or Efficiency Vermont staff member. The contractor has signed an agreement that the unit will be rendered permanently inoperable and properly recycled or disposed of. The program will target freezers with an age greater than 10 years, although data from the Efficient Product program suggests the average age of retired units is over 30 years. Savings are calculated for the estimated energy consumption during the remaining life of the existing unit.

**Algorithms**
**Energy Savings**
$\Delta$kWh = UEC * PartUse
= 1231 * 0.777
= 956 kWh

**Demand Savings**
$\Delta$kW = $\Delta$kWh/Hours
= 956 /8477
= 0.113 kW

Where:

$\Delta$kWh = gross customer annual kWh savings for the measure
UEC = Unit Energy Consumption
= 1231 kWh[1022]
PartUse = adjustment factor for weighted partial use of appliance
= 0.777[1023]
HOURS = Equivalent Full Load Hours
= 8477[1024]

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[1022] Unit Energy Consumption is based upon review of the data collected by Jaco from units retired in the program from 2009-2012. To estimate the consumption of the retired units EVT used a regression equation with multiple attributes from a recent Illinois evaluation (Opinion Dynamics; “Fridge & Freezer Recycle Rewards Program PY4 Metering Study: DRAFT Savings Results”). For information see “Appliance Recycling data2008-2012_V2.xls”.
[1023] Based on analysis of Jaco data. Participants were asked how much the freezer was run through the year. The data was weighted assuming the response “All months” equaled 12 months, “Summer” or “Winter” equaled 3 months and “Spring/Fall” equaled 6 months.

$\Delta kW$ = gross customer connected load kW savings for the measure

**Baseline Efficiencies – New or Replacement**
The existing freezer baseline consumption is based upon data collected by Jaco from units retired in the Efficient Products program from 2009-2012 and adjusted for part use consumption.

**High Efficiency**
N/A

**Loadshape**
Loadshape #4, Residential Refrigerator

**Freeridership/Spillover Factors**

| Measure Category | | Refrigeration | |
|---|---|---|---|
| Measure Code | | RFRFERPS | |
| Product Description | | Freezer Early Retirement | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | n/a | n/a |
| Cust Equip Rpl | 6013CUST | n/a | n/a |
| Farm NC | 6014FARM | n/a | n/a |
| Farm Equip Rpl | 6013FARM | n/a | n/a |
| Non Act 250 NC | 6014NANC | n/a | n/a |
| Pres Equip Rpl | 6013PRES | n/a | n/a |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6012MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | n/a | n/a |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | n/a | n/a |
| LIMF Rehab | 6018LIRH | n/a | n/a |
| RES Retrofit | 6036RETR | 1.0 | 1.0 |
| RNC VESH | 6038VESH | n/a | n/a |
| MF Mkt NC | 6019MFNC | n/a | n/a |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
8 years [1025] Analysis period is the same as the lifetime.

**Measure Cost**
The cost of pickup and recycling of the refrigerator is $50 based upon agreement with contractors or vendors who will collect secondary units when replacing the primary unit. Contractors have signed an agreement that the units will be recycled and not placed on the secondary market.

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[1024] The Summer and Winter Coincident kW are calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. To calculate an Equivalent Full Load Hours the UEC (* PartUse) is divided by the summer coincident kW (956 * .779)/0.088 = 8477 hours. The summer coincidence factor is therefore assumed to be 1.0 and a winter coincidence factor calculated as the relative winter to summer kW result from the algorithm. For the calculation see “Refrigerator kW Calculations.xls”.
[1025] KEMA “Residential refrigerator recycling ninth year retention study”, 2004

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
There are no fossil fuel savings for this measure.

**Water Descriptions**
There are no water savings for this measure.

Clothes Washing End Use

# Clothes Washer Retrofit

Measure Number: VII-H-1-c (Residential Emerging Markets, Clothes Washing End Use)

**Version Date & Revision History**

Draft date: Portfolio 81
Effective date: 1/1/2013
End date: TBD

**Referenced Documents**:

1) 2013 Clothes Washer Retrofit Savings.xls
2) http://www.eia.gov/consumption/residential/data/2009/
3) http://www1.eere.energy.gov/buildings/appliance_standards/residential/clothes_washers_support_stakeholder_negotiations.html

**Description**

This is an early retrofit measure of an existing inefficient clothes washer with a new clothes washer exceeding minimum qualifying efficiency standards established as ENERGY STAR, CEE Tier 2 or CEE Tier 3, Most Efficient or Top Ten (defined below). Savings are calculated between the average energy usage of an existing unit and that of a CEE Tier 3 unit for the remaining life of the existing unit, phlus the savings between an average baseline unit and that of a CEE Tier 3 unit for the remainder of the measure life.

Savings are provided for both specific DHW and Dryer fuel combinations and for if the fuel is unknown.

**Algorithms**

**Energy Savings**

Energy and Demand Savings are presented in the reference tables below, and are dependent on the fuel type of the DHW system and the dryer. The calculations are based on analysis of previous year's rebated units, see 2013 MF In unit Clothes Washer Savings.xls.

**Demand Savings**

$\Delta kW = \Delta kWh / Hours$

Where:

| | |
|---|---|
| $\Delta kWh$ | = gross customer annual kWh savings for the measure |
| $\Delta kW$ | = gross customer connected load kW savings for the measure |
| Hours | = Operating hours of clothes washer<br>= 322 |

**Baseline Efficiencies – New or Replacement**

The baseline efficiency is determined according to the modified energy factor (MEF) that takes into account the energy and water required per clothes washer cycle, including energy required by the clothes dryer per clothes washer cycle. For the purpose of this measure it is assumed that the remaining life of the existing clothes washer is 3 years (i.e. it is 11 years in to its 14 year life). The federal baseline for clothes washers prior to 2004 was 0.817 MEF[1026], and the average value of units tested in a 2001 DOE market assessment was 1.164.. For the remaining 11 years of the new clothes washer, the current federal baseline MEF of 1.26 is inflated by 20% to 1.51 to account for a transforming market. See 2013 Clothes Washer Retrofit Savings.xls for more details.

[1026] http://www.cee1.org/resid/seha/rwsh/press-rel.php3

**High Efficiency**
High efficiency is defined as any model meeting or exceeding the efficiency standards presented below.

| Efficiency Level | Modified Energy Factor (MEF) | Water Factor (WF) |
|---|---|---|
| ENERGY STAR | >= 2.0 | <= 6.0 |
| CEE TIER 2 | >= 2.20 | <= 4.5 |
| CEE TIER 3 | >= 2.40 | <= 4.0 |
| ENERGY STAR Most Efficient (as of 1/1/2013) | >= 2.4 (for units <=2.5 ft3)<br>>= 3.2 (for units >2.5 ft3) | <= 4.5 (for units <=2.5 ft3)<br><= 3.0 (for units >2.5 ft3) |
| Top Ten | Defined as the ten most efficient units available. | |

The modified energy factor (MEF) measures energy consumption of the total laundry cycle (unit operation, washing and drying); the higher the number, the greater the efficiency.

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

Energy and water savings estimates are based on the weighted average MEF factor for qualifying models based on the models rebated during the previous calendar year, except Top Ten which is based upon averaging the units provided on the website (http://www.toptenusa.org/Top-Ten-Clothes-Washers) as of September 2012.

**Operating Cycles**
322 clothes washer cycles / year [1027]

**Operating Hours**
322 operating hours / year [1028]

**Loadshape**
Loadshape #9, Residential Clothes Washing, Vermont State Screening Tool.

**Freeridership/Spillover Factors**

| Measure Category | | Cooking and Laundry | |
|---|---|---|---|
| Measure Code | | CKLESWER CKLT2WER, CKLT3WER, CKLMEWER, CKLTTWER | |
| Product Description | | Energy Star Clothes Washer | |
| Track Name | Track No. | Freerider | Spillover |
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |
| RES Retrofit | 6036RETR | 0.9 | 1.0 |

**Persistence**
The persistence factor is assumed to be one.

**Lifetimes**
14 years[1029].
Analysis period is the same as the lifetime.

**Measure Cost**

[1027] Weighted average of 322 clothes washer cycles per year. 2009 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section: http://www.eia.gov/consumption/residential/data/2009/
[1028] Based on assumption of average one hour per cycle.
[1029] Consistent with DOE Federal Standard Lifecycle Analysis (14.3 years): http://www1.eere.energy.gov/buildings/appliance_standards/residential/clothes_washers_support_stakeholder_negotiations.html

The full measure cost assumption is provided below:

| Efficiency Level | Full Measure Cost |
|---|---|
| ENERGY STAR | $825 |
| CEE Tier 2 | $850 |
| CEE Tier 3 | $950 |
| ENERGY STAR Most Efficient | $1100 |
| Top Ten | $1110 |

The deferred (for 3 years) baseline replacement clothes washer cost is assumed to be $600.[1030]

**O&M Cost Adjustments**
There are no operation and maintenance cost adjustments for this measure.

**Fossil Fuel Descriptions**
See reference tables below

**Water Descriptions**
The water savings for each efficiency level are presented below:

| Efficiency Level | WF | ΔWater (CCF per year) | | |
|---|---|---|---|---|
| | | Remaining life of existing unit (first 3 years) | Remaining measure life (Next 11 years) | Weighted average for use in screening[1031] |
| Existing unit | 12.87[1032] | n/a | n/a | n/a |
| Federal Standard | 7.93 | n/a | n/a | n/a |
| ENERGY STAR | 5.41 | 8.8 | 3.0 | 4.2 |
| CEE Tier 2 | 3.61 | 16.1 | 7.5 | 9.4 |
| CEE Tier 3 | 3.51 | 15.1 | 7.1 | 8.8 |
| ENERGY STAR Most Efficient | 2.90 | 16.8 | 8.5 | 10.3 |
| Top Ten | 3.54 | 16.5 | 7.8 | 9.6 |

[1030] Based on weighted average of top loading and front loading units (based on available product from the CEC Appliance database) and cost data from Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_standard.xlsm. See '2013 Clothes Washer Savings_Retrofit.xls' for details.
[1031] Efficiency Vermont's screening tool does not allow for mid-life savings adjustments for water, thus a single value is required.
[1032] US DOE, Life Cycle Cost Model, spreadsheet dated December 1999, indicates 38.61 gallons of water per cycle. Assume average size of 3 cu ft gives 12.87 WF assumption. http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/lcc_spreadsheet.xls

**Reference Tables**

**Customer Energy Savings by Water Heater and Dryer Fuel Type**[1033]

**ENERGY STAR**

For remaining life of existing unit (first 3 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 336 | 1.05 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 173 | 0.54 | 0 | 0.70 | 0 |
| Electric Dryer/Natural Gas DHW | 173 | 0.54 | 0 | 0 | 0.70 |
| Electric Dryer/Oil DHW | 173 | 0.54 | 0.70 | 0 | 0 |
| Propane Dryer/Electric DHW | 175 | 0.54 | 0 | 0.55 | 0 |
| Propane Dryer/Propane DHW | 11 | 0.04 | 0 | 1.25 | 0 |
| Propane Dryer/Oil DHW | 11 | 0.04 | 1.25 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 175 | 0.54 | 0 | 0 | 0.55 |
| Natural Gas Dryer/Natural Gas DHW | 11 | 0.04 | 0 | 0 | 1.25 |
| Natural Gas Dryer/Oil DHW | 11 | 0.04 | 1.25 | 0 | 0.00 |

For remaining measure life (Next 11 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 162 | 0.50 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 59 | 0.18 | 0 | 0.44 | 0 |
| Electric Dryer/Natural Gas DHW | 59 | 0.18 | 0 | 0 | 0.44 |
| Electric Dryer/Oil DHW | 59 | 0.18 | 0.44 | 0 | 0 |
| Propane Dryer/Electric DHW | 104 | 0.32 | 0 | 0.20 | 0 |
| Propane Dryer/Propane DHW | 2 | 0.01 | 0 | 0.64 | 0 |
| Propane Dryer/Oil DHW | 2 | 0.01 | 0.64 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 104 | 0.32 | 0 | 0 | 0.20 |
| Natural Gas Dryer/Natural Gas DHW | 2 | 0.01 | 0 | 0 | 0.64 |
| Natural Gas Dryer/Oil DHW | 2 | 0.01 | 0.64 | 0 | 0.00 |

**CEE T2**

For remaining life of existing unit (first 3 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 534 | 1.66 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 276 | 0.86 | 0 | 1.11 | 0 |

[1033] Where dryer and DHW use different fossil fuels, savings are combined under the DHW fossil fuel because a single measure can only have one fuel type for screening purposes and the DHW savings are larger than the Dryer savings.

| | | | | | |
|---|---|---|---|---|---|
| Electric Dryer/Natural Gas DHW | 276 | 0.86 | 0 | 0 | 1.11 |
| Electric Dryer/Oil DHW | 276 | 0.86 | 1.11 | 0 | 0 |
| Propane Dryer/Electric DHW | 280 | 0.87 | 0 | 0.87 | 0 |
| Propane Dryer/Propane DHW | 21 | 0.07 | 0 | 1.98 | 0 |
| Propane Dryer/Oil DHW | 21 | 0.07 | 1.98 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 280 | 0.87 | 0 | 0 | 0.87 |
| Natural Gas Dryer/Natural Gas DHW | 21 | 0.07 | 0 | 0 | 1.98 |
| Natural Gas Dryer/Oil DHW | 21 | 0.07 | 1.98 | 0 | 0.00 |

For remaining measure life (Next 11 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 277 | 0.86 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 108 | 0.34 | 0 | 0.72 | 0 |
| Electric Dryer/Natural Gas DHW | 108 | 0.34 | 0 | 0 | 0.72 |
| Electric Dryer/Oil DHW | 108 | 0.34 | 0.72 | 0 | 0 |
| Propane Dryer/Electric DHW | 175 | 0.54 | 0 | 0.35 | 0 |
| Propane Dryer/Propane DHW | 7 | 0.02 | 0 | 1.07 | 0 |
| Propane Dryer/Oil DHW | 7 | 0.02 | 1.07 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 175 | 0.54 | 0 | 0 | 0.35 |
| Natural Gas Dryer/Natural Gas DHW | 7 | 0.02 | 0 | 0 | 1.07 |
| Natural Gas Dryer/Oil DHW | 7 | 0.02 | 1.07 | 0 | 0.00 |

**CEE T3**

For remaining life of existing unit (first 3 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 587 | 1.82 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 279 | 0.87 | 0 | 1.32 | 0 |
| Electric Dryer/Natural Gas DHW | 279 | 0.87 | 0 | 0 | 1.32 |
| Electric Dryer/Oil DHW | 279 | 0.87 | 1.32 | 0 | 0 |
| Propane Dryer/Electric DHW | 326 | 1.01 | 0 | 0.89 | 0 |
| Propane Dryer/Propane DHW | 19 | 0.06 | 0 | 2.21 | 0 |
| Propane Dryer/Oil DHW | 19 | 0.06 | 2.21 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 326 | 1.01 | 0 | 0 | 0.89 |
| Natural Gas Dryer/Natural Gas DHW | 19 | 0.06 | 0 | 0 | 2.21 |
| Natural Gas Dryer/Oil DHW | 19 | 0.06 | 2.21 | 0 | 0.00 |

For remaining measure life (Next 11 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |

| | | | | | |
|---|---|---|---|---|---|
| Electric Dryer/Electric DHW | 348 | 1.08 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 124 | 0.39 | 0 | 0.96 | 0 |
| Electric Dryer/Natural Gas DHW | 124 | 0.39 | 0 | 0 | 0.96 |
| Electric Dryer/Oil DHW | 124 | 0.39 | 0.96 | 0 | 0 |
| Propane Dryer/Electric DHW | 229 | 0.71 | 0 | 0.40 | 0 |
| Propane Dryer/Propane DHW | 6 | 0.02 | 0 | 1.37 | 0 |
| Propane Dryer/Oil DHW | 6 | 0.02 | 1.37 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 229 | 0.71 | 0 | 0 | 0.40 |
| Natural Gas Dryer/Natural Gas DHW | 6 | 0.02 | 0 | 0 | 1.37 |
| Natural Gas Dryer/Oil DHW | 6 | 0.02 | 1.37 | 0 | 0.00 |

**Most Efficient**
For remaining life of existing unit (first 3 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 695 | 2.16 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 326 | 1.01 | 0 | 1.58 | 0 |
| Electric Dryer/Natural Gas DHW | 326 | 1.01 | 0 | 0 | 1.58 |
| Electric Dryer/Oil DHW | 326 | 1.01 | 1.58 | 0 | 0 |
| Propane Dryer/Electric DHW | 390 | 1.21 | 0 | 1.04 | 0 |
| Propane Dryer/Propane DHW | 22 | 0.07 | 0 | 2.62 | 0 |
| Propane Dryer/Oil DHW | 22 | 0.07 | 2.62 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 390 | 1.21 | 0 | 0 | 1.04 |
| Natural Gas Dryer/Natural Gas DHW | 22 | 0.07 | 0 | 0 | 2.62 |
| Natural Gas Dryer/Oil DHW | 22 | 0.07 | 2.62 | 0 | 0.00 |

For remaining measure life (Next 11 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 446 | 1.38 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 164 | 0.51 | 0 | 1.21 | 0 |
| Electric Dryer/Natural Gas DHW | 164 | 0.51 | 0 | 0 | 1.21 |
| Electric Dryer/Oil DHW | 164 | 0.51 | 1.21 | 0 | 0 |
| Propane Dryer/Electric DHW | 289 | 0.90 | 0 | 0.53 | 0 |
| Propane Dryer/Propane DHW | 8 | 0.02 | 0 | 1.74 | 0 |
| Propane Dryer/Oil DHW | 8 | 0.02 | 1.74 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 289 | 0.90 | 0 | 0 | 0.53 |
| Natural Gas Dryer/Natural Gas DHW | 8 | 0.02 | 0 | 0 | 1.74 |
| Natural Gas Dryer/Oil DHW | 8 | 0.02 | 1.74 | 0 | 0.00 |

**Top Ten**

For remaining life of existing unit (first 3 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 746 | 2.32 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 358 | 1.11 | 0 | 1.67 | 0 |
| Electric Dryer/Natural Gas DHW | 358 | 1.11 | 0 | 0 | 1.67 |
| Electric Dryer/Oil DHW | 358 | 1.11 | 1.67 | 0 | 0 |
| Propane Dryer/Electric DHW | 412 | 1.28 | 0 | 1.14 | 0 |
| Propane Dryer/Propane DHW | 24 | 0.08 | 0 | 2.81 | 0 |
| Propane Dryer/Oil DHW | 24 | 0.08 | 2.81 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 412 | 1.28 | 0 | 0 | 1.14 |
| Natural Gas Dryer/Natural Gas DHW | 24 | 0.08 | 0 | 0 | 2.81 |
| Natural Gas Dryer/Oil DHW | 24 | 0.08 | 2.81 | 0 | 0.00 |

For remaining measure life (Next 11 years):

| | Per Unit Savings | | | | |
|---|---|---|---|---|---|
| Dryer/DHW Fuel Combo | kWh | kW | MMBTU Oil | MMBTU Propane | MMBTU Natural Gas |
| Electric Dryer/Electric DHW | 484 | 1.50 | 0 | 0 | 0 |
| Electric Dryer/Propane DHW | 188 | 0.58 | 0 | 1.27 | 0 |
| Electric Dryer/Natural Gas DHW | 188 | 0.58 | 0 | 0 | 1.27 |
| Electric Dryer/Oil DHW | 188 | 0.58 | 1.27 | 0 | 0 |
| Propane Dryer/Electric DHW | 306 | 0.95 | 0 | 0.61 | 0 |
| Propane Dryer/Propane DHW | 10 | 0.03 | 0 | 1.88 | 0 |
| Propane Dryer/Oil DHW | 10 | 0.03 | 1.88 | 0.00 | 0 |
| Natural Gas Dryer/Electric DHW | 306 | 0.95 | 0 | 0 | 0.61 |
| Natural Gas Dryer/Natural Gas DHW | 10 | 0.03 | 0 | 0 | 1.88 |
| Natural Gas Dryer/Oil DHW | 10 | 0.03 | 1.88 | 0 | 0.00 |

**Savings if DHW and Dryer fuel is unknown:**

For remaining life of existing unit (first 3 years):

| | kWh | kW | MMBTU Natural Gas | MMBTU Propane | MMBTU Oil |
|---|---|---|---|---|---|
| Non-CEE Energy Star Units | 197.7 | 0.61 | 0.17 | 0.15 | 0.26 |
| CEE 2 | 315.3 | 0.98 | 0.27 | 0.23 | 0.41 |
| CEE 3 | 332.8 | 1.03 | 0.31 | 0.26 | 0.49 |
| Most Efficient | 391.7 | 1.22 | 0.37 | 0.30 | 0.59 |
| Top Ten | 425.0 | 1.32 | 0.39 | 0.33 | 0.62 |

For remaining measure life (Next 11 years):

| | kWh | kW | MMBTU Natural Gas | MMBTU Propane | MMBTU Oil |
|---|---|---|---|---|---|
| Non-CEE Energy Star Units | 81.8 | 0.25 | 0.10 | 0.07 | 0.16 |
| CEE 2 | 144.4 | 0.45 | 0.16 | 0.12 | 0.27 |
| CEE 3 | 174.4 | 0.54 | 0.21 | 0.16 | 0.36 |
| Most Efficient | 226.6 | 0.70 | 0.27 | 0.20 | 0.45 |
| Top Ten | 251.5 | 0.78 | 0.28 | 0.22 | 0.47 |

## Multiple End Use
# Mail Order Efficiency Kit

Measure Number: VII-J-1-c (Residential Emerging Markets, Multiple End Use)

**Version Date & Revision History:**
Draft date: Portfolio 87
Effective date: 6/1/2014
End date: TBD

**Referenced Documents:**
1. *FINAL REPORT: TIER 1 WORKSHOP MODEL 2007-2008, Prepared for the Governor's Energy Office by Energy Outreach Colorado, July 3, 2008*
2. Efficiency Kit 2014 - Savings Calculations - Feb2015.xlsx

**Description**
This characterization provides information related to the mailing of any combination of a number of free efficient products in an "Efficiency Kit" after request by a residential customer. This characterization references other product specific TRM entries that should be used to see details of each characterization, and will be identical except for details stated in the savings tables below.

Kits may include any combination of the following products:
- Standard CFL (13W)
- Screw Based SSL (11W LED)
- Low Flow Faucet Aerator (1.0 GPM)
- Controlled Power Strip

**Algorithms**

**Demand Savings**

| **Measure** | **TRM Reference** (Market) | **Difference from Reference TRM** | **Demand Savings (kW)** |
|---|---|---|---|
| Standard CFL (13W) | **Interior CFL Direct Install** (Residential Emerging Markets) | ISR = 0.80 | 0.0277 |
| Screw Based SSL (11W LED) | **Screw Based SSL (LED)** (Efficient Products) | ISR = 0.80 | 0.0294 |
| 1.0 GPM Low Flow Faucet Aerator | **Low Flow Faucet Aerator** (Residential Emerging Markets) | Assume 31% of DHW units are electric, ISR = 0.30 | 0.0017 |
| Controlled Power Strip | **Controlled Power Strip** (Efficient Products) | Office and Entertainment Centre savings weighted average[1034], ISR = 0.60 | 0.0062 |

[1034] Data gathered from the Smartstrip coupon in retail show that of the 119 sold, 60 went to Entertainment use, 11 Home Office, 5 Business Office, 1 other and 42 left blank. Entertainment and Residential Office savings are therefore weighted 5.45:1 respectively.

**Energy Savings**

| Measure | TRM Reference | Difference from Reference TRM | Energy Savings (Annual kWh) |
|---|---|---|---|
| Standard CFL (13W) | Interior CFL Direct Install | ISR = 0.80; Hours of Use = 949[1035] | 25.1 |
| Screw Based SSL (11W LED) | Screw Based SSL (LED) | ISR = 0.80; Hours of Use = 949[1036] | 26.7 |
| 1.0 GPM Low Flow Faucet Aerator | Low Flow Faucet Aerator | Assume 31% of DHW units are electric, ISR = 0.30 | 5.77 |
| Controlled Power Strip | Controlled Power Strip | Office and Entertainment Centre savings weighted average[1037], ISR = 0.60 | 43.60 |

**Baseline Efficiencies – New or Replacement**
See individual TRM entries.

**High Efficiency**
See individual TRM entries.

**Operating Hours**
See individual TRM entries.

**Loadshape**
See individual TRM entries.

**Freeridership/Spillover Factors**

| | | | |
|---|---|---|---|
| Measure Category | | Light Bulbs/Lamps, Hot Water Conservation, Electronic Technology | |
| Measure Code | | LBLCFBLB, LBLLEDSC, HWEFAUCT, EQPPWREK | |
| Product Description | | Free products mailed in Efficiency Kit | |
| Track Name | Track No. | Freerider | Spillover |
| LISF Retrofit | 6034LISF | 1.0 | 1.0 |
| RES Retrofit | 6036RETR | 0.9 | 1.0 |

**Persistence**
See individual TRM entries.

**Lifetimes**
See individual TRM entries.

1035 Northeast Residential Lighting Hours Of Use Study, 5/5/2014, Table 3-1 in report, pg. 34
1036 Northeast Residential Lighting Hours Of Use Study, 5/5/2014, Table 3-1 in report, pg. 34
1037 Entertainment and Residential Office savings are weighted 5.45:1 per previous footnote for demand savings.

**Measure Cost**
The cost of the package will be calculated as follows:

| Measure | TRM Reference | Difference from Reference TRM | Cost per unit |
|---|---|---|---|
| Standard CFL | Interior CFL Direct Install | Cost of product, kit assembly, and postage | $6.38 |
| Residential LED >=10W | Screw Based SSL (LED) | Cost of product, kit assembly, and postage | $20.30 |
| Low Flow Faucet Aerator | Low Flow Faucet Aerator | Cost of product, kit assembly, and postage | $5.80 |
| Controlled Power Strip | Controlled Power Strip | Cost of product, kit assembly, and postage | $15.80 |

**Fossil Fuel Descriptions**

| Measure | TRM Reference | Difference from Reference TRM | MMBtu Savings |
|---|---|---|---|
| 1.0 GPM Low Flow Faucet Aerator | Low Flow Faucet Aerator | Assume 13.3% of DHW units are Natural Gas, 23.9% LP, 31.4% Oil., ISR = 0.30 | Natural Gas = 0.0107<br>LP = 0.0193<br>Oil = 0.0254 |

See “Efficiency Kit 2014 - Savings Calculations - Feb2015.xlsx” for calculation of savings. DHW fuel percentages based on coupon data from EP Clothes Washer program. Fossil fuel system DHW efficiencies and savings consistent with “Low Flow Faucet Aerator” TRM.

**Water Descriptions**

| Measure | TRM Reference | Difference from Reference TRM | Water Savings (CCF) |
|---|---|---|---|
| 1.0 GPM Low Flow Faucet Aerator | Low Flow Faucet Aerator | ISR = 0.30 | 0.291 |

**Reference Tables**
See above.

## Commercial Heat and Process Fuels

### Space Heating End Use

# Efficient Space Heating System

Measure Number: VIII-C-1-b (Commercial Heat and Process Fuels, Space Heating End Use)

**Version Date & Revision History**
Draft date: Portfolio 66
Effective date: 01/01/10
End date: TBD

**Referenced Documents:**
'DOE_Large_ch5.pdf'
'DOE_Small_appendix_e.pdf'
'HDD Calculation Method.pdf'
'Small Boiler market share.xls'
'Boiler Furnace Cost Analysis - FINAL052410.xls'
"The Facts About Venting And Efficiencies" (http://www.raypak.com/pdfs/100012.pdf)
'HDD calc.xls'
'NOAA NCDC Historical Climatological Series 5-1'
(http://www.ncdc.noaa.gov/oa/documentlibrary/hcs/hcs.html)

**Description**
This measure applies to oil- and propane-fired boilers and furnaces up to 500 MBH in capacity, used in non-residential and multi-family residential space-heating applications that meet the specified minimum efficiency requirement. Fossil fuel savings are realized due to the higher AFUE or Thermal Efficiency of the qualifying equipment. This measure will provide incentives for market based opportunities, including standard equipment replacement, new equipment purchases, and new construction.

**Algorithms**
**Energy Savings**
$\Delta$MMBTU = (HDD * CF * 24 / Dt) * (Capacity / 1000) * ($1/\eta_{Base} - 1/\eta_{Eff}$)

Where:
- $\Delta$MMBTU = gross customer annual MMBtu fuel savings for the measure
- HDD = heating degree days for Vermont (assume 7,859[1038])
- CF = Correction Factor (assume 0.77[1039])
- 24 = hours per day
- Dt = design temperature difference (assume from -20 F to 70 F)
- Capacity = capacity of equipment to be installed (in MBH – 1000's of Btu/hr)
- 1000 = Conversion from MBH to MMBtu/hour
- $\eta_{Base}$ = efficiency of baseline equipment, in AFUE or Thermal Efficiency. See **ReferenceTable 1: Efficiency Standards and Qualifying Efficiencies**

**1038** 10-year weighted average (2000-2009) for Vermont, from NOAA NCDC Historical Climatological Series 5-1 (http://www.ncdc.noaa.gov/oa/documentlibrary/hcs/hcs.html). See analysis in HDD calc.xls.

1039 Principles of Heating Ventilating and Air Conditioning 6th Edition (Based on the 2009 ASHRE Handbook - Fundamentals) Chapter 8 Energy Estimating Methods Section 8.5.3 Heating Degree-Day Method (see excerpt in 'HDD Calculation Method.pdf). The factor of 0.77 is an empirical correction factor that adjusts typical HDD data downward to account for the fact that typical HDD data is based on a balance point of 65 degrees, which tends to be too high due to better insulation and increased internal electric loads of buildings.

$\eta_{Eff}$ = efficiency of new equipment, in AFUE or Thermal Efficiency.

There are no electrical energy or demand algorithms associated with this measure. Electric energy savings from efficient furnace fans included with efficient furnaces are calculated separately.

**Baseline Efficiencies**

Baseline equipment is a new standard efficiency oil- or propane-fired furnace or boiler, used for space heating in a non-residential or multi-family residential application. Baseline efficiencies are detailed below in **ReferenceTable 1: Efficiency Standards and Qualifying Efficiencies.**

**High Efficiency**

The installed oil or propane furnace or boiler must have an AFUE or thermal efficiency (Et) greater than that shown below in **ReferenceTable 1: Efficiency Standards and Qualifying Efficiencies** and be used for space-heating only in a non-residential or multi-family residential installation.

**Loadshape**

N/A.

**Freeridership/Spillover Factors**

| Measure Category | | Space Heating Equipment | |
|---|---|---|---|
| Measure Codes | | SHRFPROP, SHRFNGAS, SHRFFOIL, SHRHPROP, SHRHNGAS, SHRHFOIL, SHRBPROP, SHRBNGAS, SHRBFOIL | |
| Product Description | | Efficient Space Heating Equipment | |
| Track Name | Track No. | Freerider | Spillover |
| Act250 NC | 6014A250 | 1 × 0.95 = 0.95 * | 1.075 ** |
| Cust Equip Rpl | 6013CUST | 0.94 | 1 |
| Farm NC | 6014FARM | 1 | 1 |
| Farm Equip Rpl | 6013FARM | 1 | 1 |
| Non Act 250 NC | 6014NANC | 1 | 1.075 ** |
| Pres Equip Rpl | 6013PRES | 1 | 1 |
| C&I Retro | 6012CNIR | n/a | n/a |
| MF Mkt Retro | 6012MFMR | n/a | n/a |
| Efficient Products | 6032EPEP | 1 | 1 |
| LISF Retrofit | 6034LISF | n/a | n/a |
| LIMF Retrofit | 6017RETR | n/a | n/a |
| LIMF NC | 6018LINC | 1 | 1 |
| LIMF Rehab | 6018LIRH | 1 | 1 |
| RES Retrofit | 6036RETR | n/a | n/a |
| RNC VESH | 6038VESH | 1 | 1 |
| MF Mkt NC | 6019MFNC | 1 | 1 |

* Freeridership of 0% per agreement between DPS and EVT. All Act 250 measures will also have a 5% Adjustment Factor applied, which will be implemented through the Freeridership factor.

** Spillover of 7.5% only for 2010, based on TAG agreement with DPS, to revert to 0% in 2011.

**Persistence**

The persistence factor is assumed to be one.

**Lifetimes**

| **Equipment Type** | **Measure Lifetime** |
|---|---|
| Furnaces | 20 |

| | |
|---|---|
| Boilers | 25 |

Source: Consistent with previous lifetime estimates used by Efficiency Vermont in the state screening tool.

**Measure Cost**
The incremental costs of more efficient equipment are detailed below in **Reference Table 2: Measure Costs**.

**Incentive Level**
The incentive provided is $2 per kBtu. For example, a 350 kBtu/h system would receive an incentive of $700.

**O&M Cost Adjustments**
There are no O&M cost adjustments.

**Fossil Fuel Descriptions**
See Energy Savings algorithms above

**Water Descriptions**
There are no water algorithms or default values for this measure.

**Reference Tables**

**Table 1: Efficiency Standards and Qualifying Efficiencies**

| | ASHRAE 90.1 – 2004 Minimum Efficiency | Baseline Efficiency | Minimum Qualifying efficiency |
|---|---|---|---|
| Oil Boiler (< 300 MBH) | 80% AFUE | 82.9% AFUE(1) | 85% AFUE(2) |
| Oil Boiler (300 – 500 MBH) | 78% Et | 81% Et (3) | 87% Et |
| Oil Furnace (< 225 MBH) | 78% AFUE | 80% AFUE (3) | 85% AFUE(2) |
| Oil Furnace ( ≥ 225 MBH) | 81% Et | 81% Et (4) | 82% Et (5) |
| LP Boiler (<300 MBH) | 80% AFUE | 82.3% AFUE (1) | 85% AFUE(2) |
| LP Boiler (300 – 500 MBH) | 75% Et | 84% Et (6) | 87% Et |
| LP Furnace (< 225 MBH) | 78% AFUE | 84% AFUE (3) | 90% AFUE(2) |
| LP Furnace ( ≥ 225 MBH) | 79% Et (7) | 80% Et (8) | 82% Et (5) |

(1) Based on GAMA 2005 shipment data. See ‘Small Boiler market share.xls’.

(2) Minimum qualifying efficiency for Energy Star standard.

(3) Based on AHRI data

(4) ASHRAE standard. Lowest efficiency available from AHRI database is 80% Et.

(5) Highest Efficiency Available from AHRI database

(6) Performance threshold for non-condensing boilers

(7) Assumed Thermal Efficiency is 1% lower than combustion efficiency[1040]

(8) Lowest Efficiency Available from AHRI database

**Table2: Measure Costs**

| | Baseline Installed Cost ($ per Btu/h) | Efficient Installed Cost ($ per Btu/h) | Incremental Cost ($ per Btu/h) |
|---|---|---|---|
| Oil Boiler (< 300 kBtu/h) | $0.026 | $0.032 | $0.006 |
| Oil Boiler ( ≥ 300 kBtu/h) | $0.028 | $0.043 | $0.015 |
| LP Boiler (< 300 kBtu/h) | $0.034 | $0.045 | $0.012 |
| LP Boiler ( ≥ 300 kBtu/h) | $0.029 | $0.039 | $0.010 |
| Oil Furnace (< 225 kBtu/h) | $0.025 | $0.034 | $0.009 |
| Oil Furnace ( ≥ 225 kBtu/h) | $0.025 | $0.028 | $0.003 |
| LP Furnace (< 225 kBtu/h) | $0.028 | $0.036 | $0.009 |
| LP Furnace ( ≥ 225 kBtu/h) | $0.028 | $0.031 | $0.003 |
| Costs from analysis of DOE cost data from DOE technical support documentation (see referenced documents), as summarized in file “Boiler Furnace Cost Analysis - FINAL052410.xls.” | | | |

[1040] $E_c$ is the combustion efficiency of the equipment. $E_t$ is the thermal efficiency, and includes both combustion losses and jacket losses. Assumed that $E_t$ is 1% lower than $E_c$ based on “The Facts About Venting And Efficiencies” (http://www.raypak.com/pdfs/100012.pdf), in which thermal efficiencies range from 1% to 3% less than combustion efficiencies. Used 1% as a conservative estimate.