Hawaiʻi Energy Efficiency Program

July 1, 2019 through June 30, 2020

Technical Reference Manual (TRM)

PY 2019

V2.1

Measure Savings Calculations

May 20, 2020

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*Updated for PY19 TRM

MAJOR CHANGES FROM PY2018 TO PY2019 TRM

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Changes from PY18 (Renamed)	Updated and renamed Changes sheet
Introduction	Review/update of text
Signatures	Update of Signature sheet
Glossary	Review/update/addition of definitions, including adding formal definition of demand savings
Key Metrics - Avoided Costs	Review/update of avoided costs
Key Metrics - NTG, All Programs	Review/update of NTG ratios using benchmarking analysis; changed value for BHTR
Key Metrics - NTG, Upstream LED bulbs	Change between v1.2 and v2.1 of PY19 TRM: Update of NTG ratio for upstream LEDs to include market effects
Key Metrics - SLF	Review/update of system loss factors
Master EUL	Review/update of EULs using benchmarking
Savings Factors	Review/update of lighting/cooling interactive effect factors using Hawaiʻi-specific load shape data for residential and benchmarking with secondary data for commercial
EFLH & CF (Renamed)	Review/update of HOU/EFLH and CF values using Hawaiʻi-specific load shape data and benchmarking
Custom	Review/update of calculation methodology and assumptions; updates focused on Distribution Transformer, Chillers, and Ductless Systems
C_HVAC_Chiller, C_HVAC_Chiller_WKST	Review/update of calculation methodology and assumptions; updated baseline to ASHRAE 90.1-2016 Change between v1.2 and v2.0 of PY19 TRM: Corrected cell reference errors in calculation worksheet
C_HVAC_EMS	Review/update of calculation methodology and assumptions; added small and large hotel options Change between v1.2 and v2.0 of PY19 TRM: Clarified definition of small and large hotels

C_HVAC_VFD Water Pump	Review/update of calculation methodology and assumptions; added semi-prescriptive calculator
C_HVAC_VRF	Review/update of calculation methodology and assumptions; updated baseline to ASHRAE 90.1-2016
C_HVAC_VRF_WKST (New)	Added calculation worksheet for commercial VRF systems
C_HVAC_Window AC, C_HVAC_WindowAC_WKST	Change between v1.2 and v2.0 of PY19 TRM: Added new measure entry and calculation worksheet Change between v2.0 and v2.1 of PY19 TRM: Clarified the minimum efficiency requirements for standard vs. connected systems
C_Light_General	Review/update of calculation methodology and assumptions; updated baseline approach
C_Light_Exterior (New)	Separated Exterior Lighting from Interior Lighting
C_Light_Dimmable(Nonlinear LED)	Review/update of calculation methodology and assumptions; updated baseline approach
C_Lighting_Refrigerated Case	Review/update of calculation methodology and assumptions; updated baseline approach; added option for medium and low temperature units
C_Light_Occupancy Sensor	Review/update of calculation methodology and assumptions; added semi-prescriptive calculator
C_Light_Stairwell Bi-Level	Review/update of calculation methodology and assumptions; added semi-prescriptive calculator
C_Light_Energy Advantage	Review/update of description
C_PumpMotor_VFD Booster Pump	Review/update of calculation methodology and assumptions
C_PumpMotor_VFD Pool Pump	Review/update of calculation methodology and assumptions; added options for different hp ranges and single- and dual-speed baselines
C_WH_Solar	Review/update of calculation methodology and assumptions; added semi-prescriptive calculator
R_Appliance_Refrigerator	Review/update of calculation methodology and assumptions; added freezers and multiple configurations; added RUL for turned-in units
R_HVAC_Ductless (Renamed)	Review/update of calculation methodology and assumptions; renamed R_HVAC_VRF Split to R_HVAC_Ductless; added to R_HVAC_AC_WKST Change between v1.2 and v2.1 of PY19 TRM: Changed the minimum efficiency requirement to 16 SEER
R_HVAC_AC_WKST (New)	Added calculation worksheet for residential AC systems

R_Light_Holiday String Light	Change between v1.2 and v2.0 of PY19 TRM: Added new measure entry
R_Light_LED	Review/update of calculation methodology and assumptions; updated baseline approach; added semi-prescriptive calculator
R_Light_Linear LED	Change between v1.2 and v2.0 of PY19 TRM: Added new measure entry
R_Light_Occupancy Sensor	Review/update of calculation methodology and assumptions; updated baseline approach; added semi-prescriptive calculator
R_Light_Security Light	Change between v1.2 and v2.0 of PY19 TRM: Added new measure entry
R_Other_Peer Group Comparison	Review/update of description
R_PumpMotor_VFD Pool Pump	Review/update of calculation methodology and assumptions; added options for different hp ranges and single- and dual-speed baselines
R_WH_Faucet Aerator	Change between v1.2 and v2.0 of PY19 TRM: Added Online Marketplace Blended Savings
R__WH_LFShowerhead	Change between v1.2 and v2.0 of PY19 TRM: Added Online Marketplace Blended Savings
R_WH_SWH	Review/update of calculation methodology and assumptions; added semi-prescriptive calculator
R_WH_SWH Tune Up	Review/update of calculation methodology and assumptions
R_Appliance_Dishwasher	New measure for PY19; review/update of proposed calculation methodology and assumptions
R_PlugProcess_Switch Plug, R_PlugProcess_Switch_Plug_CALC	Added midyear in PY18; review/update of calculation methodology and assumptions
R_Appliance_Air Purifier	Added midyear in PY18; review/update of calculation methodology and assumptions
R_HVAC_Dehumidifier	Added midyear in PY18; review/update of calculation methodology and assumptions
R_HVAC_Window AC, R_HVAC_AC_WKST	Modified midyear in PY18; review/update of calculation methodology and assumptions; added to R_HVAC_AC_WKST Change between v1.2 and v2.0 of PY19 TRM: Added additional capacity bins to the measure entry and calculation worksheet Change between v2.0 and v2.1 of PY19 TRM: Clarified the minimum efficiency requirements for standard vs. connected systems

R_HVAC_Central AC Retrofit, R_HVAC_AC_WKST	Review/update of calculation methodology and assumptions; added to R_HVAC_AC_WKST Added option for retrofit of pre-2006 vintage units in measure entry and calculation worksheet
Issues Log	Update of Issues Log

INTRODUCTION

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UPDATE STATUS

Updated in Spring 2020 for PY19 TRM v2.1.

Technical Reference Manual (TRM)

All energy efficiency programs need to estimate the amount of energy and demand that is saved for standard measures. This allows an effective program to promote these standard measures across markets with an incentive amount that is appropriate for the amount of energy and/or demand that is saved. Hawaiʻi Energy maintains these energy saving estimates in the TRM.

The TRM is intended to be a flexible and living document. New measures may be added as new program designs are implemented. These measures are often not yet characterized, so new information will be gathered through evaluations or research. Savings for current measures may change as the market evolves.

There are four main reasons to update TRM values:

- *New Measure Additions* – As new technologies are introduced to the Hawaiʻi Energy portfolio, they will be characterized and added to the manual. In addition, new program design and new areas of interest (e.g., Market Transformation) may result in the need for new measure characterization.

- *Existing Measure Updates* – Updates will be required for a number of reasons. Examples include increase in the federal code or standard for efficiency of a measure; new information from field tests; altered qualification criteria; increase in measure priority; changes in program delivery (e.g., direct installation to point-of-sale); move from custom to deemed or vice versa; decrease in measure cost; or a new evaluation that provides a better value of an assumption for a variable. As programs mature, characterizations need to be updated to meet the changes in the market and the program.

- *Retiring Existing Measures* – Existing TRM measures may be removed from the Hawaiʻi Energy portfolio when the economics of a measure become such that it is no longer cost-effective or the free-rider rate is too high, or for other reasons. Before retiring an existing TRM measure, there should be agreement among the Commission, EEM, Hawaiʻi Energy, and the EM&V Consultant.

- *Third-Party EM&V Consultant TRM Review* – Periodically, the EM&V Consultant will provide a review of the current TRM and make recommendations based on current market research, in-field savings verification of measures, and evolving program priorities. Updates and improvements are then made in collaboration with the EEM, Hawaiʻi Energy, and the Commission and then implemented in the subsequent program year.

The following subsection describes how the TRM was developed and the key assumptions that were used in estimating the energy (kWh) savings and peak demand (kW) reduction impacts claimed by the Program.

Overview of the TRM Derivation

Each measure in the TRM includes a description of the baseline case and the high-efficiency case for the measure. The energy saved is the difference between the energy use for the baseline case and the energy use for the high-efficiency case. Similarly, the peak demand reduction is the difference between the coincident peak demand for the baseline case and the coincident peak demand for the high-efficiency case. For some measures and program delivery approaches, a dual baseline is needed to account for baseline changes that occur during the life of the measure. Lifetime energy savings reflect the cumulative saving accrued for the life of the measure.

Customer level energy and peak demand estimates are a function of many variables. When practical, assumptions for key variables used in the estimation approaches are based on Hawaiʻi specific data. Where Hawaiʻi data is not available or it is cost-prohibitive to obtain, data from similar programs in similar climate zones is used with appropriate adjustments based on engineering judgment.

The savings estimates used in the initial Hawaiʻi Energy TRM were drawn largely from the KEMA Evaluation Report for 2005 through 2007. At that time, the KEMA report was the most recent information available on specific markets. The values contained within that report were built upon previous evaluation reports and in-field measurements.

Because that report used "average" field measured data instead of generalizable engineering equations to estimate savings for many measures, the approaches provided in the TRM attempted to develop savings calculations based on typical measure characteristics. The primary use of the KEMA report values was to guide development of the first TRM, including market assumptions, especially for the baseline energy use, to more accurately estimate the typical savings.

Over the years, updates have been made to some measures and aspects of the TRM to reflect program modifications, evolving market conditions, changes to codes and standards, and availability of newer data from program evaluations and benchmarking against industry best practices. However, prior to program year 2019 (PY19), the last major TRM review and update was conducted during the 2012 program year. Given this timeframe and general industry practice, the TRM was due for a major review and update. The current EM&V Consultant (the AEG team) carried out comprehensive updates for the PY19 TRM, along with developing a TRM Framework to guide ongoing updates.

The AEG team referred to roughly 100 resources during the PY19 TRM update. A few of the key information sources include the following:

- Uniform Methods Project
- U.S. Department of Energy

- Environmental Protection Agency
- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)
- International Energy Conservation Code
- California Public Utilities Commission, Database for Energy Efficiency Resources (DEER)
- Regional Technical Forum, Library of Unit Energy Savings Measures
- Multiple Technical Reference Manuals for jurisdictions across the U.S.
- Various memorandums prepared by former EM&V Consultant, Opinion Dynamics

Additionally, the primary sources the AEG team used to update key parameters with Hawaiʻi-specific data are listed below:

- Hawaiʻi Energy PY17 program data and preliminary PY17 Verification results.
- Commercial and Residential Hourly Load Profiles for all TMY3 Locations in the United States, OpenEI Datasets, Open Data Catalog, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy. Available at: https://openei.org/doe-opendata/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states.

- National Renewable Energy Laboratory's Building Energy Optimization (BEopt) Software. Version 2.8.0.0. U.S. Department of Energy. January 2018. Available at: https://beopt.nrel.gov/. AEG developed a prototype home and ran various simulations using Honolulu weather data.

- Baseline Energy Appliance, Equipment and Building Characteristics Study Report, Prepared for the State of Hawaii Public Utilities Commission, Prepared by Evergreen Economics, February 26, 2014.

- 2019 Hawaii Statewide Baseline Energy Use Study, Prepared for the Hawaii Public Utilities Commission, Prepared by Applied Energy Group, 2020.

SIGNATURES

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GLOSSARY

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UPDATE STATUS

Updated in Fall 2018 for PY19 TRM.

TERM	DEFINITION
Annual Operating Hours (AOH)	See “Operating Hours” definition. Also referred to as “Hours of Use.”
Avoided Costs	Essentially the marginal cost for a public utility to produce one more unit of power. Because Qualifying Facilities (QFs) reduce the utility's need to produce this additional power themselves, the price utilities pay for QF power has been set to the avoided, or marginal, cost.
Baseline	Conditions, such as energy consumption and demand, which would have occurred without implementation of the subject energy efficiency measure. Baseline conditions are sometimes referred to as the counterfactual. There are several baseline options and a range of definitions for these options used in the efficiency industry.
Coefficient of Variation	The sample standard deviation divided by the sample mean ($Cv = \sigma/\mu$).
Coincident Demand	The demand of a device, circuit, end-use, building, or population that occurs at the same time as the utility’s system peak load.
Coincidence Factor (CF)	The factor used to determine the coincident peak demand reduction. It represents the fraction of the full load demand that corresponds with utility system peak period. Range = 0-1. See also “System Peak Period” and “Coincident Peak Demand Reduction” definitions.

Coincident Peak Demand Reduction	The reduction in peak electricity use in units of kW from the baseline to the use associated with the energy-efficient measure installation, where the reduction in peak electricity use occurs simultaneously with the servicing utility system's maximum use during a specific period. Hawaiʻi Energy's current definition for coincident peak demand savings is the average demand savings that occur, from implementation of an efficiency measure, during the non-holiday, weekday hours between 5 and 9 PM. This aligns with HECO's System Peak Period. See also "System Peak Period" definition.
Commission	The State of Hawaii Public Utilities Commission (HPUC) is a quasi-judicial body responsible for guiding the development of state utility policies that best serve the long-term interest of Hawaiʻi utility ratepayers, with the goal of the provision of high quality public utility service in Hawaiʻi at reasonable costs.
Common Practice	The predominant technology(ies) implemented or practice(s) undertaken in a particular region or sector. Common practices can be used to define a baseline.
Connected Load	The maximum wattage of the equipment, under normal operating conditions.
Cost-effectiveness	An indicator of the relative performance or economic attractiveness of any energy efficiency investment or practice. The present value of the estimated benefits produced by an energy efficiency program is compared to the estimated total costs to determine if the proposed investment or measure is desirable from a variety of perspectives (e.g., whether the estimated benefits exceed the estimated costs from a societal perspective).
Custom Measures	Energy efficiency measures that provide efficiency solutions to unique situations that are not amendable to fully deemed savings values or for which an individualized savings determination approach is preferable. Custom measures rely on site-specific information (e.g., hours of operation, horsepower, existing equipment efficiency) that determines their impacts (e.g., energy savings).

Deemed Calculation — Agreed-to engineering algorithm(s) used to calculate energy and/or demand savings associated with installed efficiency measure(s). Referred to in some TRMs as stipulated algorithm(s), standard protocols, or site-specific protocols. Deemed calculations that use only deemed variables or factors define fully deemed savings values. Deemed calculations are used to determine partially deemed savings values when used with a combination of (1) deemed variables/factors and (2) site- or project-specific variables/factors.

Deemed Savings Method — The process used to derive fully deemed savings values.

Deemed Savings Values — Predetermined estimates of energy or peak demand savings attributable to individual energy efficiency measures implemented in a particular type of building, application, climate zone, etc. Referred to in some TRMs as unit energy savings or stipulated savings values. These are documented, numerical values for specific energy efficiency measures, often in the form of per-unit savings that define the agreed-upon performance of an individual energy efficiency measure. Deemed savings values may be either:

- **Fully deemed savings values**—values that are fixed regardless of any site- or project-specific conditions, variables, or factors, or
- **Partially deemed (semi-prescriptive) savings values**—values determined with algorithms, which have as inputs some combination of (1) deemed variables or factors and (2) site- or project-specific conditions, variables, and factors.

Deemed Variable — Values for input assumptions that determine the performance of an energy efficiency measure under different operating conditions, applications, climates, etc. Also referred to as a stipulated variable.

Default Value — When a measure indicates that an input to a prescriptive savings algorithm may take on a range of values, an average value is also provided in many cases. This value is considered the default input to the algorithm, and should be used when the other alternatives listed in the measure are not applicable.

Demand Savings — See the “Coincident Peak Demand Reduction” definition.

Demand-Side Management — Strategies used to manage energy demand, including energy efficiency, load management, fuel substitution, and load building.

Early Retirement; Early Replacement

When equipment that is still functioning is replaced early because of a program intervention and energy savings benefits, this is referred to as "early retirement" or "early replacement." The remaining life of the existing equipment is estimated and adjustments are made to the benefits and the costs. An early retirement scenario occurs when existing, functional, actively used equipment is replaced with similar, higher efficiency equipment. The equipment being replaced should have at least one year of remaining useful life (RUL). In this case, a dual baseline will have to be considered, which uses the pre-existing equipment as the baseline for savings during the RUL period, and code requirement/industry standard practice baseline for estimating the balance of the EUL period for the new equipment.

Effective Useful Life (EUL)

The median number of years that a measure is in place and operational after installation. This definition implicitly includes equipment life and measure persistence (defined below) but not savings persistence. (Definition is from the Uniform Methods Project.) See also "Savings Persistence" definition.

- **"Equipment life"** is the number of years installed equipment will operate before it fails.
- **"Measure persistence"** takes into account business turnover, early retirement or failure of the installed equipment, and any other reason the measure would be removed or discontinued.

Energy Efficiency

"Energy efficiency" refers to measures that reduce the amount of energy required to achieve a given task or end use.

Energy Efficiency Manager (EEM)

The Energy Efficiency Manager team is an independent contractor team that assists the Commission with the administration of contracts with the Program Administrator and the EM&V Contractor.

Energy Savings

Reduction in energy use as compared to a baseline consumption. Electricity savings are generally expressed in units of kWh.

Equivalent Full Load Hours (EFLH)

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).

Evaluation or Evaluation, Measurement and Verification (EM&V)	Evaluation is an applied inquiry process for collecting and synthesizing evidence that culminates in conclusions about the state of affairs, accomplishments, value, merit, worth, significance, or quality of a program, product, person, policy, proposal, or plan. Impact evaluation in the energy efficiency arena is an investigation process to determine energy or demand impacts achieved through the program activities, encompassing, but not limited to: savings verification, measure level research, and program level research. Additionally, evaluation may occur outside of the bounds of this TRM structure to assess the design and implementation of the program.
EM&V Contractor	The EM&V Contractor is an entity designated by the Commission to provide independent evaluation, measurement, and verification services for the Public Benefits Fee (PBF) Programs, Energy Efficiency Portfolio Standard (EEPS) and other programs and/or activities as directed by the Commission. The EM&V Contractor reports to the EEM.
Failure and Failure Rate	"Failure" is defined as an instance where an implementation contractor reports that a measure has been installed, but a subsequent inspection finds that the equipment is non-operational and/or not properly installed and that difference has not been accounted for elsewhere. "Failure rate" should be defined as the percent of inspected installation sites where any equipment fails inspection (i.e., the equipment is either not installed or not operating) and that possibility has not been otherwise accounted for. Note, the definition of failure is intended to not count issues related to persistence or normal measure lives.
Free-ridership	Program savings attributable to free-riders (program participants who would have implemented a program measure or practice in the absence of the program). (Definition is from Uniform Methods Project.)
Gross Savings	The difference in energy consumption with the energy efficiency measures promoted by the program in place versus what consumption would have been without those measures in place. (Definition is from Uniform Methods Project.)
Hawaiʻi Energy	Hawaiʻi Energy is the brand name for the third-party administered ratepayer-funded conservation and energy efficiency programs for Hawaiʻi, Honolulu and Maui counties.

High Efficiency	General term for technologies and processes that require less energy, water, or other inputs to operate.
Hours of Use (HOU)	See "Operating Hours" definition. Also referred to as "Annual Operating Hours."
Impact Evaluation	An assessment of the program-specific, directly or indirectly induced changes (e.g., changes in energy use and/or demand) associated with an energy efficiency program.
In-Service Rate (ISR)	Some measure types require special attention because ISRs, or installation rates, have been found to be relatively low. For example, the ISR represents the percentage of incented residential lighting products that are ultimately installed by program participants. ISRs vary substantially based on the program delivery mechanism, but they are particularly important in giveaway or upstream programs where the customer is responsible for installation. ISRs should be included in TRM calculations for relevant measure types.
Interactive Effects	Energy effects from an energy efficiency measure that occur outside the measurement boundary of the individual measure. For example, there are interactive effects between lighting and HVAC equipment, since efficient lighting installed in conditioned spaces decreases air conditioning loads, but increases heating loads.
Interactive Effects Factor (IE, IEF, or IF)	The metric used to measure interactive effects. See also "Interactive Effects."
Key Stakeholder Group	The Hawaiʻi TRM development and update process is guided by a group of key stakeholders—Hawaiʻi Energy, the Commission, the EEM, and the EM&V Consultant ("Key Stakeholder Group"). This group oversees and manages the project, comments on work products, and ensures that the TRM meets the needs of the Hawaiʻi stakeholders. The Key Stakeholder Group participates in every aspect of the development of the TRM and the TRM Framework. Group members provide data and technical input, review draft savings calculations, and attend teleconferences to review, comment, and participate in the development of the TRM and TRM Framework.

Lifetime 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 removal, remodeling or demolition. Two important distinctions fall under this definition: Effective Useful Life (EUL) and Remaining Useful Life (RUL). See the "Effective Useful Life" and "Remaining Useful Life" definitions.

Lifetime Savings Savings may vary over the lifetime of a measure. Savings estimate should typically apply throughout the period between measure delivery and the end of the measure lifetime. If the RUL of a pre-conditions measure is expected to be greater than 0 years but less than 25 years (0<RUL<25 years), then two baselines must be used in estimating lifetime savings. The first baseline applies between measure-delivery and when the RUL of the pre-condition expires. The second baseline applies between expiration of the RUL and the end of the measure lifetime. For example, an air compressor might be scheduled for replacement in 3 years, but is replaced sooner with a more efficient model. The lifetime of the efficient air compressor might be 20 years; however, the RUL would be 3. The first baseline applies to years 1 through 3. A second baseline is applied in years 4 through 20.

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

Logic Model A graphical depiction and description of the logical relationships between the inputs, activities, outputs, and outcomes of a program.

Market Effects Changes in the structure of a market or the behavior of participants in a market that is reflective of an increase in the adoption of energy efficient products, services, or practices and is causally related to market intervention(s) (e.g., programs).

Market Penetration A measure of the diffusion of a technology, product, or practice in a defined market, as represented by the percentage of annual sales for a product or practice, the percentage of the existing installed stock for a product or category of products, or the percentage of existing installed stock that uses a practice.

Market Saturation	A percentage indicating the proportion of a specified end-user market that contains a particular product. An example would be the percentage of all households in a given geographical area that have a certain appliance.
Market Transformation Programs	Hawai'i Energy's EE portfolio includes a suite of programs labeled as "Market Transformation." These programs aim to provide strategic interventions in the market in order to create lasting efficiencies and ultimately pave the way for the integration of clean energy solutions.
Measure	A high efficiency technology or procedure that results in energy savings as compared to the baseline efficiency.
Measure Cost	The incremental (for time of sale measures) or full cost (both capital and labor for retrofit measures) of implementing the High Efficiency measure.
Measure Description	A detailed description of the technology or procedure and the criteria it must meet to be eligible as an energy efficient measure.
Measure Level Research	An evaluation process that takes a deeper look into measure level savings achieved through program activities driven by the goal of providing Hawai'i-specific research to facilitate updating measure-specific TRM input values or algorithms.
Net Savings	The difference in energy consumption with the program in place versus what consumption would have been without the program in place. The factors most often considered in net savings calculations are free-ridership, spillover (both participant and nonparticipant), and market effects. (Definition is from Uniform Methods Project.)
Net-to-Gross (NTG) Ratio or NTGR	A ratio of the net impacts to the gross impacts of an energy efficiency measure or program.
Operating Hours	The hours that equipment is expected to operate in a given period of time (e.g., day, month, year).
Peak Demand	The average demand savings that occur from implementation of an energy efficiency measure during the non-holiday, weekday hours between 5 and 9 PM. This aligns with HECO's System Peak Period: 5-9 PM on the average weekday throughout the year, regardless of the season or month.

Persistence Factor (PF)	The metric used to measure Savings Persistence. Range = 0-100%. See also "Savings Persistence" definition.
Persistence Study	A study to assess changes in program impacts over time (including retention and degradation).
Portfolio	Either (a) a collection of similar programs addressing the same market (e.g., a portfolio of residential programs), technology (e.g., motor-efficiency programs), or mechanisms (e.g., loan programs) or (b) the set of all programs conducted by one organization, such as a utility (and which could include programs that cover multiple markets, technologies, etc.).
Potential Studies	Studies conducted to assess market baselines and savings potentials for different technologies and customer markets. Potential is typically defined in terms of technical potential, market potential, and economic potential.
Prescriptive Measures	See "Deemed" measure definitions.
Program	A group of projects, with similar characteristics and installed in similar applications. Examples could include a utility program to install energy-efficient lighting in commercial buildings, a developer's program to build a subdivision of homes that have photovoltaic systems, or a state residential energy efficiency code program.
Program Year (PY)	The time period approved for program implementation. The Hawaiʻi Energy program year runs from July 1st to the following June 30th.
Regression Analysis	Analysis of the relationship between a dependent variable (response variable) to specified independent variables (explanatory variables). The mathematical model of their relationship is the regression equation.
Remaining Useful Life (RUL)	Applies to retrofit or replacement measures. For example, if an existing working refrigerator is replaced with a high efficiency unit, the RUL is an assumption of how many more years the existing unit would have lasted. If the RUL cannot be determined from the age of the measure, the RUL is usually assumed to be 1/3 of the EUL.

Replace on Burnout When a piece of equipment has stopped working and is being replaced, this is referred to as "replace on burnout." The benefits are calculated as the cost of the energy saved by using the efficient measure as compared with the energy that would have been used by an off the shelf (less efficient) "stock" version of the measure.

Retrofit Isolation The savings measurement approach defined in IPMVP Options A and B, as well as ASHRAE Guideline 14, that determines energy or demand savings through the use of meters to isolate the energy flows for the system(s) under consideration. IPMVP Option A involves "Key Parameter Measurement" and IPMVP Option B involves "All Parameter Measurement."

Savings Persistence The percentage of change in expected savings due to changed operating hours, changed process operations, and/or the performance degradation of equipment efficiency relative to the baseline efficiency option. For example, an industrial plant that reduces operation from two shifts to one shift may then have a savings persistence factor of 50%, as only half of the projected energy savings would be realized. Also, improper operation of the equipment may negatively affect savings persistence, so training and commissioning could improve savings persistence. Finally, most equipment efficiency degrades over time, so annual energy savings may increase or decrease relative to the efficiency degradation of the baseline efficiency option. (Definition is from the Uniform Methods Project.)

Spillover Spillover refers to energy savings that are due to the influence of a program but are not counted in program records. Spillover can be broken out in three categories: 1) Participant Internal Spillover; 2) Participant External Spillover; and 3) Non-Participant Spillover.

System Loss Factor (SLF) Energy savings at the customer level are equivalent to even greater savings at the power plant busbar (where the electrons enter the grid) due to energy losses during transmission and distribution. The system loss factor (SLF) is defined as marginal electricity losses from the busbar to the customer meter – expressed as a percent of meter-level savings. Each island in Hawaiʻi has a different SLF due to differences in infrastructure. SLF values are derived using island-level loss data published for HECO, MECO, and HELCO. The customer-level electricity savings are multiplied by (1+SLF) to get the system-level savings, or savings at the power plant busbar.

System Peak Period HECO's current definition of system peak period is 5-9 PM on the average non-holiday weekday throughout the year, regardless of the season or month.

Technical Advisory Group TRM and TRM Framework development is guided by a spirit of collaboration and shared goals. The Technical Advisory Group ("TAG") provides input to this process. The TAG is made up of a broader group of stakeholders, including utilities, the consumer advocate, consultants, and other credible resources.

Technical Reference Manual A resource that contains energy efficiency measure information used in program planning, implementation, tracking, and reporting and evaluation of impacts associated with the subject measures.

Total Resource Benefit (TRB) Total Resource Benefit is the present value of avoided utility costs over the life of the efficiency measures installed through the program. The utilities' total avoided cost of all saved energy and capacity avoided is called the Total Resource Benefit.

Total Resource Cost (TRC) Total Resource Cost is the customer's project or incremental cost to purchase and install the energy-efficient equipment or make operational changes above what would have been done anyway.

TRB-TRC Ratio The societal cost test of the TRB/TRC provides a metric of how much "return on investment" is provided by: (1) Saving energy versus generating it (kWh reductions) and (2) Avoiding the need for increased power plant capacity (Peak kW reductions).

KEY METRICS

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UPDATE STATUS

Updated in Summer 2019 for PY19 TRM. LED Upstream NTG ratio updated in Winter 2020 for the PY19 TRM v2.1.

DEVELOPMENT OF AVOIDED COSTS

Economic benefits to the State of Hawaii from efficiency include the avoided costs associated with the energy that is saved. The value of the energy that is saved is called the Total Resource Benefit (TRB). To estimate the TRB for individual measures, programs or the whole portfolio, future avoided energy costs ($/kWh) and avoided capacity costs ($/kW) need to be estimated.

Proxy Avoided Costs

There are several ways to determine avoided energy and capacity values, with perhaps the best way being an integrated resource planning approach with a capacity expansion model simulating distributed electricity resources competing against conventional generation options. Another approach is to utilize detailed information gathered from historic or projected power purchase agreements. For the results presented here, a less rigorous approach was used in order to determine interim numbers that would only be used for and applicable to Hawaiʻi Energy TRB calculations; and then only until HECO's Integrated Grid Planning (IGP) process is able to provide values that could replace these estimates. Refer to the following memorandum and analysis spreadsheet for details on development of the avoided energy and capacity costs.

- Recommendations for Avoided Costs for the Sole Purpose of Providing Interim Updates for Calculation of Hawaiʻi Energy Program Total Resource Benefits, Memorandum, Prepared for Hawaii Public Utilities Commission, Hawaiian Electric Companies, and Hawaiʻi Energy, Prepared by Steve Schiller, Energy Efficiency Manager and Kelly Parmenter, Applied Energy Group, April 25, 2019.

- PY19-PY21 Avoided Capacity and Energy Cost Calculations, Analysis Spreadsheet, Prepared by Steve Schiller, Energy Efficiency Manager and Kelly Parmenter, Applied Energy Group, April 28, 2019.

Table 1 lists the annualized avoided capacity costs by county for PY19, PY20, and PY21. No firm capacity generation facilities are projected to be added in the 2019-2028 planning horizon for the County of Hawaii, besides the 21.5 MW Honua biomass plant scheduled to begin operation in 2019. Therefore, the EEM and AEG team has assumed the avoided capacity costs for the County of Hawaii are zero ($0/kW-yr) for the purposes of the PY19-PY21 analysis.

Table 1. Annualized Avoided Capacity Costs

County	PY	Value [1]	Unit
Oahu	PY19	198	$/kW-yr 2019$
	PY20	203	$/kW-yr 2020$
	PY21	208	$/kW-yr 2021$
Maui	PY19	580	$/kW-yr 2019$
	PY20	593	$/kW-yr 2020$
	PY21	607	$/kW-yr 2021$
Hawaii	PY19	0	$/kW-yr 2019$
	PY20	0	$/kW-yr 2020$
	PY21	0	$/kW-yr 2021$

[1] Escalation Factor 2.3% /yr, from HECO and MECO 2018 Electric Utility System Cost Data Reports.

Table 1 sources: Annualized values were derived from capacity costs in the following three sources using the methodology described in the PY19-PY21 Avoided Capacity and Energy Cost Calculations, Analysis Spreadsheet, Prepared by Steve Schiller, Energy Efficiency Manager and Kelly Parmenter, Applied Energy Group, April 28, 2019.

1. HECO 2018 Electric Utility System Cost Data Report, submitted to HPUC per Section 6-74-17, June 29, 2018.
2. MECO 2018 Electric Utility System Cost Data Report, submitted to HPUC per Section 6-74-17, June 29, 2018.
3. HELCO 2018 Electric Utility System Cost Data Report, submitted to HPUC per Section 6-74-17, June 29, 2018.

Table 2 lists the avoided energy costs by county for PY19, PY20, and PY21. The costs represent mostly fuel costs and a small share of variable O&M costs.

Table 2. Average Annual Avoided Energy Costs

County	PY	Value [1]	Unit
Oahu	PY19	0.134	$/kWh-yr 2019$
	PY20	0.138	$/kWh-yr 2020$
	PY21	0.142	$/kWh-yr 2021$
Maui	PY19	0.153	$/kWh-yr 2019$
	PY20	0.158	$/kWh-yr 2020$
	PY21	0.163	$/kWh-yr 2021$
Hawaii	PY19	0.148	$/kWh-yr 2019$
	PY20	0.152	$/kWh-yr 2020$
	PY21	0.157	$/kWh-yr 2021$

[1]Escalation Factor 3.0% /yr, from Hawai'i Energy PY18 TRM

Table 2 sources: Average annual avoided energy cost values were derived from Schedule Q monthly values for Oahu, Maui Division, and Hawaii using last 12 months of data available as of 4/9/2019 (https://www.hawaiianelectric.com/documents/billing_and_payment/rates/avoided_energy_cost/avoid_energy_cost_table.pdf). The methodology is described in the PY19-PY21 Avoided Capacity and Energy Cost Calculations, Analysis Spreadsheet, Prepared by Steve Schiller, Energy Efficiency Manager and Kelly Parmenter, Applied Energy Group, April 28, 2019.

TOTAL RESOURCE BENEFIT (TRB)

The Total Resource Benefit (TRB) is the estimated total net present value (NPV) of the avoided cost for the utility from the reduced lifetime demand (kW) and energy (kWh) from energy efficiency projects and measures. **The avoided cost values should be multiplied by net customer-level savings instead of net system-level savings for estimating the TRB. This is because the avoided costs already account for transmission and distribution (T&D) losses.** Per an email from Lisa Giang, HECO, to Steven Schiller dated 12/11/18 “T&D losses are accounted for in the Companies estimates of the net generation required to meet customer demand. The Companies electricity sales forecasts (e.g. kWh) are assumed to be energy consumption at an end user’s site. The T&D losses incurred to supply electricity to our customers are accounted for in the quantity of generation required by utility and independent power producers by adjusting or increasing the sales forecast by an estimated T&D loss factor.”

The time value of money is represented by a discount rate of 6% per the Hawai'i Energy PY18 TRM. The discount rate is used to convert all costs and benefits to a “net present value” for comparing alternative costs and benefits in the same years’ dollars.

The cumulative NPV values can be used in the TRB calculations for measures with a single baseline. For example, the TRB calculation for a measure installed in Oahu in PY19 with a measure life of 8 years and a single baseline period could use the cumulative NPV values of $1,303/kW and $0.970/kWh from Table 3 in the calculation.

However, for measures with a dual baseline, the yearly NPV values must be used since there are two separate savings periods. For example, if the duration of the first baseline period is 2 years, the annual NPV values for Measure Year 1 and Measure Year 2 would be used in the calculations along with the annual impacts associated with that first 2-year baseline period. Then, if the second baseline period is 6 years (for a total measure life of 8 years), the annual values for Measure Years 3 through 8 would be used with the annual impacts associated with the second 6-year baseline period.

Table 3. Total Resource Benefit Calculation for PY19

Discount Rate
6%

		Avoided Capacity Costs Discounted Annual $/kW-yr			Avoided Energy Costs Discounted Annual $/kWh-yr			Avoided Capacity Costs NPV Cumulative from Final Year			Avoided Energy Costs NPV Cumulative from Final Year		
		Oahu	Maui	Hawaii	Oahu	Maui	Hawaii	Oahu	Maui	Hawaii	Oahu	Maui	Hawaii
Year	Measure Year	$/kW-yr	$/kW-yr	$/kW-yr	$/kWh-yr	$/kWh-yr	$/kWh-yr	$/kW	$/kW	$/kW	$/kWh	$/kWh	$/kWh
2019	1	$198	$580	$0	$0.134	$0.153	$0.148	$198	$580	$0	$0.134	$0.153	$0.148
2020	2	$187	$547	$0	$0.130	$0.149	$0.143	$385	$1,127	$0	$0.264	$0.302	$0.291
2021	3	$176	$516	$0	$0.126	$0.145	$0.140	$561	$1,643	$0	$0.391	$0.447	$0.431
2022	4	$166	$487	$0	$0.123	$0.141	$0.136	$727	$2,130	$0	$0.513	$0.588	$0.567
2023	5	$157	$459	$0	$0.119	$0.137	$0.132	$884	$2,590	$0	$0.632	$0.725	$0.699
2024	6	$148	$433	$0	$0.116	$0.133	$0.129	$1,032	$3,023	$0	$0.748	$0.858	$0.828
2025	7	$140	$409	$0	$0.113	$0.129	$0.125	$1,172	$3,432	$0	$0.861	$0.987	$0.953
2026	8	$132	$386	$0	$0.110	$0.125	$0.121	$1,303	$3,818	$0	$0.970	$1.112	$1.074
2027	9	$124	$364	$0	$0.107	$0.122	$0.117	$1,428	$4,182	$0	$1.077	$1.234	$1.191
2028	10	$117	$343	$0	$0.104	$0.118	$0.114	$1,545	$4,525	$0	$1.181	$1.352	$1.305
2029	11	$111	$324	$0	$0.101	$0.115	$0.111	$1,655	$4,849	$0	$1.281	$1.467	$1.416
2030	12	$104	$306	$0	$0.097	$0.112	$0.108	$1,760	$5,154	$0	$1.379	$1.579	$1.524
2031	13	$98	$288	$0	$0.095	$0.108	$0.105	$1,858	$5,443	$0	$1.473	$1.687	$1.629
2032	14	$93	$272	$0	$0.092	$0.105	$0.102	$1,951	$5,715	$0	$1.566	$1.793	$1.731
2033	15	$88	$257	$0	$0.090	$0.103	$0.099	$2,038	$5,971	$0	$1.656	$1.896	$1.830
2034	16	$83	$242	$0	$0.087	$0.100	$0.096	$2,121	$6,213	$0	$1.743	$1.995	$1.927
2035	17	$78	$228	$0	$0.085	$0.097	$0.094	$2,199	$6,441	$0	$1.827	$2.092	$2.020
2036	18	$74	$215	$0	$0.082	$0.094	$0.091	$2,272	$6,657	$0	$1.910	$2.186	$2.111
2037	19	$69	$203	$0	$0.080	$0.091	$0.088	$2,342	$6,860	$0	$1.989	$2.277	$2.199
2038	20	$65	$192	$0	$0.078	$0.089	$0.086	$2,407	$7,052	$0	$2.067	$2.366	$2.285
2039	21	$62	$181	$0	$0.075	$0.086	$0.084	$2,469	$7,233	$0	$2.143	$2.453	$2.369
2040	22	$58	$171	$0	$0.073	$0.084	$0.081	$2,527	$7,403	$0	$2.216	$2.537	$2.450
2041	23	$55	$161	$0	$0.071	$0.082	$0.079	$2,582	$7,564	$0	$2.287	$2.618	$2.529
2042	24	$52	$152	$0	$0.069	$0.079	$0.077	$2,634	$7,716	$0	$2.356	$2.697	$2.606
2043	25	$49	$143	$0	$0.067	$0.077	$0.075	$2,683	$7,859	$0	$2.423	$2.775	$2.680

Table 4. Total Resource Benefit Calculation for PY20 (Reserved for PY20 TRM)

Discount Rate
6%

		Avoided Capacity Costs Discounted Annual $/kW-yr			Avoided Energy Costs Discounted Annual $/kWh-yr			Avoided Capacity Costs NPV Cumulative from Final Year			Avoided Energy Costs NPV Cumulative from Final Year		
		Oahu	Maui	Hawaii	Oahu	Maui	Hawaii	Oahu	Maui	Hawaii	Oahu	Maui	Hawaii
Year	Measure Year	$/kW-yr	$/kW-yr	$/kW-yr	$/kWh-yr	$/kWh-yr	$/kWh-yr	$/kW	$/kW	$/kW	$/kWh	$/kWh	$/kWh
2020	1	$203	$593	$0	$0.138	$0.158	$0.152	$203	$593	$0	$0.138	$0.158	$0.152
2021	2	$192	$559	$0	$0.134	$0.154	$0.148	$395	$1,152	$0	$0.272	$0.312	$0.300
2022	3	$181	$528	$0	$0.130	$0.150	$0.144	$575	$1,680	$0	$0.402	$0.461	$0.444
2023	4	$170	$498	$0	$0.126	$0.145	$0.140	$746	$2,178	$0	$0.528	$0.607	$0.585
2024	5	$161	$470	$0	$0.123	$0.141	$0.136	$906	$2,648	$0	$0.651	$0.748	$0.721
2025	6	$152	$443	$0	$0.120	$0.137	$0.132	$1,058	$3,091	$0	$0.770	$0.884	$0.853
2026	7	$143	$418	$0	$0.116	$0.133	$0.128	$1,201	$3,509	$0	$0.886	$1.017	$0.981
2027	8	$135	$394	$0	$0.113	$0.129	$0.124	$1,336	$3,903	$0	$1.000	$1.146	$1.106
2028	9	$127	$372	$0	$0.110	$0.125	$0.121	$1,464	$4,275	$0	$1.109	$1.271	$1.227
2029	10	$120	$351	$0	$0.107	$0.122	$0.118	$1,584	$4,626	$0	$1.216	$1.393	$1.345
2030	11	$113	$331	$0	$0.103	$0.118	$0.114	$1,697	$4,958	$0	$1.319	$1.512	$1.459
2031	12	$107	$312	$0	$0.101	$0.115	$0.111	$1,804	$5,270	$0	$1.420	$1.626	$1.570
2032	13	$101	$295	$0	$0.098	$0.112	$0.108	$1,905	$5,565	$0	$1.518	$1.738	$1.678
2033	14	$95	$278	$0	$0.095	$0.109	$0.105	$2,000	$5,843	$0	$1.613	$1.847	$1.783
2034	15	$90	$262	$0	$0.092	$0.106	$0.102	$2,090	$6,105	$0	$1.705	$1.953	$1.885

2035	16	$85	$247	$0	$0.090	$0.103	$0.099	$2,175	$6,352	$0	$1.795	$2.055	$1.985
2036	17	$80	$233	$0	$0.087	$0.100	$0.096	$2,254	$6,586	$0	$1.882	$2.155	$2.081
2037	18	$75	$220	$0	$0.085	$0.097	$0.094	$2,330	$6,806	$0	$1.967	$2.252	$2.175
2038	19	$71	$208	$0	$0.082	$0.094	$0.091	$2,401	$7,014	$0	$2.049	$2.346	$2.266
2039	20	$67	$196	$0	$0.080	$0.092	$0.089	$2,468	$7,210	$0	$2.129	$2.438	$2.354
2040	21	$63	$185	$0	$0.078	$0.089	$0.086	$2,531	$7,395	$0	$2.207	$2.527	$2.440
2041	22	$60	$174	$0	$0.075	$0.086	$0.084	$2,591	$7,569	$0	$2.282	$2.613	$2.524
2042	23	$56	$165	$0	$0.073	$0.084	$0.081	$2,647	$7,734	$0	$2.355	$2.697	$2.605
2043	24	$53	$155	$0	$0.071	$0.082	$0.079	$2,701	$7,889	$0	$2.426	$2.779	$2.684
2044	25	$50	$146	$0	$0.069	$0.079	$0.077	$2,751	$8,035	$0	$2.496	$2.858	$2.761

Table 5. Total Resource Benefit Calculation for PY21 (Reserved for PY21 TRM)

Discount Rate
6%

		Avoided Capacity Costs Discounted Annual $/kW-yr			Avoided Energy Costs Discounted Annual $/kWh-yr			Avoided Capacity Costs NPV Cumulative from Final Year			Avoided Energy Costs NPV Cumulative from Final Year		
		Oahu	Maui	Hawaii	Oahu	Maui	Hawaii	Oahu	Maui	Hawaii	Oahu	Maui	Hawaii
Year	Measure Year	$/kW-yr	$/kW-yr	$/kW-yr	$/kWh-yr	$/kWh-yr	$/kWh-yr	$/kW	$/kW	$/kW	$/kWh	$/kWh	$/kWh
2021	1	$208	$607	$0	$0.142	$0.163	$0.157	$208	$607	$0	$0.142	$0.163	$0.157
2022	2	$196	$573	$0	$0.138	$0.158	$0.153	$404	$1,180	$0	$0.280	$0.321	$0.310
2023	3	$185	$540	$0	$0.133	$0.154	$0.149	$589	$1,720	$0	$0.413	$0.475	$0.458
2024	4	$175	$510	$0	$0.130	$0.149	$0.144	$764	$2,230	$0	$0.543	$0.625	$0.603
2025	5	$165	$481	$0	$0.127	$0.145	$0.140	$929	$2,710	$0	$0.670	$0.770	$0.743
2026	6	$155	$454	$0	$0.123	$0.140	$0.136	$1,084	$3,164	$0	$0.793	$0.910	$0.879
2027	7	$147	$428	$0	$0.120	$0.137	$0.132	$1,231	$3,592	$0	$0.913	$1.047	$1.011
2028	8	$138	$404	$0	$0.116	$0.133	$0.128	$1,369	$3,996	$0	$1.030	$1.180	$1.139
2029	9	$131	$381	$0	$0.113	$0.129	$0.125	$1,500	$4,376	$0	$1.143	$1.309	$1.264
2030	10	$123	$359	$0	$0.110	$0.125	$0.121	$1,623	$4,736	$0	$1.252	$1.435	$1.385
2031	11	$116	$339	$0	$0.107	$0.122	$0.118	$1,739	$5,075	$0	$1.359	$1.557	$1.503
2032	12	$110	$320	$0	$0.104	$0.119	$0.114	$1,848	$5,394	$0	$1.463	$1.675	$1.618
2033	13	$103	$302	$0	$0.101	$0.115	$0.111	$1,952	$5,696	$0	$1.563	$1.790	$1.729
2034	14	$98	$285	$0	$0.098	$0.112	$0.108	$2,049	$5,981	$0	$1.661	$1.902	$1.837
2035	15	$92	$268	$0	$0.095	$0.109	$0.105	$2,141	$6,249	$0	$1.756	$2.011	$1.942
2036	16	$87	$253	$0	$0.092	$0.106	$0.102	$2,228	$6,502	$0	$1.849	$2.117	$2.045
2037	17	$82	$239	$0	$0.090	$0.103	$0.099	$2,310	$6,741	$0	$1.938	$2.220	$2.144
2038	18	$77	$225	$0	$0.087	$0.100	$0.097	$2,387	$6,967	$0	$2.026	$2.319	$2.240
2039	19	$73	$213	$0	$0.085	$0.097	$0.094	$2,460	$7,179	$0	$2.110	$2.417	$2.334
2040	20	$69	$201	$0	$0.082	$0.094	$0.091	$2,529	$7,380	$0	$2.193	$2.511	$2.426
2041	21	$65	$189	$0	$0.080	$0.092	$0.089	$2,594	$7,569	$0	$2.273	$2.602	$2.514
2042	22	$61	$179	$0	$0.078	$0.089	$0.086	$2,655	$7,748	$0	$2.350	$2.692	$2.600
2043	23	$58	$168	$0	$0.075	$0.087	$0.084	$2,713	$7,916	$0	$2.426	$2.778	$2.684
2044	24	$54	$159	$0	$0.073	$0.084	$0.081	$2,767	$8,075	$0	$2.499	$2.862	$2.766
2045	25	$51	$150	$0	$0.071	$0.082	$0.079	$2,818	$8,225	$0	$2.570	$2.944	$2.845

GROSS-TO-NET CALCULATIONS

The algorithms shown with each measure calculate gross customer electric savings without counting the effects of line losses from the generator to the customer or free ridership. The formula for converting gross customer-level savings to net generation-level savings are as follows:

$$\text{Net Program kWh} = \text{Gross Customer Level } \Delta\text{kWh} \times (1 + \text{SLF}) \times \text{NTGR}$$

$$\text{Net Program kW} = \text{Gross Customer Level } \Delta\text{kW} \times (1 + \text{SLF}) \times \text{NTGR}$$

Net kWh : kWh energy savings at generation-level, net of free riders and system losses

Net kW : kW savings at generation-level, net of free riders and system losses

Gross Cust. ΔkWh : Gross customer level annual kWh savings for the measure
Gross Cust. ΔkW : Gross customer level connected load kW savings for the measure
SLF : System Loss Factor (see Table 7 in the "System Loss Factor" section below)
NTGR : Net-to-Gross Ratio

Net-to-Gross Ratio (NTGR)
In Fall 2018, AEG reviewed the NTG ratios by updating the benchmarking approach taken by Evergreen Economics during the PY11 evaluation and leveraging NTG data collected by Opinion Dynamics in 2018. The benchmarking analysis resulted in a new NTG ratio of 0.91 for BHTR. More details on the NTG review and update are in the file titled "AEG HPUC NTG Benchmarking Analysis." In Winter 2020, AEG updated the LED Upstream NTG ratio to include market effects.

Table 6. Net-to-Gross Ratios by Program (Reviewed/Updated for PY19 TRM)

Program			**NTGR**	**Revised for PY19**
BEEM	Business Energy Efficiency Measures	All BEEM Measures	0.75	No
CBEEM	Custom Business Energy Efficiency Measures	All CBEEM Measures	0.75	No
BESM	Business Energy Services and Maintenance	All BESM Measures	0.95	No
BHTR	Business Hard-to-Reach	All BHTR Measures	0.91	Yes
REEM	Residential Energy Efficiency Measures	Peer Group Comparison - Quarterly Paper Report	1.00	No
		LED (upstream) [i]	0.575	Yes
		All other REEM Measures	0.79	No
CREEM	Custom Residential Energy Efficiency Measures	All CREEM Measures	0.65	No
RESM	Residential Energy Services and Maintenance	All RESM Measures	0.92	No
RHTR	Residential Hard-to-Reach	All RHTR Measures	1.00	No
Effective Program Total Based on PY19 Portfolio Plan			TBD	TBD

Notes: [i] This value was updated for the PY19 TRM, v2.1 during the mid-year update. See the following memorandum for more information: LED Market Transformation Attribution to Hawai'i Energy, Memorandum, Prepared for Energy Efficiency Manager and Hawaii Public Utilities Commission, Prepared by Applied Energy Group, December 15, 2019.

Sources: 1. AEG's 2018 Analysis File titled "AEG HPUC NTG Benchmarking Analysis."

2. Evaluation of the Hawaiʻi Energy Conservation and Efficiency Programs, Program Year 2011, Evergreen Economics, June 20, 2013, Appendix D: Net-to-Gross Assessment Memo. NTG benchmarking analysis covered four resources: Wisconsin Focus on Energy (2011), CPUC DEER (2006-2007), Massachusetts Energy Efficiency Advisory Council (2010), and NYSERDA (2011-12).

3. Opinion Dynamics, Hawaiʻi Baseline and Net-to-Gross Framework, Memorandum, Submitted to Steve Schiller, June 27, 2018.

4. LED Market Transformation Attribution to Hawai'i Energy, Memorandum, Prepared for Energy Efficiency Manager and Hawaii Public Utilities Commission, Prepared by Applied Energy Group, December 15, 2019.

SYSTEM LOSS FACTOR (SLF)

Energy savings at the customer level are equivalent to even greater savings at the power plant busbar (where the electrons enter the grid) due to energy losses during transmission and distribution. The system loss factor (SLF) is defined as marginal electricity losses from the busbar to the customer meter – expressed as a percent of meter-level savings. Each island in Hawaiʻi has a different SLF due to differences in infrastructure. SLF values are derived using island-level loss data published for HECO, MECO, and HELCO. The customer-level electricity savings are multiplied by (1+SLF) to get the system-level savings, or savings at the power plant busbar.

Table 7 provides the SLF values updated for the PY19 TRM. The values were derived using the following approach:

1. Obtaining data on "Losses and Unaccounted for Energy" from Hawaiian Electric Company's website (https://www.hawaiianelectric.com/about-us/key-performance-metrics/power-supply-and-generation). Note that the published losses include "…amount of energy that is lost as heat or through other means (such as theft) or used by the Company between the point where energy generated at power plants enters the grid to the point of measurement at customer's meters."

2. Calculating average loss factors from the data in Step 1 for each island for the last five years (2014-2018).
3. Adjusting the loss factors in Step 2 to remove losses due to theft and the utility's own electricity consumption in its building and facilities, so that the losses only reflect transmission and distribution losses. An engineering estimate of 0.1% off of each of the values from Step 2 was used for the adjustment.

Table 7. System Loss Factors by Island

System Loss Factors	
Hawaiʻi	6.3%
Lanai	4.3%
Maui	5.0%
Molokai	8.5%
Oahu	4.2%

For more information on the derivation of SLF values for PY19, please refer to the following memo: Recommendations for PY19 System Loss Factors (SLF) for Hawaiʻi Energy Programs Goals and Reporting, Memorandum, Prepared by Steve Schiller, EEM team, Prepared for Ashley Norman and Dave Parsons, HPUC, January 4, 2019.

EFFECTIVE USEFUL LIFE

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UPDATE STATUS

Updated in Fall 2018 for PY19 TRM.

TABLE OF VALUES

Effective Useful Life (EUL) is the median length of time (in years) that an energy efficiency measure is functional. The EUL estimated for each measure is shown in the following table:

Residential Measures				
Program	**Measure Type**	**Description**	**EUL (years)**	**PY19 TRM Review/Update Approach**
REEM	Water Heating	Solar Water Heating	18	AEG 2018 Analysis[1]
		Heat Pumps	15	DEER 2020[2]
	Lighting	LED (See R_Light_LED, Table 2)	Varies	Depends on HOU[3]
		Occupancy Sensor	10	AEG 2018 Analysis
		Linear LED	25	Capped at 25 yr
		LED Security Light	6	Based on HOU
		LED String Lights	5	Engr. Estimate
	HVAC	Ductless Split System	15	AEG 2018 Analysis
		Window AC w/ and w/o recycling	9	DEER 2020
		Ceiling Fans	5	Not updated[4]
		Solar Attic Fans	20	Not updated
		Whole House Fans	20	DEER 2020
		Dehumidifier	12	Not updated
	Appliances	Refrigerator	14	AEG 2018 Analysis
		Freezer	17	AEG 2018 Analysis
		Refrigerator Turn-In (Remaining Useful Life)	8	AEG 2018 Analysis
		Freezer Turn-In (Remaining Useful Life)	7	AEG 2018 Analysis
		Garage Refrigerator/Freezer Bounty	14	Not updated
		Dishwasher	11	DEER 2020
		Clothes Washer (Tier I/II/III)	11	DEER 2020
		Clothes Dryer	14	Not updated
		Television	10	DEER 2020
		Set top box	5	Not updated
		Electronics Soundbar	4	DEER 2020
		Pool VFD Controller Pumps	10	AEG 2018 Analysis
		Advanced Power Strip and Switch Plug	5	DEER 2020
		Air Purifier	9	Not updated
	Control Systems	Room Occupancy Sensors & Timers	8	Not updated
		Peer Group Comparison	1	Not updated
		Whole House Energy Metering	4	Not updated
		Water Cooler Timer	8	Not updated
CREEM	Custom	Efficiency Project Auction	5	Not updated

RESM	Design and Audits	Efficiency Inside	15	Not updated
	Water Heating	Solar Water Heater Tune Up	5	No data found[5]
	HVAC	Central Air Conditioning Retrofit	15	DEER 2020
	HVAC	Central Air Conditioning Tune-Up	3	DEER 2020
RHTR	Hard to Reach Grants	CFL Exchange	6	Not updated
		Refrigerator Turn-In (Remaining Useful Life)	8	AEG 2018 Analysis
		Freezer Turn-In (Remaining Useful Life)	7	AEG 2018 Analysis
	Water Heating	Solar Water Heating	18	AEG 2018 Analysis
	Direct Install	Energy Saving Kits	6	Not updated
		Faucet Aerators	10	AEG 2018 Analysis
		Low Flow Showerheads	10	DEER 2020
		Smart Thermostats	3	DEER 2020

Commercial Measures

Program	Measure Type	Description	EUL (years)	PY19 TRM Review/Update Approach
BEEM	Water Heating	Solar Water Heating - Electric Resistance	18	AEG 2018 Analysis
		Solar Water Heating - Heat Pump	18	AEG 2018 Analysis
		Heat Pump - conversion - Electric Resistance	10	Not updated
		Heat Pump Upgrade	10	Not updated
		Single Family Solar Water Heating	18	AEG 2018 Analysis
	Lighting	General, Baseline (See C_Light_General, Table 6)	Varies	Depends on HOU
		General, Efficient Case (See C_Light_General, Table 7)	Varies	Depends on HOU
		LED Exit Signs	18	Lamp Life/8760
		LED Refrigerator Case Lighting	8	Lamp Life/6205
		LED Street and Parking Lot Fixture	12	Lamp Life/4100
		Occupancy Sensor	8	AEG 2018 Analysis
		Stairwell Bi-Level Dimming Fluorescent	8	AEG 2018 Analysis
	HVAC	Chillers	22	AEG 2018 Analysis
		Chiller Plant Efficiency kW/Ton Meter	20	Not updated
		Garage Active Ventilation Control	8	Not updated
		Package Units	15	DEER 2020
		Window AC	9	DEER 2020
		VFR Split System – New Construction	20	AEG 2018 Analysis
		VFR Split System – Existing	20	AEG 2018 Analysis
		VFD – AHU	15	DEER 2020
		VFD – Chilled Water / Condenser Water	15	AEG 2018 Analysis
	Water Pumping	VFD Dom Water Booster Packages	15	AEG 2018 Analysis
		VFD Pool Pump	10	AEG 2018 Analysis
	Motors	Premium Efficiency Motors	15	DEER 2020
		ECM w/ Controller – evap fan motors	15	Not updated
		ECM – Fan Coil Fans	15	Not updated
	Industrial Process	Kitchen Exhaust Hood Demand Ventilation	15	Not updated
		Refrigerated Case Night Covers	5	DEER 2020

	Building Envelope	Window Film	10	DEER 2020
		Cool Roof	15	DEER 2020
	Business Equipment	ENERGY STAR Refrigerator	14	AEG 2018 Analysis
		Clothes Washer	11	DEER 2020
		Energy Savings Kit	6	Not updated
	Control Systems	Energy Management System (EMS)	15	AEG 2018 Analysis
		Condominium submetering	8	Not updated
		Small Business submetering	8	Not updated
CBEEM	Custom	Custom <= 5 years	5	Not updated
		Custom > 5 years	13	Not updated
		Efficiency Project Auction	10	Not updated
		Re/Retro Commissioning	3	DEER 2020
BESM	Design and Audits	Benchmark Metering	1	Not updated
		Decision Maker - Real time submeters	1	Not updated
		Energy Audit	N/A	Not updated
		Energy Study Implementation - 100%	N/A	Not updated
		Energy Study Assistance - 50%	N/A	Not updated
		Design Assistance - 50%	N/A	Not updated
		Water/Wastewater Catalyst	15	Not updated
BHTR	Direct Install	SBDI - Lighting, Efficient Case (See C_Light_General, Table 7)	Varies	Depends on HOU
		SBDI - Lighting, Pre-Existing Baseline RUL (See C_Light_General, Table 8)	Varies	Depends on HOU; RUL = 1/3 EUL
	Grants	Water cooler timer	5	Not updated
	Restaurant	SBDI - Kitchen Exhaust Hood Demand Ventilation	15	Not updated
		Low flow spray rinse nozzles	5	DEER 2020
		ENERGY STAR Kitchen Equipment	12	Not updated
	Custom	Customized Retrofit	Custom	Not updated
		Anti-Sweat Heater Controls	12	Not updated
		Transformer	Custom[6]	AEG 2018 Analysis

[1] AEG 2018 Analysis:

a) Compared all of the EULs in the Hawaiʻi Energy PY18 TRM's Master EUL list to DEER2020 EUL values.

b) Compared EULs for all applicable measures in the Hawaiʻi Energy PY18 TRM's Master EUL list to EUL analysis conducted by AEG for the residential sector in Fall 2017 and for the commercial sector in Spring 2017. (The previous analysis was performed for two other utility clients, both on the mainland U.S.).

c) For all PY19 priority measures (except lamp replacement), conducted new EUL benchmarking analysis using AEG's DEEM tool (Database of Energy Efficiency Measures) and additional research of TRMs and best practices (see Resources listed below). The EULs for most lamp measures are based on the lamp life and hours of use of the lighting, which varies by building type.

d) For all priority measures, used the median or average value of sources reviewed in Step c as the new PY19 updated EUL. (The median was used in most cases, except for when the average value appeared most representative.)

e) For other non-priority measures for which there was an EUL in DEER2020, used the DEER2020 value as the new PY19 updated EUL.

[2] DEER 2020: EUL was verified/updated to DEER 2020 value.

[3] Depends on HOU: EUL depends on the rated lamp life and HOU for each specific building type.

[4] Not updated: EUL for measure was not updated because it was not listed in DEER2020 and/or was not a priority measure for update.

[5] No data found: This was a priority measure, but no EUL could be found during benchmarking.

[6] Default EUL is 30 years for distribution transformers. Documentation that the transformer is underloaded during average and peak operating conditions and is in good working order is required to justify EUL>30 years.

RESOURCES

- AEG's 2018 Analysis File titled "AEG HPUC EUL Analysis."
- California Public Utilities Commission, Database of Energy Efficiency Resources, 2020 update, (DEER2020), READI v.2.5.0, Ex Ante Database Support Table Export, EUL_basis, created on 8/24/2018, available here: www.deeresources.com/index.php/homepage. Spreadsheet.
- CEE High Efficiency Residential Swimming Pool Initiative, Consortium for Energy Efficiency, Boston, MA, January 2013, page 18. States life of 5-7 years for motor when used year-round per personal communication with Regal Beloit, Aug. 12.
- Connecticut's 2018 Program Savings Document, 13th Edition, filed December 15, 2017. https://www.energizect.com/sites/default/files/2018-PSD-FINAL-121217.pdf.
- ENERGY STAR, Pool Pump Calculator, last updated 2013, accessed Fall 2018, available here: https://www.energystar.gov/products/other/pool_pumps. Spreadsheet.
- Hagerman, Joseph, Department of Energy Building Technologies Program, Presentation: "Circulator Pumps, Appliance Standards and Rulemaking", Federal Advisory Committee (ASRAC) Working Group, Fifth Meeting, July 12-13, 2016. EERE-2016-BT-STD-0004.
- IESO Prescriptive Measures and Assumptions List. Independent Electricity System Operator. January 1, 2015. Document.
- Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 6.0, Volume 3: Residential Measures, FINAL, Feb. 8, 2017.
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- New Mexico Technical Resource Manual for the Calculation of Energy Efficiency Savings, 2016. Section 3.5. p.31. Cites DEER 2008 as source for EUL.
- Northwest Power Conservation Council (NWPCC). Commercial VRF, Version 6 - Seventh Power Plan Conservation Supply Workbooks. February 25, 2016. Spreadsheet.
- Northwest Power Conservation Council (NWPCC). Residential Refrigerator/Freezer, Version 4 - Seventh Power Plan Conservation Supply Workbooks. February 25, 2016. Spreadsheet.

- Northwest Power Conservation Council (NWPCC). Residential Single Family Heat Pump, Version 5 - Seventh Power Plan Conservation Supply Workbooks. February 25, 2016. Spreadsheet
- Pool Pumps Summary - Calmac.org, www.calmac.org/publications/Pool_Pumps_RSW_II_6-15-2015_FINAL.xlsx. Spreadsheet.
- Public Service Company of Colorado. 2017/2018 Demand-Side Management Plan. Colorado Public Utilities Commission. July 1, 2016. Document.
- Regional Technical Forum. Air Source Heat Pump Upgrades SF - Unit Energy Savings Workbook, Version 4.2. Northwest Power and Conservation Council. December 05, 2017. Spreadsheet.
- Regional Technical Forum. Commercial Grocery Display Case Lighting - Unit Energy Savings Workbook, Version 1.1. Northwest Power and Conservation Council. Oct. 1, 2018. Spreadsheet.
- Regional Technical Forum. ComResCirculatorPumps_1_2.xlsm. Northwest Power and Conservation Council. Sep 26, 2017. Spreadsheet.
- Regional Technical Forum. Efficient Pool Pumps - Unit Energy Savings Workbook, Version 2.1. Northwest Power and Conservation Council. February 27, 2018. Spreadsheet.
- Regional Technical Forum. New Manufactured Homes and HVAC - Unit Energy Savings Workbook, Version 3.4. Northwest Power and Conservation Council. June 15, 2017. Spreadsheet.
- Regional Technical Forum. ResFridgeFreezeDecommissioning_v5_1.xlsm. Northwest Power and Conservation Council. January 12, 2018. Spreadsheet. RULs are from 2018 analysis of detailed RUL data in DOE Technical Support Document, REFRIGERATORS, REFRIGERATOR-FREEZERS, AND FREEZERS, November 2009.
- Regional Technical Forum. Residential Refrigerator and Freezers - Unit Energy Savings Workbook, Version 4.3. Northwest Power and Conservation Council. December 5, 2016. Spreadsheet.
- Savings Calculator for ENERGY STAR Appliances, Available at: https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx. Accessed October 16, 2018.
- Southern California Edison. Non-DEER Workpaper - Smart/Connected Refrigerator, SCE17AP009 Version 0. California Public Utilities Commission Database of Energy Efficiency Resources. March 17, 2017. Document.
- Southern California Edison. Non-DEER Workpaper - VFD Retrofit to Central Plant Systems, SCE17HC039 Version 0. California Public Utilities Commission Database of Energy Efficiency Resources. January 01, 2017. Document.
- State of Minnesota, Technical Reference Manual for Energy Conservation Improvement Programs, Version 2.2, May 2, 2018.
- Tennessee Valley Authority Technical Reference Manual, Version 6.0, Oct. 1, 2017.
- U.S. Energy Information Administration. Annual Energy Outlook 2018, National Energy Modeling System (NEMS) Input Files. U.S. Department of Energy. February 6, 2018. Spreadsheet.
- Vermont Energy Investment Corporation. Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 5.0. Illinois Energy Efficiency Stakeholder Advisory Group. February 2016. Document.

SAVINGS FACTORS

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UPDATE STATUS

Updated in Fall 2018 for PY19 TRM.

Measure 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.

For “custom” measures, Hawaiʻi Energy performs site-specific customized calculations. In this case, Hawaiʻi Energy 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).

Hawaiʻi Energy 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 prescriptive and custom measures. That is, if a 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.

Lighting/Cooling Interactive Effects Factors (IE)

The lighting/cooling interactive effects factors for demand ($IE_{C,D}$) and energy ($IE_{C,E}$) were updated for the PY19 TRM. Refer to the AEG analysis file titled "AEG HPUC Update of Com-Lighting Measures - Analysis file" for more information.

Table 1: Lighting/Cooling Load Interactive Effects Factors by Building Type, $IE_{C,D}$ and $IE_{C,E}$

Building Type	Omni-Directional, Directional, and Decorative		High Bay, Linear, U-Bend, Troffer	
	$IE_{C,D}$	$IE_{C,E}$	$IE_{C,D}$	$IE_{C,E}$
Misc./Avg. Commercial	1.25	1.13	1.26	1.13
Cold Storage	1.26	1.56	1.25	1.62
Education	1.30	1.25	1.31	1.25
Grocery	1.11	1.14	1.09	1.14
Health	1.23	1.14	1.24	1.15
Hotel/Motel	1.27	1.38	1.27	1.36
Industrial	1.19	1.12	1.20	1.13
Office	1.08	1.25	1.07	1.26
Restaurant	1.22	1.28	1.24	1.28
Retail	1.39	1.14	1.36	1.15
Warehouse	1.15	1.01	1.16	1.01

Notes:

a. The IE values were derived using a four step process:

1) Tabulation of DEER's IE factors for San Diego (IECC CZ 3B);

2) Tabulation of IE factors from LBNL 1994 study for IECC CZ 3B and IECC CZ 1A;

3) Mapping of DEER and LBNL building types to Hawaiʻi Energy's building types listed above;

4) Adjustment of the DEER IE factors for CZ 3B using ratio of LBNL factors for CZ 1A and CZ 3B to determine IE factors for Hawaiʻi (CZ 1A). The equation is:
$IE_{Hawaii} = IE_{DEER,\ 3B} * (IE_{LBNL,1A} / IE_{LBNL,3B})$.

b. Assume no interactive effects for exit signs due to lack of representative data.

Persistence Factor (PF)

Persistence factors may be used to reduce lifetime measure savings in recognition that initial engineering estimates of annual savings may not persist long term due to changed operating hours, changed process operations, and/or the performance degradation of equipment efficiency relative to the baseline efficiency option.

Many of the measure algorithms contain 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 the first year savings, lifetime savings, and total resource benefits.

EQUIPMENT OPERATING HOURS AND COINCIDENCE FACTORS

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UPDATE STATUS

Updated in Fall 2018 for PY19 TRM.

General Commercial Lighting Hours of Use (HOU) & Coincidence Factor (CF)

The lighting hours of use and coincidence factors were updated for the PY19 TRM. Refer to these AEG analysis files for more information: "AEG HPUC Update of Com-Lighting Measures - Analysis file" and "AEG HPUC EFLH and CF Analysis - Non-Holiday Weekdays."

Table 1a. General Commercial Lighting: Annual Hours of Use

Building Type	Exit Sign	Omni-Directional, Directional, and Decorative	High Bay	Linear, U-Tube, Troffer
Misc./Avg. Commercial	8,760	1,831	3,047	1,963
Cold Storage	8,760	4,710	4,820	4,700
Education	8,760	1,498	2,176	1,702
Grocery	8,760	4,900	5,450	4,770
Health	8,760	5,370	5,870	5,100
Hotel/Motel	8,760	1,284	4,775	1,130
Industrial	8,760	2,145	2,860	2,305
Office	8,760	1,780	2,480	1,980
Restaurant	8,760	3,700	3,610	3,500
Retail	8,760	2,363	3,983	3,690
Warehouse	8,760	1,690	2,245	1,970

Source: DEER2020 hours of use for San Diego IOU; no occupancy sensor. HOU were originally developed for DEER2016.

Table 1b. General Commercial Lighting: Coincidence Factors

Building Type	Exit Sign	Omni-Directional, Directional, and Decorative	High Bay	Linear, U-Bend, Troffer
Misc./Avg. Commercial	1.00	0.31	0.53	0.34
Cold Storage	1.00	0.20	0.20	0.20
Education	1.00	0.28	0.40	0.32
Grocery	1.00	0.70	0.78	0.68
Health	1.00	0.66	0.72	0.63
Hotel/Motel	1.00	0.26	0.96	0.23
Industrial	1.00	0.53	0.58	0.59

Office	1.00	0.22	0.31	0.25
Restaurant	1.00	0.52	0.50	0.49
Retail	1.00	0.32	0.54	0.50
Warehouse	1.00	0.07	0.10	0.08

Notes:

a. The CF values were derived using a three step process:

1) AEG analysis of DOE's OpenEI general lighting load shapes simulated with Hawaiʻi-specific prototypes, weather data, and peak demand period to determine i) unadjusted CF values for general lighting during Hawaiʻi's peak demand period of 5-9 pm on non-holiday weekdays, and ii) unadjusted EFLH values for general lighting (= annual lighting energy use in kWh divided by maximum lighting demand in kW).

2) Mapping of OpenEI's and DEER's building types to Hawaiʻi Energy's building types listed above;

3) Adjustment of the OpenEI CF values to specific lighting types (bulbs, highbay, linear lamps) using DEER's annual HOUs for San Diego. The adjustment equation is $CF_{OpenEI}*(HOU_{SD}/EFLH_{OpenEI})$.

b. San Diego is a good proxy for Hawaiʻi for lighting usage. The OpenEI prototypes yield the same energy, demand, EFLH, and CF factors for San Diego, Honolulu, Kahului, and Keahole-Kona weather stations. (Therefore, the same results are applicable to all Hawaiian counties.)

General Commercial Cooling Equivalent Full Load Hours (EFLH) and Coincident Factor (CF)

The general cooling equivalent full load hours and coincidence factors were updated for the PY19 TRM. Refer to these AEG analysis files for more information: "AEG HPUC Update of Commercial Chillers - Analysis File" and "AEG HPUC EFLH and CF Analysis - Non-Holiday Weekdays."

Table 2. General Commercial Cooling: Equivalent Full Load Hours & Coincidence Factors

Building Type	EFLH	CF
Misc./Avg. Commercial	2,594	0.38
Cold Storage	Varies	Varies
Education	2,549	0.43
Grocery	1,531	0.27
Health	4,891	0.55
Hotel/Motel	4,910	0.60
Industrial	Varies	Varies
Office	2,754	0.48
Restaurant	2,451	0.40
Retail	1,913	0.29
Warehouse	1,033	0.01

Use custom approach for entries noted as "Varies."

Source: AEG's analysis of DOE's OpenEI load shapes using Hawaiʻi-specific prototypes, weather data, and peak demand period.

Commercial Water Heating Equivalent Full Load Hours (EFLH) and Coincident Factor (CF)

The commercial water heating equivalent full load hours and coincidence factors were updated for the PY19 TRM. Refer to these AEG analysis files for more information: "AEG HPUC Update of Com-Solar Water Heater - Analysis file" and "AEG HPUC EFLH and CF Analysis - Non-Holiday Weekdays."

Table 4. General Commercial Water Heating: Equivalent Full Load Hours & Coincidence Factors

Building Type	EFLH	CF
Misc./Avg. Commercial	2,322	0.29
Cold Storage	Varies	Varies
Education	1,916	0.25
Grocery	4,406	0.60
Health	2,247	0.20
Hotel/Motel	3,008	0.35
Industrial	Varies	Varies
Office	2,632	0.30
Restaurant	3,947	0.74
Retail	Varies	Varies
Warehouse	Varies	Varies

Use custom approach for entries noted as "Varies."

Source: AEG's analysis of DOE's OpenEI load shapes using Hawaiʻi-specific prototypes, weather data, and peak demand period.

Custom Measures

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OVERVIEW

In addition to prescriptive energy conservation measures that are defined within this Technical Reference Manual, there are projects that are handled on a case-by-case basis through our custom incentive program. Custom projects may be complex projects with multiple components, first-of-their-kind projects, or special projects that are unique to a particular customer. A few examples of custom incentive projects from past years include:

- A new packaging machine for a water bottling facility.
- A condominium submetering installation with submetering on electrical consumption as well as chilled water usage at the individual condo level.
- A whole-building retro-commissioning project with “pre” and “post” metering.

In PY17, Hawaiʻi Energy moved some formerly prescriptive projects to the custom category, mainly for the reason that these projects occur infrequently. These include Transformers, Residential New Construction, and Heat Pump Water Heater-to-Heat Pump Water Heater upgrades. Below is a list and description of a selection of custom measures. Due to the nature of our custom program, this list is not intended to be comprehensive.

COMMERCIAL: Distribution Transformers

UPDATE STATUS

Updated in Fall 2018 for PY19 TRM.

MEASURE DETAILS

Description

The replacement of an existing transformer with a higher efficiency unit.

Program Criteria

Transformer projects must meet the eligibility criteria below:

- Replacement unit must exceed DOE2016 energy efficiency standard. (See 10 CFR 431.196 "Energy conservation standards and their effective dates" for DOE efficiency standards effective Jan. 1, 2016.)
- Single-phase and three-phase low-voltage distribution transformers in commercial building applications.
- Except for the case of new construction, the new transformer must serve the same load as the pre-existing transformer.

Unit of Measure

One transformer

Baseline Equipment

A dual baseline approach should be used for transformer projects that qualify for early retirement. The first baseline is the pre-existing transformer. The second baseline is a transformer that meets current federal codes and standards (DOE2016). Early retirement consideration and eligibility should be defined for custom transformer projects as follows:

1) The pre-existing transformer is functioning with remaining useful life of > 0 years (based on the EUL), and

2) The vintage (and therefore RUL) of the pre-existing transformer can be ascertained and is well-documented.

In cases where the loading on the pre-existing transformer is unknown for a given project, an EUL of 30 years should be used when determining eligibility for early retirement. The EUL of 30 years is consistent with the average EUL found in a literature review of other TRMs and distribution transformer guidance documents. In addition, the energy and demand savings should be calculated for no-load conditions.

In cases where the average and peak loading conditions are known and well documented for a given project, the EUL will be dependent on the loading characteristics and condition of the pre-existing transformer. Data from the literature may be used to estimate the EUL as a function of loading, with a not-to-exceed EUL of 50 years. Energy and demand savings should be calculated using the project-specific loading conditions.

A single baseline approach should be applied in the following cases:

1) The age of the transformer exceeds the EUL,
2) The transformer is no longer functioning, or
3) It is a new construction project.

If the new transformer will serve a load that is greater than 10% higher than the load served by the pre-existing transformer, treat as New Construction.

High Efficiency Equipment

High efficiency transformer that exceeds current federal codes and standards (DOE2016).

RESOURCES

- Title 10: Energy, PART 431—ENERGY EFFICIENCY PROGRAM FOR CERTAIN COMMERCIAL AND INDUSTRIAL EQUIPMENT, Subpart K—Distribution Transformers, §431.196 Energy conservation standards and their effective dates, Electronic Code of Federal Regulations, U.S. Government Publishing Office.
- Transformer Replacement Program, Low-Voltage Dry-Type 25-300 KVA Transformers, Implementation Manual, Version 2, National Grid, January 24, 2018.
- Michigan Energy Measure Database, 2018 MEMD Master Database, https://www.michigan.gov/mpsc/0,4639,7-159-52495_55129---,00.html. Spreadsheet.
- State of Minnesota, Technical Reference Manual for Energy Conservation Improvement Programs, Version 2.2, May 2, 2018.

- Northwest Power Conservation Council (NWPCC), Commercial Data Centers, Version 6 - Seventh Power Plan Conservation Supply Workbooks, February 25, 2016. Spreadsheet.
  Northwest Power Conservation Council (NWPCC), Industrial Tool, Version 9 - Seventh Power Plan Conservation Supply Workbooks, February 25, 2016. Spreadsheet.
- Tennessee Valley Authority Technical Resource Manual, Version 4.0, Prepared by DNV KEMA, October 2015. (Measure is discontinued in Version 5.0, 2016 and Version 6.0, 2017.)
- Connecticut Program Savings Document, 11th Edition for 2016 Program Year, October 1, 2015. (Measure is discontinued in 12th Edition for 2017 Program Year and 13th Edition for 2018 Program Year.)
- Determination Analysis of Energy Conservation Standards for Distribution Transformers, ORNL-6847, Oak Ridge National Laboratory, Oak Ridge, TN, 1996, https://www.osti.gov/servlets/purl/405744.

OTHER EXAMPLES OF CUSTOM MEASURES

Residential New Construction

Hawaiʻi Energy has moved the Residential New Construction incentive from previous TRM versions to a custom incentive due to the complex and unique nature of these projects. Residential homes vary in size, orientation, construction, and equipment and therefore require a customized approach when estimating energy savings. Residential New Construction projects may include a subset of prescriptive measures, such as ENERGY STAR appliances, which may still be rebated on a prescriptive basis.

Commercial Heat Pump Water Heater Upgrade

Commercial heat pump water heater projects will be handled on a custom basis. The amount of energy needed to generate sufficient hot water for various business facilities fluctuates due to many contributing factors. Each business type operates differently, thus creating the challenge of defining certain variables within the savings algorithms to represent all business types. Factors such as occupancy, efficiency, water heater size, hot water demand, temperature settings, and location are examples that require custom inputs to accurately estimate energy savings. Commercial heat pump water heater to heat pump water heaters retrofits are eligible for incentives on the grounds that the current building code allows for installation of standard electric resistance water heaters (SERWH) in this application. Therefore SERWH may be treated as the baseline efficiency for this type of project. Commercial heat pump water heater projects are infrequent and may be evaluated on a case-by-case basis.

Chillers (Updated for PY19 TRM)

As a guideline, the following chiller retrofits should be evaluated as custom projects: water-cooled chillers larger than or equal to 600 tons, air-cooled chillers larger than or equal to 300 tons, and any chiller part of a larger, multi-system plant. Projects that are part of a larger project with a variety of efficiency measures being installed simultaneously, or other unique projects, would be a candidate for custom evaluation, at the discretion of Hawaiʻi Energy. This threshold was set for the following reasons:

- Larger chiller projects are usually quite complex, and may involve other system changes, such as controls upgrades, pump modifications, VFD upgrades and more. Calculating savings on a prescriptive or even semi-prescriptive basis of tonnage and nameplate efficiency only would be inadequate in most cases for larger chiller projects.
- Hawaiʻi Energy acknowledges that performing true custom savings calculations is more time, cost, and labor-intensive, due to the additional requirements for pre and post metering. These barriers may actually inhibit the feasibility of a project to move forward, and therefore Hawaiʻi Energy would limit the number of custom projects per year.
- Hawaiʻi Energy opted for a cut-off tonnage that aligns with the tonnage break points in IECC code for chiller efficiency, i.e. 300/600 tons.

Ductless Systems (New for PY19 TRM)
As a guideline, commercial VRF retrofits for systems with capacities greater than 240,000 Btu/h should be evaluated as custom projects. Projects that are part of a larger project with a variety of efficiency measures being installed simultaneously, or other unique projects, would be a candidate for custom evaluation, at the discretion of Hawaiʻi Energy. This threshold was chosen based on capacity break points in ASHRAE and IECC code for air-cooled AC and heat pump efficiencies; evaluating a VRF system on a prescriptive or even semi-prescriptive basis would be inadequate for most larger projects at this capacity.

VFD
As a guideline, Hawaiʻi Energy has established an upper threshold of 200 horsepower for prescriptive rebates on variable frequency drives. This value was chosen after a literature review. The NEEP VSD Load shape Project (2014) determined a savings metric for prescriptive energy and demand savings for VSDs on various applications for motors up to 200 hp. In addition, the NREL Chapter 18 VFD Evaluation Protocol (2017) recommended this method for prescriptive evaluation. The NREL Chapter stated that a customized evaluation "is more common for facilities that are applying incentives for a variety of measures in a building." VFD projects that are part of a larger project with a variety of efficiency measures being installed simultaneously would be a candidate for Custom evaluation, at the discretion of Hawaiʻi Energy.

Commercial Kitchen Dishwashers
Commercial kitchen dishwashers was added as a new custom measure in PY18, with the intention to convert this measure to a prescriptive measure in a subsequent year. Energy and demand savings will be calculated on a case-by-base basis using the Fishnick Dishwasher Life Cycle Cost Calculator.

Advanced Residential Intelligent Efficiency Services (ARIES)
ARIES is an opt-in deployment of emerging technology and program services designed to provide significant enhancements over historical approaches with improved:

- Savings impact, measurement methods, and understanding of savings sources
- Customer interest, engagement, satisfaction, trust and overall value
- Cost structure and future curve for long term persistence and cost-effectiveness

The source of savings can be considered as coming from the following 4 categories of home energy impact areas, in rough order of estimated impact and cost/complexity:

- “Always On” – We estimate the average “baseline” power draw in homes to be ~250 Watts, whereas many homes have far lower continuous draws of 100W or less. Eliminating 50 Watts of always on would amount to 6% household savings. ARIES will prioritize engaging customers to target this opportunity through gamified feedback.
- “Adjustments & Maintenance” – Changing setting and schedules, or habits associated with devices like electronics and appliances. The savings potential in this category is higher for large electric uses like heat pumps, water and space heaters, etc. Depending upon customer context, could represent additional 5% savings or more. ARIES will assess customer-specific savings potential and act accordingly with informational interventions.
- “Eliminate” – Many households accumulate energy-using products or equipment over time that they may not need. ARIES will help enhance customers’ visibility and awareness of vestigial device usage and encourage them to consider whether customers have an opportunities to reduce their energy clutter.
- “Upgrade” – Akin to conventional program activity, ARIES customers might replace existing devices with new ones that have a different energy impact. Out of program equipment changes can be tracked to better understand savings lifetimes, and in-program actions allow for double-counting adjustments.

The nature and high quality of energy information and customer insights developed by ARIES affords a significant opportunity to advance other opportunities that may serve other energy system stakeholders to support public interest.

COMMERCIAL: Refrigerator

Return to TOC

MEASURE DETAILS

Description

ENERGY STAR certified refrigerator as specified below replacing a non-ENERGY STAR refrigerator and turning in the existing refrigerator to be recycled. Also, turn-in only refrigerators rebate available.
The PY15 residential refrigerator measure was duplicated for this commercial refrigerator measure.

Program Criteria

Appliance must comply with ENERGY STAR. ENERGY STAR refrigerators utilize improvements in insulation and compressors.

Unit of Measure

One refrigerator

Baseline Equipment

Baseline energy usage based on 2009 ENERGY STAR Information for the appliances are as follows:

	Demand Baseline (kW)	Energy Baseline (kWh)	Notes
Non ES Qualifying Refrigerator	---	540	19.0 - 21.4 Top Freezer

High Efficiency Equipment

	Demand Baseline (kW)	Energy Baseline (kWh)	Notes
ES Qualifying Refrigerator	---	435	19.0 - 21.4 Top Freezer

ALGORITHMS

$$\Delta E_{.replace} = E_{.base} - E_{.he}$$

$$\Delta E_{.replace\&turn\text{-}in} = E_{.base} - E_{.he} + 717$$

$$\Delta P_{.replace} = (E_{.base} - E_{.he}) / HRS$$

$$\Delta P_{.replace\&turn\text{-}in} = (E_{.base} - E_{.he} + 717) / HRS$$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
$E_{.base}$	Energy usage of the baseline equipment	540	kWh	
$E_{.he}$	Energy usage of the higher efficiency equipment	435	kWh	

ΔE	Energy reduction	Calculated	kWh	
ΔP	Power demand reduction	Calculated	kWh	
CF	Coincidence factor, percent of time equipment load corresponds with utility peak load	100	%	
PF	Persistence factor, % of measures installed and operating	100	%	
HRS	Equivalent full load hours, or hours of lighting for business operation	8760	hrs	
DC	Duty cycle, how often compressor is active	70	%	Hawai'i Energy metered data
Measure Life	Expected duration of energy savings	14	yrs	

SAVINGS

		Energy Use		Reference
New Non-ENERGY STAR Refrigerator		540.00		Table 4.1.1.f
New ENERGY STAR Refrigerator	-	435.00		Table 4.1.1.f
		105.00	kWh/yr	Table 4.1.1.e

#1 - Purchase of ENERGY STAR Refrigerator		105.00		Table 4.1.1.e
#2 - Removal of old unit from service (off the grid)	+	717.00		Table 4.1.1.e
#1+#2 = Purchase ES and recycle old unit		822.00	kWh/yr	

	Energy Use	Ratio		Contribution		
Post-1993 Refrigerator	640	55.4%		354.54		Table 4.1.1.g
Pre-1993 Refrigerator	1131	44.6%	+	504.46		Table 4.1.1.g
				859.00	kWh/yr	

Energy Savings Opportunities for Program Sponsors

Opportunity	Annual Savings			
	Per Unit		Aggregate U.S. Potential	
	kWh	$	MWh	$ million
1. Increase the number of buyers that purchase ENERGY STAR qualified refrigerators. • 9.3 million units were sold in 2008. • 70 percent were not ENERGY STAR. • 6.5 million potential units per year could be upgraded.	105	11.64	675,928	75
2. Decrease the number of units kept on the grid when new units are purchased. • 8.7 million primary units were replaced in 2008. • 44 percent remained in use, whether	717	79.53	2,746,062	305

they were converted to second units, sold, or given away. • 3.8 million units are candidates for retirement every year.				
3. Decrease the number of second units. • 26 percent of households had a second refrigerator in 2008. • 29.6 million units are candidates for retirement.	859	95.28	25,442,156	2,822
4. Replace pre-1993 units with new ENERGY STAR qualified models. • 19 percent of all units in use in 2008 were manufactured before 1993. • 27.3 million total potential units are candidates for targeted replacement.	730	81	19,946,440	2,212

Sources: See endnote 10.

Energy and Cost Comparison for Upgrading to ENERGY STAR

Purchase Decision	New Non-ENERGY STAR Qualified Refrigerator	New ENERGY STAR Qualified Refrigerator
Annual Consumption	540 kWh	435 kWh
	$60	$48
Annual Savings	–	105 kWh
	–	$12
Average Lifetime	12 years	12 years
Lifetime Savings	–	1,260 kWh
	–	$140
Price Premium	–	$30 - $100
Simple Payback Period	–	3-9 years

Note: Calculations based on shipment-weighted average annual energy consumption of 2008 models. An ENERGY STAR qualified model uses 20 percent less energy than a new non-qualified refrigerator of the same size and configuration.

Source: See endnote 10.

Energy and Cost Comparison for Removing a Second Refrigerator from the Grid

Fate of Unit	Post-1993 Unit		Pre-1993 Unit	
	Remains on the Grid	Removed from the Grid	Remains on the Grid	Removed from the Grid
Annual Consumption	640 kWh	–	1,131 kWh	–
	$71	–	$125	–
Annual Savings	–	640 kWh	–	1,131 kWh

Annual Savings	–	$71	–	$125
Average Lifetime*	6	–	6	–
Lifetime Savings*	–	3,840 kWh	–	6,788 kWh
	–	$426	–	$753
Removal Cost	–	$50 - $100	–	$50 - $100
Simple Payback Period	–	1-2 years	–	<1 year

***Assumes unit has six years of functionality remaining.**

Sources: See endnote 10.

Measure Name	Peak Demand Savings	Annual Energy Savings
ES Refrigerator	0.017 kW	105.00 kWh
ES Refrigerator w/ Turn-in	0.140 kW	859.00 kWh
Turn-in Only	0.134 kW	822.00 kWh

COMMERCIAL: Cool Roof

Return to TOC

MEASURE DETAILS

Description

This section covers installation of “cool roof” roofing materials in commercial buildings with mechanical cooling. The cool roof is assumed to have a solar absorptance of 0.3(1) compared to a standard roof with solar absorptance of 0.8(2). Energy and demand saving are realized through reductions in the building cooling loads. The approach utilizes DOE-2.2 simulations on a series of commercial prototypical building models. Energy and demand impacts are normalized per thousand square feet of roof space.

Program Criteria

Building must have a means of mechanical cooling and cool roof must meet solar absorptance criteria.

Unit of Measure

Per 1000 square feet of material

Baseline Equipment

Roof with a solar absorptance of 0.80

High Efficiency Equipment

Roof with a solar absorptance of 0.30

ALGORITHMS

ΔE = 250 kWh per 1000-SF

$\Delta P = CF * (0.0001 / SF)$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
ΔE	Annual energy reduction per ft^2	Calculated	kWh	250 kWh per 1000 SF
ΔP	Peak power demand reduction per ft^2	Calculated	kW	0.100 kW per 1000 SF
CF	Coincidence factor, percent of time equipment load corresponds with utility peak load	50	%	
Measure Life	Expected duration of energy savings	15	yrs	

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings
Cool Roof	0.05	250

COMMERCIAL: Window Film

Return to TOC

MEASURE DETAILS

Description

Window film reduces solar heat gain, reducing load on cooling systems.

Program Criteria

• Film must have a minimum five-year manufacturer's warranty and one-year installer's warranty.
• Rebates shall be paid on actual square footage of glass in a conditioned space.
• Windows may be clear or factory tinted, single or double pane, but must not have reflected glass.
• Windows significantly shaded by buildings, trees or awnings are not eligible for rebates.
• Replacement of deteriorated window film is eligible for 50% of the rebate if the customer did not receive a rebate for the existing film.

Unit of Measure

One square foot (SF) of window area

Baseline Equipment

No window tinting/film installed.

High Efficiency Equipment

• Shading Coefficient < 0.5
• Solar Heat Gain Coefficient (SHGC) < 0.435
• SC = 0.87*SHGC

ALGORITHMS

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
ΔP	Peak power demand reduction per ft^2	Calculated	kW	
ΔE	Annual energy reduction per ft^2	Calculated	kWh	
PF	Persistance Factor	100	%	
CF	Coincidence factor, percent of time	100	%	
Measure Life	Expected duration of energy savings	10	yrs	

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings
Hotel	0.001 kW/sq.ft.	5.60 kWh/sq.ft.

Office	0.001 kW/sq.ft.	4.50 kWh/sq.ft.
Other	0.002 kW/sq.ft.	4.50 kWh/sq.ft.
Average	0.001 kW/sq.ft.	4.87 kWh/sq.ft.

COMMERCIAL: Combination Oven

Return to TOC

MEASURE DETAILS

Description

Commercial combination ovens offer the ability to steam food in the oven cavity. These oven are capable of steaming, proofing and reheating various food products in addition to the normal functions of baking and roasting. Foods can be cooked in a variety of ways: in a convection oven dry heat only mode, a steam only mode, and a combination of dry heat and steam modes. Food to be cooked partially in one mode at a certain temperature and then finished in another mode and at a separate temperature by utilizing the programmability of combination ovens. Combination ovens range in size from 6 pan countertop models up to 40 pan stand-alone models.

Program Criteria

Program follows ENERGY STAR guidelines, unless specified otherwise.

Unit of Measure

One oven

Baseline Equipment

See tables below.

High Efficiency Equipment

See tables below.

ALGORITHMS

$$\Delta E_{.annual} = E_{.total,base} - E_{.total,ee}$$

$$E_{.total} = E_{.cook} + E_{.steam} + E_{.preheat}$$

$$E_{.cook} = [(LBS_{.day} * DAYS * ETF_{.cook}) / \eta_{.cook}] + [\%_{.cook} * P_{.cook,idle} * HRS_{.cook,idle} * DAYS]$$

$$E_{.steam} = [(LBS_{.day} * DAYS * ETF_{.steam}) / \eta_{.steam}] + [\%_{.steam} * P_{.steam,idle} * HRS_{.steam,idle} * DAYS]$$

$$E_{.preheat} = \#_{.preheat} * E_{.preheat} * DAYS$$

$$HRS_{.idle} = HRS_{.day} - (LBS_{.day} / CAP_{.cook|steam}) - (\#_{.preheat} * T_{.preheat})$$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
$\eta_{.cook}$	Efficiency of cooking mode	Table	-	
$\eta_{.steam}$	Efficiency of steaming mode	Table	-	
$ETF_{.cook}$	Energy needed to cook 1lb of food	0.0732	kWh/lb	
$ETF_{.steam}$	Energy needed to steam 1lb of food	0.0308	kWh/lb	
$P_{.cook,idle}$	Idle power draw of cooking mode	Table	kWh	
$P_{.steam,idle}$	Idle power draw of steaming mode	Table	kWh	
$HRS_{.cook,idle}$	Idle time in cooking mode	Calculated	hrs	

$HRS_{.steam,idle}$	Idle time in steaming mode	Calculated	hrs	
$E_{.preheat}$	Preheating energy usage	Table	kWh	
$\#_{.preheat}$	Number of preheating cycles	1	-	
$T_{.preheat}$	Duration of preheating	0.25	hrs	
$\%_{.cook}$	Percentage of time in cooking mode	0.5	-	
$\%_{.steam}$	Percentage of time in steaming mode	0.5	-	
$CAP_{.cook}$	Production capacity of cooking mode	Table	lbs/hr	
$CAP_{.steam}$	Production capacity of steaming mode	Table	lbs/hr	
$LBS_{.day}$	Pounds of food to be processed in a day	Table	lbs/day	
$HRS_{.day}$	Hours of equipment operation per day	12	hrs/day	
DAYS	Annual days of equipment operation	365	days	
CF	Coincidence factor, portion of time equipment load corresponds with utility peak load	0.84	-	
Measure Life	Expected duration of energy savings	12	yrs	

ALL	η_cook	η_steam
Base	0.65	0.40
Efficient	0.70	0.50

< 15 Pans	E_cook,idle	E_steam,idle	E_preheat	CAP_cook	CAP_steam	LBS_day
Base	1.50	10.00	3.00	80	100	200
Efficient	1.00	5.00	1.50	100	120	

15 - 28 Pans	E_cook,idle	E_steam,idle	E_preheat	CAP_cook	CAP_steam	LBS_day
Base	3.75	12.50	3.75	100	150	250
Efficient	2.50	6.00	2.00	152	200	

> 28 Pans	E_cook,idle	E_steam,idle	E_preheat	CAP_cook	CAP_steam	LBS_day
Base	5.25	18.00	5.63	275	350	400
Efficient	4.00	9.00	3.00	325	400	

SAVINGS

< 15 Pans		Cooking kWh	Idle kWh	Subtotal	Preheat kWh	Annual Usage
Base	Convection	8220.92	2532.19	10753.11	1095.00	35262.86 kWh
	Steam	5621.00	17793.75	23414.75		
Efficient	Convection	7633.71	1779.38	9413.09	547.50	23658.43 kWh
	Steam	4496.80	9201.04	13697.84		

15 - 28 Pans		Cooking kWh	Idle kWh	Subtotal	Preheat kWh	Annual Usage
Base	Convection	10276.15	6330.47	16606.62	1368.75	48004.23 kWh
	Steam	7026.25	23002.60	30028.85		
Efficient	Convection	9542.14	4610.53	14152.67	730.00	32001.17 kWh
	Steam	5621.00	11497.50	17118.50		

> 28 Pans		Cooking kWh	Idle kWh	Subtotal	Preheat kWh	Annual Usage
Base	Convection	16441.85	9864.33	26306.18	2054.95	74447.59 kWh
	Steam	11242.00	34844.46	46086.46		
Efficient	Convection	15267.43	7679.04	22946.47	1095.00	50691.94 kWh
	Steam	8993.60	17656.88	26650.48		

Equipment Size	**Peak Demand Savings**	**Annual Energy Savings**
< 15 Pans	2.226 kW	11,604.43 kWh
15 - 28 Pans	3.069 kW	16,003.06 kWh
> 28 Pans	4.556 kW	23,755.65 kWh

COMMERCIAL: Convection Oven

Return to TOC

MEASURE DETAILS

Description

Commercial convection ovens are widely used in the foodservice industry and have a wide variety of uses from baking and roasting to warming and reheating. Convection ovens are also used for nearly all types of food preparation, including foods typically prepared using other types of appliances (e.g., griddles, fryers, etc.). ENERGY STAR commercial ovens are about 20 percent more energy efficient than standard models.

Program Criteria

• Full-size electric convection ovens are defined by the ability to accept a minimum of five (5) standard full-size sheet pans (18 in. x 26 in. x 1 in.). Qualifying ovens must meet ENERGY STAR requirements by having a tested heavy-load (potato) cooking efficiency in accordance with ASTM F1496. Cooking energy efficiency must be greater than or equal to 70 percent (≥70%) and must not exceed the maximum idle energy rate of 1.6 kW (≤1.6kW).

• Half-size electric convection ovens are defined by the ability to accept a minimum of five (5) sheet pans measuring (18 in. x 13 in. x 1 in.). Qualifying ovens must meet ENERGY STAR requirements by having a tested heavy-load (potato) cooking efficiency in accordance with ASTM F1496. Cooking energy efficiency must be greater than or equal to 70 percent (≥70%) and must not exceed the maximum idle energy rate of 1.0 kW (≤1.0kW).

Unit of Measure

One oven

Baseline Equipment

Non-ENERGY STAR

High Efficiency Equipment

ENERGY STAR

ALGORITHMS

$$E_{.conventional} = (PREHEAT_{.rate,bs} * PREHEAT_{.time}) + (IDLE_{.rate,bs} * IDLE_{.time}) + (MASS_{.food} * ASTM_{.energy} / EFF_{.bs})$$

$$E_{.EnergyStar} = (PREHEAT_{.rate,ee} * PREHEAT_{.time}) + (IDLE_{.rate,ee} * IDLE_{.time}) + (MASS_{.food} * ASTM_{.energy} / EFF_{.ee})$$

$$\Delta E = E_{.conventional} - E_{.EnergyStar}$$

$$\Delta P = (\Delta E / HRS) * CF$$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
ΔP	Demand savings	Calculated	kW	
ΔE	Annual energy savings	Calculated	kWh/yr	

CF	Coincidence factor, percent of time equipment load corresponds with utility peak load	84%	-	
HRS	Equivalent full load hours, or hours of lighting for business operation	4,380	hrs/yr	12 hrs/day, 365 days/year
Measure Life	Expected duration of energy savings	12	yrs	

SAVINGS

FULL SIZE OVEN

	DEFAULT	USER ENTRY	
Average daily operation	12	12	hours
Annual days of operation	365	365	days
Food cooked per day	100	100	pounds
Incremental cost	0	0	dollars

	Conventional	ENERGY STAR	
Cooking energy efficiency	0.65	0.7	
Production capacity	70	80	lbs/hr
# of preheats per day	1	1	
Preheat length	15	15	min
Preheat energy rate	6000	4000	W
Idle energy rate	2000	1600	W
ASTM energy to food	73.2		Wh/lb
Equipment lifetime	12		yrs

	Conventional	ENERGY STAR	
Annual operation	4380.00		hrs
Daily preheat energy	1500.00	1000.00	Wh
Daily cooking energy	11261.54	10457.14	Wh
Daily idle time	10.32	10.50	hrs
Daily idle energy	20642.86	16800.00	Wh
Total daily energy	33404.40	28257.14	Wh

	Conventional	ENERGY STAR	
Annual Energy Use per Oven	12192.60	10313.86	kWh

HALF SIZE OVEN

	DEFAULT	USER ENTRY	
Average daily operation	12	12	hours
Annual days of operation	365	365	days
Food cooked per day	100	100	pounds
Incremental cost	0	0	dollars

	Conventional	ENERGY STAR	
Cooking energy efficiency	65%	70%	%

Production capacity	45	50	lbs/hr
Number of preheats per day	1	1	#
Preheat length	15	15	min
Preheat energy rate	4000	3600	W
Idle energy rate	1500	1000	W
ASTM energy to food	73.2		Wh/lb
Equipment lifetime	12		yrs

	Conventional	ENERGY STAR	
Annual operation	4380.00		hrs
Daily preheat energy	1000.00	900.00	Wh
Daily cooking energy	11261.54	10457.14	Wh
Daily idle time	9.53	9.75	hrs
Daily idle energy	14291.67	9750.00	Wh
Total daily energy	26553.21	21107.14	Wh

	Conventional	ENERGY STAR	
Annual Energy Use per Oven	9691.92	7704.11	kWh

Equipment Size	Peak Demand Savings	Annual Energy Savings
Full Size	0.360 kW	1878.75 kWh
Half Size	0.381 kW	1987.81 kWh

References

Equipment specifications:	- ENERGY STAR specification
	- Food Service Technology Center (FSTC) research on available models, 2009
Operating Hours:	- FSTC research on average use, 2009
Equipment cost:	- EPA research on available models using AutoQuotes, 2010
Equipment lifetime:	- FSTC research on available models, 2009

COMMERCIAL: Demand-Controlled Ventilation

Return to TOC

MEASURE DETAILS

Description

Kitchen ventilation with DCKV hood exhaust. Demand ventilation uses temperature and/or smoke sensing to adjust ventilation rates. This saves energy comparing with the traditional 100% on/off kitchen ventilation system.

Program Criteria

To qualify for a Hawaiʻi Energy Commercial Kitchen Demand Ventilation Controls Rebate, the following conditions must be met:

1. The control system must be used in conjunction with variable speed fan motor controls.
2. All motors must meet NEMA Premium Efficiency standards and be UL® Approved
3. Temperature and optical sensors must have the ability to sense and ramp up or down the ventilation rate based on the presence of temperature, smoke, or steam from cooking activity
4. Temperature and Infrared cooking sensors must have the ability to measure temperature at the cooking surface to ramp ventilation up or down based on when cooking starts
5. Hawaiʻi Energy Incentive Worksheet must be submitted with rebate application

Unit of Measure

Fan HP

Baseline Equipment

100% on/off kitchen exhaust fan

High Efficiency Equipment

Kitchen ventilation with demand-controlled ventilation according to temperature and/or smoke sensing

ALGORITHMS

$$\text{peak kW savings per HP} = [(0.746 / \eta) - kW_{.in}] * CF$$

$$\text{annual kWh savings per HP} = [0.746 * (HRS / \eta)] - [kW_{.in} * (HRS / \eta)]$$

$$kW_{.in} = kW_{.out} / \eta$$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
$kW_{.in}$	Input demand of controlled fan per HP	0.38	kW	Table
$kW_{.out}$	Output power of fan per HP	Calculated	kW	
η	Efficiency of fan system	0.90	-	Table

CF	Coincidence factor % of time savings correspond with utility peak, 5pm to 9pm	100	%	
HRS	Operating hours at rated fan speed	5,824	hours	16 hrs/day, 7 days/wk, 52 wk/yr
Measure Life	Expected duration of energy savings	15	years	

SAVINGS

% Rated RPM	% Run Time	Op Hours	Output kW/HP	Efficiency	Input kW/HP	kWh/hp/yr
100%	5%	291.2	0.746	0.9	0.829	241.372
90%	20%	1164.8	0.544	0.9	0.604	703.842
80%	25%	1456.0	0.382	0.9	0.424	617.913
70%	25%	1456.0	0.256	0.9	0.284	413.954
60%	15%	873.6	0.161	0.9	0.179	156.409
50%	10%	582.4	0.093	0.9	0.104	60.343
40%	0%	0.0	0.048	0.9	0.053	0.000
30%	0%	0.0	0.020	0.9	0.022	0.000
20%	0%	0.0	0.006	0.9	0.007	0.000
10%	0%	0.0	0.001	0.9	0.001	0.000
				Weight Avg:	0.377	
					Total:	2193.834

Measure Name	Peak Demand Savings	Annual Energy Savings
DCV	0.452 kW/hp	2633.61 kWh/hp

COMMERCIAL: Electric Griddle

Return to TOC

MEASURE DETAILS

Description

Energy-efficient commercial electric griddles reduce energy consumption primarily through the application of advanced controls and improved temperature uniformity.

Program Criteria

This measure applies to ENERGY STAR or equivalent electric commercial griddles in retrofit and new construction applications. This appliance is designed for cooking food in oil or its own juices by direct contact with either a flat, smooth, hot surface or a hot channeled cooking surface where plate temperature is thermostatically controlled.

Unit of Measure

Per linear foot of cooking surface with assumed depth of 2 feet.

Baseline Equipment

Electric griddle that does not meet ENERGY STAR efficiency requirements.

High Efficiency Equipment

Meets ENERGY STAR efficiency requirements. Requirements apply to single and double-sided griddles.

Performance Parameters	Requirements
Heavy-Load Cooking Energy Efficiency	>= 70%
Idle Energy Rate	<= 320 watts per ft^2

ALGORITHMS

$$\Delta E_{.total} = E_{.base} - E_{.he}$$

$$\Delta E_{.base} \text{ or } \Delta E_{.he} = E_{.cook} + E_{.idle} + E_{.preheat}$$

$$E_{.cook,total} = (LBS_{.food} * E_{.food} / \eta_{.cook}) * DAYS$$

$$E_{.idle,total} = E_{.idle} * [HRS_{.daily} - (LBS_{.food} / CAP) - (MIN_{.preheat} / 60)] * DAYS$$

$$E_{.preheat,total} = E_{.preheat} * DAYS$$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
$HRS_{.daily}$	Daily operating hours	12	hrs	FSTC
$MIN_{.preheat}$	Time to preheat	15	min	FSTC
$E_{.food}$	ASTM defined energy to food	0.139	kWh/lb	FSTC
DAYS	Days of operation per year	365	days	FSTC

$\eta_{.cook}$	Cooking energy efficiency	Table	%	FSTC, ENERGY STAR
$E_{.idle}$	Idle energy rate	Table	kW/ft	FSTC, ENERGY STAR
CAP	Production capacity	Table	lbs/hr	FSTC
$E_{.preheat}$	Daily preheating energy	Table	kWh/ft	FSTC
$LBS_{.food}$	Food cooked per day	Table	lbs/day	FSTC
CF	Coincidence factor	100	%	
PF	Persistance factor	100	%	
Measure Life	Expected duration of energy savings	12	years	ENERGY STAR

General assumptions used for deriving deemed electric savings are values taken from the Food Service Technology Center (FSTC) work papers. These deemed values assume that the griddles are 3 x 2 feet in size. Parameters in the table are per linear foot, with an assumed depth of 2 feet.

Parameters	Baseline Electric Griddle	Efficient Electric Griddle
Preheat Energy (E_preheat)	1.33	0.67
Idle Energy Rate (E_idle)	0.80	0.64
Cooking Energy Efficiency (η_cook)	65%	70%
Production Capacity (CAP)	11.70	16.33
Lbs of cooked per day, per ft (LBS_food)	33.33	33.33

SAVINGS

Base (kWh/year) per linear foot	
Cook	2602 kWh
Idle	2599 kWh
Preheat	485 kWh
Total Energy Usage	5686 kWh
Power Demand	1.298 kW

Efficient (kWh/year) per linear foot	
Cook	2416 kWh
Idle	2268 kWh
Preheat	245 kWh
Total Energy Usage	4928 kWh
Power Demand	1.125 kW

Measure Name	Peak Demand Savings	Annual Energy Savings
Electric Griddle	0.173 kW	757.88 kWh

COMMERCIAL: Electric Steam Cooker

Return to TOC

MEASURE DETAILS

Description

The installation of a qualified ENERGY STAR commercial steam cooker. ENERGY STAR steam cookers save energy during cooling and idle times due to improved cooking efficiency and idle energy rates.

Program Criteria

Meet ENERGY STAR efficiency requirements.

Unit of Measure

Per pan

Baseline Equipment

The Baseline Efficiency case is a conventional electric steam cooker with a cooking energy efficiency of 30%, pan production of 23.3 pounds per hour, and an idle energy rate of 1.2 kW.

High Efficiency Equipment

The High Efficiency case is an ENERGY STAR electric steam cooker with a cooking energy efficiency of 50%, pan production capacity of 16.7 pounds per hour, and an idle energy rate of 0.4 kW.

ALGORITHMS

(See below)

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
HRS_daily	Daily operating hours	12	hrs	FSTC
%_steam	Percentage of time in steam mode	40%	-	FSTC
E_food	ASTM defined energy to food	30.8	Wh/lb	FSTC
DAYS	Annual days of operation	365	days	FSTC
η_cook	Cooking energy efficiency	Table	-	FSTC, ENERGY STAR
E_idle	Idle energy rate	Table	W	FSTC, ENERGY STAR
CAP	Production capacity	Table	lbs/hr	FSTC
LBS_food	Food cooked per day	100	lbs/day	FSTC
CF	Coincidence factor	1	-	
Measure Life	Expected duration of energy savings	12	yrs	

SAVINGS

Average daily operation	12	hours
Annual days of operation	365	days
Food cooked per day	100	pounds
Number of pans per unit	3	

	Conventional	**ENERGY STAR**	
Type	boiler based	boilerless	
Time in constant steam mode	40%	40%	
Cooking energy efficiency	30%	50%	
Production capacity per pan	23.3	16.7	pounds/hour/pan
Idle energy rate	1,200	400	W
ASTM energy to food	30.8		Wh/pound
Equipment lifetime	12		years

	Conventional	**ENERGY STAR**	
Annual operation	4,380.00		hours
Daily pre-heat energy	1,500.00	1,500.00	Wh
Daily cooking energy	10,266.67	6,160.00	Wh
Daily idle time	10.57	10.00	hour
Daily idle energy	37,950.01	14,750.53	Wh
Total daily energy	49,716.68	22,410.53	Wh

	Conventional	**ENERGY STAR**	**Savings (3-pan)**
Annual Energy Use per Cooker	18,146.59	8,179.84	9,966.75

Measure Name	**Peak Demand Savings**	**Annual Energy Savings**
Electric Steam Cooker	0.759 kW/pan	3322.25 kWh/pan

References

Source: https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx

Equipment specifications:
- ENERGY STAR specification
- Food Service Technology Center (FSTC) research on available models, 2009

Operating Hours: - FSTC research on average use, 2009

Equipment life: - FSTC research on available models, 2009

Notes on Modifications from Original ENERGY STAR Calculator

Cooking energy efficiency for baseline steam cookers is the average efficiency for steam generator and boiler-based cookers. Idle energy rate for baseline steam cookers is the average rate for steam generator and boiler-based cookers.

COMMERCIAL: Fryer

Return to TOC

MEASURE DETAILS

Description

This measure applies to ENERGY STAR or its equivalent electric commercial open-deep fat fryers in retrofit and new construction applications. Commercial fryers consist of a reservoir of cooking oil that allows food to be fully submerged without touching the bottom of the vessel. Electric fryers use a heating element immersed in the cooking oil. High efficiency standard and large vat fryers offer shorter cook times and higher production rates through the use of heat exchanger design. Standby losses are reduced in more efficient models through the use of fry pot insulation.

Program Criteria

Meet ENERGY STAR energy efficiency requirements. ENERGY STAR requirements apply to a standard fryer and a large vat fryer. A standard fryer measures 14 to 18 inches wide with a vat capacity from 25 to 60 pounds. A large vat fryer measures 18 inches to 24 inches wide with a vat capacity greater than 50 pounds.

Performance Parameters	Standard Fryer	Large Vat Fryer
Heavy-Load Cooking Energy Efficiency	>= 80%	>= 80%
Idle Energy Rate	<= 1.0 kW	<= 1.1 kW

Unit of Measure

One fryer

Baseline Equipment

See table below.

High Efficiency Equipment

See table below.

ALGORITHMS

$$\Delta E_{.total} = E_{.base} - E_{.he}$$

$$\Delta E_{.base} \text{ or } \Delta E_{.he} = E_{.cook} + E_{.idle} + E_{.preheat}$$

$$E_{.cook,total} = LBS_{.food} * (E_{.food} / \eta_{.cook}) * DAYS$$

$$E_{.idle,total} = E_{.idle} * [HRS_{.daily} - (LBS_{.food} / CAP) - (MIN_{.preheat} / 60)] * DAYS$$

$$E_{.preheat,total} = E_{.preheat} * DAYS$$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
$HRS_{.daily}$	Daily operating hours	12	hrs	FSTC

$MIN_{.preheat}$	Time to preheat	15	min	FSTC
$E_{.food}$	ASTM defined energy to food	0.167	kWh/lb	FSTC
DAYS	Annual days of operation	365	days	FSTC
$\eta_{.cook}$	Cooking energy efficiency	Table	%	FSTC, ENERGY STAR
$E_{.idle}$	Idle energy rate	Table	kW	FSTC, ENERGY STAR
CAP	Production capacity	Table	lbs/hr	FSTC
$E_{.preheat}$	Preheating energy	Table	kWh/day	FSTC
$LBS_{.food}$	Food cooked per day	Table	lbs/day	FSTC
CF	Coincidence factor	100	%	
PF	Persistance factor	100	%	
Measure Life	Expected duration of energy savings	12	yrs	

General assumptions used for deriving deemed electric savings are values taken from the Food Service Technology Center (FSTC) work papers.

Parameters	Baseline Electric Fryer		Efficient Electric Fryer	
	Standard	Large Vat	Standard	Large Vat
Preheat Energy (E_preheat)	2.3	2.5	1.7	2.1
Idle Energy Rate (E_idle)	1.05	1.35	1	1.1
Cooking Energy Efficiency (η_cook)	75%	70%	80%	80%
Production Capacity per ft (CAP)	65	100	70	110
Lbs of food cooked per day, per ft (LBS_food)	150	150	150	150

SAVINGS

Baseline Fryer	Standard	Large Vat
Cook	12191 kWh	13062 kWh
Idle	3619 kWh	5051 kWh
Preheat	840 kWh	913 kWh
Total Base Energy	16649 kWh	19025 kWh
Power Demand	3.801 kW	4.344 kW

Efficient Fryer	Standard	Large Vat
Cook	11429 kWh	11429 kWh
Idle	3507 kWh	4170 kWh
Preheat	621 kWh	767 kWh
Total Base Energy	15556 kWh	16366 kWh
Power Demand	3.552 kW	3.736 kW

Measure Name	Peak Demand Savings	Annual Energy Savings
Standard Electric Fryer	0.250 kW	1093.09 kWh
Large Vat Electric Fryer	0.607 kW	2659.29 kWh

COMMERCIAL: Hot Food Holding Cabinet

Return to TOC

MEASURE DETAILS

Description

Commercial insulated hot food holding cabinet models that meet program requirements incorporate better insulation, reducing heat loss, and may also offer additional energy saving devices such as magnetic door electric gaskets, auto-door closures, or dutch doors. The insulation of the cabinet also offers better temperature uniformity within the cabinet from top to bottom. This means that qualified hot food holding cabinets are more efficient at maintaining food temperature while using less energy.

Program Criteria

• Full-size holding cabinets are defined as any holding cabinet with an internal measured volume of greater than or equal to 15 cubic feet (≥15 ft.3). This measure does not include cook-and-hold equipment. All measures must be electric hot food holding cabinets that are fully insulated and have doors. Qualifying cabinets must not exceed the maximum idle energy rate of 20 Watts per cubic foot in accordance with the ASTM Standard test method.

• Half-size holding cabinets are defined as any holding cabinet with an internal measured volume of less than 15 cubic feet (<15 ft.3). This measure does not include cook-and-hold or retherm equipment. All measures must be electric hot food holding cabinets that are fully insulated and have doors. Qualifying cabinets must not exceed the maximum idle energy rate of 20 Watts per cubic foot in accordance with the ASTM Standard test method.

Unit of Measure

Per cabinet

Baseline Equipment

The baseline equipment is assumed to be a standard hot food holding cabinet with an idle energy rate of 40 watts per cubic foot.

High Efficiency Equipment

The efficient equipment is assumed to be an ENERGY STAR qualified hot food holding cabinet with an idle energy rate of 20 watts per cubic foot.

ALGORITHMS

$$\Delta kWh = HRS_{.daily} * DAYS * (kW_{.bs} - kW_{.he})$$

$$\Delta kW = (kW.bs - kW.he) * CF$$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
$kW_{.bs}$	Baseline equipment demand	See below	kW	

$kW_{.he}$	High efficiency equipment demand	See below	kW	
HRS_daily	Daily hours of operation	15	hrs	
DAYS	Annual days of operation	365	days	
CF	Coincidence factor	100	%	
Measure Life	Expected duration of energy savings	12	yrs	

SAVINGS

Energy usage calculations are based on 15 hours a day, 365 days per year operation at a typical temperature setting of 150°F. The different sizes for the holding cabinets (half size and full size) have proportional operating energy rates. Operating energy rate for the full size holding cabinets was obtained in accordance with the ASTM Standard.
The energy savings calculations listed in the following tables use Title 20 (California) as the baseline for potential energy savings requiring all hot food holding cabinets sold in California to meet a normalized idle energy rate of 40 Watts/ft³.

Performance	Full-Size		Half-Size	
	Baseline	High Efficiency	Baseline	High Efficiency
Power Demand	1.000 kW	0.280 kW	0.380 kW	0.050 kW
Annual Energy Use	5475.00 kWh	1533.00 kWh	2080.50 kWh	273.75 kWh
Power Demand Reduction	0.720 kW		0.330 kW	
Annual Energy Reduction	3942.00 kWh		1806.75 kWh	

The demand reduction estimation is based on measured data for standard efficiency insulated holding cabinets and for high-efficiency insulated holding cabinets. The measured data are derived from tests conducted under ASTM Standard Test Method for the Performance of Hot Food Holding Cabinets.

Cabinet Size	Cabinet Volume	Normalized Idle Energy Rate	Total Idle Energy Rate
Full-Size	25 cubic ft	11.30 W/cubic ft	0.280 kW
Half-Size	10 cubic ft	5.70 W/cubic ft	0.050 kW

Measure Name	Peak Demand Savings	Annual Energy Savings
Full-Size Cabinet	0.720 kW	3942.00 kWh
Half-Size Cabinet	0.330 kW	1806.75 kWh

COMMERCIAL: Ice Machine

Return to TOC

MEASURE DETAILS

Description

This measure applies to Energy Efficient air-cooled commercial ice makers in retrofit and new construction applications installed in conditioned spaces. Commercial ice makers are classified into three equipment types; ice-making heads (IMHs), remote condensing units (RCUs) and self-contained units (SCUs). The measure described here applies to ice makers that use a batch process to make cubed ice. The industry standard for energy use and performance of commercial ice machines is AHRI Standard 810. Key parameters reported for ice makers include the Equipment Type, Harvest Rate (lbs of ice/24hrs) and Energy Consumption Rate. The AHRI Directory of Certified Equipment150 lists these values by equipment manufacturer and model number.

Program Criteria

This incentive applies towards the purchase of new or replacement energy efficient Air-cooled ice machines. Used or rebuilt equipment is not eligible. Customers must provide proof that the appliance meets the energy efficiency specifications listed in the table below.

Unit of Measure

One ice machine

Baseline Equipment

Non-ENERGY STAR

High Efficiency Equipment

Equipment meeting and/or exceeding ENERGY STAR performance requirements.

Equipment Type	Ice Harvest Rate (IHR) (lbs/24 hrs)	Energy Use Rate (kWh/100 lbs)	Potable Water Limit (gal/100 lbs)	Federal Minimum Standard Energy Use Rate (kWh/100 lbs)
Ice Making Heads	< 450	≤ 8.72 - 0.0073*IHR	≤ 20	10.26 - 0.0086*IHR
	≥ 450	≤ 5.86 - 0.0009*IHR	≤ 20	6.89 - 0.0011*IHR
Remote Condensing Units	< 1000	≤ 7.52 - 0.0032*IHR	≤ 20	8.85 - 0.0038*IHR
	≥ 1000	≤ 4.34	≤ 20	5.10
	< 934	≤ 7.52 - 0.0032*IHR	≤ 20	8.85 - 0.0038*IHR
	≥ 934	≤ 4.51	≤ 20	5.30
Self-Contained Units	< 175	≤ 15.3 - 0.0399*IHR	≤ 30	18.0 - 0.069*IHR
	≥ 175	≤ 8.33	≤ 30	9.80

ALGORITHMS

$$\Delta kWh = (E_{.base,100lb} - E_{.he,100lb}) / 100 * DC * IHR * DAYS$$

$$\Delta kW = \Delta kWh \,/\, HRS * CF$$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Notes**
$E_{.base,100lb}$	Base energy use per 100lbs of ice	Table	kWh	
$E_{.he,100lb}$	Efficient energy use per 100lbs of ice	Table	kWh	
DC	Duty cycle of ice machine	75	%	Assumed 75%
IHR	Harvest rate	Table	lbs/day	
DAYS	Annual days of operation	365	days	
HRS	Annual operating hours	User input	hrs	
CF	Coincidence factor	100	%	
Measure Life	Expected duration of energy savings	12	yrs	

SAVINGS

***Example* Savings Calculation:**

		Ice Harvest Rate (IHR)				
		101 - 300	**301 - 500**	**501 - 1000**	**1001 - 1500**	**> 1500**
Average IHR in Range		200	400	750	1250	1750
Energy Usage per 100 lbs	**Baseline (E_base,100lb)**	9.8	6.82	6.07	5.1	5.1
	Efficient (E_ee,100lb)	8.33	5.8	5.19	4.34	4.34
Daily Energy Usage	**Baseline**	14.7	20.5	34.1	47.8	66.9
	Efficient	12.5	17.4	29.2	40.7	57.0
Annual Energy Usage	**Baseline**	5,366	7,468	12,462	17,452	24,432
	Efficient	4,561	6,351	10,656	14,851	20,791
Average Power Demand	**Baseline**	0.613	0.853	1.423	1.992	2.789
	Efficient	0.521	0.725	1.216	1.695	2.373
Peak Demand Reduction (kW)		0.092	0.128	0.206	0.297	0.416
Annual Energy Reduction (kWh/yr)		805	1,117	1,807	2,601	3,641

Measure Name	Peak Demand Savings	Annual Energy Savings
101 - 300	0.092 kW	804.83 kWh
301 - 500	0.128 kW	1116.90 kWh
501 - 1000	0.206 kW	1806.75 kWh

1001 - 1500	0.297 kW	2600.63 kWh
> 1500	0.416 kW	3640.88 kWh

COMMERCIAL: Low-Flow Spray Nozzle

Return to TOC

MEASURE DETAILS

Description

All pre-rinse valves use a spray of water to remove food waste from dishes prior to cleaning in a dishwasher. They reduce water consumption, water heating cost, and waste water (sewer) charges. Pre-rinse spray valves include a nozzle, squeeze lever, and dish guard bumper. Energy savings depend on the facility's method of water heating (electric resistance or heat pump). If the facility does not have electric water heating (i.e. gas or propane), there are no electric savings for this measure. The spray valves usually have a clip to lock the handle in the "on" position. Pre-rinse valves are inexpensive and easily interchangeable with different manufacturers' assemblies.

Program Criteria

Program follows ENERGY STAR guidelines, unless specified otherwise.

Unit of Measure

One spray valve

Baseline Equipment

The baseline equipment is assumed to be a spray valve with a flow rate of 2.25 gallons per minute.

High Efficiency Equipment

The efficient equipment is assumed to be a pre-rinse spray valve with a flow rate of 1.28 gallons per minute.

ALGORITHMS

$$\Delta kWh = GPD * \%_{.hot} * 8.34 * \Delta T * [(1 / \eta) / 3412]$$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Notes**
GPD	Water usage reduction	116.4	gpd	0.97 gpm 120 mins per day
$\%_{.hot}$	Percentage of water used by pre-rinse valve that is heated	69	%	
ΔT	Temperature rise through water heater	65	°F	
η	Water heater thermal efficiency	Dependent	-	Electric Resistance = 0.98; Heat Pump = 3.0
Constant	Energy content of heated water	8.34	BTU/gal/°F	
Constant	Factor to convert BTU to kWh	3,412	BTU/kWh	

Measure Life	Expected duration of energy savings	5	yrs	

SAVINGS

Building type	Operating Schedule (Days/Year)	Electric Resistance Savings (kWh/year)	Heat Pump Savings (kWh/year)	Demand Savings (kW)
Restaurants/Institutions	365	4,752.69	1,552.54	1.03
Dormitories	274	3,567.77	1,165.47	0.90
K-12 Schools	200	2,604.21	850.71	0.79

Measure Name	Peak Demand Savings	Annual Energy Savings
Electric Resistance, Restaurants/Institutions	1.03 kW	4752.69 kWh
Electric Resistance, Dormitories	0.90 kW	3567.77 kWh
Electric Resistance, K-12 Schools	0.79 kW	2604.21 kWh
Heat Pump, Restaurants/Institutions	1.03 kW	1552.54 kWh
Heat Pump, Dormitories	0.90 kW	1165.47 kWh
Heat Pump, K-12 Schools	0.79 kW	850.71 kWh

COMMERCIAL: Freezer

Return to TOC

MEASURE DETAILS

Description

This measure relates to the installation of a new reach-in 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 will significantly reduce energy consumption.

Program Criteria

This measure could relate to the replacing of an existing unit at the end of its useful life, or the installation of a new system in a new or existing building.

Unit of Measure

One freezer

Baseline Equipment

In order for this characterization to apply, the baseline equipment is assumed to be a solid or glass door freezer meeting the minimum federal manufacturing standards. It is assumed that the volume for baseline is the average of the range. For example if range is 0 to 15, the average volume is 7.5.

High Efficiency Equipment

In order for this characterization to apply, the efficient equipment is assumed to be a solid or glass door freezer meeting the minimum ENERGY STAR efficiency level standards.

ALGORITHMS

$$\Delta kWh = (E_{.base} - E_{.he}) * DAYS$$

$$\Delta kW = (\Delta kWh / HRS) * CF$$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
$E_{.base}$	Baseline equipment energy usage	See below	kWh	
$E_{.he}$	High efficiency equipment energy usage	See below	kW	
DAYS	Annual days of operation	365	days	
HRS	Annual operating hours	8,760	hrs	
CF	Coincidence factor	1	-	
Measure Life	Expected duration of energy savings	12	yrs	

SAVINGS

Volume	Typical Volume	Volumetric Factor (kWh/ft^3)		Fixed Energy (kWh)		Adjusted Energy (kWh/day)		Energy Savings (kWh/yr)	Demand Savings (kW)
		Base	Efficient	Base	Efficient	Base	Efficient		
Solid Door									
0 < V 15	7.5	0.400	0.250	1.380	1.250	4.380	3.125	458.08	0.052
15 < V < 30	22.5	0.400	0.400	1.380	-1.000	10.380	8.000	868.70	0.099
30 < V < 50	40.0	0.400	0.163	1.380	6.125	17.380	12.645	1728.28	0.197
50 < V	60.0	0.400	0.158	1.380	6.333	25.380	15.813	3491.96	0.399
Glass Door									
0 < V 15	7.5	0.750	0.607	4.100	0.893	9.725	5.446	1562.02	0.178
15 < V < 30	22.5	0.750	0.733	4.100	-1.000	20.975	15.493	2001.11	0.228
30 < V < 50	40.0	0.750	0.250	4.100	13.500	34.100	23.500	3869.00	0.442
50 < V	60.0	0.750	0.450	4.100	3.500	49.100	30.500	6789.00	0.775

Measure Name	Peak Demand Savings	Annual Energy Savings
Solid-Door, 0 < V 15	0.052 kW	458.08 kWh
Solid-Door, 15 < V < 30	0.099 kW	868.70 kWh
Solid-Door, 30 < V < 50	0.197 kW	1728.28 kWh
Solid-Door, 50 < V	0.399 kW	3491.96 kWh
Glass-Door, 0 < V 15	0.178 kW	1562.02 kWh
Glass-Door, 15 < V < 30	0.228 kW	2001.11 kWh
Glass-Door, 30 < V < 50	0.442 kW	3869.00 kWh
Glass-Door, 50 < V	0.775 kW	6789.00 kWh

COMMERCIAL: Refrigerator

Return to TOC

MEASURE DETAILS

Description

This measure relates to the installation of a new reach-in commercial refrigerator meeting ENERGY STAR efficiency standards. ENERGY STAR labeled commercial refrigerators 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 will significantly reduce energy consumption.

Program Criteria

This measure could relate to the replacing of an existing unit at the end of its useful life, or the installation of a new system in a new or existing building.

Unit of Measure

Baseline Equipment

In order for this characterization to apply, the baseline equipment is assumed to be a solid or glass door refrigerator meeting the minimum federal manufacturing standards. It is assumed that the volume for baseline is the average of the range. For example if range is 0 to 15, the average volume is 7.5.

High Efficiency Equipment

In order for this characterization to apply, the efficient equipment is assumed to be a solid or glass door refrigerator meeting the minimum ENERGY STAR efficiency level standards.

ALGORITHMS

$$\Delta kWh = (E_{.base} - E_{.he}) * DAYS$$

$$\Delta kW = (\Delta kWh / HRS) * CF$$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Notes**
$E_{.base}$	Baseline equipment energy usage	See below	kWh	
$E_{.he}$	High efficiency equipment energy usage	See below	kW	
DAYS	Annual days of operation	365	days	
HRS	Annual operating hours	8,760	hrs	
CF	Coincidence factor	1	-	
Measure Life	Expected duration of energy savings	12	yrs	

SAVINGS

Volume	Typical Volume	Volumetric Factor		Fixed Energy		Adjusted Energy		Energy Savings	Demand Savings
		Base	Efficient	Base	Efficient	Base	Efficient		
Solid Door									
0 < V 15	7.5	0.100	0.089	2.040	1.411	2.790	2.079	259.70	0.030
15 < V < 30	22.5	0.100	0.037	2.040	2.200	4.290	3.033	458.99	0.052
30 < V < 50	40.0	0.100	0.056	2.040	1.635	6.040	3.875	790.23	0.090
50 < V	60.0	0.100	0.060	2.040	1.416	8.040	5.016	1103.76	0.126
Glass Door									
0 < V 15	7.5	0.120	0.118	3.340	1.382	4.240	2.267	720.15	0.082
15 < V < 30	22.5	0.120	0.140	3.340	1.050	6.040	4.200	671.60	0.077
30 < V < 50	40.0	0.120	0.089	3.340	2.625	8.140	6.185	713.58	0.081
50 < V	60.0	0.120	0.110	3.340	1.500	10.540	8.100	890.60	0.102

Measure Name	Peak Demand Savings	Annual Energy Savings
Solid-Door, 0 < V 15	0.030 kW	259.70 kWh
Solid-Door, 15 < V < 30	0.052 kW	458.99 kWh
Solid-Door, 30 < V < 50	0.090 kW	790.23 kWh
Solid-Door, 50 < V	0.126 kW	1103.76 kWh
Glass-Door, 0 < V 15	0.082 kW	720.15 kWh
Glass-Door, 15 < V < 30	0.077 kW	671.60 kWh
Glass-Door, 30 < V < 50	0.081 kW	713.58 kWh
Glass-Door, 50 < V	0.102 kW	890.60 kWh

COMMERCIAL: Design Assistance

Return to TOC

MEASURE DETAILS

Description

Design Assistance is available to building owners and their design teams to encourage the implementation of energy efficient building systems. Considering energy efficiency during the initial phases of planning and design greatly increase the feasibility of implementation. Incentives for energy efficiency are project-specific and offered as upfront assistance for additional costs incurred during the design phase. The long-term benefits include energy use reduction for the state of Hawaiʻi and a reduction in operating costs, equipment lifecycle improvement for building owners, and improved comfort for building users.

Program Criteria

- Application with written pre-approval from Hawaiʻi Energy
- Project in planning or initial design phase
- Total resource benefit ratio greater than or equal to 1

Unit of Measure

n/a

Baseline Equipment

The baseline efficiency case assumes compliance with the efficiency requirements as mandated by the Hawaiʻi State Energy Code or industry accepted standard practice.

High Efficiency Equipment

The high efficiency scenario is specific to each project and may include one or more energy efficiency measures. Energy and demand savings calculations are based on comparing a base case analysis and enhanced cased analysis on equipment efficiencies and operating characteristics and are determined on a case-by-case basis. The energy efficiency measures must be proven cost-effective, pass total resource benefit, and have a payback greater than or equal to 1.

ALGORITHMS

Gross energy and demand savings estimates for design assistance are calculated using engineering analysis and project-specific details. Custom analyses typically include a weather dependent load bin analysis, whole building energy model simulation, or other engineering analysis and include estimates of savings, costs, and an evaluation of the project's cost-effectiveness.

SAVINGS

A base case and enhanced case model must be produced with a clear comparison. All assumptions, data, and formulas used in energy efficiency calculations must be clearly documented. Standard engineering principles must be applied, and all references cited. Energy saving calculations shall also reflect the interactive effects of other simultaneous technologies to prevent the overstatement of actual savings. Proposed base and enhanced cases must be performed by a qualified person or firm. In some cases, a professional engineer may be required to provide verification of the analysis.

COMMERCIAL: Energy Study

Return to TOC

MEASURE DETAILS

Description

The Energy Study is an indirect impact product that offers Hawaiʻi businesses with analysis services to identify energy saving opportunities. The goal of the energy study is to provide a method for commercial and industrial customers to learn how their business uses energy today and to identify measures that will help them save energy and reduce operating costs in the future. The focus is on a customer's core energy efficiency opportunities.

Program Criteria

• Program approval is required prior to the start of work on the energy study.
• The program reserves the right to review all materials that result from a program-supported study including, but not limited to, final reports, consultant recommendations, and metered data.
• The study must be performed by a qualified person or firm. A brief summary of the consultant's qualifications should be submitted with the application. In some cases, a professional engineer may be required to provide verification of the analysis.
• At any time, customers may contact program staff to discuss a project, get assistance in preparing an application, or with any program-related questions.

Unit of Measure

n/a

Baseline Equipment

n/a

High Efficiency Equipment

n/a

ALGORITHMS

Gross energy and demand savings estimates for energy studies are calculated using engineering analysis and project-specific details. Energy study analyses typically include estimates of savings, costs, and an evaluation of the cost-effectiveness of potential projects/upgrades.

SAVINGS

All assumptions, data and formulas used in energy efficiency calculations must be clearly documented. Standard engineering principles must be applied, and all references cited. Energy saving calculations shall also reflect the interactive effects of other simultaneous technologies to prevent the overstatement of the actual savings.

The Energy Study shall include the following information and be presented in the following format:

1) Executive Summary
    a) Energy Conservation Measures (ECMs) Proposed
    b) Summary of Baseline and Enhanced Case Assumptions
    c) Actionable Recommendations in "loading order."

2) Technical Information and Analysis
    a) Energy Consumption Analysis
        i) Two years of billing data (weatherized and compared to some pertinent operating metric)
    b) Description of the project
    c) Proposed Energy Conservation Measures (ECM)
        i) Descriptive Name
        ii) Schematic System Drawing
        iii) Current Peak Demand (kW), Energy Usage (kWh), Effective Full Load Run Hours
        iv) Proposed Peak Demand (kW), Energy Usage (kWh), Effective Full Load Run Hours
        v) % Change for above
        vi) Estimated Installation Cost
        vii) Project timeline
        viii) Measure Life
        ix) Simple Payback
    d) Base case information
        i) Short term/spot baseline thermal, fluid, and electrical measurements for major equipment to be changed with ECMs
        ii) Permanent metering data (This metering will qualify for additional cost assistance)
        iii) Sizing/Performance Reviews (Pump Curves, Cooling Bin Data etc.)
    e) Enhanced case information
        i) How will performance be measured in the future.
        ii) Description of where energy savings occurs (lower run time, more efficient operations etc.)
    f) Estimated energy and demand savings associated with your proposed project
        i) Applicable figures and tables
        ii) Simple payback period and/or life cycle costs
    g) Estimated costs including design, materials, and installation

3) Appendix
    a) Raw and Analyzed Data (Cooling Models, Field Data, Pictures, Metering Data etc.)
    b) Building Plans (Mechanical, Electrical Schedules, Layouts etc.)

COMMERCIAL: Chiller

Return to TOC

UPDATE STATUS

Updated Chiller Worksheet in Fall 2019 for PY19 TRM v2.0.

MEASURE DETAILS

Description

The following is a semi-prescriptive method for calculating chiller savings for one-for-one replacements of standalone chillers.

The following chiller retrofits should be evaluated as custom projects: water-cooled chillers larger than or equal to 600 tons, air-cooled chillers larger than or equal to 300 tons, and any chiller part of a larger, multi-system plant.[1] In addition, a custom approach should be used for early retirement chiller projects and chillers installed in industrial or cold storage applications.

Program Criteria

To be eligible, chiller efficiency must exceed IECC 2015 code (consistent with ASHRAE 90.1-2016) code, Path A or Path B, by 10% or more.[2]

Unit of Measure

Savings are calculated per chiller.

Baseline Equipment

The baseline equipment meets the current State of Hawaiʻi code, which is IECC 2015 and is consistent with the national ASHRAE 90.1-2016 standard that manufacturers adhere to. All counties are expected to adopt IECC 2015 or better by March 2019.[3]

High Efficiency Equipment

High efficiency equipment must exceed ASHRAE efficiencies by 10% or more. An additional tier (20% above ASHRAE) has also been included for this measure. Actual nameplate data for rated efficiency will be compared against ASHRAE standard efficiency.

ALGORITHMS

Peak Demand Reduction, kW

$$\Delta kW = TONS * (PE_{BL} - PE_{EE}) * CF \qquad (1)$$

Annual Energy Savings, kWh/yr

$$\Delta kWh = TONS * (IPLV_{BL} - IPLV_{EE}) * EFLH \qquad (2)$$

Lifetime Energy Savings, kWh

$$\Delta kWh_{life} = \Delta kWh * EUL \quad (3)$$

DEFINITIONS & ASSUMPTIONS				
Variable	Description	Value	Unit	Source/Notes
TONS	Chiller nominal cooling capacity, in tons	User input	tons	≤600 tons for water-cooled; ≤300 tons for air-cooled
PE_{BL}	Peak efficiency of baseline chiller at full load	See Chiller Worksheet	kW/ton	Equal to the minimum efficiency requirements of the ASHRAE 90.1-2016 standard
PE_{EE}	Peak efficiency of installed high efficiency chiller at full load	User input	kW/ton	At least 10% better than the ASHRAE 90.1-2016 standard
$IPLV_{BL}$	Part-load efficiency of baseline chiller expressed as Integrated Part Load Value (IPLV),	See Chiller Worksheet	kW/ton	Equal to the minimum efficiency requirements of the ASHRAE 90.1-2016 standard
$IPLV_{EE}$	Part-load efficiency of installed high efficiency chiller	User input	kW/ton	At least 10% better than the ASHRAE 90.1-2016 standard
CF	Coincidence factor for commercial cooling with chiller	See Table 1	-	AEG's analysis of DOE's OpenEI load shapes using Hawai'i-specific prototypes, weather data, and peak demand period
EFLH	Equivalent full load hours for commercial cooling with chiller	See Table 1	hrs	AEG's analysis of DOE's OpenEI load shapes using Hawai'i-specific prototypes and weather data
EUL	Effective useful life of measure	22	yrs	Median of various sources from AEG's Fall 2018 Benchmarking

SAVINGS

See accompanying Chiller Worksheet: (C_HVAC_Chiller_WKST)

The following equivalent full load hours and coincidence factors are recommended per building type based on EnergyPlus simulations of DOE prototypes with Honolulu weather (OpenEI datasets). [4] Retrofits in cold storage and industrial facilities should be evaluated as custom measures unless the equipment is used for HVAC and not process cooling loads.

Table 1: Equivalent Full Load Hours and Coincidence Factors for Commercial Cooling in Hawai'i

Building Type	EFLH	CF
Avg. Commercial	2,594	0.38

Cold Storage	Varies	Varies
Education	2,549	0.43
Grocery	1,531	0.27
Health	4,891	0.55
Hotel/Motel	4,910	0.60
Industrial	Varies	Varies
Office	2,754	0.48
Restaurant	2,451	0.40
Retail	1,913	0.29
Warehouse	1,033	0.01

Use custom approach for entries noted as "Varies."

FOOTNOTES

[1] The Uniform Methods Project. Chapter 14: Chiller Evaluation Protocol. September 2014. Available electronically at: <https://energy.gov/eere/about-us/ump-protocols>.

[2] The IECC 2015 with Hawaiʻi Amendments Commercial Reviewer and Designer Checklist requires efficient HVAC equipment to be 10% better than the minimum efficiency. Available at: <https://hawaiienergy.com/files/resources/2015-IECC_CommercialReviewer_Checklist.pdf>

[3] Code baseline specification based on Hawaiʻi Energy: <https://hawaiienergy.com/resources#hawaii-codes> and <http://energy.hawaii.gov/hawaii-energy-building-code/2015-iecc-update>.

All equipment is expected to meet minimum ASHRAE standards. ASHRAE requires a subscription to see the standard in full; AEG used staff subscriptions to ASHRAE to obtain the latest 90.1-2016 standard. The minimum efficiency levels are also summarized in various publicly available sources, including this one from Trane: <https://www.trane.com/content/dam/Trane/Commercial/global/products-systems/education-training/engineers-newsletters/standards-codes/ADMAPN053EN_0315.pdf>

[4] Office of Energy Efficiency and Renewable Energy. Commercial and Residential Hourly Load Profiles for All TMY3 Locations in the United States. U.S. Department of Energy Open Data Catalog. Available at: <https://openei.org/doe-opendata/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states>.

ADDITIONAL RESOURCES

- AEG's Analysis Files titled "AEG HPUC Update - Commercial Chillers - Analysis File" and "AEG HPUC Mid-Year PY19 TRM Updates_Analysis File."
- Oversizing of HVAC System: Signatures and Penalties, University of Idaho, Integrated Design Lab-Boise, available here: <http://www.idlboise.com/pdf/papers/ENB_3018_RTU_Measurement_accepted.pdf>. Used to determine correct HVAC oversizing adjustment for EFLH and CF analysis.

- Southern California Edison. Air-Cooled Constant Speed Screw Chiller. Workpaper SCE17HC030, Revision 1. November 16, 2017. Available at: <http://www.deeresources.net/workpapers>.
- Southern California Edison. Water Cooled Chiller. Workpaper SCE17HC043, Revision 0. November 14, 2017. Available at: <http://www.deeresources.net/workpapers>.

COMMERCIAL: Chiller Savings Calculator

Return to TOC

Step 1: Enter chiller nameplate data

Enter chiller type:	Centrifugal
Enter chiller tonnage:	149 tons
Enter building type:	Avg. Commercial
Enter your FL_ee here:	0.300 kW/ton
Enter your IPLV_ee here:	0.300 kW/ton

Step 2: Determine if it qualifies

Higher than ASHRAE:	**10% Higher?**	**20% Higher?**
Path A:	pass	pass
Path B:	pass	fail

ASHRAE 90.1 Baseline	Path A	Path B
FL_base	0.610 kW/ton	0.695 kW/ton
IPLV_base	0.550 kW/ton	0.440 kW/ton
FL_delta	0.310 kW/ton	0.395 kW/ton
IPLV_delta:	0.250 kW/ton	0.140 kW/ton

Step 3: Calculate savings

CF:	0.38
EFLH:	2,594
Use:	Path A
kW savings:	17.552
kWh/yr savings:	96,626.50
Lifetime kWh:	2,125,783.00
Meets	Tier 2 (ASHRAE + 20%)

ASHRAE 90.1-2016 + 10% (Efficient Case Minimum)

Positive Displacement (Reciprocating, Rotary Screw, Scroll)	**Units: kW/ton**		**< 75 Tons**	**>= 75 tons & < 150 tons**	**>= 150 tons & < 300 tons**	**>= 300 tons & < 600 tons**	**>= 600 tons**
	Path A	FL	0.675	0.648	0.594	0.549	0.504
		IPLV	0.540	0.504	0.486	0.468	0.450
	Path B	FL	0.702	0.675	0.612	0.563	0.527
		IPLV	0.450	0.441	0.396	0.369	0.342

Centrifugal	**Units: kW/ton**		**< 150 Tons**	**>= 150 tons & < 300 tons**	**>= 300 tons & < 400 tons**	**>= 400 tons & < 600 tons**	**>= 600 tons**
	Path A	FL	0.549	0.549	0.504	0.504	0.504
		IPLV	0.495	0.495	0.468	0.450	0.450
	Path B	FL	0.626	0.572	0.536	0.527	0.527
		IPLV	0.396	0.360	0.351	0.342	0.342

Air-cooled with condenser	**Units: EER (Btu/W)**		**< 150 Tons**	**>= 150 Tons**	**Units: kW/ton**	**< 150 Tons**	**>= 150 Ton**
	Path A	FL	11.1	11.1	Path A	1.080	1.080
		IPLV	15.1	15.4		0.796	0.779
	Path B	FL	10.7	10.7	Path B	1.125	1.125
		IPLV	17.4	17.7		0.690	0.678

Positive Displacement (Reciprocating, Rotary Screw	**Units: kW/ton**		**< 75 Tons**	**>= 75 tons & < 150 tons**	**>= 150 tons & < 300 tons**	**>= 300 tons & < 600 tons**	**>= 600 tons**
	Path A	FL	0.750	0.720	0.660	0.610	0.560
		IPLV	0.600	0.560	0.540	0.520	0.500

ASHRAE 90.1-2016 (Baseline)

Rotary Screw, Scroll)	Path B	FL	0.780	0.750	0.680	0.625	0.585
		IPLV	0.500	0.490	0.440	0.410	0.380

Centrifugal	Units: kW/ton		< 150 Tons	>= 150 tons & < 300 tons	>= 300 tons & < 400 tons	>= 400 tons & < 600 tons	>= 600 tons
	Path A	FL	0.610	0.610	0.560	0.560	0.560
		IPLV	0.550	0.550	0.520	0.500	0.500
	Path B	FL	0.695	0.635	0.595	0.585	0.585
		IPLV	0.440	0.400	0.390	0.380	0.380

Air-cooled with condenser	Units: EER (Btu/W)		< 150 Tons	>= 150 Tons	Units: kW/ton	< 150 Tons	>= 150 Ton
	Path A	FL	10.1	10.1	Path A	1.188	1.188
		IPLV	13.7	14		0.876	0.857
	Path B	FL	9.7	9.7	Path B	1.237	1.237
		IPLV	15.8	16.1		0.759	0.745

https://codes.iccsafe.org/content/IECC2015/chapter-4-ce-commercial-energy-efficiency

ASHRAE 90.1-2016 (Efficient Case Tier 2)

Positive Displacement (Reciprocating, Rotary Screw, Scroll)	Units: kW/ton		< 75 Tons	>= 75 tons & < 150 tons	>= 150 tons & < 300 tons	>= 300 tons & < 600 tons	>= 600 tons
	Path A	FL	0.600	0.576	0.528	0.488	0.448
		IPLV	0.480	0.448	0.432	0.416	0.400
	Path B	FL	0.624	0.600	0.544	0.500	0.468
		IPLV	0.400	0.392	0.352	0.328	0.304

Centrifugal	Units: kW/ton		< 150 Tons	>= 150 tons & < 300 tons	>= 300 tons & < 400 tons	>= 400 tons & < 600 tons	>= 600 tons
	Path A	FL	0.488	0.488	0.448	0.448	0.448
		IPLV	0.440	0.440	0.416	0.400	0.400
	Path B	FL	0.556	0.508	0.476	0.468	0.468
		IPLV	0.352	0.320	0.312	0.304	0.304

Air-cooled with condenser	Units: EER (Btu/W)		< 150 Tons	>= 150 Tons	Units: kW/ton	< 150 Tons	>= 150 Ton
	Path A	FL	12.1	12.1	Path A	0.990	0.990
		IPLV	16.4	16.8		0.730	0.714
	Path B	FL	11.6	11.6	Path B	1.031	1.031

	Path B	IPLV	19.0	19.3	Path B	0.633	0.621

COMMERCIAL: A/C & Heat Pump

Return to TOC

MEASURE DETAILS

Description

The replacement of package and split unit air conditioners with higher efficiency models.

Program Criteria

To be eligible, AC must meet or exceed CEE Proposed Standards, Tier 1 or Tier 2 or Advanced Tier

Unit of Measure

One ton of cooling capacity

Baseline Equipment

Honolulu code IECC 2006

High Efficiency Equipment

Equipment must meet or exceed IECC 2015. Actual nameplate data for rated efficiency will be compared against baseline equipment

ALGORITHMS

peak kW savings = $(\eta_{.bs} - \eta_{.he}) * TON * CF$

annual kWh savings = $(\eta_{.bs} - \eta_{.he}) * TON * EFLH$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
$\eta_{.bs}$	Baseline rated efficiency, which depends on cooling capacity of proposed equipment.	See worksheet	Btu/hr-W	< 65,000 BTU/hr units are rated in SEER. Hawai'i Energy assumes IECC 2006 code
$\eta_{.he}$	Proposed measure rated efficiency.	See worksheet	Btu/hr-W	< 65,000 BTU/hr units are rated in SEER. Hawai'i Energy requires CEE Proposed Standards Tier 1/2/Advanced
TON	Unit of equipment cooling capacity	variable	tons	one ton of cooling = 12,000 BTU/h
EFLH	Annual operating hours	Table	hrs	See EFLH & CF tab
CF	Coincidence factor	Table	-	See EFLH & CF tab
Measure Life	Expected duration of energy savings	15	yrs	

SAVINGS

See accompanying AC Worksheet (C_HVAC_AC_WKST)

COMMERCIAL: AC and Heat Pump Savings Calculator

Return to TOC

Step 1: Enter AC nameplate data

Enter AC type:	Split
Enter AC size (Btuh):	65000
Enter building type:	Health
Enter your FL_ee here:	12.2 EER
Enter your PL_ee here:	14.0 IEER

Step 2: Determine if it qualifies

Tier 1 FL:	12.2 EER	pass
Tier 1 PL:	14 IEER	pass
Tier 2 FL:	12.2 EER	pass
Tier 2 PL:	15.4 IEER	fail
Tier 3 FL:	12.6 EER	fail
Tier 3 PL:	18 IEER	fail

Step 3: Calculate savings against baseline

IEER_b:	10.3 EER	1.17 kW/ton	
IEER_ee:	12.2 EER	0.98 kW/ton	Tier 1
Delta:	0.18 kW/ton		
CF:	0.55		
EFLH:	4891 hours		
kW savings:	0.541		
kWh/yr savings:	4,806.93		

Incentive qualifications: CEE Proposed Standards

	Tier 1		Tier 2		Advanced Tier	
	Packaged	Split	Packaged	Split	Packaged	Split
< 65,000	12 EER 15 SEER	12.5 EER 15 SEER	12 EER 16 SEER	13 EER 16 SEER	12.5 EER 17 SEER	13 EER 18 SEER
≥65,000 to 135,000	12.2 EER 14 IEER		12.2 EER 15.4 IEER		12.6 EER 18 IEER	
≥135,000 to 240,000	12.2 EER 13.2 IEER		12.2 EER 14.2 IEER		12.2 EER 17 IEER	
≥240,000 to 760,000	10.5 EER 12.3 IEER		10.8 EER 13.2 IEER		10.8 EER 14.5 IEER	
≥760,000	9.9 EER 11.6 IEER		10.4 EER 12.3 IEER		na	

Baseline specifications: IECC 2006 code

	Packaged	Split
< 65,000	9.7 SEER	10 SEER
≥65,000 to 135,000	10.3 EER	
≥135,000 to 240,000	9.7 EER	
≥240,000 to 760,000	9.5 EER 9.7 IEER	
≥760,000	9.2 EER 9.4 IEER	

COMMERCIAL: Window AC

Return to TOC

UPDATE STATUS

Added in Fall 2019 for PY19 TRM v2.0. Updated in Winter 2020 for PY19 TRM v2.1.

MEASURE DETAILS

Description

The early removal and recycling of a pre-existing inefficient window air conditioning unit and replacement with a new ENERGY STAR qualifying unit, or the installation of a new ENERGY STAR unit without recycling a previous unit through the program. This measure applies to ENERGY STAR dual inverter driven window AC systems.

Program Criteria

For early replacement with recycling projects, documentation must be provided to show that the pre-existing unit was operating and had a meaningful remaining useful life prior to replacement.

Unit of Measure

One window AC unit.

Baseline Equipment

Equipment is assumed to be a window AC unit without reverse cycle, with louvered sides, and a capacity range of less than 28,000 Btu/h. For window AC units not meeting this type or capacity range, confirm program eligibility with Hawai'i Energy and use a custom approach to calculate impacts.

For early replacement with recycling, a dual baseline is required to estimate impacts. The efficiency during the first baseline period corresponds to federal minimum requirements for units manufactured between Oct. 1, 2000 and May 31, 2014 and the efficiency during the second baseline period corresponds to federal minimum requirements for units manufactured as of Jun. 1, 2014. (See Table 1.)

For addition of new systems without recycling a previous unit, or for replacement on burnout of a pre-existing unit, a single baseline that corresponds to federal minimum requirements for units manufactured as of Jun. 1, 2014 is used. (See Table 1.)

High Efficiency Equipment

High efficiency equipment is a new window AC unit without reverse cycle, with louvered sides, and a capacity range of less than 28,000 Btu/h that meets or exceeds the minimum requirements per the ENERGY STAR Product Specification for Room Air Conditioners, Version 4.1. (See Table 1.) This measure includes dual inverter window AC units that are ENERGY STAR certified.

For PY19, all window AC units must meet or exceed the $CEER_{Min}$ ENERGY STAR qualifications.

For PY20 and later, standard window AC units that are not "Connected" (or, "Smart") must meet or exceed the $CEER_{Base}$ qualifications. Connected (Smart) window ACs must meet or exceed the $CEER_{Min}$ ENERGY STAR qualifications.

Table 1: Baseline and ENERGY STAR Specifications

Capacity Bin (Btu/h)	1st Baseline[1]		2nd Baseline[2]		ENERGY STAR[3]			
	$CEER_{BL,1}$	$EER_{BL,1}$	$CEER_{BL,2}$	$EER_{BL,2}$	$CEER_{Base}$	EER_{Base}	$CEER_{Min}$	EER_{Min}
< 8,000	9.6	9.7	11.0	11.1	12.1	12.2	11.5	11.6
8,000 to 13,999	9.7	9.8	10.9	11.0	12.0	12.1	11.4	11.5
14,000 to 19,999	9.6	9.7	10.7	10.8	11.8	11.9	11.2	11.3
20,000 to 27,999	8.4	8.5	9.4	9.5	10.3	10.4	9.8	9.9

[1] See federal minimum $EER_{BL,1}$ requirements for units manufactured between Oct. 1, 2000 to May 31, 2014 at <https://www.govinfo.gov/content/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf>, paragraph (b) on page 472. $CEER_{BL,1}$ is assumed to be $EER_{BL,1}$ / 1.01.

[2] See federal minimum $CEER_{BL,2}$ requirements for units manufactured as of Jun. 1, 2014 at <https://www.govinfo.gov/content/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf>, paragraph (b) on page 472. $EER_{BL,2}$ is assumed to be $CEER_{BL,2}$ * 1.01.

[3] See ENERGY STAR Version 4.1 Room Air Conditioners Program Requirements, available here: <https://www.energystar.gov/products/heating_cooling/air_conditioning_room/partners>. EER is assumed to be CEER * 1.01.

ALGORITHMS

First Baseline Peak Demand Reduction, kW (Early Replacement Only)

$$\Delta kW_{1st} = Capacity * ((1/EER_{BL,1} - 1/EER_{EE})/1000) * CF * PF \quad (1)$$

Second Baseline Peak Demand Reduction, kW (or, Single Baseline for Replace on Burnout)

$$\Delta kW_{2nd} = Capacity * ((1/EER_{BL,2} - 1/EER_{EE})/1000) * CF * PF \quad (2)$$

First Baseline Annual Energy Savings, kWh/yr (Early Replacement Only)

$$\Delta kWh_{1st} = Capacity * ((1/CEER_{BL,1} - 1/CEER_{EE})/1000) * EFLH * PF \quad (3)$$

Second Baseline Annual Energy Savings, kWh/yr (or, Single Baseline for Replace on Burnout)

$$\Delta kWh_{2nd} = Capacity * ((1/CEER_{BL,2} - 1/CEER_{EE})/1000) * EFLH * PF \quad (4)$$

Early Replacement Lifetime Energy Savings, kWh

$$\Delta kWh_{life,ER} = \Delta kWh_{1st} * RUL + \Delta kWh_{2nd} * (EUL - RUL) \quad (5)$$

$life\ ER$ $1st$ $2nd$

Replace on Burnout Lifetime Energy Savings, kWh

$$\Delta kWh_{life,ROB} = \Delta kWh_{2nd} * EUL \tag{6}$$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Source/Notes**
Capacity	Cooling capacity of installed window AC unit	Based on installed unit	Btu/h	Assumes capacity of < 28,000 Btu/h.[1]
$EER_{BL,1}$	Energy efficiency ratio of baseline unit for first baseline period (early replacement)	See Table 1	Btu/Wh	Federal minimum requirement for units manufactured between Oct. 1, 2000 and May 31, 2014.
$EER_{BL,2}$	Energy efficiency ratio of baseline unit for second baseline period (early replacement) or for single baseline (replace on burnout)	See Table 1	Btu/Wh	Assumed to be $CEER_{BL,2}$ * 1.01 per ENERGY STAR data.[2]
EER_{EE}	Energy efficiency ratio of installed high efficiency unit	As installed	Btu/Wh	EER_{EE} is assumed to be $CEER_{EE}$ * 1.01 per ENERGY STAR data.[2]
$CEER_{BL,1}$	Combined energy efficiency ratio of baseline unit for first baseline period (early replacement)	See Table 1	Btu/Wh	Assumed to be $EER_{BL,1}$ / 1.01 per ENERGY STAR data.[2]
$CEER_{BL,2}$	Combined energy efficiency ratio of baseline unit for second baseline period (early replacement) or for single baseline (replace on burnout)	See Table 1	Btu/Wh	Federal minimum requirement for units manufactured as of Jun. 1, 2014.
$CEER_{EE}$	Combined energy efficiency ratio of installed high efficiency unit	As installed	Btu/Wh	Must meet ENERGY STAR Version 4.1 minimum. For PY19, $CEER_{EE} \geq CEER_{Min}$ for all systems. For PY20 and later, $CEER_{EE} \geq CEER_{Min}$ for connected systems and $CEER_{EE} \geq CEER_{Base}$ for standard systems.[3] See Table 1.
CF	Coincidence factor	See Table 2	-	AEG's analysis of DOE's OpenEI load shapes using Hawai'i-specific prototypes, weather data, and peak demand period.

EFLH	Equivalent full load cooling hours	See Table 2	hrs/yr	AEG's analysis of DOE's OpenEI load shapes using Hawaiʻi-specific prototypes and weather data.
PF	Persistence factor	1	-	
Constant	Watt/kilowatt conversion	1,000	W/kW	
RUL	Remaining useful life of measure	3	yrs	Assumed to be 1/3 EUL.
EUL	Effective useful life of measure	9	yrs	DEER 2020.

[1] For room AC units outside of this capacity range, use a custom approach to calculate impacts.

[2] ENERGY STAR specification provided equivalent EER and CEER ratings. For the most popular size band, the EER rating is approximately 1% higher than the CEER. See ENERGY STAR Version 3.0 Room Air Conditioners Program Requirements.

[3] ENERGY STAR has a CEER allowance for connected systems, where $CEER_{Min} = CEER_{Base} - 0.05 * CEER_{Base}$. Per ENERGY STAR, connected systems "shall include the appliance plus all elements (hardware, software) required to enable communication in response to consumer-authorized energy related commands (not including third-party remote management which may be made available solely at the discretion of the manufacturer). These elements may be resident inside or outside of the appliance. This capability shall be supported through one or more means, as identified in Section 4.B.2" of ENERGY STAR Version 4.1 Room Air Conditioners Program Requirements, available here: <https://www.energystar.gov/products/heating_cooling/air_conditioning_room/partners>.

SAVINGS

See the accompanying Window AC worksheet:
(C_HVAC_WindowAC_WKST)

The following equivalent full load hours and coincidence factors are recommended per building type based on simulations of DOE prototypes with Honolulu weather (OpenEI datasets). Applicable building types for this Window AC measure are Education, Grocery, Hotel/Motel, Office, Restaurant, and Retail.

Table 2: Equivalent Full Load Hours and Coincidence Factors for Commercial Cooling in Hawaiʻi

Building Type	EFLH	CF
Avg. Commercial	NA	NA
Cold Storage	NA	NA
Education	2,549	0.43
Grocery	1,531	0.27
Health	NA	NA
Hotel/Motel	4,910	0.60
Industrial	NA	NA
Office	2,754	0.48
Restaurant	2,451	0.40
Retail	1,913	0.29
Warehouse	NA	NA

NA = Building type is not applicable for window AC measure.

RESOURCES

- AEG's Analysis File titled "AEG HPUC Mid-Year PY19 TRM Updates_Analysis File." In addition, the files titled "AEG HPUC Update of Commercial Chillers - Analysis File" and "AEG HPUC EFLH and CF Analysis - Non-Holiday Weekdays" include Hawaiʻi-specific simulation results for determining air conditioning EFLH and CF.
- California Public Utilities Commission, Database of Energy Efficiency Resources, 2020 update, (DEER2020), READI v.2.5.0, Ex Ante Database Support Table Export, EUL_basis, created on 8/24/2018, available here: www.deeresources.com/index.php/homepage. Spreadsheet.
- Code of Federal Regulations, 10 CFR 430.32, Subpart C, Energy and Water Conservation Standards and Their Effective Dates, (b) Room Air Conditioners, page 472, available here: <https://www.govinfo.gov/content/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf>.
- Efficiency Vermont, Technical Reference User Manual, Measure Savings Algorithms and Cost Assumptions, No. 2014-87, Mar. 16, 2015.
- ENERGY STAR Version 3.0 Room Air Conditioners Program Requirements, available here: <https://www.energystar.gov/products/spec/room_air_conditioners_specification_version_3_0_pd>.
- ENERGY STAR Version 4.1 Room Air Conditioners Program Requirements, available here: <https://www.energystar.gov/products/heating_cooling/air_conditioning_room/partners>.
- Michigan Energy Measure Database, v. 2018, https://www.michigan.gov/mpsc/0,4639,7-159-52495_55129---,00.html, filename: "mi_master_measure_database_2018-112917_609672_7."
- Open EI Datasets. Office of Energy Efficiency and Renewable Energy. Commercial and Residential Hourly Load Profiles for All TMY3 Locations in the United States. U.S. Department of Energy Open Data Catalog. Available at: <https://openei.org/doe-opendata/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states>.
- Oversizing of HVAC System: Signatures and Penalties, University of Idaho, Integrated Design Lab-Boise, available here: <http://www.idlboise.com/pdf/papers/ENB_3018_RTU_Measurement_accepted.pdf>. Used to determine correct HVAC oversizing adjustment for EFLH and CF analysis.
- Pennsylvania Technical Reference Manual, State of Pennsylvania, June 2016.
- Texas Technical Reference Manual, Version 6.0, Volume 3: Nonresidential Measures, Program Year 2019, Public Utility Commission of Texas, November 2018.
- 2020 Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 8.0, Volume 2: Commercial and Industrial Measures, Final, Oct. 17, 2019, Effective Jan. 1, 2020, page 195.

COMMERCIAL: Window AC Savings Calculator

Return to TOC

Step 1: Enter AC nameplate data

Is Room AC a Connected (Smart) System?	Yes
Enter Building Type:	Retail
Enter AC type:	Room AC w/ recycling (20,000-27,999 Btu/h)
Enter AC size (Btu/h):	25,000
Enter Full Load Efficiency:*	9.8 EER
Enter Part-Load Efficiency:**	9.8 CEER

* If EER is unknown, use EER = 1.01 * CEER

**If CEER is unknown, use CEER = EER / 1.01

Step 2: Determine if it qualifies

EER_EE_Min	9.9		
CEER_EE_Min	9.8	Pass	
$EER_{BL,2}$	9.5		
$CEER_{BL,2}$	9.4		
$EER_{BL,1}$	8.5	Only for early replacement	
$CEER_{BL,1}$	8.4	Only for early replacement	

Step 3: Calculate savings

CF:	0.29	
EFLH:	1,913	
PF:	1.0	
kW reduction:	0.023	
kW reduction (ER):	0.113	Only for early replacement; this is savings during first baseline period
kWh/yr savings:	207.66	
kWh/yr savings (ER):	813.35	Only for early replacement; this is savings during first baseline period
Lifetime kWh:	3,686.01	

Baseline Specifications

System Type	Replace on Burnout		Early Replacement (First Baseline)	
	$CEER_{BL,2}$	$EER_{BL,2}$	$CEER_{BL,1}$	$EER_{BL,1}$
Room AC w/ recycling (< 8,000 Btu/h)	11.0	11.1	9.6	9.7
Room AC w/o recycling (< 8,000 Btu/h)	11.0	11.1		
Room AC w/ recycling (8,000-13,999 Btu/h)	10.9	11.0	9.7	9.8
Room AC w/o recycling (8,000-13,999 Btu/h)	10.9	11.0		
Room AC w/ recycling (14,000-19,999 Btu/h)	10.7	10.8	9.6	9.7
Room AC w/o recycling (14,000-19,999 Btu/h)	10.7	10.8		
Room AC w/ recycling (20,000-27,999 Btu/h)	9.4	9.5	8.4	8.5
Room AC w/o recycling (20,000-27,999 Btu/h)	9.4	9.5		

Minimum EE Qualifications and Parameters Table

System Type	CEER_EE_Min	EER_EE_Min	CEER_EE_Base	EER_EE_Base	PF	EUL
Room AC w/ recycling (< 8,000 Btu/h)	11.5	11.6	12.1	12.2	1.0	9
Room AC w/o recycling (< 8,000 Btu/h)	11.5	11.6	12.1	12.2	1.0	9
Room AC w/ recycling (8,000-13,999 Btu/h)	11.4	11.5	12.0	12.1	1.0	9
Room AC w/o recycling (8,000-13,999 Btu/h)	11.4	11.5	12.0	12.1	1.0	9
Room AC w/ recycling (14,000-19,999 Btu/h)	11.2	11.3	11.8	11.9	1.0	9
Room AC w/o recycling (14,000-19,999 Btu/h)	11.2	11.3	11.8	11.9	1.0	9
Room AC w/ recycling (20,000-27,999 Btu/h)	9.8	9.9	10.3	10.4	1.0	9
Room AC w/o recycling (20,000-27,999 Btu/h)	9.8	9.9	10.3	10.4	1.0	9

Note: CEER_EE_Base represents the minimum ENERGY STAR efficiency for standard Room AC systems, while CEER_EE_Min represents the minimum ENERGY STAR efficiency for "Connected" (Smart) Room AC systems. The stricter CEER_EE_Base requirements for standard Room AC systems will only apply for PY20 and later. For PY19, the CEER_EE_Min values will apply for both standard and "Connected" Room AC systems.

COMMERCIAL: VFD HVAC Water Pump and Fan

Return to TOC

UPDATE STATUS

Updated in Fall 2018 for PY19 TRM.

MEASURE DETAILS

Description

Variable frequency drive and control installed on full speed pumps and fans, or damped fans, used in HVAC systems.

Program Criteria

* Require pre-notification before projects begin.
* The program reserves the right to perform on-site verifications, both pre- and post-installation.
* Existing equipment must not have a VFD (i.e. – incentives are not available for replacement).
* VFDs on pumps larger than 200 hp may be analyzed on a fully custom basis.
* The VFDs must actively control and vary the pump speed.
* Since VFDs are required by code for a variety of HVAC applications, this measure is only eligible if a VFD would not have been required otherwise.

Unit of Measure

One VFD.

Baseline Equipment

A chilled water or condenser water pump or HVAC fan with no VFD.

High Efficiency Equipment

Motor/pump with VFD installed.

ALGORITHMS

Peak Demand Reduction, kW

$$\Delta kW = HP * kW_{perHP} * (LF/\eta) * CF * SVG_d \quad (1)$$

Annual Energy Savings, kWh/yr

$$\Delta kWh = HP * kW_{perHP} * (LF/\eta) * HRS * SVG_e \quad (2)$$

Lifetime Energy Savings, kWh

$$\Delta kWh_{life} = \Delta kWh * EUL \quad (3)$$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Source/Notes**
HP	Nameplate horsepower	User input	HP	Project specific
kW_{perHP}	kW equivalent of 1 horse power	0.746	kW/HP	Project specific
LF	Load factor (% of full load power in typical operation)	75%	-	LBNL[1]
η	Rated motor efficiency	User input	-	See "C_HVAC_VFD Water Pump Reference" table if nameplate efficiency is missing
SVG_d	Demand savings factor, %. The assumed average reduction of full load enabled by the VFD as a result of lower speed or lower power need.	Table 1	-	Derived using CMUA calculator cited below. [2]
SVG_e	Energy savings factor, %. The assumed average reduction of kWh enabled by the VFD as a result of lower speed or power operation over time.	Table 1	-	CMUA TRM401 Energy Savings Calculator for Pump and Fan VFD [3]
CF	Coincidence factor	User input (CF = 0.5 if unknown)	-	Not accurately stipulated; a custom input is recommended [4]
HRS	Annual equivalent full load operating hours of fan or pump	User input (Table 2 if unknown)	hrs	Not accurately stipulated; a custom input is recommended [5]
EUL	Effective useful life of measure	15	yrs	No change from PY18 TRM; EUL was verified during AEG's 2018 benchmarking

[1] Improving Motor and Drive System Performance: A Sourcebook for Industry, Prepared by Lawrence Berkeley National Laboratory and Resource Dynamics Corporation, Prepared for U.S. Department of Energy, September 2008, pg 15, available here: <https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/motor.pdf>.

[2] Approach for demand savings factors is not specified in PY18 TRM, but during the PY19 TRM update, AEG found the values to be reasonable based on the energy savings factors.

[3] The calculator is available for download here: https://www.cmua.org/energy-efficiency-technical-reference-manual. Click "TRM Spreadsheet 3 - 300 through 505" and then the file is named "TRM401_energy savings calculator_pump and fan VFD_v4_1_14"

[4] The coincidence factor cannot be stipulated based on the cooling system CF, since it will have an inverse relationship to cooling system CF. For example, if a chiller operates at full load during the entire peak demand period, its CF will be high (1.0), but the VFD's CF will be 0 (there will actually be demand penalty due to efficiency losses with addition of VFD controller operating at 100% flow). Therefore, the CF for the VFD measure must be determined by a custom method that ideally takes into account a difference in the load shapes before and after installation of the VFD. In absence of project-specific CF, assume CF = 0.5, since it is reasonable to expect that the VFD demand savings occur during half of the 5-9 pm peak demand period.

[5] Equation 2 requires the annual equivalent full load operating hours of the fan or pump. These hours will vary by fan/pump operating hours, pre-existing control type, and load shape and cannot be accurately stipulated based on cooling system EFLHs. In absence of project-specific HRS, use either 1) the TRM401 calculator to estimate energy savings (preferred), or 2) the EFLHs in Table 2.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

Table 1. Percent Demand and Energy Savings from VFD Given Various Baseline Controls, SVG_d and SVG_e

Measure Savings	Fan kW (typical)	Fan kWh (total)	Pump kW	Pump kWh
Constant Volume	57.0%	49.8%	57.0%	51.0%
Eddy Current Drive	N/A	N/A	20.0%	24.3%
Inlet Damper Box	31.0%	35.6%	N/A	N/A
Inlet Guide Vane, FC	6.0%	10.1%	N/A	N/A
Outlet Damper	22.0%	27.2%	N/A	N/A
Throttle Valve	N/A	N/A	47.0%	45.5%
Average	29.0%	31.0%	41.0%	40.0%

Source: Table 1 is derived from CMUA Energy Savings Calculator-Pump and Fan VFD Retrofit. The calculator is available for download here: https://www.cmua.org/energy-efficiency-technical-reference-manual. Click "TRM Spreadsheet 3 - 300 through 505" and then the file is named "TRM401_energy savings calculator_pump and fan VFD_v4_1_14". This calculator is cited in the CMUA 2017 TRM.

The most typical VFD operation (at 60-80% of rated flow) reduces load from 100% to 43%. However, at 0% flow the VFD is still drawing 5% load in the fan case and 27% load in the pump case.

SAVINGS

Preferred Approach: Semi-Prescriptive Savings Calculator
(Based on user input of project-specific parameters)

Select whether the VFD is for a fan or pump

Fan VFD

Select the type of baseline controls

Constant Volume SVG_d = 57.0% SVG_e = 49.8%

Enter the nameplate horsepower, HP

2

Enter the rated motor efficiency, %

85.5%

Enter the coincidence factor

0.5

Estimate using project-specific information (preferred).
If unknown, use CF = 0.5.

Enter the annual equivalent full load operating hours of the pre-existing fan or pump

4,000	If equivalent full load hours for the fan or pump are unknown, use either: 1) the CMUA TRM410 calculator and enter fan or pump total operating hours and other project parameters to calculate energy (kWh) savings (preferred), or 2) enter the EFLH for cooling for the correct building type from Table 2.

Measure Name	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Fan VFD	0.373 kW	2,607.07 kWh	39,106.05 kWh

Note: Savings in blue result from sample entries above. **They are for illustrative purposes only.**

Alternative Approach: Deemed Per-HP Savings

Table 2. Fan and Pump VFD: Deemed Energy and Demand Savings per HP (Use Rated Motor Efficiency or Water Pump Reference table for η)

Building Type	CF	HRS[1]	Demand Savings Fan (kW/HP)	Energy Savings Fan (kWh/HP)	Demand Savings Chilled Water Pump (kW/hp)	Energy Savings Chilled Water Pump (kWh/hp)	Demand Savings Condenser Water Pump (kW/hp)	Energy Savings Condenser Water Pump (kWh/hp)
Misc. Commercial	0.50	2,594	=0.081/η	=449.92/η	=0.115/η	=580.54/η	=0.115/η	=580.54/η
Cold Storage	0.50	Varies	Varies	Varies	Varies	Varies	Varies	Varies
Education	0.50	2,549	=0.081/η	=442.11/η	=0.115/η	=570.47/η	=0.115/η	=570.47/η
Grocery	0.50	1,531	=0.081/η	=265.54/η	=0.115/η	=342.64/η	=0.115/η	=342.64/η
Health	0.50	4,891	=0.081/η	=848.32/η	=0.115/η	=1094.61/η	=0.115/η	=1094.61/η
Hotel/Motel	0.50	4,910	=0.081/η	=851.61/η	=0.115/η	=1098.86/η	=0.115/η	=1098.86/η
Industrial	0.50	Varies	Varies	Varies	Varies	Varies	Varies	Varies
Office	0.50	2,754	=0.081/η	=477.67/η	=0.115/η	=616.35/η	=0.115/η	=616.35/η
Restaurant	0.50	2,451	=0.081/η	=425.11/η	=0.115/η	=548.53/η	=0.115/η	=548.53/η
Retail	0.50	1,913	=0.081/η	=331.80/η	=0.115/η	=428.13/η	=0.115/η	=428.13/η
Warehouse	0.50	1,033	=0.081/η	=179.17/η	=0.115/η	=231.19/η	=0.115/η	=231.19/η

1 These are EFLH values from AEG's analysis of DOE's OpenEI load shapes for the Cooling end-use using Hawaiʻi-specific prototypes and weather data. Use as a proxy for "HRS" for the HVAC VFD measure only if project-specific data is not available.

Note: This measure has a single baseline. For deemed lifetime energy savings, multiply the energy savings by the EUL.

RESOURCES

- AEG's Analysis File titled "AEG HPUC Update - Com-VFD Water Pump - Analysis file."

- CMUA 2017 TRM, Section 8.1 Pump and Fan Variable Frequency Drive Control Measure, pg. 8.1, available here: <https://www.cmua.org/files/CMUA-POU-TRM_2017_FINAL_12-5-2017%20-%20Copy.pdf>. References the TRM401 pump and fan calculator for savings.
- CMUA TRM401 Energy Savings Calculator for Pump and Fan VFD. The calculator is available for download here: https://www.cmua.org/energy-efficiency-technical-reference-manual. Click "TRM Spreadsheet 3 - 300 through 505" and then the file is named "TRM401_energy savings calculator_pump and fan VFD_v4_1_14"
- Improving Motor and Drive System Performance: A Sourcebook for Industry, Prepared by Lawrence Berkeley National Laboratory and Resource Dynamics Corporation, Prepared for U.S. Department of Energy, September 2008, pg 15, available here: <https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/motor.pdf>.

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If nameplate rated motor efficiency is missing, this table may be used as a source of motor efficiency. Many motors manufactured after Jun 1, 2016 must now meet NEMA premium efficiency requirements. (For the current Federal codes, see https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#se10.3.431_125.)

Induction Motor Efficiency Standards

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Induction Motor Efficiency Standards
See notes at end of tables

Enclosure	Speed	Horsepower	Volt	Old NEMA	NEMA EPACT	IEEE 841	NEMA Premium
ODP	3600	1	460				77.0
ODP	3600	1.5	460	80.0	82.5		84.0
ODP	3600	2	460	82.5	84.0		85.5
ODP	3600	3	460	82.5	84.0		85.5
ODP	3600	5	460	85.5	85.5		86.5
ODP	3600	7.5	460	85.5	87.5		88.5
ODP	3600	10	460	87.5	88.5		89.5
ODP	3600	15	460	89.5	89.5		90.2
ODP	3600	20	460	90.2	90.2		91.0
ODP	3600	25	460	91.0	91.0		91.7
ODP	3600	30	460	91.0	91.0		91.7
ODP	3600	40	460	91.7	91.7		92.4
ODP	3600	50	460	91.7	92.4		93.0
ODP	3600	60	460	93.0	93.0		93.6
ODP	3600	75	460	93.0	93.0		93.6
ODP	3600	100	460	93.0	93.0		93.6
ODP	3600	125	460	93.0	93.6		94.1
ODP	3600	150	460	93.6	93.6		94.1
ODP	3600	200	460	93.6	94.5		95.0
ODP	3600	250	460		94.5		95.0
ODP	3600	300	460		95.0		95.4
ODP	3600	350	460		95.0		95.4
ODP	3600	400	460		95.4		95.8
ODP	3600	450	460		95.8		95.8
ODP	3600	500	460		95.8		95.8
ODP	1800	1	460	82.5	82.5		85.5
ODP	1800	1.5	460	82.5	84.0		86.5
ODP	1800	2	460	82.5	84.0		86.5
ODP	1800	3	460	86.5	86.5		89.5
ODP	1800	5	460	86.5	87.5		89.5
ODP	1800	7.5	460	88.5	88.5		91.0
ODP	1800	10	460	88.5	89.5		91.7

ODP	1800	15	460	90.2	91.0		93.0
ODP	1800	20	460	91.0	91.0		93.0

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Induction Motor Efficiency Standards
See notes at end of tables

Enclosure	Speed	Horsepower	Volt	Old NEMA	NEMA EPACT	IEEE 841	NEMA Premium
ODP	1800	15	460	90.2	91.0		93.0
ODP	1800	20	460	91.0	91.0		93.0
ODP	1800	25	460	91.7	91.7		93.6
ODP	1800	30	460	91.7	92.4		94.1
ODP	1800	40	460	92.4	93.0		94.1
ODP	1800	50	460	92.4	93.0		94.5
ODP	1800	60	460	93.0	93.6		95.0
ODP	1800	75	460	93.6	94.1		95.0
ODP	1800	100	460	93.6	94.1		95.4
ODP	1800	125	460	93.6	94.5		95.4
ODP	1800	150	460	94.1	95.0		95.8
ODP	1800	200	460	94.1	95.0		95.8
ODP	1800	250	460		95.4		95.8
ODP	1800	300	460		95.4		95.8
ODP	1800	350	460		95.4		95.8
ODP	1800	400	460		95.4		95.8
ODP	1800	450	460		95.8		96.2
ODP	1800	500	460		95.8		96.2
ODP	1200	1	460	77.0	80.0		82.5
ODP	1200	1.5	460	82.5	84.0		86.5
ODP	1200	2	460	84.0	85.5		87.5
ODP	1200	3	460	85.5	86.5		88.5
ODP	1200	5	460	86.5	87.5		89.5
ODP	1200	7.5	460	88.5	88.5		90.2
ODP	1200	10	460	90.2	90.2		91.7
ODP	1200	15	460	89.5	90.2		91.7
ODP	1200	20	460	90.2	91.0		92.4
ODP	1200	25	460	91.0	91.7		93.0
ODP	1200	30	460	91.7	92.4		93.6
ODP	1200	40	460	91.7	93.0		94.1
ODP	1200	50	460	91.7	93.0		94.1
ODP	1200	60	460	92.4	93.6		94.5
ODP	1200	75	460	93.0	93.6		94.5
ODP	1200	100	460	93.6	94.1		95.0

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Induction Motor Efficiency Standards
See notes at end of tables

Enclosure	Speed	Horsepower	Volt	Old NEMA	NEMA EPACT	IEEE 841	NEMA Premium
ODP	1200	125	460	93.6	94.1		95.0
ODP	1200	150	460	93.6	94.5		95.4
ODP	1200	200	460	94.1	94.5		95.4
ODP	1200	250	460		95.4		95.4
ODP	1200	300	460		95.4		95.4

ODP	1200	350	460		95.4		95.4
ODP	1200	400	460				95.8
ODP	1200	450	460				96.2
ODP	1200	500	460				96.2
ODP	900	1	460	72.0	74.0		
ODP	900	1.5	460	75.5	75.5		
ODP	900	2	460	85.5	85.5		
ODP	900	3	460	86.5	86.5		
ODP	900	5	460	87.5	87.5		
ODP	900	7.5	460	88.5	88.5		
ODP	900	10	460	89.5	89.5		
ODP	900	15	460	89.5	89.5		
ODP	900	20	460	90.2	90.2		
ODP	900	25	460	90.2	90.2		
ODP	900	30	460	91.0	91.0		
ODP	900	40	460	90.2	91.0		
ODP	900	50	460	91.7	91.7		
ODP	900	60	460	92.4	92.4		
ODP	900	75	460	93.6	93.6		
ODP	900	100	460	93.6	93.6		
ODP	900	125	460	93.6	93.6		
ODP	900	150	460	93.6	93.6		
ODP	900	200	460	93.6	93.6		
ODP	900	250	460		94.5		
ODP	900	300	460				
ODP	900	350	460				
ODP	900	400	460				
ODP	900	450	460				
ODP	900	500	460				

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Induction Motor Efficiency Standards
See notes at end of tables

Enclosure	Speed	Horsepower	Volt	Old NEMA	NEMA EPACT	IEEE 841	NEMA Premium
TEFC	3600	1	460		75.5	77.0	77.0
TEFC	3600	1.5	460	78.5	82.5	84.0	84.0
TEFC	3600	2	460	81.5	84.0	85.5	85.5
TEFC	3600	3	460	82.5	85.5	86.5	86.5
TEFC	3600	5	460	85.5	87.5	88.5	88.5
TEFC	3600	7.5	460	85.5	88.5	89.5	89.5
TEFC	3600	10	460	87.5	89.5	90.2	90.2
TEFC	3600	15	460	87.5	90.2	91.0	91.0
TEFC	3600	20	460	88.5	90.2	91.0	91.0
TEFC	3600	25	460	89.5	91.0	91.7	91.7
TEFC	3600	30	460	89.5	91.0	91.7	91.7
TEFC	3600	40	460	90.2	91.7	92.4	92.4
TEFC	3600	50	460	90.2	92.4	93.0	93.0
TEFC	3600	60	460	91.7	93.0	93.6	93.6
TEFC	3600	75	460	92.4	93.0	93.6	93.6
TEFC	3600	100	460	93.0	93.6	94.1	94.1
TEFC	3600	125	460	93.0	94.5	95.0	95.0
TEFC	3600	150	460	93.0	94.5	95.0	95.0
TEFC	3600	200	460	94.1	95.0	95.4	95.4

TEFC	3600	250	460		95.4	95.4	95.8
TEFC	3600	300	460		95.4	95.4	95.8
TEFC	3600	350	460		95.4	95.4	95.8
TEFC	3600	400	460		95.4	95.4	95.8
TEFC	3600	450	460		95.4	95.4	95.8
TEFC	3600	500	460		95.4	95.4	95.8
TEFC	1800	1	460	80.0	82.5	84.0	85.5
TEFC	1800	1.5	460	81.5	84.0	85.5	86.5
TEFC	1800	2	460	82.5	84.0	85.5	86.5
TEFC	1800	3	460	84.0	87.5	88.5	89.5
TEFC	1800	5	460	85.5	87.5	88.5	89.5
TEFC	1800	7.5	460	87.5	89.5	90.2	91.7
TEFC	1800	10	460	87.5	89.5	90.2	91.7
TEFC	1800	15	460	88.5	91.0	91.7	92.4

Induction Motor Efficiency Standards
See notes at end of tables

Enclosure	Speed	Horsepower	Volt	Old NEMA	NEMA EPACT	IEEE 841	NEMA Premium
TEFC	1800	20	460	90.2	91.0	91.7	93.0
TEFC	1800	25	460	91.0	92.4	93.0	93.6
TEFC	1800	30	460	91.0	92.4	93.0	93.6
TEFC	1800	40	460	91.7	93.0	93.6	94.1
TEFC	1800	50	460	92.4	93.0	93.6	94.5
TEFC	1800	60	460	93.0	93.6	94.1	95.0
TEFC	1800	75	460	93.0	94.1	94.5	95.4
TEFC	1800	100	460	93.6	94.5	95.0	95.4
TEFC	1800	125	460	93.6	94.5	95.0	95.4
TEFC	1800	150	460	94.1	95.0	95.4	95.8
TEFC	1800	200	460	94.5	95.0	95.4	96.2
TEFC	1800	250	460		95.0	95.0	96.2
TEFC	1800	300	460		95.4	95.4	96.2
TEFC	1800	350	460		95.4	95.4	96.2
TEFC	1800	400	460		95.4	95.4	96.2
TEFC	1800	450	460		95.4	95.4	96.2
TEFC	1800	500	460		95.8	95.4	96.2
TEFC	1200	1	460	75.5	80.0	81.5	82.5
TEFC	1200	1.5	460	82.5	85.5	86.5	87.5
TEFC	1200	2	460	82.5	86.5	87.5	88.5
TEFC	1200	3	460	84.0	87.5	88.5	89.5
TEFC	1200	5	460	85.5	87.5	88.5	89.5
TEFC	1200	7.5	460	87.5	89.5	90.2	91.0
TEFC	1200	10	460	87.5	89.5	90.2	91.0
TEFC	1200	15	460	89.5	90.2	91.0	91.7
TEFC	1200	20	460	89.5	90.2	91.0	91.7
TEFC	1200	25	460	90.2	91.7	92.4	93.0
TEFC	1200	30	460	91.0	91.7	92.4	93.0
TEFC	1200	40	460	91.7	93.0	93.6	94.1
TEFC	1200	50	460	91.7	93.0	93.6	94.1
TEFC	1200	60	460	91.7	93.6	94.1	94.5
TEFC	1200	75	460	93.0	93.6	94.1	94.5
TEFC	1200	100	460	93.0	94.1	94.5	95.0

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Induction Motor Efficiency Standards
See notes at end of tables

Enclosure	Speed	Horsepower	Volt	Old NEMA	NEMA EPACT	IEEE 841	NEMA Premium
TEFC	1200	125	460	93.0	94.1	94.5	95.0
TEFC	1200	150	460	94.1	95.0	95.4	95.8
TEFC	1200	200	460	94.1	95.0	95.4	95.8
TEFC	1200	250	460		95.0	95.0	95.8
TEFC	1200	300	460		95.0	95.0	95.8
TEFC	1200	350	460		95.0	95.0	95.8
TEFC	1200	400	460				95.8
TEFC	1200	450	460				95.8
TEFC	1200	500	460				95.8
TEFC	900	1	460	72.0	74.0	75.5	
TEFC	900	1.5	460	75.5	77.0	78.5	
TEFC	900	2	460	82.5	82.5	84.0	
TEFC	900	3	460	81.5	84.0	85.5	
TEFC	900	5	460	84.0	85.5	86.5	
TEFC	900	7.5	460	85.5	85.5	86.5	
TEFC	900	10	460	87.5	88.5	89.5	
TEFC	900	15	460	88.5	88.5	89.5	
TEFC	900	20	460	89.5	89.5	90.2	
TEFC	900	25	460	89.5	89.5	90.2	
TEFC	900	30	460	90.2	91.0	91.7	
TEFC	900	40	460	90.2	91.0	91.7	
TEFC	900	50	460	91.0	91.7	92.4	
TEFC	900	60	460	91.7	91.7	92.4	
TEFC	900	75	460	93.0	93.0	93.6	
TEFC	900	100	460	93.0	93.0	93.6	
TEFC	900	125	460	93.6	93.6	94.1	
TEFC	900	150	460	93.6	93.6	94.1	
TEFC	900	200	460	94.1	94.1	94.5	
TEFC	900	250	460		94.5	94.5	
TEFC	900	300	460				
TEFC	900	350	460				
TEFC	900	400	460				
TEFC	900	450	460				

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Induction Motor Efficiency Standards
See notes at end of tables

Enclosure	Speed	Horsepower	Volt	Old NEMA	NEMA EPACT	IEEE 841	NEMA Premium
TEFC	900	500	460				
ODP	3600	250	4000				94.5
ODP	3600	300	4000				94.5
ODP	3600	350	4000				94.5
ODP	3600	400	4000				94.5
ODP	3600	450	4000				94.5
ODP	3600	500	4000				94.5
ODP	1800	250	4000				95.0
ODP	1800	300	4000				95.0

ODP	1800	350	4000				95.0
ODP	1800	400	4000				95.0
ODP	1800	450	4000				95.0
ODP	1800	500	4000				95.0
ODP	1200	250	4000				95.0
ODP	1200	300	4000				95.0
ODP	1200	350	4000				95.0
ODP	1200	400	4000				95.0
ODP	1200	450	4000				95.0
ODP	1200	500	4000				95.0
ODP	3600	300	4000				94.5
ODP	3600	350	4000				94.5
ODP	3600	400	4000				94.5
ODP	3600	450	4000				94.5
ODP	3600	500	4000				94.5
ODP	900	250	4000				
ODP	900	300	4000				
ODP	900	350	4000				
ODP	900	400	4000				
ODP	900	450	4000				
ODP	900	500	4000				
TEFC	3600	250	4000			95.0	95.0
TEFC	3600	300	4000			95.0	95.0
TEFC	3600	350	4000			95.0	95.0

Induction Motor Efficiency Standards
See notes at end of tables

Enclosure	Speed	Horsepower	Volt	Old NEMA	NEMA EPACT	IEEE 841	NEMA Premium
TEFC	3600	400	4000			95.0	95.0
TEFC	3600	450	4000			95.0	95.0
TEFC	3600	500	4000			95.0	95.0
TEFC	1800	250	4000			95.0	95.0
TEFC	1800	300	4000			95.0	95.0
TEFC	1800	350	4000			95.0	95.0
TEFC	1800	400	4000			95.0	95.0
TEFC	1800	450	4000			95.0	95.0
TEFC	1800	500	4000			95.0	95.0
TEFC	1200	250	4000			95.0	95.0
TEFC	3600	300	4000			95.0	95.0
TEFC	3600	350	4000			95.0	95.0
TEFC	3600	400	4000			95.0	95.0
TEFC	3600	450	4000			95.0	95.0
TEFC	3600	500	4000			95.0	95.0
TEFC	900	250	4000			95.0	
TEFC	900	300	4000			95.0	
TEFC	900	350	4000			95.0	
TEFC	900	400	4000			95.0	
TEFC	900	450	4000			95.0	
TEFC	900	500	4000			95.0	

Notes:

Speed Synchronous speed: equal to 7200 / #poles

Horsepower	Rated Horsepower
Volt	Volt Code: 460 means = or < 600 V; 4000 means > 600 V
Old NEMA	Earliest NEMA standard for “Energy Efficient” label.
	Lower than current “Energy Efficient” standard
NEMA EPACT	Current NEMA standard for “Energy Efficient” label.
	Sames as EPAct but EPAct doesn’t exist at >200 HP or <1200 RPM
IEEE 841	IEEE 841-2001 standard
NEMA Premium	NEMA standard for “Premium Efficient” label.

WSUEEP02_029 April 2002, Revised July 2002, Updated October 2005

COMMERCIAL: VRF

Return to TOC

UPDATE STATUS

Updated in Spring 2019 for PY19 TRM.

MEASURE DETAILS

Description

Inverter-driven direct expansion AC and heat pump systems that use variable flow distributed refrigerant technology for cooling and heating are able to more closely match the AC system's output with the building's cooling requirements. These systems consist of: an outdoor unit with a single variable speed compressor or multiple staged compressors capable of varying system capacity and distributing refrigerant through a piping network, indoor evaporator units with variable speed fans designed for single zone air distribution, and zonal temperature controls. Variable refrigerant flow implies three or more steps of control on common, interconnecting piping.

Program Criteria

Eligible equipment shall have a minimum rated efficiency that is at least 10% higher than the energy code-compliant standard for equivalently-sized equipment. Systems with capacities ≥ 240,000 Btu/h in total should be evaluated on a custom basis.

Unit of Measure

Measure impacts are calculated per system.

Baseline Equipment

The baseline equipment meets the current State of Hawaiʻi code, which is IECC 2015 and is consistent with the national ASHRAE 90.1-2016 standard that manufacturers adhere to. All counties are expected to adopt IECC 2015 or better by March 2019.

High Efficiency Equipment

High efficiency equipment must exceed ASHRAE efficiencies by 10% or more. An additional tier (20% above ASHRAE) has also been included for this measure. Actual nameplate data for rated efficiency will be compared against ASHRAE standard efficiency.

ALGORITHMS

Peak Demand Reduction, kW

$$\Delta kW = Capacity * ((1/EER_{BL} - 1/EER_{EE})/1000) * CF \tag{1}$$

Annual Energy Savings, kWh/yr

$$\Delta kWh = Capacity * ((1/IEER_{BL} - 1/IEER_{EE})/1000) * EFLH \tag{2}$$

[SEER used in place of IEER for units <65,000 Btu/h]

Lifetime Energy Savings, kWh

$$\Delta kWh_{life} = \Delta kWh * EUL \quad (3)$$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Source/Notes**
Capacity	Capacity, in Btu/h, of installed unit	Based on installed unit	Btu/h	As installed
EER_{BL}	Full load energy efficiency rating of baseline unit	See Table 1	Btu/Wh	Equal to the minimum efficiency requirements of the ASHRAE 90.1-2016 standard
EER_{EE}	Full load energy efficiency rating of installed high efficiency unit	User input	Btu/Wh	As installed. At least 10% better than ASHRAE 90.1.
$IEER_{BL}$ or $SEER_{BL}$	Integrated or Seasonal Energy Efficiency Rating of baseline unit. SEER used for units <65,000 Btu/h.	See Table 1	Btu/Wh	ASHRAE 90.1-2016
$IEER_{EE}$ or $SEER_{EE}$	Integrated or Seasonal Energy Efficiency Rating installed high efficiency unit. SEER used for units <65,000 Btu/h.	User input	Btu/Wh	As installed. At least 10% better than ASHRAE 90.1.
EFLH	Equivalent full load cooling hours	See Table 2	hrs	AEG's analysis of DOE's OpenEI load shapes using Hawaiʻi-specific prototypes and weather data
CF	Coincidence factor	See Table 2	-	AEG's analysis of DOE's OpenEI load shapes using Hawaiʻi-specific prototypes, weather data, and peak demand period
EUL	Effective useful life of measure	20	years	AEG's Fall 2018 Benchmarking

Table 1: VRF Multisplit System, Minimum Baseline Efficiency[1]

System Type	Capacity Bin	Part-Load Efficiency		Full Load
		SEER	**IEER**	**EER**
Split System AC	< 65,000 Btu/h	14	--	*11.5*[2]
Single Package AC	< 65,000 Btu/h	14	--	*11.5*
Air-Cooled AC	≥ 65,000 and < 135,000 Btu/h	--	12.9	11.2
Air-Cooled AC	≥ 135,000 and < 240,000 Btu/h	--	12.4	11
Air-Cooled AC	≥ 240,000 and < 760,000 Btu/h	--	11.6	10
Air-Source HP	< 65,000 Btu/h	14	--	*11.5*

Air-Source HP	≥ 65,000 and < 135,000 Btu/h	--	12.2	11
Air-Source HP	≥ 135,000 and < 240,000 Btu/h	--	11.6	10.6
Air-Source HP	≥ 240,000 Btu/h	--	10.6	9.5

Table 1 Sources: ANSI/ASHRAE/IES Standard 90.1 -2016, Table 6.8.1-1 and 6.8.1-2; 2015 International Energy Conservation Code Tables C403.2.3(1) and C403.2.3(2)

Table 1 Footnotes:

1. The efficiencies for units ≥ 65,000 Btu/h were developed using the "Electric Resistance Heat (or None)" option in the ASHRAE 90.1 tables. Gas-fired space heating systems are not expected in Hawaiʻi.

2. The Air Conditioning, Heating, and Refrigeration Institute (AHRI) equipment directory was used to determine a 1st quartile value of 11.5 EER for 14.0 SEER units. Since full-load efficiencies are not specified for this equipment, the peak efficiency of installed equipment does not have to be 10% more efficient for the EER parameter.

SAVINGS

For calculations specific to the unit in question, please see the accompanying VRF calculation worksheet: (C_HVAC_VRF_WKST)

The following full load hours and coincidence factors are recommended per building type based on NREL simulations of DOE prototypes with Honolulu weather. Retrofits in cold storage and industrial facilities should be evaluated as custom measures unless the equipment is used for HVAC and not process cooling loads. When used for HVAC, other building type designations (e.g., Office) may be applied.

Table 2: Equivalent Full Load Hours and Coincident Factors for Commercial Cooling in Hawaiʻi

Building Type	EFLH	CF
Avg. Commercial	2,594	0.38
Cold Storage	Varies	Varies
Education	2,549	0.43
Grocery	1,531	0.27
Health	4,891	0.55
Hotel/Motel	4,910	0.60
Industrial	Varies	Varies
Office	2,754	0.48
Restaurant	2,451	0.40
Retail	1,913	0.29
Warehouse	1,033	0.01

EFLH and CF values developed using: Office of Energy Efficiency and Renewable Energy. Commercial and Residential Hourly Load Profiles for All TMY3 Locations in the United States. U.S. Department of Energy Open Data Catalog. Available at: https://openei.org/doe-opendata/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states.

RESOURCES

- AEG's Analysis File titled "AEG HPUC Update - Ductless Systems - Analysis File."

- Hawai‘i Energy. Code baseline specification based on Hawai‘i Energy: <https://hawaiienergy.com/resources#hawaii-codes> and <http://energy.hawaii.gov/hawaii-energy-building-code/2015-iecc-update>.

  All equipment is expected to meet minimum ASHRAE standards. ASHRAE requires a subscription to see the standard in full; AEG used staff subscriptions to ASHRAE to obtain the latest 90.1-2016 standard. The minimum efficiency levels are also summarized in various publicly available sources, including this one from Trane: <https://www.trane.com/content/dam/Trane/Commercial/global/products-systems/education-training/engineers-newsletters/standards-codes/ADMAPN053EN_0315.pdf>.

- Hawai‘i Energy. The IECC 2015 with Hawai‘i Amendments Commercial Reviewer and Designer Checklist requires efficient HVAC equipment to be 10% better than the minimum efficiency. Available at: <https://hawaiienergy.com/files/resources/2015-IECC_CommercialReviewer_Checklist.pdf>.

- Office of Energy Efficiency and Renewable Energy. Commercial and Residential Hourly Load Profiles for All TMY3 Locations in the United States. U.S. Department of Energy Open Data Catalog. Available at: <https://openei.org/doe-opendata/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states>.
- Oversizing of HVAC System: Signatures and Penalties, University of Idaho, Integrated Design Lab-Boise, available here: <http://www.idlboise.com/pdf/papers/ENB_3018_RTU_Measurement_accepted.pdf>. Used to determine correct HVAC oversizing adjustment for EFLH and CF analysis.

Commercial: HVAC Savings Calculator - Variable Refrigerant Flow Systems

Return to TOC

Step 1: Enter AC nameplate data

Enter AC type:	Split System AC	
Enter AC size (Btu/h):	160,000	
Enter building type:	Avg. Commercial	
Enter Full Load Efficiency:	12.2	EER
Enter Part-Load Efficiency:	14.0	IEER

Step 2: Determine if it qualifies

	Full Load	Part Load
Tier 1 (ASHRAE + 10%)	Pass	Pass
Tier 2 (ASHRAE + 20%)	Fail	Fail
Capacity Bin:	≥ 135,000 and < 240,000 Btu/h	
Corresponding Baseline Efficiency (Full Load):	11	EER
Corresponding Baseline Efficiency (Part-Load):	12.4	IEER

Step 3: Calculate savings

CF:	0.38
EFLH:	2,594
kW savings:	0.544
kWh/yr savings:	3,825.25
Lifetime kWh:	76,505.00
Meets	Tier 1 (ASHRAE + 10%)

Note: This is a new calculator. While this is currently set up to be consistent with the VRF analysis, it should be readily applicable to commercial AC/Heat Pump measures.

Table 1: VRF Multisplit System, Minimum Baseline Efficiencies (ASHRAE 90.1-2016)

System Type	Capacity Bin	Part-Load Efficiency		Full Load Efficiency	Concatenation
		SEER	IEER	EER	
Split System AC	< 65,000 Btu/h	14	--	*11.5*	Split System AC - < 65,000 Btu/h
Single Package AC	< 65,000 Btu/h	14	--	*11.5*	Single Package AC - < 65,000 Btu/h
Split System AC	≥ 65,000 and < 135,000 Btu/h	--	12.9	11.2	Split System AC - ≥ 65,000 and < 135,000 Btu/h
Split System AC	≥ 135,000 and < 240,000 Btu/h	--	12.4	11	Split System AC - ≥ 135,000 and < 240,000 Btu/h
Split System AC	≥ 240,000 Btu/h	--	11.6	10	Split System AC - ≥ 240,000 Btu/h
Single Package AC	≥ 65,000 and < 135,000 Btu/h	--	12.9	11.2	Single Package AC - ≥ 65,000 and < 135,000 Btu/h
Single Package AC	≥ 135,000 and < 240,000 Btu/h	--	12.4	11	Single Package AC - ≥ 135,000 and < 240,000 Btu/h
Single Package AC	≥ 240,000 Btu/h	--	11.6	10	Single Package AC - ≥ 240,000 Btu/h
Air-Source HP	< 65,000 Btu/h	14	--	*11.5*	Air-Source HP - < 65,000 Btu/h
Air-Source HP	≥ 65,000 and < 135,000 Btu/h	--	12.2	11	Air-Source HP - ≥ 65,000 and < 135,000 Btu/h
Air-Source HP	≥ 135,000 and < 240,000 Btu/h	--	11.6	10.6	Air-Source HP - ≥ 135,000 and < 240,000 Btu/h
Air-Source HP	≥ 240,000 Btu/h	--	10.6	9.5	Air-Source HP - ≥ 240,000 Btu/h

VRF Multisplit System, Minimum Qualifying Efficiencies - Tier 1 (ASHRAE 90.1-2016 + 10%)

System Type	Capacity Bin	Part-Load Efficiency		Full Load Efficiency
		SEER	IEER	EER
Split System AC	< 65,000 Btu/h	15.4	--	*11.5*
Single Package AC	< 65,000 Btu/h	15.4	--	*11.5*
Split System AC	≥ 65,000 and < 135,000 Btu/h	--	14.2	12.3
Split System AC	≥ 135,000 and < 240,000 Btu/h	--	13.6	12.1
Split System AC	≥ 240,000 and < 760,000 Btu/h	--	12.8	11.0
Single Package AC	≥ 65,000 and < 135,000 Btu/h	--	14.2	12.3
Single Package AC	≥ 135,000 and < 240,000 Btu/h	--	13.6	12.1
Single Package AC	≥ 240,000 and < 760,000 Btu/h	--	12.8	11.0
Air-Source HP	< 65,000 Btu/h	15.4	--	*11.5*
Air-Source HP	≥ 65,000 and < 135,000 Btu/h	--	13.4	12.1
Air-Source HP	≥ 135,000 and < 240,000 Btu/h	--	12.8	11.7
Air-Source HP	≥ 240,000 Btu/h	--	11.7	10.5

VRF Multisplit System, Minimum Qualifying Efficiencies - Tier 2 (ASHRAE 90.1-2016 + 20%)

System Type	Capacity Bin	Part-Load Efficiency	Full Load Efficiency

System Type	Capacity Btu	SEER	IEER	EER
Split System AC	< 65,000 Btu/h	16.8	--	*11.5*
Single Package AC	< 65,000 Btu/h	16.8	--	*11.5*
Split System AC	≥ 65,000 and < 135,000 Btu/h	--	15.5	13.4
Split System AC	≥ 135,000 and < 240,000 Btu/h	--	14.9	13.2
Split System AC	≥ 240,000 and < 760,000 Btu/h	--	14.0	12.0
Single Package AC	≥ 65,000 and < 135,000 Btu/h	--	15.5	13.4
Single Package AC	≥ 135,000 and < 240,000 Btu/h	--	14.9	13.2
Single Package AC	≥ 240,000 and < 760,000 Btu/h	--	14.0	12.0
Air-Source HP	< 65,000 Btu/h	16.8	--	*11.5*
Air-Source HP	≥ 65,000 and < 135,000 Btu/h	--	14.8	13.2
Air-Source HP	≥ 135,000 and < 240,000 Btu/h	--	14.0	12.7
Air-Source HP	≥ 240,000 Btu/h	--	12.8	11.4

Equivalent Full Load Hours and Coincident Factors for Commercial Cooling in Hawaiʻi

Building Type	EFLH	CF
Avg. Commercial	2,594	0.38
Cold Storage	Varies	Varies
Education	2,549	0.43
Grocery	1,531	0.27
Health	4,891	0.55
Hotel/Motel	4,910	0.60
Industrial	Varies	Varies
Office	2,754	0.48
Restaurant	2,451	0.40
Retail	1,913	0.29
Warehouse	1,033	0.01

COMMERCIAL: Guest Room Energy Management System

Return to TOC

UPDATE STATUS

Updated in Fall 2019 for PY19 TRM v2.0.

MEASURE DETAILS

Description

A Guest Room Energy Management System uses a passive infrared occupancy sensor to sense whether the guest room in a hotel/motel is occupied or unoccupied, and then powers down or adjusts the setpoints of the HVAC unit during periods of no occupancy. The controller may be physically located in a separate control box, jointly with an occupancy sensor, or jointly with a thermostat depending on the vendor and existing site parameters.

Program Criteria

• All entry and lanai doors must have door switches or other technologies that will de-energize the fan coil unit (FCU) when the door remains open.
• All main rooms must have occupancy sensors that will de-energize the FCU when no movement is detected for a given period of time (not to exceed 15 minutes).
• Thermostat controls must be preset.
• Applicant must be on a Commercial Rate Schedule (reference utility bill).

Unit of Measure

Per room/unit controlled by EMS.

Baseline Equipment

No Guest Room EMS controls.

High Efficiency Equipment

Guest Room EMS controls.

ALGORITHMS

Peak Demand Reduction, kW/room

$$\Delta kW = \Delta kW\ per\ Room \quad (1)$$

Annual Energy Savings, kWh/yr-room

$$\Delta kWh = \Delta kWh\ per\ Room \quad (2)$$

Lifetime Energy Savings, kWh/room

$$\Delta kWh_{life} = \Delta kWh * EUL \quad (3)$$

life

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Source/Notes**
ΔkWh per Room	Deemed annual energy savings per room, per unit	See Table 1	kWh/yr	See Footnote 1
ΔkW per Room	Deemed demand reduction per room, per unit	See Table 1	kW	See Footnote 1
EUL	Effective useful life of measure	15	years	No change from PY18 TRM; EUL was verified during AEG's 2018 benchmarking.

[1] Savings were determined using an average savings percentage of 35% from five (5) PTAC case studies documented in a 2016 Pacific Gas & Electric (PG&E) Non-DEER Workpaper applied to consumption estimates from Hawai'i commercial prototype hourly load profiles from the U.S. DOE OpenEI Data Catalog. Demand reductions were then determined using the method recommended by the PG&E workpaper and coincidence factors determined from Hawai'i hourly load profiles.

SAVINGS

Table 1: Deemed Savings per Room/Unit for Guest Room Energy Management System

Building Type	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Large Hotel, 100+ Rooms	0.368 kW/room	1,214.10 kWh/room	18,211.50 kWh/room
Small Hotel/Motel, <100 Rooms	0.274 kW/room	872.29 kWh/room	13,084.35 kWh/room

RESOURCES

- AEG's Analysis File titled "AEG HPUC Update - Guest Room EMS - Analysis File" and "AEG HPUC Mid-Year PY19 TRM Updates_Analysis File."
- BC Hydro M&V Study. The Blue Horizon Hotel, "Two Passive Infrared Motion Sensor Systems for in Room Energy Hotel Management" November 2007.
- DOE New Construction Commercial Reference Building Prototype Summary Files. Version 1.3_5.0. September 27, 2010. Available as part of the compressed files at: https://www.energy.gov/eere/buildings/new-construction-commercial-reference-buildings.
- FEMP Case Study. The Music Road Hotel, "Demonstration and Evaluation of HVAC Controller for Lodging Facilities", July 2002.
- KEMA Focus On Energy Evaluation, WI: bpdeemedsavingsmanuav10_evaluationreport.pdf.
- Office of Energy Efficiency and Renewable Energy. Commercial and Residential Hourly Load Profiles for All TMY3 Locations in the United States. U.S. Department of Energy Open Data Catalog. Available at: https://openei.org/doe-opendata/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states.

- Pacific Gas and Electric Company. PTAC/PTHP/Split AC Controller. Work Paper PGE3PHVC149 Revision 2, Measure Code HA82. January 1, 2016. Available at: http://www.deeresources.net/workpapers.

- QuEST PTAC Controls Program, Technical Work Paper (PG&E): HOSPITALITY – PTAC QUEST).doc

COMMERCIAL: Interior Lighting

Return to TOC

UPDATE STATUS

Updated in Fall 2018 for PY19 TRM.

MEASURE DETAILS

Description

Hawaiʻi Energy offers several types of prescriptive lighting measures for Commercial buildings through the BEEM and BHTR programs. The measures related to replacing lamps and fixtures with LED alternatives of comparable brightness (lumens) are covered here.

Program Criteria

This measure is applicable to both the BEEM and BHTR programs.

The replacement LED lamp must be on the Consortium for Energy Efficiency's (CEE's) most recent Commercial Lighting Qualifying Products List, have an ENERGY STAR label, or be on DesignLights Consortium's Qualified Product List (DLC QPL).

For direct install projects, the replacement lamps must be of equivalent brightness (measured in lumens) as the baseline lamps. In the case of the delamping measure, the replacement lamp (with an added reflector as needed) must be of sufficient brightness to meet the requirements of the space. For delamping, the lamp and lamp holder ("tombstone") must be permanently removed.

Unit of Measure

One lamp.

Baseline Equipment

Several of the lighting measures require a dual baseline approach to account for either: 1) early replacement, or 2) changes in federal codes and standards that will take place in the near future.

For BEEM, lighting is delivered through a midstream approach; the most applicable baseline is replace on burnout (ROB). For BHTR, lighting is delivered through the Small Business Direct Install Lighting (SBDIL) program; since lighting is directly installed, the most applicable baseline is early replacement.

For ROB projects, the baseline must comply with federal codes and standards that are in place at the time of the replacement as well as with any known future federal requirements that will be in place during the equipment's lifetime. Therefore, all lamps that are subject to the 2020 Backstop requirement of 45 lumens per Watt set forth in the Energy Independence and Securities Act (EISA) 2007 legislation must use a dual baseline for PY19. The first baseline will be current standard as of 2019; the second baseline will be the future standard as of 2020. For PY20 and later, there will be a single baseline until such time that a new standard is set.

All early replacement projects (only applicable to BHTR/SBDIL linear lamps) require a dual baseline. The first baseline is the pre-existing equipment, which has been estimated as a blend of 30% T12 and 70% T8 fluorescent lamps. The pre-existing equipment is assumed to have a remaining useful life (RUL) of one-third of the Effective Useful Life (EUL) of the fluorescent lamps. The second baseline must comply with the current federal requirements for general service fluorescent lamps that took effect on January 26, 2018 (10 CFR 430.32(n), paragraph (4)). Only lamps that are in working order at the time of the replacement qualify for early replacement. If the pre-existing lamps cannot be verified to be in working order, an ROB baseline must be used.

High Efficiency Equipment

For lamp replacement projects, the high efficiency case is an LED lamp that meets program criteria. For delamping projects, the high efficiency case is no lamp.

ALGORITHMS

First Baseline Peak Demand Reduction, kW

$$\Delta kW_{1st} = \left(kW_{base,1} - kW_{EE}\right) * ISR * CF * IE_{C,D} * PF \quad (1)$$

Second Baseline Peak Demand Reduction, kW

$$\Delta kW_{2nd} = \left(kW_{base,2} - kW_{EE}\right) * ISR * CF * IE_{C,D} * PF \quad (2)$$

First Baseline Annual Energy Savings, kWh/yr

$$\Delta kWh_{1st} = \left(kW_{base,1} - kW_{EE}\right) * ISR * HOU_{year} * IE_{C,E} * PF \quad (3)$$

Second Baseline Annual Energy Savings, kWh/yr

$$\Delta kWh_{2nd} = \left(kW_{base,2} - kW_{EE}\right) * ISR * HOU_{year} * IE_{C,E} * PF \quad (4)$$

Lifetime Energy Savings, kWh (Dual Baseline, ROB)

$$\Delta kWh_{life,dual} = \Delta kWh_{1st} * EUL_{1st} + \Delta kWh_{2nd} * (EUL_{EE} - EUL_{1st}) \quad (5)$$

Lifetime Energy Savings, kWh (Dual Baseline, Early Replacement)

$$\Delta kWh_{life,dual} = \Delta kWh_{1st} * RUL + \Delta kWh_{2nd} * (EUL_{EE} - RUL) \quad (6)$$

Lifetime Energy Savings, kWh (Single Baseline)

$$\Delta kWh_{life,single} = \Delta kWh_{2nd} * EUL_{EE} \quad (7)$$

Remaining Useful Life (only applicable to Early Replacement)

$$RUL = 1/3 * EUL_{pre-existing} \quad (8)$$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Source/Notes**
$kW_{base,1}$	Wattage of the first baseline lamp	See Table 1	kW	ROB: Current federal standard Early replacement: Pre-existing
$kW_{base,2}$	Wattage of the second baseline lamp	See Table 1	kW	ROB: Future federal standard Early replacement: Current/future federal standard
kW_{EE}	Wattage of the proposed efficient lamp	See Table 2	kW	DLC QPL and other benchmarking performed in 2018
ISR	Lifetime in-service rate	0.98	-	AEG's Fall 2018 Benchmarking (ISR = 1 for delamping measure and early replacement (BHTR))
CF	Peak demand coincidence factor	See Table 3	-	AEG's analysis of DOE's OpenEI load shapes using Hawai'i-specific prototypes, weather data, and peak demand period, adjusted to specific lighting types

$IE_{C,D}$	Interactive effects factor to account for cooling demand savings due to reducing waste heat with efficient lighting	See Table 4	-	DEER20201 interactive effect factors for San Diego, adjusted to Hawaiʻi's weather zone using LBNL simulation results2
$IE_{C,E}$	Interactive effects factor to account for cooling energy savings due to reducing waste heat with efficient lighting	See Table 4	-	DEER20201 interactive effect factors for San Diego, adjusted to Hawaiʻi's weather zone using LBNL simulation results2
HOU_{year}	Average hours of use per year	See Table 5	hr/yr	BEEM: DEER2020[1] hours of use for San Diego (CA's southern-most latitude); no occupancy sensor BHTR/SBDIL: Custom hours
PF	Persistence factor	1.00	-	Footnote 3
EUL_{1st}	Effective useful life of first baseline lamp	See Table 6	yrs	Calculated by dividing rated lamp life[4] by HOU_{year} and setting upperbound EUL = 25 yr and lowerbound EUL = 1 yr
EUL_{EE}	Effective useful life of efficient lamp	See Table 7	yrs	Calculated by dividing rated lamp life[4] by HOU_{year} and setting upperbound EUL = 25 yr and lowerbound EUL = 1 yr
RUL	Remaining useful life of pre-existing lamp	See Table 8	yrs	See Equation 8; only applicable to early replacement (SBDIL projects)
$EUL_{pre\text{-}existing}$	Effective useful life of pre-existing lamp	See Table 6	yrs	Assumes EUL of fluorescent T12/T8 blend is equal to EUL of Fluorescent lamps listed in Table 6

[1] The DEER interactive effect factors and hours of use were developed for DEER2016 and they are still applicable to DEER2020.

[2] "Lighting/HVAC Interactions and Their Effects on Annual and Peak HVAC Requirements in Commercial Buildings," Sezgen, A. O., Y. J. Huang, Lawrence Berkeley Laboratory, ACEEE Summer Study, 1994.

[3] Use value of PF=1 until more data is available on PF of LEDs relative to baseline lighting.

[4] Sources of rated lamp life include DEER, DLC, and other benchmarking.

Table 1. Baseline Wattages, $kW_{base,1}$ and $kW_{base,2}$

Lighting Type	Baseline #1, kW				Baseline #2, kW				Base-line	Source
	Pre-Existing (SBDIL only)		Meets Current Standard (as of 2018/2019)		Meets Current Standard (as of 2018/2019)		Meets Future Standard (2020+)			
LED Exit Sign	-	-	Incandescent sign, various types ranging from 1x5W to 2x50W	0.038	-	-	-	-	Single	Appendix B SFW, average across incandescent exit signs
LED Linear (T8), 8'	8', various ballast types, 70% F96T8 & 30% F96T12	0.059	-	-	8' F96T8, electronic ballast	0.057	-	-	Single Dual	Appendix B SFW, per lamp averages across fixture types
LED Linear (T8), 4'	4', various ballast types, 70% F32T8 & 30% F40T12	0.036	-	-	4' F32T8, electronic ballast	0.031	-	-	Single Dual	Appendix B SFW, per lamp averages across fixture types
LED Linear (T8), 3'	3', various ballast types, 70% F25T8 & 30% F30T12	0.027	-	-	3' F25T8, electronic ballast	0.023	-	-	Single Dual	Appendix B SFW, per lamp averages across fixture types

LED Linear (T8), 2'	2', various ballast types, 70% F17T8 & 30% F20T12	0.019	-	-	2' F17T8, electronic ballast	0.016	-	-	Single Dual	Appendix B SFW, per lamp averages across fixture types
LED Linear (T5), 4'	-	-	4' F28T5, electronic ballast	0.032	-	-	-	-	Single	Appendix B SFW, per lamp averages across fixture types
LED Linear (T5 HO), 4'	-	-	4' F54T5 HO, electronic ballast	0.059	-	-	-	-	Single	Appendix B SFW, per lamp averages across fixture types
LED--Omni-Directional lamp, Screw Base	-	-	Wtd. Avg. EISA Tier 1 lamp	0.047	-	-	Wtd. Avg. EISA Tier 2	0.024	Dual	EISA Tier 1 and 2 requirements, weighted using HE program data[1]
LED--Omni-Directional lamp, Pin Base	-	-	Pin base CFL lamp	0.026	-	-	-	-	Single	Manufacturer data
LED--MR16 lamp	-	-	Halogen 50W MR16 lamp, 500 lumens	0.050	-	-	EISA Tier 2	0.011	Dual	1) Halogen; 2) 45 lumen/W
LED--PAR20 lamp	-	-	Halogen 39 W lamp (50W incan. equivalent), 520 lumens	0.039	-	-	EISA Tier 2	0.012	Dual	1) Halogen; 2) 45 lumen/W
LED--PAR30 lamp	-	-	Halogen 60 W lamp (75W incan. equivalent), 920 lumens	0.060	-	-	EISA Tier 2	0.020	Dual	1) Halogen; 2) 45 lumen/W
LED--PAR38 lamp	-	-	Halogen 60 W lamp (75W incan. equivalent), 1090 lumens	0.060	-	-	EISA Tier 2	0.024	Dual	1) Halogen; 2) 45 lumen/W
LED-Decorative Candelabra 25W equivalent	-	-	25W incandescent lamp	0.025	-	-	EISA Tier 2	0.006	Dual	1) Standard incandescent; 2) 45 lumen/W
LED-Decorative Candelabra 40W equivalent	-	-	40W incandescent lamp	0.040	-	-	EISA Tier 2	0.012	Dual	1) Standard incandescent; 2) 45 lumen/W
LED-Decorative Med Base 40W equivalent	-	-	40W incandescent lamp	0.040	-	-	EISA Tier 2	0.012	Dual	1) Standard incandescent; 2) 45 lumen/W
LED-Decorative Med Base 60W equivalent	-	-	60W incandescent lamp	0.060	-	-	EISA Tier 2	0.020	Dual	1) Standard incandescent; 2) 45 lumen/W
LED Troffer, 1 ft. x 4 ft.	-	-	Fixture with (2) 4' F32T8	0.062	-	-	-	-	Single	Benchmarking; no change from PY18 TRM
LED Troffer, 2 ft. x 2 ft.	-	-	Fixture with (2) FU31T8/6	0.064	-	-	-	-	Single	Benchmarking; no change from PY18 TRM
LED Troffer, 2 ft. x 4 ft.	-	-	No change from PY18 TRM	0.109	-	-	-	-	Single	Benchmarking; no change from PY18 TRM
(2) LED 2' linear replace (2) Fl. U-bend	-	-	(2) FU31T8/6	0.058	-	-	-	-	Single	Appendix B SFW, per lamp averages across fixture types
(2) LED U-bend replace (2) Fl. U-bend)	-	-	(2) FU31T8/6	0.058	-	-	-	-	Single	Appendix B SFW, per lamp averages across fixture types

LED: HID replacement, <35W	-	-	HID 50W-100W Baseline: 64W, 86W, 128W	0.093	-	-	-	-	Single	Fixture wattage from benchmarking; no change from PY18 TRM
LED: HID replacement, 35W-149W	-	-	HID 150W-250W Baseline: 188W, 240W, 295W	0.241	-	-	-	-	Single	Fixture wattage from benchmarking; no change from PY18 TRM
LED: HID replacement, 150W-220W	-	-	HID 310W-600W Baseline: 365W, 457W, 665W	0.496	-	-	-	-	Single	Fixture wattage from benchmarking; no change from PY18 TRM
LED: HID replacement, >220W	-	-	HID 750W-1000W Baseline: 840W, 1100W	0.970	-	-	-	-	Single	Fixture wattage from benchmarking; no change from PY18 TRM

[1] Weighting assumes 8% 100W eq., 29% 75W eq., 57% 60W eq., 6% 40W eq. based on former Hawaiʻi Energy program data for similar lamp types.

Table 2. High Efficiency Wattages, kW_{EE}

Lighting Type	Linear LED, kW		Other LED, kW[5]
	Type A[1]	Type B[2] and Type C[3]	
LED Exit Sign	-	-	0.005
LED Linear (T8), 8'	0.042	0.039	-
LED Linear (T8), 4'	0.018	0.016	-
LED Linear (T8), 3'	0.016	0.014	-
LED Linear (T8), 2'	0.013	0.010	-
LED Linear (T5), 4'	0.023	0.021	-
LED Linear (T5 HO), 4'	0.030	0.028	-
LED--Omni-Direct. lamp, Screw Base[4]	-	-	0.010
LED--Omni-Direct. lamp, Pin Base[4]	-	-	0.009
LED--MR16 lamp[4]	-	-	0.005
LED--PAR20 lamp[4]	-	-	0.007
LED--PAR30 lamp[4]	-	-	0.012
LED--PAR38 lamp[4]	-	-	0.013
LED-Decorative Candelabra 25W eq.	-	-	0.004
LED-Decorative Candelabra 40W eq.	-	-	0.004
LED-Decorative Med Base 40W eq.	-	-	0.005

Table 3. Coincidence Factors, CF
(Applicable to Counties of Oahu, Maui, and Hawaiʻi)

Building Type	Exit Sign	Omni-Directional, Directional, and Decorative	High Bay	Linear, U-Bend, Troffer
Avg. Commercial	1.00	0.31	0.53	0.34
Cold Storage	1.00	0.20	0.20	0.20
Education	1.00	0.28	0.40	0.32
Grocery	1.00	0.70	0.78	0.68
Health	1.00	0.66	0.72	0.63
Hotel/Motel	1.00	0.26	0.96	0.23
Industrial	1.00	0.53	0.58	0.59
Office	1.00	0.22	0.31	0.25
Restaurant	1.00	0.52	0.50	0.49
Retail	1.00	0.32	0.54	0.50
Warehouse	1.00	0.07	0.10	0.08

Notes:

a. The CF values were derived using a three step process:

1) AEG analysis of DOE's OpenEI general lighting load shapes simulated with Hawaiʻi-specific prototypes, weather data, and peak demand period to determine i) unadjusted CF values for general lighting during Hawaiʻi's peak demand period of 5-9 pm on non-holiday weekdays, and ii) unadjusted EFLH values for general lighting (= annual lighting energy use in kWh divided by maximum lighting demand in kW).

2) Mapping of OpenEI's and DEER's building types to Hawaiʻi Energy's building types listed above;

3) Adjustment of the OpenEI CF values to specific lighting types (bulbs, highbay, linear lamps) using DEER's annual HOUs for San Diego. The adjustment equation is $CF_{OpenEI}*(HOU_{SD}/EFLH_{OpenEI})$.

LED-Decorative Med Base 60W eq.	-	-	0.006
LED Troffer, 1 ft x 4 ft	-	-	0.035
LED Troffer, 2 ft x 2 ft	-	-	0.030
LED Troffer, 2 ft x 4 ft	-	-	0.040
(2) LED 2' linear replace (2) Fl. U-bend	0.026	0.021	-
(2) LED U-bend replace (2) Fl. U-bend	0.035	0.030	-
LED: HID replace, <35W	-	-	0.028
LED: HID replace, 35W-149W	-	-	0.078
LED: HID replace, 150W-220W	-	-	0.170
LED: HID replace, >220W	-	-	0.270

[1] Type A installation: Ballast left in place, reduced savings due to losses.

[2] Type B installation: Bypassing fluorescent ballast and utilizing internal LED driver.

[3] Type C installation: Removing fluorescent ballast and utilizing an external driver; more efficient than the Type B internal driver, however also consumes a little more power.

Therefore, this Program assumes Types B & C energy and demand savings to be equivalent. However, a Type C installation is preferred for longevity due to use of an external LED driver and complete removal of the fluorescent ballast.

[4] Wattages represent a blend of dimmable and non-dimmable equipment. See C_Light_Dimmable(Nonlinear LED) for details.

[5] Wattages are from DLC QPL and other benchmarking performed in 2018.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

b. San Diego is a good proxy for Hawaiʻi for lighting usage. The OpenEI prototypes yield the same energy, demand, EFLH, and CF factors for San Diego, Honolulu, Kahului, and Keahole-Kona weather stations. (Therefore, the same results are applicable to all Hawaiian counties.)

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Table 4. Interactive Effects Factors, IEC,D and IEC,E (Applicable to Counties of Oahu, Maui, and Hawaiʻi)

Building Type	Omni-Directional, Directional, and Decorative		High Bay, Linear, U-Bend, Troffer	
	$IE_{C,D}$	$IE_{C,E}$	$IE_{C,D}$	$IE_{C,E}$
Avg. Commercial	1.25	1.13	1.26	1.13
Cold Storage	1.26	1.56	1.25	1.62
Education	1.30	1.25	1.31	1.25
Grocery	1.11	1.14	1.09	1.14
Health	1.23	1.14	1.24	1.15
Hotel/Motel	1.27	1.38	1.27	1.36
Industrial	1.19	1.12	1.20	1.13
Office	1.08	1.25	1.07	1.26
Restaurant	1.22	1.28	1.24	1.28
Retail	1.39	1.14	1.36	1.15
Warehouse	1.15	1.01	1.16	1.01

Notes:

a. The IE values were derived using a four step process:

1) Tabulation of DEER's IE factors for San Diego (IECC CZ 3B);
2) Tabulation of IE factors from LBNL 1994 study for IECC CZ 3B and IECC CZ 1A;
3) Mapping of DEER and LBNL building types to Hawaiʻi Energy's building types listed above;

4) Adjustment of the DEER IE factors for CZ 3B using ratio of LBNL factors for CZ 1A and CZ 3B to determine IE factors for Hawaiʻi (CZ 1A). The equation is: $IE_{Hawaii} = IE_{DEER, 3B}*(IE_{LBNL,1A}/IE_{LBNL,3B})$.

b. Assume no interactive effects for exit signs due to lack of representative data.

Table 5. Annual Hours of Use, HOU_{year}

Building Type	Exit Sign	Omni-Directional, Directional, and Decorative	High Bay	Linear, U-Tube, Troffer
Avg. Commercial	8,760	1,831	3,047	1,963
Cold Storage	8,760	4,710	4,820	4,700
Education	8,760	1,498	2,176	1,702
Grocery	8,760	4,900	5,450	4,770
Health	8,760	5,370	5,870	5,100
Hotel/Motel	8,760	1,284	4,775	1,130
Industrial	8,760	2,145	2,860	2,305
Office	8,760	1,780	2,480	1,980
Restaurant	8,760	3,700	3,610	3,500
Retail	8,760	2,363	3,983	3,690
Warehouse	8,760	1,690	2,245	1,970

Source: DEER2020 hours of use for San Diego IOU; no occupancy sensor. HOU were originally developed for DEER2016.

Table 6. Effective Useful Life of Baseline Lamp (Dual Baseline, ROB), EUL_{1st}

Building Type	Incandescent Exit Sign	Fluorescent Linear, U-bend, Troffer	Incandescent Decorative	Halogen-Incandescent Omni-Directional	CFL	Halogen MR and PAR type	HID
Avg. Commercial	1	12	1	1	5	2	23
Cold Storage	1	5	1	1	2	1	15
Education	1	14	1	2	6	3	25
Grocery	1	5	1	1	2	1	13
Health	1	5	1	1	2	1	12
Hotel/Motel	1	21	1	2	7	3	15
Industrial	1	10	1	1	4	2	24
Office	1	12	1	2	5	2	25
Restaurant	1	7	1	1	2	1	19
Retail	1	7	1	1	4	2	18
Warehouse	1	12	1	2	5	2	25

Source: Calculated by dividing rated lamp life by HOU_{year} and setting upperbound EUL = 25 yr and lowerbound EUL = 1 yr. Sources of rated lamp life include DEER, DLC, Lighting Research Center, and other benchmarking.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32

Table 7. Effective Useful Life of Efficient Lamp, EUL_{EE}

Building Type	LED Exit Sign	LED Omni-Directional, Directional, and Decorative	LED High Bay	LED Linear, U-Tube, Troffer
Avg. Commercial	18	8	16	25
Cold Storage	18	3	10	11
Education	18	10	23	25
Grocery	18	3	9	10
Health	18	3	9	10
Hotel/Motel	18	12	10	25
Industrial	18	7	17	22
Office	18	8	20	25
Restaurant	18	4	14	14
Retail	18	6	13	14
Warehouse	18	9	22	25

Table 8. Remaining Useful Life of Pre-Existing Lamp, RUL

Building Type	Fluorescent T12/T8 Blend
Avg. Commercial	4
Cold Storage	2
Education	5
Grocery	2
Health	2
Hotel/Motel	7
Industrial	3
Office	4
Restaurant	2
Retail	2
Warehouse	4

Source: Calculated by dividing rated lamp life by HOU $_{year}$ and setting upperbound EUL = 25 yr and lowerbound EUL = 1 yr. Sources of rated lamp life include DEER, DLC, and other benchmarking.

Note: Only applies to SBDIR. Assumes EUL of pre-existing lamp divided by 3.

SAVINGS

Menu of Deemed Savings Tables (click to navigate to correct savings tables)

Lighting Type	Single Baseline			
Delamping	First Year Savings	Lifetime Savings		
Exit Signs	First Year Savings	Lifetime Savings		
LED Troffers	First Year Savings	Lifetime Savings		
T8 Linear (ROB)	First Year Savings	Lifetime Savings		
T5 Linear	First Year Savings	Lifetime Savings		
U-Bend Replacements	First Year Savings	Lifetime Savings		
LED Corn Cob	First Year Savings	Lifetime Savings		
Pin-Based Omni-Directional	First Year Savings	Lifetime Savings		
Lighting Type	**Dual Baseline**			
T8 Linear (Early Replacement)[1]	First Year kW (Pre-Existing)		First Year kW (Federal Standard)	
Directional & Screw Base Omni	First Year (PY19)	First Year (PY20+)	Lifetime (PY19)	Lifetime (PY20+)
Decorative LEDs	First Year (PY19)	First Year (PY20+)	Lifetime (PY19)	Lifetime (PY20+)

[1] First year and lifetime kWh calculations for SBDIL early replacement use custom HOU, so no deemed savings are provided.

First Year Savings: Delamping

Table 9. Calculated First Year Unit Savings: Delamping (With or Without Reflector)

	Peak Demand Savings (kW)				Annual Energy Savings (kWh/year)			
Building Type	**2' Lamp**	**3' Lamp**	**4' Lamp**	**8' Lamp**	**2' Lamp**	**3' Lamp**	**4' Lamp**	**8' Lamp**
Avg. Commercial	0.007	0.010	0.013	0.024	35.49	51.02	68.76	126.44
Cold Storage	0.004	0.006	0.008	0.014	121.82	175.12	236.03	434.00
Education	0.007	0.010	0.013	0.024	34.04	48.93	65.95	121.27
Grocery	0.012	0.017	0.023	0.042	87.00	125.07	168.57	309.95
Health	0.012	0.018	0.024	0.045	93.84	134.90	181.82	334.31
Hotel/Motel	0.005	0.007	0.009	0.017	24.59	35.35	47.64	87.60
Industrial	0.011	0.016	0.022	0.040	41.67	59.91	80.74	148.47
Office	0.004	0.006	0.008	0.015	39.92	57.38	77.34	142.20
Restaurant	0.010	0.014	0.019	0.035	71.68	103.04	138.88	255.36
Retail	0.011	0.016	0.021	0.039	67.90	97.60	131.55	241.88
Warehouse	0.001	0.002	0.003	0.005	31.84	45.76	61.68	113.41

Note: Assumes the baseline is a fluorescent T8 lamp with electronic ballast that meets current federal standard.

Lifetime Savings: Delamping

Table 10. Calculated Lifetime Unit Savings: Delamping (With or Without Reflector)

	Lifetime Energy Savings (kWh)			
Building Type	**2' Lamp**	**3' Lamp**	**4' Lamp**	**8' Lamp**
Avg. Commercial	887.25	1,275.50	1,719.00	3,161.00
Cold Storage	1,340.02	1,926.32	2,596.33	4,774.00
Education	851.00	1,223.25	1,648.75	3,031.75
Grocery	870.00	1,250.70	1,685.70	3,099.50
Health	938.40	1,349.00	1,818.20	3,343.10
Hotel/Motel	614.75	883.75	1,191.00	2,190.00
Industrial	916.74	1,318.02	1,776.28	3,266.34
Office	998.00	1,434.50	1,933.50	3,555.00
Restaurant	1,003.52	1,442.56	1,944.32	3,575.04
Retail	950.60	1,366.40	1,841.70	3,386.32
Warehouse	796.00	1,144.00	1,542.00	2,835.25

Note: Assumes the baseline is a fluorescent T8 lamp with electronic ballast that meets current federal standard.

First Year Savings: Exit Signs

Table 11. Calculated First Year Unit Savings: LED Exit Signs (8760 HOURS)

Building Type	Peak Demand Savings (kW)	Annual Energy Savings (kWh/year)
All	0.032	283.30

Lifetime Savings: Exit Signs

Table 12. Calculated Lifetime Unit Savings: LED Exit Signs (8760 HOURS)

Building Type	Lifetime Energy Savings (kWh)
All	5,099.40

First Year Savings: Decorative LEDs, Dual Baseline

Table 13. Calculated First Year Unit Savings: Decorative LEDs (PY19)

	Candelabra 25 W		Candelabra 40 W		Med Base 40 W		Med Base 60 W	
Building Type	**kW**	**kWh/yr**	**kW**	**kWh/yr**	**kW**	**kWh/yr**	**kW**	**kWh/yr**
Avg. Commercial	0.008	42.58	0.014	73.00	0.013	70.97	0.021	109.49
Cold Storage	0.005	151.21	0.009	259.22	0.009	252.02	0.013	388.83
Education	0.007	38.54	0.013	66.06	0.012	64.23	0.019	99.09
Grocery	0.016	114.96	0.027	197.07	0.027	191.60	0.041	295.61
Health	0.017	125.99	0.029	215.98	0.028	209.98	0.043	323.97
Hotel/Motel	0.007	36.47	0.012	62.51	0.011	60.78	0.017	93.77
Industrial	0.013	49.44	0.022	84.76	0.022	82.40	0.033	127.14
Office	0.005	45.79	0.008	78.50	0.008	76.32	0.013	117.75
Restaurant	0.013	97.47	0.022	167.09	0.022	162.44	0.034	250.63
Retail	0.009	55.44	0.016	95.04	0.015	92.40	0.024	142.56
Warehouse	0.002	35.13	0.003	60.22	0.003	58.55	0.004	90.33

Table 14. Calculated First Year Unit Savings: Decorative LEDs (PY20+)

	Candelabra 25 W		Candelabra 40 W		Med Base 40 W		Med Base 60 W	
Building Type	**kW**	**kWh/yr**	**kW**	**kWh/yr**	**kW**	**kWh/yr**	**kW**	**kWh/yr**
Avg. Commercial	0.001	4.06	0.003	16.22	0.003	14.19	0.005	28.39
Cold Storage	0.000	14.40	0.002	57.61	0.002	50.40	0.003	100.81
Education	0.001	3.67	0.003	14.68	0.002	12.85	0.005	25.69
Grocery	0.002	10.95	0.006	43.79	0.005	38.32	0.011	76.64
Health	0.002	12.00	0.006	47.99	0.006	42.00	0.011	83.99
Hotel/Motel	0.001	3.47	0.003	13.89	0.002	12.16	0.005	24.31
Industrial	0.001	4.71	0.005	18.83	0.004	16.48	0.009	32.96
Office	0.000	4.36	0.002	17.44	0.002	15.26	0.003	30.53
Restaurant	0.001	9.28	0.005	37.13	0.004	32.49	0.009	64.98
Retail	0.001	5.28	0.003	21.12	0.003	18.48	0.006	36.96
Warehouse	0.000	3.35	0.001	13.38	0.001	11.71	0.001	23.42

Lifetime Savings: Decorative LEDs, Dual Baseline

Table 15. Calculated Lifetime Unit Savings: Decorative LEDs (PY19)

	Lifetime Energy Savings (kWh)			
Building Type	**Candelabra 25 W**	**Candelabra 40 W**	**Med Base 40 W**	**Med Base 60 W**
Avg. Commercial	71.00	186.54	170.30	308.22
Cold Storage	180.01	374.44	352.82	590.45
Education	71.57	198.18	179.88	330.30
Grocery	136.86	284.65	268.24	448.89
Health	149.99	311.96	293.98	491.95
Hotel/Motel	74.64	215.30	194.54	361.18
Industrial	77.70	197.74	181.28	324.90

Office	76.31	200.58	183.14	331.46
Restaurant	125.31	278.48	259.91	445.57
Retail	81.84	200.64	184.80	327.36
Warehouse	61.93	167.26	152.23	277.69

Table 16. Calculated Lifetime Unit Savings: Decorative LEDs (PY20+)

	Lifetime Energy Savings (kWh)			
Building Type	**Candelabra 25 W**	**Candelabra 40 W**	**Med Base 40 W**	**Med Base 60 W**
Avg. Commercial	32.48	129.76	113.52	227.12
Cold Storage	43.20	172.83	151.20	302.43
Education	36.70	146.80	128.50	256.90
Grocery	32.85	131.37	114.96	229.92
Health	36.00	143.97	126.00	251.97
Hotel/Motel	41.64	166.68	145.92	291.72
Industrial	32.97	131.81	115.36	230.72
Office	34.88	139.52	122.08	244.24
Restaurant	37.12	148.52	129.96	259.92
Retail	31.68	126.72	110.88	221.76
Warehouse	30.15	120.42	105.39	210.78

First Year Savings: LED Troffers

Table 17. Calculated First Year Unit Savings: LED Troffers

	Peak Demand Savings (kW)			Annual Energy Savings (kWh/year)		
Building Type	**1'x4' Fixture**	**2'x2' Fixture**	**2'x4' Fixture**	**1'x4' Fixture**	**2'x2' Fixture**	**2'x4' Fixture**
Avg. Commercial	0.011	0.014	0.029	57.82	73.04	150.43
Cold Storage	0.007	0.008	0.017	198.48	250.71	516.35
Education	0.011	0.014	0.028	55.46	70.05	144.28
Grocery	0.019	0.024	0.050	141.75	179.06	368.77
Health	0.020	0.026	0.053	152.89	193.12	397.74
Hotel/Motel	0.008	0.010	0.020	40.06	50.60	104.22
Industrial	0.018	0.023	0.048	67.90	85.77	176.64
Office	0.007	0.009	0.018	65.03	82.15	169.19
Restaurant	0.016	0.020	0.041	116.78	147.52	303.82
Retail	0.018	0.022	0.046	110.62	139.73	287.78
Warehouse	0.002	0.003	0.006	51.87	65.52	134.93

Lifetime Savings: LED Troffers

Table 18. Calculated Lifetime Unit Savings: LED Troffers

	Lifetime Energy Savings (kWh)		
Building Type	**1'x4' Fixture**	**2'x2' Fixture**	**2'x4' Fixture**
Avg. Commercial	1,445.50	1,826.00	3,760.75
Cold Storage	2,183.28	2,757.81	5,679.85
Education	1,386.50	1,751.25	3,607.00
Grocery	1,417.50	1,790.60	3,687.70
Health	1,528.90	1,931.20	3,977.40
Hotel/Motel	1,001.50	1,265.00	2,605.50
Industrial	1,493.80	1,886.94	3,886.08
Office	1,625.75	2,053.75	4,229.75
Restaurant	1,634.92	2,065.28	4,253.48
Retail	1,548.68	1,956.22	4,028.92
Warehouse	1,296.75	1,638.00	3,373.25

First Year Savings: T8 Linear LED Lamps, ROB, Single Baseline

Table 19a. Calculated First Year Unit Savings: T8 Linear LED Lamps, Demand Savings

	Peak Demand Savings (kW)

Building Type	2' Type A	2' Type B/C	3' Type A	3' Type B/C	4' Type A	4' Type B/C	8' Type A	8' Type B/C
Avg. Commercial	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008
Cold Storage	0.001	0.001	0.002	0.002	0.003	0.004	0.004	0.004
Education	0.001	0.002	0.003	0.004	0.005	0.006	0.006	0.007
Grocery	0.002	0.004	0.005	0.007	0.009	0.011	0.011	0.013
Health	0.002	0.004	0.005	0.007	0.010	0.012	0.012	0.014
Hotel/Motel	0.001	0.002	0.002	0.003	0.004	0.004	0.004	0.005
Industrial	0.002	0.004	0.005	0.007	0.009	0.010	0.011	0.012
Office	0.001	0.001	0.002	0.002	0.003	0.004	0.004	0.005
Restaurant	0.002	0.003	0.004	0.006	0.008	0.009	0.009	0.011
Retail	0.002	0.004	0.005	0.006	0.008	0.010	0.010	0.012
Warehouse	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.002

Table 19b. Calculated First Year Unit Savings: T8 Linear LED Lamps, Energy Savings

	Annual Energy Savings (kWh/year)							
Building Type	**2' Type A**	**2' Type B/C**	**3' Type A**	**3' Type B/C**	**4' Type A**	**4' Type B/C**	**8' Type A**	**8' Type B/C**
Avg. Commercial	6.96	12.39	15.22	20.65	27.39	32.83	33.69	39.13
Cold Storage	23.88	42.53	52.23	70.89	94.02	112.67	115.66	134.31
Education	6.67	11.88	14.60	19.81	26.27	31.48	32.32	37.53
Grocery	17.05	30.38	37.30	50.63	67.15	80.47	82.60	95.92
Health	18.39	32.76	40.23	54.60	72.42	86.79	89.09	103.46
Hotel/Motel	4.82	8.59	10.54	14.31	18.98	22.74	23.34	27.11
Industrial	8.17	14.55	17.87	24.25	32.16	38.54	39.57	45.95
Office	7.82	13.94	17.11	23.23	30.81	36.92	37.90	44.01
Restaurant	14.05	25.03	30.73	41.71	55.32	66.30	68.05	79.03
Retail	13.31	23.70	29.11	39.51	52.40	62.80	64.46	74.86
Warehouse	6.24	11.11	13.65	18.52	24.57	29.44	30.22	35.10

Lifetime Savings: T8 Linear LED Lamps, ROB, Single Baseline

Table 20. Calculated Lifetime Unit Savings: T8 Linear LED Lamps

	Lifetime Energy Savings (kWh)							
Building Type	**2' Type A[1]**	**2' Type B/C**	**3' Type A[1]**	**3' Type B/C**	**4' Type A[1]**	**4' Type B/C**	**8' Type A[1]**	**8' Type B/C**
Avg. Commercial	57.97	309.78	126.81	516.28	228.25	820.63	280.78	978.23
Cold Storage	87.55	467.85	191.52	779.75	344.73	1,239.39	424.08	1,477.42
Education	55.60	297.10	121.63	495.18	218.92	787.08	269.31	938.23
Grocery	56.84	303.76	124.34	506.26	223.82	804.69	275.33	959.23
Health	61.31	327.62	134.11	546.03	241.40	867.90	296.96	1,034.59
Hotel/Motel	40.16	214.63	87.85	357.70	158.13	568.55	194.53	677.73
Industrial	59.90	320.10	131.03	533.48	235.85	847.97	290.14	1,010.81
Office	65.20	348.40	142.62	580.68	256.72	922.95	315.80	1,100.20
Restaurant	65.56	350.35	143.42	583.93	258.16	928.13	317.57	1,106.38
Retail	62.10	331.86	135.85	553.10	244.53	879.13	300.81	1,047.97
Warehouse	52.00	277.85	113.74	463.10	204.74	736.10	251.87	877.45

[1] Estimated useful life for Type A linear LED replacements was capped at the remaining useful life of the linear fixture/ballast, which was estimated as the EUL of a new fixture divided by 3 per typical DEER calculations. This is done because Type A linear LEDs are installed on the existing fixture, use the existing ballast, and are thus limited by the remaining lifetime of the existing fixture. After the existing ballast reaches the end of its useful life, it is likely that the whole fixture is fully replaced with an LED troffer.

First Year Savings: T8 Linear LED Lamps, Early Replacement, Dual Baseline

Table 21. Calculated First Year Unit Savings: T8 Linear LED Lamps, Demand Savings (Pre-Existing baseline, SBDIL only)

	First Baseline Peak Demand Savings (kW)							
Building Type	**2' Type A**	**2' Type B/C**	**3' Type A**	**3' Type B/C**	**4' Type A**	**4' Type B/C**	**8' Type A**	**8' Type B/C**
Avg. Commercial	0.003	0.004	0.005	0.006	0.008	0.009	0.007	0.009
Cold Storage	0.002	0.002	0.003	0.003	0.004	0.005	0.004	0.005
Education	0.003	0.004	0.005	0.006	0.007	0.008	0.007	0.008
Grocery	0.005	0.006	0.008	0.010	0.013	0.015	0.013	0.015
Health	0.005	0.007	0.009	0.011	0.014	0.016	0.014	0.016

Hotel/Motel	0.002	0.003	0.003	0.004	0.005	0.006	0.005	0.006
Industrial	0.004	0.006	0.008	0.010	0.012	0.014	0.012	0.014
Office	0.002	0.002	0.003	0.004	0.005	0.005	0.005	0.005
Restaurant	0.004	0.005	0.007	0.008	0.011	0.012	0.011	0.012
Retail	0.004	0.006	0.007	0.009	0.012	0.014	0.012	0.014
Warehouse	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002

Note: First Year Energy Savings for SBDIL are to be calculated with custom HOU using Equation (3) for the first (Pre-Existing) baseline period.

Table 22. Calculated First Year Unit Savings: T8 Linear LED Lamps, Demand Savings (Federal Standard Baseline)

	Peak Demand Savings (kW)							
Building Type	**2' Type A**	**2' Type B/C**	**3' Type A**	**3' Type B/C**	**4' Type A**	**4' Type B/C**	**8' Type A**	**8' Type B/C**
Avg. Commercial	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008
Cold Storage	0.001	0.001	0.002	0.002	0.003	0.004	0.004	0.004
Education	0.001	0.002	0.003	0.004	0.005	0.006	0.006	0.007
Grocery	0.002	0.004	0.005	0.007	0.009	0.011	0.011	0.013
Health	0.002	0.004	0.005	0.007	0.010	0.012	0.012	0.014
Hotel/Motel	0.001	0.002	0.002	0.003	0.004	0.004	0.004	0.005
Industrial	0.002	0.004	0.005	0.007	0.009	0.010	0.011	0.012
Office	0.001	0.001	0.002	0.002	0.003	0.004	0.004	0.005
Restaurant	0.002	0.003	0.004	0.006	0.008	0.009	0.009	0.011
Retail	0.002	0.004	0.005	0.006	0.008	0.010	0.010	0.012
Warehouse	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.002

Note: This table matches Table 19a, but is used as second baseline period for early replacement projects (SBDIL).

Note: First Year Energy Savings for SBDIL are to be calculated with custom HOU using Equation (4) for the second (Federal Standard) baseline period.

Lifetime Savings: T8 Linear LED Lamps, Early Replacement, Dual Baseline

Note: Lifetime Energy Savings for SBDIL are to be calculated with custom HOU using Equation (6).

First Year Savings: T5 Linear LED Lamps, ROB, Single Baseline

Table 23. Calculated First Year Unit Savings: Linear LED Lamps, 4' T5/T5 HO

	Peak Demand Savings (kW)				Annual Energy Savings (kWh/year)			
Building Type	**T5 Type A**	**T5 Type B/C**	**T5HO Type A**	**T5HO Type B/C**	**T5 Type A**	**T5 Type B/C**	**T5HO Type A**	**T5HO Type B/C**
Avg. Commercial	0.004	0.005	0.012	0.013	19.13	24.56	63.04	68.48
Cold Storage	0.002	0.003	0.007	0.008	65.66	84.32	216.39	235.04
Education	0.004	0.005	0.012	0.013	18.35	23.56	60.46	65.68
Grocery	0.006	0.008	0.021	0.023	46.90	60.22	154.54	167.86
Health	0.007	0.009	0.022	0.024	50.58	64.95	166.68	181.05
Hotel/Motel	0.003	0.003	0.008	0.009	13.25	17.02	43.68	47.44
Industrial	0.006	0.008	0.020	0.022	22.46	28.84	74.02	80.41
Office	0.002	0.003	0.008	0.008	21.52	27.63	70.90	77.01
Restaurant	0.005	0.007	0.017	0.019	38.64	49.61	127.32	138.30
Retail	0.006	0.008	0.019	0.021	36.60	46.99	120.60	131.00
Warehouse	0.001	0.001	0.003	0.003	17.16	22.03	56.55	61.42

Lifetime Savings: T5 Linear LED Lamps, ROB, Single Baseline

Table 24. Calculated Lifetime Unit Savings: Linear LED Lamps, 4' T5/T5 HO

	Lifetime Energy Savings (kWh)

Building Type	T5 Type A[1]	T5 Type B/C	T5HO Type A[1]	T5HO Type B/C
Avg. Commercial	159.42	614.00	525.33	1,712.00
Cold Storage	240.75	927.52	793.43	2,585.44
Education	152.92	589.00	503.83	1,642.00
Grocery	156.33	602.20	515.13	1,678.60
Health	168.60	649.50	555.60	1,810.50
Hotel/Motel	110.42	425.50	364.00	1,186.00
Industrial	164.71	634.48	542.81	1,769.02
Office	179.33	690.75	590.83	1,925.25
Restaurant	180.32	694.54	594.16	1,936.20
Retail	170.80	657.86	562.80	1,834.00
Warehouse	143.00	550.75	471.25	1,535.50

[1] Estimated useful life for Type A linear LED replacements was capped at the remaining useful life of the linear fixture/ballast, which was estimated as the EUL of a new fixture divided by 3 per typical DEER calculations. This is done because Type A linear LEDs are installed on the existing fixture, use the existing ballast, and are thus limited by the remaining lifetime of the existing fixture. After the existing ballast reaches the end of its useful life, it is likely that the whole fixture is fully replaced with an LED troffer.

First Year Savings: U-Bend LED Replacement, ROB, Single Baseline

Table 25. Calculated First Year Unit Savings: U-Bend LED Replacements

	Peak Demand Savings (kW)				Annual Energy Savings (kWh/year)			
Building Type	(2) X 2' Type A	(2) X 2' Type B/C	(2) x U-Bend Type A	(2) x U-Bend Type B/C	(2) X 2' Type A	(2) X 2' Type B/C	(2) x U-Bend Type A	(2) x U-Bend Type B/C
Avg. Commercial	0.014	0.016	0.010	0.012	70.43	81.30	50.00	60.87
Cold Storage	0.008	0.009	0.006	0.007	241.76	279.07	171.62	208.93
Education	0.013	0.015	0.009	0.012	67.55	77.98	47.95	58.38
Grocery	0.024	0.027	0.017	0.020	172.66	199.31	122.57	149.21
Health	0.025	0.029	0.018	0.021	186.23	214.96	132.20	160.94
Hotel/Motel	0.009	0.011	0.007	0.008	48.80	56.33	34.64	42.17
Industrial	0.022	0.026	0.016	0.019	82.70	95.47	58.71	71.47
Office	0.008	0.010	0.006	0.007	79.21	91.44	56.23	68.46
Restaurant	0.019	0.022	0.014	0.017	142.25	164.20	100.98	122.93
Retail	0.022	0.025	0.015	0.019	134.74	155.53	95.65	116.44
Warehouse	0.003	0.003	0.002	0.003	63.18	72.93	44.85	54.60

Note: LED tubes are assumed to be used in interior applications only.

Lifetime Savings: U-Bend LED Replacement, ROB, Single Baseline

Table 26. Calculated Lifetime Unit Savings: U-Bend LED Replacements

	Lifetime Energy Savings (kWh)			
Building Type	(2) X 2' Type A[1]	(2) X 2' Type B/C	(2) x U-Bend Type A[1]	(2) x U-Bend Type B/C
Avg. Commercial	586.92	2,032.50	416.67	1,521.75
Cold Storage	886.45	3,069.77	629.27	2,298.23
Education	562.92	1,949.50	399.58	1,459.50
Grocery	575.53	1,993.10	408.57	1,492.10
Health	620.77	2,149.60	440.67	1,609.40
Hotel/Motel	406.67	1,408.25	288.67	1,054.25
Industrial	606.47	2,100.34	430.54	1,572.34
Office	660.08	2,286.00	468.58	1,711.50
Restaurant	663.83	2,298.80	471.24	1,721.02
Retail	628.79	2,177.42	446.37	1,630.16
Warehouse	526.50	1,823.25	373.75	1,365.00

Note: LED tubes are assumed to be used in interior applications only.

[1] Estimated useful life for Type A linear LED replacements was capped at the remaining useful life of the linear fixture/ballast, which was estimated as the EUL of a new fixture divided by 3 per typical DEER calculations. This is done because Type A linear LEDs are installed on the existing fixture, use the existing ballast, and are thus limited by the remaining lifetime of the existing fixture. After the existing ballast reaches the end of its useful life, it is likely that the whole fixture is fully replaced with an LED troffer.

First Year Savings: LED Corn Cob, ROB, Single Baseline

Table 27. Calculated First Year Unit Savings: LED Corn Cob

	Peak Demand Savings (kW)				Annual Energy Savings (kWh/year)			
Building Type	**<35W**	**35W-149W**	**150W-220W**	**>220W**	**<35W**	**35W-149W**	**150W-220W**	**>220W**
Avg. Commercial	0.043	0.107	0.213	0.458	219.33	550.00	1,100.00	2,361.97
Cold Storage	0.016	0.040	0.080	0.172	497.40	1,247.31	2,494.63	5,356.56
Education	0.033	0.084	0.167	0.359	173.26	434.49	868.99	1,865.92
Grocery	0.054	0.136	0.272	0.583	395.77	992.46	1,984.93	4,262.12
Health	0.057	0.143	0.285	0.612	430.01	1,078.32	2,156.65	4,630.84
Hotel/Motel	0.078	0.195	0.390	0.836	413.67	1,037.35	2,074.70	4,454.88
Industrial	0.044	0.111	0.222	0.477	205.87	516.25	1,032.50	2,217.01
Office	0.021	0.053	0.106	0.228	199.05	499.16	998.31	2,143.61
Restaurant	0.039	0.099	0.198	0.425	294.34	738.13	1,476.25	3,169.87
Retail	0.047	0.117	0.235	0.504	291.77	731.68	1,463.36	3,142.19
Warehouse	0.007	0.019	0.037	0.080	144.44	362.20	724.40	1,555.47

Lifetime Savings: LED Corn Cob, ROB, Single Baseline

Table 28. Calculated Lifetime Unit Savings: LED Corn Cob

	Lifetime Energy Savings (kWh)			
Building Type	**<35W**	**35W-149W**	**150W-220W**	**>220W**
Avg. Commercial	3,509.28	8,800.00	17,600.00	37,791.52
Cold Storage	4,974.00	12,473.10	24,946.30	53,565.60
Education	3,984.98	9,993.27	19,986.77	42,916.16
Grocery	3,561.93	8,932.14	17,864.37	38,359.08
Health	3,870.09	9,704.88	19,409.85	41,677.56
Hotel/Motel	4,136.70	10,373.50	20,747.00	44,548.80
Industrial	3,499.79	8,776.25	17,552.50	37,689.17
Office	3,981.00	9,983.20	19,966.20	42,872.20
Restaurant	4,120.76	10,333.82	20,667.50	44,378.18
Retail	3,793.01	9,511.84	19,023.68	40,848.47
Warehouse	3,177.68	7,968.40	15,936.80	34,220.34

First Year Savings: Pin-Base Omni-Directional, ROB, Single Baseline

Table 29. Calculated First Year Unit Savings: Pin-Base Omni-Directional

Building Type	Peak Demand Savings (kW)	Annual Energy Savings (kWh/year)
Avg. Commercial	0.007	35.21
Cold Storage	0.004	125.06
Education	0.006	31.87
Grocery	0.013	95.07
Health	0.014	104.19
Hotel/Motel	0.006	30.16
Industrial	0.011	40.89
Office	0.004	37.87
Restaurant	0.011	80.61
Retail	0.008	45.85
Warehouse	0.001	29.05

Lifetime Savings: Pin-Base Omni-Directional, ROB, Single Baseline

Table 30. Calculated Lifetime Unit Savings: Pin-Base Omni-Directional

Building Type	Lifetime Energy Savings (kWh)
Avg. Commercial	281.68
Cold Storage	375.18
Education	318.70
Grocery	285.21
Health	312.57
Hotel/Motel	361.92
Industrial	286.23
Office	302.96
Restaurant	322.44
Retail	275.10
Warehouse	261.45

First Year Savings: Directional and Screw-Base Omni-Directional LEDs, Dual Baseline

Table 31. Calculated First Year Unit Savings: Directional and Screw-Base Omni-Directional LEDs (PY19)

	First Baseline Peak Demand Savings (kW)					First Baseline Annual Energy Savings (kWh/yr)				
Building Type	MR16	PAR20	PAR30	PAR38	Omni-Screw	MR16	PAR20	PAR30	PAR38	Omni-Screw
Avg. Commercial	0.017	0.012	0.018	0.018	0.014	91.16	65.27	97.72	95.28	76.52
Cold Storage	0.011	0.008	0.012	0.012	0.009	323.73	231.79	347.02	338.35	271.75
Education	0.016	0.011	0.017	0.017	0.013	82.50	59.07	88.44	86.23	69.25
Grocery	0.034	0.025	0.037	0.036	0.029	246.12	176.22	263.82	257.23	206.60
Health	0.036	0.026	0.038	0.037	0.030	269.72	193.12	289.13	281.90	226.42
Hotel/Motel	0.015	0.010	0.016	0.015	0.012	78.07	55.90	83.69	81.60	65.53
Industrial	0.028	0.020	0.030	0.029	0.023	105.85	75.79	113.46	110.63	88.85
Office	0.010	0.007	0.011	0.011	0.009	98.03	70.19	105.09	102.46	82.29
Restaurant	0.028	0.020	0.030	0.029	0.023	208.67	149.40	223.68	218.09	175.16
Retail	0.020	0.014	0.021	0.020	0.016	118.69	84.98	127.23	124.05	99.63
Warehouse	0.004	0.003	0.004	0.004	0.003	75.21	53.85	80.62	78.60	63.13

Table 32. Calculated First Year Unit Savings: Directional and Screw-Base Omni-Directional LEDs (PY20+)

	Peak Demand Savings (kW)					Annual Energy Savings (kWh/yr)				
Building Type	MR16	PAR20	PAR30	PAR38	Omni-Screw	MR16	PAR20	PAR30	PAR38	Omni-Screw
Avg. Commercial	0.002	0.002	0.003	0.004	0.005	12.08	10.52	16.61	22.28	28.79
Cold Storage	0.001	0.001	0.002	0.003	0.004	42.91	37.37	59.00	79.13	102.25
Education	0.002	0.002	0.003	0.004	0.005	10.93	9.52	15.04	20.17	26.06
Grocery	0.005	0.004	0.006	0.008	0.011	32.62	28.41	44.85	60.16	77.73
Health	0.005	0.004	0.007	0.009	0.011	35.75	31.14	49.16	65.93	85.19
Hotel/Motel	0.002	0.002	0.003	0.004	0.005	10.35	9.01	14.23	19.08	24.66
Industrial	0.004	0.003	0.005	0.007	0.009	14.03	12.22	19.29	25.87	33.43
Office	0.001	0.001	0.002	0.003	0.003	12.99	11.32	17.87	23.96	30.96
Restaurant	0.004	0.003	0.005	0.007	0.009	27.66	24.09	38.03	51.00	65.91
Retail	0.003	0.002	0.004	0.005	0.006	15.73	13.70	21.63	29.01	37.49
Warehouse	0.000	0.000	0.001	0.001	0.001	9.97	8.68	13.71	18.38	23.75

Lifetime Savings: Directional and Screw-Base Omni-Directional LEDs, Dual Baseline

Table 33. Calculated Lifetime Unit Savings: Directional and Screw-Base Omni-Directional LEDs (PY19)

	Lifetime Energy Savings (kWh)				
Building Type	MR16	PAR20	PAR30	PAR38	Omni-Screw
Avg. Commercial	254.800	193.660	295.100	324.240	278.05
Cold Storage	409.550	306.530	465.020	496.610	476.25
Education	324.010	243.850	370.600	399.880	346.98
Grocery	311.360	233.040	353.520	377.550	362.06
Health	341.220	255.400	387.450	413.760	396.8

Hotel/Motel	327.360	248.790	379.140	416.520	377.66
Industrial	281.850	212.680	323.370	350.610	289.43
Office	274.000	208.300	317.400	348.680	350.34
Restaurant	291.650	221.670	337.770	371.090	372.89
Retail	300.300	224.760	340.980	364.140	287.08
Warehouse	220.210	168.460	257.210	285.860	292.51

Table 34. Calculated Lifetime Unit Savings: Directional and Screw-Base Omni-Directional LEDs (PY20+)

	Lifetime Energy Savings (kWh)				
Building Type	**MR16**	**PAR20**	**PAR30**	**PAR38**	**Omni-Screw**
Avg. Commercial	96.640	84.160	132.880	178.240	230.32
Cold Storage	128.730	112.110	177.000	237.390	306.75
Education	109.300	95.200	150.400	201.700	260.6
Grocery	97.860	85.230	134.550	180.480	233.19
Health	107.250	93.420	147.480	197.790	255.57
Hotel/Motel	124.200	108.120	170.760	228.960	295.92
Industrial	98.210	85.540	135.030	181.090	234.01
Office	103.920	90.560	142.960	191.680	247.68
Restaurant	110.640	96.360	152.120	204.000	263.64
Retail	94.380	82.200	129.780	174.060	224.94
Warehouse	89.730	78.120	123.390	165.420	213.75

RESOURCES

- 10 CFR 430.32(n) General service fluorescent lamps and incandescent reflector lamps. Paragraph (4).
- 2016 Statewide Customized Offering Procedures Manual for Business. Appendix B: Table of Standard Fixture Wattages. July 2014, Version 6.0.
- ACEEE, "Lighting/HVAC Interactions and Their Effects on Annual and Peak HVAC Requirements in Commercial Buildings," Sezgen, A. O., Y. J. Huang, Lawrence Berkeley Laboratory, *ACEEE Summer Study* , 1994.
- AEG's 2018 Analysis File titled "AEG HPUC Update of Com-Lighting Measures - Analysis file."
- AEG's 2018 Analysis of U.S. Department of Energy's OpenEI Commercial Hourly Load Profiles using Hawaiʻi-specific data. OpenEI data files available here: https://openei.org/doe-opendata/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states.
- Arkansas Technical Reference Manual, Version 7.0, Arkansas Public Service Commission, 2017.
- California Public Utilities Commission (CPUC), DEER2016, Interior Lighting Hours-of-Use (HOU), Peak Period Coincident Demand (CDF), and HVAC Interactive Effects (IE) for San Diego, CA, Updated May 27, 2015, available here: http://www.deeresources.com. (There were no additional updates to interior lighting HOU, CDF, and IE factors in DEER2020.)
- California Public Utilities Commission (CPUC), DEER2020, Ex Ante database Support Table Export, EUL_basis, 1/1/2013 - 1/1/2021, available here: http://www.deeresources.com.
- Consortium of Energy Efficiency (CEE), Commercial Lighting Qualifying Product Lists, August 2018 T8 Replacement Lamps.xlsx, https://library.cee1.org/content/commercial-lighting-qualifying-products-lists.
- DesignLights Consortium (DLC), https://www.designlights.org, https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/.
- Efficiency Vermont Technical Reference User Manual, Measure Savings Algorithms and Cost Assumptions, 2015.
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- Hawaiʻi Energy PY17 Program Data for BEEM. Filename: "EMV Extract UPDATED 20181015." Spreadsheet. AEG used data to develop shares of participant energy savings (kWh) by building type. The shares were then used to estimate weighted averages of key parameters for the average commercial building type ("Avg. Commercial").
- Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 6.0, Volume 2: Commercial and Industrial Measures, FINAL, Feb. 8, 2017.
- Lighting Research Center, Publications, 061Incandescent, page 114, Halogen A, https://www.lrc.rpi.edu/resources/publications/lpbh/061Incandescent.pdf, accessed 11/7/2018.
- Mid-Atlantic Technical Reference Manual, Version 8, Final, May 2018.
- Program Year 2017 (PY17) Program Tracking Data for Hawaiʻi Energy's BEEM program.
- Regional Technical Forum. Non-Residential Lighting, Midstream - Unit Energy Savings Workbook, Version 1.3 (NonResLightingMidstream_v1.3.xlsm). Northwest Power and Conservation Council. April 10, 2018. Spreadsheet.
- Rhode Island Technical Reference Manual – 2018 Program Year, National Grid, 2017.
- SBDIL Custom Hours Investigation Results, Memorandum, Submitted by Opinion Dynamics, Submitted to Energy Efficiency Manager, Dec. 12, 2017.
- U.S. Department of Energy, Appliance and Equipment Standards Rulemakings and Notices, General Service Fluorescent Lamps, accessed 11/4/2018, https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=22&redirect=true.
- Uniform Methods Project, Chapter 2: Commercial and Industrial Lighting Evaluation Protocol, D. Gowans, Left Fork Energy, and C. Telarico, DNV GL, C. Kurnik, National Renewable Energy Laboratory, October 2017.

COMMERCIAL: Exterior Lighting

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UPDATE STATUS

Added/updated in Fall 2018 for PY19 TRM. (Exterior Lighting was combined with Interior Lighting in the "General" tab in the PY18 TRM.)

MEASURE DETAILS

Description

Replacement of exterior High Intensity Discharge (HID) fixtures with LED luminaires in outdoor street and exterior area applications. Other types of exterior lighting may be addressed with a custom approach.

Program Criteria

The replacement LED fixture must be on the Consortium for Energy Efficiency's (CEE's) most recent Commercial Lighting Qualifying Products List, have an ENERGY STAR label, or be on DesignLights Consortium's Qualified Product List (DLC QPL).

Unit of Measure

One fixture.

Baseline Equipment

Exterior HID fixture.

High Efficiency Equipment

Exterior LED fixture.

ALGORITHMS

Peak Demand Reduction, kW

$$\Delta kW = (kW_{base} - kW_{EE}) * ISR * CF * PF \quad (1)$$

Annual Energy Savings, kWh/yr

$$\Delta kWh = (kW_{base} - kW_{EE}) * ISR * HOU_{year} * PF \quad (2)$$

Lifetime Energy Savings, kWh

$$\Delta kWh_{life} = \Delta kWh * EUL_{EE} \quad (3)$$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Source/Notes
kW_{base}	Wattage of the baseline lamp	See Table 1	kW	Assumes replace on burnout (ROB)

kW_{EE}	Wattage of the proposed efficient lamp	See Table 1	kW	DLC QPL and other benchmarking performed in 2018
ISR	In-service rate	1.00	-	AEG's Fall 2018 Benchmarking
CF	Peak demand coincidence factor	0.62	-	AEG's analysis of average annual sunset time in Honolulu (6:32 PM) and overlap with the 5-9 PM peak demand period.
HOU_{year}	Average hours of use per year	4,100	hr/yr	HECO Rate Schedule F, 2018. Assumes no motion sensors.
PF	Persistence factor	1.00	-	Footnote 1
EUL_{EE}	Effective useful life of efficient lamp	12	yrs	Based on Rated Lamp Life[2] of 50,000 hr and HOU of 4,100 hr/yr

[1] Use value of PF=1 until more data is available on PF of LEDs relative to baseline lighting.

[2] Source of rated lamp life includes DEER, DLC, and other benchmarking.

Table 1. Wattages, kW_{base} and kW_{EE}

Lighting Type	Baseline Wattage, kW_{base}		Efficient Wattage, kW_{EE}		Source
LED: HID replacement, <35W	HID 50W-100W Baseline: 64W, 86W, 128W	0.093	LED: HID replace, <35W	0.028	Benchmarking; no change from PY18 TRM
LED: HID replacement, 35W-149W	HID 150W-250W Baseline: 188W, 240W, 295W	0.241	LED: HID replace, 35W-149W	0.078	Benchmarking; no change from PY18 TRM
LED: HID replacement, 150W-220W	HID 310W-600W Baseline: 365W, 457W, 665W	0.496	LED: HID replace, 150W-220W	0.170	Benchmarking; no change from PY18 TRM
LED: HID replacement, >220W	HID 750W-1000W Baseline: 840W, 1100W	0.970	LED: HID replace, >220W	0.270	Benchmarking; no change from PY18 TRM

SAVINGS

First Year Savings: LED Exterior Fixtures, ROB, Single Baseline

Table 2. Calculated First Year Unit Demand Savings

	Peak Demand Savings (kW)			
Lighting Type	**<35W**	**35W-149W**	**150W-220W**	**>220W**
Exterior	0.040	0.101	0.202	0.434

Table 3. Calculated First Year Unit Energy Savings

	Annual Energy Savings (kWh/year)			
Lighting Type	**<35W**	**35W-149W**	**150W-220W**	**>220W**
Exterior	266.50	668.30	1,336.60	2,870.00

Lifetime Savings: LED Exterior Fixtures, ROB, Single Baseline

Table 4. Calculated Lifetime Unit Savings

	Lifetime Energy Savings (kWh)			
Lighting Type	**<35W**	**35W-149W**	**150W-220W**	**>220W**
Exterior	3,198.00	8,019.60	16,039.20	34,440.00

RESOURCES

- 2016 Statewide Customized Offering Procedures Manual for Business. Appendix B: Table of Standard Fixture Wattages. July 2014, Version 6.0.
- AEG's 2018 Analysis File titled "AEG HPUC Update of Com-Lighting Measures - Analysis file."
- AEG's Analysis of Sunset Data for Honolulu, HI. Source: Sunrise-Sunset online tool, accessed 11/4/2018, https://sunrise-sunset.org/.
- DesignLights Consortium (DLC), https://www.designlights.org, https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/.
- Hawaiian Electric Company, Rate Schedule F, Public Street Lighting, Highway Lighting and Park and Playground Floodlighting, Revised Sheet No. 59, Effective September 1, 2018.
- Mid-Atlantic Technical Reference Manual, Version 8, Final, May 2018.

COMMERCIAL: Dimmable Lighting (Non-Linear LED)

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UPDATE STATUS

Updated in Fall 2018 for PY19 TRM.

MEASURE DETAILS

Description

Replacement of non-linear EISA-compliant omni-directional and directional lamps with LED lamps in existing buildings. A percentage of the replacement LED lamps are assumed to be dimmable.

Program Criteria

This measure is applicable to both the BEEM and BHTR programs.
Incentivized LED lamps must be ENERGY STAR labeled or Design Lights Consortium (DLC) listed.

Unit of Measure

One lamp.

Baseline Equipment

This measure has a dual baseline for PY19. The first baseline is an omni-directional or directional halogen-incandescent or CFL lamp that complies with Energy Independence and Securities Act (EISA) 2007 legislation that had 2012-2014 effective dates (EISA Tier 1). The second baseline is a lamp that complies with the EISA Tier 2 2020 Backstop requirement of 45 lumens per watt. For PY20 and later, there is a single baseline (EISA Tier 2). The baseline lamps are assumed to be undimmed.

High Efficiency Equipment

The high efficiency case is an omni-directional or directional LED lamp. A percentage of the replacement lamps are assumed to be dimmable.

ALGORITHMS

Wattage of High Efficiency Case

$$kW_{EE,blend} = \left(kW_{EE} * \%_{dimmable} * (1 - SVG_{dim})\right) + (kW_{EE} * \%_{non-dimmable}) \quad (1)$$

First Baseline Peak Demand Reduction, kW

$$\Delta kW_{1st} = \left(kW_{base,1} - kW_{EE,blend}\right) * ISR * CF * IE_{C,D} * PF \quad (2)$$

Second Baseline Peak Demand Reduction, kW

$$\Delta kW_{2nd} = \left(kW_{base,2} - kW_{EE,blend}\right) * ISR * CF * IE_{C,D} * PF \quad (3)$$

First Baseline Annual Energy Savings, kWh/yr

$$\Delta kWh_{1st} = \left(kW_{base,1} - kW_{EE,blend}\right) * ISR * HOU_{year} * IE_{C,E} * PF \quad (4)$$

Second Baseline Annual Energy Savings, kWh/yr

$$\Delta kWh_{2nd} = \left(kW_{base,2} - kW_{EE,blend}\right) * ISR * HOU_{year} * IE_{C,E} * PF \quad (5)$$

Lifetime Energy Savings, kWh (Applicable to PY19)

$$\Delta kWh_{life,dual} = \Delta kWh_{1st} * EUL_{1st} + \Delta kWh_{2nd} * (EUL_{EE} - EUL_{1st}) \quad (7)$$

Lifetime Energy Savings, kWh (Applicable to PY20 and later)

$$\Delta kWh_{life,single} = \Delta kWh_{2nd} * EUL_{EE} \quad (8)$$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Source/Notes**
$kW_{EE,blend}$	Wattage of high efficiency case, including dimmable blend consideration	See Table 1	kW	
kW_{EE}	Wattage of high efficiency case, undimmed	See Table 1	kW	
$\%_{dimmable}$	Percent of lamps incentivized that are dimmable	See Table 1	-	Historical program data
$\%_{non\text{-}dimmable}$	Percent of lamps incentivized that are non-dimmable	See Table 1	-	Historical program data
SVG_{dim}	Percent savings from dimming lamps	34%	-	Williams et al[1] and AEG's Fall 2018 Benchmarking; corresponds to "institutional" and "personal" dimming with continuously dimmable lamps
$kW_{base,1}$	Wattage of the first baseline lamp	See Table 1	kW	
$kW_{base,2}$	Wattage of the second baseline lamp	See Table 1	kW	
ISR	Lifetime in-service rate	0.98	-	AEG's Fall 2018 Benchmarking
CF	Peak demand coincidence factor	See C_Light_General tab, Table 3	-	AEG's analysis of DOE's OpenEI load shapes using Hawaiʻi-specific prototypes, weather data, and peak demand period, adjusted to specific lighting types
$IE_{C,D}$	Interactive effects factor to account for cooling demand savings due to reducing waste heat with efficient lighting	See C_Light_General tab, Table 4	-	DEER20202 interactive effect factors for San Diego, adjusted to Hawaiʻi's weather zone using LBNL simulation results3

$IE_{C,E}$	Interactive effects factor to account for cooling energy savings due to reducing waste heat with efficient lighting	See C_Light_General tab, Table 4	-	DEER20202 interactive effect factors for San Diego, adjusted to Hawai'i's weather zone using LBNL simulation results3
HOU_{year}	Average hours of use per year	See C_Light_General tab, Table 5	hr/yr	DEER2020[2] hours of use for San Diego (CA's southern-most latitude); no occupancy sensor
PF	Persistence factor	1.00	-	Footnote 4
EUL_{1st}	Effective useful life of first baseline lamp	See C_Light_General tab, Table 6	yrs	Calculated by dividing rated lamp life[5] by HOU_{year} and setting upperbound EUL = 25 yr and lowerbound EUL = 1 yr
EUL_{EE}	Effective useful life of efficient lamp	See C_Light_General tab, Table 7	yrs	Calculated by dividing rated lamp life[5] by HOU_{year} and setting upperbound EUL = 25 yr and lowerbound EUL = 1 yr

[1] Williams, Alison, Atkinson, Barbara, Garbesi, Karina, & Rubinstein, Francis, “A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings”. Lawrence Berkeley National Laboratory. September 2011. Table 6, p. 14. Weighted average by number of “reviewed” and “non reviewed” papers.

[2] The DEER interactive effect factors and hours of use were developed for DEER2016 and they are still applicable to DEER2020.

[3] "Lighting/HVAC Interactions and Their Effects on Annual and Peak HVAC Requirements in Commercial Buildings," Sezgen, A. O., Y. J. Huang, Lawrence Berkeley Laboratory, ACEEE Summer Study, 1994.

[4] Use value of PF=1 until more data is available on PF of LEDs relative to baseline lighting.

[5] Sources of rated lamp life include DEER, DLC, and other benchmarking.

Table 1. Measure Descriptions

Lighting Type	$kW_{base,1}$	$kW_{base,2}$	kW_{EE}	$\%_{dim}$	$\%_{non\text{-}dim}$	$kW_{EE,blend}$	Notes
LED: Omni-Directional, A19 Screw Base	0.047	0.024	0.010	12%	88%	0.010	Wattages represent a weighted average by lamp type (EISA lumen bin). See R_Light_LED for details.
LED: Omni-Directional, Pin Base	0.026	-	0.009	12%	88%	0.009	Base: Pin base CFL; EE: Replacement LED product
LED: MR16	0.050	0.011	0.007	66%	34%	0.005	Base: 1) Halogen; 2) EISA Tier 2 requirement of 45 lumen/W; EE: Representative ENERGY STAR certified products

LED: PAR20	0.039	0.012	0.007	8%	92%	0.007	Base: 1) Halogen; 2) EISA Tier 2 requirement of 45 lumen/W; EE: Representative ENERGY STAR certified products
LED: PAR30	0.060	0.020	0.013	27%	73%	0.012	Base: 1) Halogen; 2) EISA Tier 2 requirement of 45 lumen/W; EE: Representative ENERGY STAR certified products
LED: PAR38	0.060	0.024	0.015	39%	61%	0.013	BS: 1) Halogen; 2) EISA Tier 2 requirement of 45 lumen/W; EE: Representative ENERGY STAR certified products

SAVINGS

The savings in Tables 2-7 below are the same as in Tables 29-34 in the C_Light_General tab.

First Year Savings: Pin-Base Omni-Directional, Single Baseline

Table 2. Calculated First Year Unit Savings: Pin-Base Omni-Directional

Building Type	Peak Demand Savings (kW)	Annual Energy Savings (kWh/year)
Avg. Commercial	0.007	35.21
Cold Storage	0.004	125.06
Education	0.006	31.87
Grocery	0.013	95.07
Health	0.014	104.19
Hotel/Motel	0.006	30.16
Industrial	0.011	40.89
Office	0.004	37.87
Restaurant	0.011	80.61
Retail	0.008	45.85
Warehouse	0.001	29.05

Lifetime Savings: Pin-Base Omni-Directional, ROB, Single Baseline

Table 3. Calculated Lifetime Unit Savings: Pin-Base Omni-Directional

Building Type	Lifetime Energy Savings (kWh)
Avg. Commercial	281.68
Cold Storage	375.18
Education	318.70
Grocery	285.21
Health	312.57
Hotel/Motel	361.92
Industrial	286.23
Office	302.96
Restaurant	322.44
Retail	275.10
Warehouse	261.45

First Year Savings: Directional and Screw-Base Omni-Directional LEDs, Dual Baseline

Table 4. Calculated First Year Unit Savings: Directional and Screw-Base Omni-Directional LEDs (PY19)

	Peak Demand Savings (kW)					Annual Energy Savings (kWh/yr)				
Building Type	**MR16**	**PAR20**	**PAR30**	**PAR38**	**Omni-Screw**	**MR16**	**PAR20**	**PAR30**	**PAR38**	**Omni-Screw**
Avg. Commercial	0.017	0.012	0.018	0.018	0.014	91.16	65.27	97.72	95.28	76.52
Cold Storage	0.011	0.008	0.012	0.012	0.009	323.73	231.79	347.02	338.35	271.75
Education	0.016	0.011	0.017	0.017	0.013	82.50	59.07	88.44	86.23	69.25
Grocery	0.034	0.025	0.037	0.036	0.029	246.12	176.22	263.82	257.23	206.60
Health	0.036	0.026	0.038	0.037	0.030	269.72	193.12	289.13	281.90	226.42
Hotel/Motel	0.015	0.010	0.016	0.015	0.012	78.07	55.90	83.69	81.60	65.53
Industrial	0.028	0.020	0.030	0.029	0.023	105.85	75.79	113.46	110.63	88.85
Office	0.010	0.007	0.011	0.011	0.009	98.03	70.19	105.09	102.46	82.29
Restaurant	0.028	0.020	0.030	0.029	0.023	208.67	149.40	223.68	218.09	175.16
Retail	0.020	0.014	0.021	0.020	0.016	118.69	84.98	127.23	124.05	99.63
Warehouse	0.004	0.003	0.004	0.004	0.003	75.21	53.85	80.62	78.60	63.13

Table 5. Calculated First Year Unit Savings: Directional and Screw-Base Omni-Directional LEDs (PY20+)

	Peak Demand Savings (kW)					Annual Energy Savings (kWh/yr)				
Building Type	**MR16**	**PAR20**	**PAR30**	**PAR38**	**Omni-Screw**	**MR16**	**PAR20**	**PAR30**	**PAR38**	**Omni-Screw**
Avg. Commercial	0.002	0.002	0.003	0.004	0.005	12.08	10.52	16.61	22.28	28.79
Cold Storage	0.001	0.001	0.002	0.003	0.004	42.91	37.37	59.00	79.13	102.25
Education	0.002	0.002	0.003	0.004	0.005	10.93	9.52	15.04	20.17	26.06
Grocery	0.005	0.004	0.006	0.008	0.011	32.62	28.41	44.85	60.16	77.73
Health	0.005	0.004	0.007	0.009	0.011	35.75	31.14	49.16	65.93	85.19
Hotel/Motel	0.002	0.002	0.003	0.004	0.005	10.35	9.01	14.23	19.08	24.66
Industrial	0.004	0.003	0.005	0.007	0.009	14.03	12.22	19.29	25.87	33.43
Office	0.001	0.001	0.002	0.003	0.003	12.99	11.32	17.87	23.96	30.96
Restaurant	0.004	0.003	0.005	0.007	0.009	27.66	24.09	38.03	51.00	65.91
Retail	0.003	0.002	0.004	0.005	0.006	15.73	13.70	21.63	29.01	37.49
Warehouse	0.000	0.000	0.001	0.001	0.001	9.97	8.68	13.71	18.38	23.75

Lifetime Savings: Directional and Screw-Base Omni-Directional LEDs, Dual Baseline

Table 6. Calculated Lifetime Unit Savings: Directional and Screw-Base Omni-Directional LEDs (PY19)

	Lifetime Energy Savings (kWh)				
Building Type	**MR16**	**PAR20**	**PAR30**	**PAR38**	**Omni-Screw**
Avg. Commercial	254.80	193.66	295.10	324.24	278.05
Cold Storage	409.55	306.53	465.02	496.61	476.25
Education	324.01	243.85	370.60	399.88	346.98
Grocery	311.36	233.04	353.52	377.55	362.06
Health	341.22	255.40	387.45	413.76	396.80
Hotel/Motel	327.36	248.79	379.14	416.52	377.66
Industrial	281.85	212.68	323.37	350.61	289.43
Office	274.00	208.30	317.40	348.68	350.34
Restaurant	291.65	221.67	337.77	371.09	372.89
Retail	300.30	224.76	340.98	364.14	287.08
Warehouse	220.21	168.46	257.21	285.86	292.51

Table 7. Calculated Lifetime Unit Savings: Directional and Screw-Base Omni-Directional LEDs (PY20+)

	Lifetime Energy Savings (kWh)				
Building Type	**MR16**	**PAR20**	**PAR30**	**PAR38**	**Omni-Screw**
Avg. Commercial	96.640	84.160	132.880	178.240	230.320
Cold Storage	128.730	112.110	177.000	237.390	306.750
Education	109.300	95.200	150.400	201.700	260.600
Grocery	97.860	85.230	134.550	180.480	233.190
Health	107.250	93.420	147.480	197.790	255.570
Hotel/Motel	124.200	108.120	170.760	228.960	295.920
Industrial	98.210	85.540	135.030	181.090	234.010
Office	103.920	90.560	142.960	191.680	247.680
Restaurant	110.640	96.360	152.120	204.000	263.640
Retail	94.380	82.200	129.780	174.060	224.940
Warehouse	89.730	78.120	123.390	165.420	213.750

RESOURCES

- AEG's 2018 Analysis File titled "AEG HPUC Update of Com-Lighting Measures - Analysis file."
- AEG's 2018 Analysis of U.S. Department of Energy's OpenEI Commercial Hourly Load Profiles using Hawaiʻi-specific data. OpenEI data files available here: https://openei.org/doe-opendata/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states.
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- California Public Utilities Commission (CPUC), DEER2020, Ex Ante database Support Table Export, EUL_basis, 1/1/2013 - 1/1/2021, available here: http://www.deeresources.com.
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- Lighting/HVAC Interactions and Their Effects on Annual and Peak HVAC Requirements in Commercial Buildings, Sezgen, A. O., Y. J. Huang, Lawrence Berkeley Laboratory, ACEEE Summer Study, 1994.
- Program Year 2017 (PY17) Program Tracking Data for Hawaiʻi Energy's BEEM program.
- Public Utility Commission of Texas, Texas Technical Reference Manual, Version 5.0, Volume 3: Nonresidential Measures, Program Year (PY) 2018, October 2017.
- Regional Technical Forum. Non-Residential Lighting, Midstream - Unit Energy Savings Workbook, Version 1.3 (NonResLightingMidstream_v1.3.xlsm). Northwest Power and Conservation Council. April 10, 2018. Spreadsheet.
- State of Pennsylvania Technical Reference Manual, Pennsylvania Public Utilities Commission, June 2016.
- Williams, Alison, Atkinson, Barbara, Garbesi, Karina, & Rubinstein, Francis, “A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings”. Lawrence Berkeley National Laboratory. September 2011.

COMMERCIAL: Refrigerated Case Lighting

Return to TOC

UPDATE STATUS

Updated in Fall 2018 for PY19 TRM.

MEASURE DETAILS

Description

This measure involves retrofitting the linear fluorescent lighting system within an existing low or medium temperature refrigerated case with efficient LED refrigerated case lighting.

Program Criteria

New refrigerated cases do not qualify for this measure. The qualifying technology must be specifically designed for refrigerated case lighting applications. For example, lamps in the DLC "General Application: Case Lighting" category qualify. An equivalent category of lamps rated by ENERGY STAR or Lighting Facts may qualify as well, pending Program approval.

Unit of Measure

One retrofit kit.

Baseline Equipment

Early replacement projects require a dual baseline. The first baseline is the pre-existing equipment, which has been estimated as a blend of 40% T12 and 60% T8 fluorescent lamps. The pre-existing equipment is assumed to have a remaining useful life (RUL) of one-third of the Effective Useful Life (EUL) of the fluorescent lamps. The second baseline must comply with the current federal code for general service fluorescent lamps that took effect on January 26, 2018 (10 CFR 430.32(n), paragraph (4)). Only lamps that are in working order at the time of the replacement qualify for early replacement. If the pre-existing lamps cannot be verified to be in working order, a replace on burnout (ROB) baseline must be used.

ROB projects have a single baseline. The baseline must comply with current federal codes and standards for general service fluorescent lamps, which took effect January 26, 2018.

High Efficiency Equipment

LED replacement lamp unit.

ALGORITHMS

First Baseline Peak Demand Reduction, kW

$$\Delta kW_{1st} = \left(kW_{base,1} - kW_{EE}\right) * ISR * CF * \left(1 + WH_{C,D} + WH_{R,D}\right) * PF \quad (1)$$

Second Baseline Peak Demand Reduction, kW

$$\Delta kW_{2nd} = \left(kW_{base,2} - kW_{EE}\right) * ISR * CF * \left(1 + WH_{C,D} + WH_{R,D}\right) * PF \quad (2)$$

First Baseline Annual Energy Savings, kWh/yr

$$\Delta kWh_{1st} = \left(kW_{base,1} - kW_{EE}\right) * ISR * HOU_{year} * \left(1 + WH_{C,E} + WH_{R,E}\right) * PF \quad (3)$$

Second Baseline Annual Energy Savings, kWh/yr

$$\Delta kWh_{2nd} = \left(kW_{base,2} - kW_{EE}\right) * ISR * HOU_{year} * \left(1 + WH_{C,E} + WH_{R,E}\right) * PF \quad (4)$$

Lifetime Energy Savings, kWh (Dual Baseline, Early Replacement)

$$\Delta kWh_{life,dual} = \Delta kWh_{1st} * RUL + \Delta kWh_{2nd} * (EUL_{EE} - RUL) \quad (5)$$

Lifetime Energy Savings, kWh (Single Baseline, ROB)

$$\Delta kWh_{life,single} = \Delta kWh_{2nd} * EUL_{EE} \quad (6)$$

Remaining Useful Life (only applicable to Early Replacement)

$$RUL = 1/3 * EUL_{pre-exist} \quad (7)$$

Waste Heat Factors due to Interaction with Building Space Cooling System

$$WH_{C,D} = \left(IE_{C,D} - 1\right) * 0.5 \quad (8)$$

$$WH_{C,E} = \left(IE_{C,E} - 1\right) * 0.5 \quad (9)$$

Waste Heat Factors due to Interaction with Case Refrigeration System

$$WH_{R,D} = (3.412 kBtu/kWh) * 0.5/EER_R \quad (10)$$

$$WH_{R,E} = WH_{R,D} \quad (11)$$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Source/Notes**
$kW_{base,1}$	Wattage of the first baseline lamp	Table 1	kW	Manufacturer catalogs; includes ballast power factor of 0.98 for T8 and 0.90 for T12, as cited in RTF 2018 workbook[1]

$kW_{base,2}$	Wattage of the second baseline lamp	Table 1	kW	Manufacturer catalogs; includes ballast power factor of 0.98 for T8, as cited in RTF 2018 workbook[1]
kW_{EE}	Wattage of the proposed efficient lamp	Table 1	kW	Hawaiʻi Energy PY17 installation data for measure; assumes LED driver efficiency of 0.89 (driver efficiency from RTF 2018 workbook[1])
ISR	Lifetime in-service rate	1.00	-	AEG's Fall 2018 Benchmarking
CF	Peak demand coincidence factor	0.88	-	Adjustment of AEG's general lighting CF for the Grocery segment by ratio of $HOU_{refrig\_case}/HOU_{gen\_grocery\_light}$
HOU_{year}	Average hours of use per year	6,205	hr/yr	No change from PY18 TRM[2]
PF	Persistence factor	1.00	-	Footnote 3
$WH_{C,D}$	Waste heat factor due to lighting interaction with building space cooling system demand	0.05	-	See Equation 8; assumes 50% of lighting impacts general space cooling demand[4]
$WH_{C,E}$	Waste heat factor due to lighting interaction with building space cooling system energy use	0.07	-	See Equation 9; assumes 50% of lighting impacts general space cooling energy use[4]
$IE_{C,D}$	Interactive effects factor to account for cooling demand savings due to reducing waste heat with efficient lighting	1.09	-	From C_Light_General tab, Table 4
$IE_{C,E}$	Interactive effects factor to account for cooling energy savings due to reducing waste heat with efficient lighting	1.14	-	From C_Light_General tab, Table 4
$WH_{R,D}$	Waste heat factor due to lighting interaction with case refrigeration system demand	See Table 2	-	Assumes 50% of lighting impacts case refrigeration demand[4]
$WH_{R,E}$	Waste heat factor due to lighting interaction with case refrigeration system energy use	See Table 2	-	Assumes 50% of lighting impacts case refrigeration energy use[4]
EER_R	Energy efficiency ratio of case refrigeration system	See Table 2	kBtu/ kWh	From RTF 2018[1]
RUL	Remaining useful life of pre-existing lamp	1	yrs	Per Equation 7, assumes 1/3 $EUL_{pre-existing}$, rounded to nearest year

$EUL_{pre\text{-}existing}$	Effective useful life of pre-existing lamp	4	yrs	Assumes lamp life of 24,000 hours
EUL_{EE}	Effective useful life of efficient lamp	8	yrs	Assumes lamp life of 50,000 hours

[1] Regional Technical Forum. Commercial Grocery Display Case Lighting - Unit Energy Savings Workbook, Version 1.1. Northwest Power and Conservation Council. Oct. 1, 2018. Spreadsheet.

[2] The original source is Theobald, M. A., Emerging Technologies Program: Application Assessment Report #0608, LED Supermarket Case Lighting Grocery Store, Northern California, Pacific Gas and Electric Company, January 2006. Assumes refrigerated case lighting typically operates 17 hours per day, 365 days per year. Benchmarking results indicate that refrigerated case lighting is not tied to general store lighting.

[3] Use value of PF=1 until more data is available on PF of LEDs relative to baseline lighting.

[4] Based on a ratio of 0.5 used in the Department of Energy TSD for Commercial Refrigeration, Table 5.6.1. "Fraction of lighting power into case for lighting outside of air curtain (W/W)" (https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/cre2_nopr_tsd_2013_08_28.pdf). The same logic implies the fraction of lighting power outside of the refrigerated case for lighting that is inside of the case is 50%. So, the assumption is that 50% of lighting affects general cooling load and 50% of lighting affects case refrigeration load.

Table 1. Measure Descriptions: Wattages

Lighting Type	$kW_{base,1}$	$kW_{base,2}$	kW_{EE}
4' retrofit kit	0.0442	0.0382	0.0188
5' retrofit kit	0.0553	0.0478	0.0225
6' retrofit kit	0.0664	0.0574	0.0252

The pre-existing baseline ($kW_{base,1}$) consists of a 60%/40% T8/T12 blend.

Table 2. Waste Heat Factors for Refrigeration

Case Type	EER_R [1]	$WH_{R,D}$	$WH_{R,E}$ [2]
Medium Temperature (Refrigerators/ Coolers)	10.60	0.16	0.16
Low Temperature (Freezers)	4.10	0.42	0.42

[1] From RTF 2018 Workbook. EERs are the regional weighted averages from Standard Information Workbook v3.2. A future update to the Hawai‘i TRM should include Hawai‘i-specific EER data from market research.

[2] Assume the energy and demand waste heat factors for refrigeration are equivalent. This is consistent with other sources reviewed.

SAVINGS

First Year Savings: Early Replacement, Dual Baseline

Case Type	Measure Name	Peak Demand Savings	Annual Energy Savings
Medium Temperature (Refrigerators/Coolers)	4-foot lamp	0.027 kW	194.31 kWh
	5-foot lamp	0.035 kW	250.53 kWh

(Refrigerators/Coolers)	6-foot lamp	0.044 kW	314.38 kWh
Low Temperature (Freezers)	4-foot lamp	0.033 kW	234.59 kWh
	5-foot lamp	0.042 kW	302.46 kWh
	6-foot lamp	0.053 kW	379.55 kWh

First Year Savings: Replace on Burnout, Single Baseline

Case Type	Measure Name	Peak Demand Savings	Annual Energy Savings
Medium Temperature (Refrigerators/Coolers)	4-foot lamp	0.021 kW	148.48 kWh
	5-foot lamp	0.027 kW	193.24 kWh
	6-foot lamp	0.034 kW	245.64 kWh
Low Temperature (Freezers)	4-foot lamp	0.025 kW	179.26 kWh
	5-foot lamp	0.033 kW	233.30 kWh
	6-foot lamp	0.042 kW	296.55 kWh

Lifetime Savings: Early Replacement, Dual Baseline

Case Type	Measure Name	Lifetime Energy Savings
Medium Temperature (Refrigerators/Coolers)	4-foot lamp	1,233.67 kWh
	5-foot lamp	1,603.21 kWh
	6-foot lamp	2,033.86 kWh
Low Temperature (Freezers)	4-foot lamp	1,489.41 kWh
	5-foot lamp	1,935.56 kWh
	6-foot lamp	2,455.40 kWh

Lifetime Savings: Replace on Burnout, Single Baseline

Case Type	Measure Name	Lifetime Energy Savings
Medium Temperature (Refrigerators/Coolers)	4-foot lamp	1,187.84 kWh
	5-foot lamp	1,545.92 kWh
	6-foot lamp	1,965.12 kWh
Low Temperature (Freezers)	4-foot lamp	1,434.08 kWh
	5-foot lamp	1,866.40 kWh
	6-foot lamp	2,372.40 kWh

RESOURCES

- AEG's 2018 Analysis File titled "AEG HPUC Update of Com-Lighting Measures - Analysis file."
- California Public Utilities Commission, Database of Energy Efficiency Resources, 2020 update, (DEER2020), READI v.2.5.0, Ex Ante Database Support Table Export, EUL_basis, created on 8/24/2018, available here: www.deeresources.com/index.php/homepage. Spreadsheet.

- Department of Energy, TSD for Commercial Refrigeration, Table 5.6.1. "Fraction of lighting power into case for lighting outside of air curtain (W/W)" (https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/cre2_nopr_tsd_2013_08_28.pdf).
- Michigan Energy Measure Database, v. 2018, https://www.michigan.gov/mpsc/0,4639,7-159-52495_55129---,00.html, filename: "mi_master_measure_database_2018-112917_609672_7"
- Mid-Atlantic Technical Reference Manual, Version 8, Final, May 2018.
- Program Year 2017 (PY17) Program Tracking Data for Hawaiʻi Energy's LED Refrigerated Case Lighting projects.
- Regional Technical Forum. Commercial Grocery Display Case Lighting - Unit Energy Savings Workbook, Version 1.1. Northwest Power and Conservation Council. Oct. 1, 2018. Spreadsheet.
- State of Minnesota, Technical Reference Manual for Energy Conservation Improvement Programs, Version 2.2, May 2, 2018.
- State of Pennsylvania Technical Reference Manual, Pennsylvania Public Utilities Commission, June 2016.
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- Theobald, M. A., Emerging Technologies Program: Application Assessment Report #0608, LED Supermarket Case Lighting Grocery Store, Northern California, Pacific Gas and Electric Company, January 2006.

COMMERCIAL: Light Occupancy Sensor

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UPDATE STATUS

Updated in Fall 2018 for PY19 TRM.

MEASURE DETAILS

Description

This measure is for wall switch sensors that control the use of lighting in areas around the facility with variable use.

Program Criteria

The savings approach for this measure assumes the occupancy sensors are installed in existing buildings that have not yet been required to comply with current ANSI/ASHRAE/IES Standard 90.1 requirements for occupancy sensors.

Ultrasonic and infrared sensors are eligible.

Unit of Measure

One sensor.

Baseline Equipment

Manual switch.

High Efficiency Equipment

Occupancy sensor installed.

ALGORITHMS

Peak Demand Reduction, kW

$$\Delta kW = (P_{ctrl}/1000) * RTR * ISR * CF * IE_{C,D} * PF \quad (1)$$

Annual Energy Savings, kWh/yr

$$\Delta kWh = (P_{ctrl}/1000) * RTR * ISR * HRS * IE_{C,E} * PF \quad (2)$$

Lifetime Energy Savings, kWh

$$\Delta kWh_{life} = \Delta kWh * EUL_{EE} \quad (3)$$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Source/Notes

P_{ctrl}	Total wattage controlled by sensor	Actual (default = 56.32)	W	Default is 2L F32T8 with 0.88 ballast factor controlled by one sensor
Constant	Conversion factor from W to kW	1,000	W/kW	
RTR	Runtime reduction factor from sensor	0.24	-	AEG's Fall 2018 Benchmarking; median of 16 reviewed sources
ISR	Lifetime in-service rate	0.98	-	AEG's Fall 2018 Benchmarking
CF	Coincidence factor	See Table 1	-	AEG's analysis of DOE's OpenEI load shapes using Hawaiʻi-specific prototypes, weather data, and peak demand period, adjusted to specific lighting types[1]
HRS	Hours of lighting operation	See Table 1	hrs	DEER2020[2] hours of use with no occupancy sensors for San Diego (CA's southern-most latitude)
$IE_{C,D}$	Interactive effects factor to account for cooling demand savings due to reducing waste heat with efficient lighting	See Table 1	-	DEER2020[2] interactive effect factors for San Diego, adjusted to Hawaiʻi's weather zone using LBNL simulation results;[3] Assumes 50% of spaces with occupancy sensors are air conditioned
$IE_{C,E}$	Factor reflecting impact of lighting savings on cooling load	See Table 1	-	DEER2020[2] interactive effect factors for San Diego, adjusted to Hawaiʻi's weather zone using LBNL simulation results;[3] Assumes 50% of spaces with occupancy sensors are air conditioned
PF	Persistence factor	1.00	-	Assumes that savings persistence is accounted for in the EUL
EUL_{EE}	Effective useful life of occupancy sensor measure	8	yrs	AEG's Fall 2018 Benchmarking; median of 16 reviewed sources

[1] This approach assumes that the occupancy pattern during 5-9 pm is consistent with rest of day, which may not be the case for some building types (e.g., offices). Overall, this is likely to yield conservative values for CF.

[2] The DEER interactive effect factors and hours of use were developed for DEER2016 and they are still applicable to DEER2020.

[3] "Lighting/HVAC Interactions and Their Effects on Annual and Peak HVAC Requirements in Commercial Buildings," Sezgen, A. O., Y. J. Huang, Lawrence Berkeley Laboratory, ACEEE Summer Study, 1994.

Table 1. Key Parameters for Occupancy Sensor Measure

(Applicable to Counties of Oahu, Maui, and Hawai'i)

Building Type	CF	HRS	$IE_{C,D}$	$IE_{C,E}$	Weights	Source
Avg. Commercial	0.34	2,428	1.10	1.13	-	Weighted averages based on kWh savings by building type associated with actual PY17 occupancy sensor projects.
Cold Storage	0.20	4,700	1.13	1.31	0%	Values tie back to C_Light_General tab, Tables 3, 4, and 5.
Education	0.32	1,702	1.16	1.13	2%	
Grocery	0.68	4,770	1.05	1.07	2%	
Health	0.63	5,100	1.12	1.08	21%	
Hotel/Motel	0.23	1,130	1.14	1.18	38%	
Industrial	0.59	2,305	1.10	1.07	1%	
Office	0.25	1,980	1.04	1.13	32%	
Restaurant	0.49	3,500	1.12	1.14	0%	
Retail	0.50	3,690	1.18	1.08	4%	
Warehouse	0.08	1,970	1.08	1.01	0%	

Notes:

a. Assumes linear, U-bend, or troffer lamps are controlled. (Values would be different for omni-directional, directional, decorative, or high bay lighting.)

b. The CF values were derived using the three step process described in the C_Light_General tab.

c. Baseline HRS are from DEER2020 hours of use for San Diego IOU for no occupancy sensor case.

d. The IE values were derived using the four step process described in the C_Light_General tab.

SAVINGS

Deemed Savings (based on default value for P_{ctrl})

Building Type	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Avg. Commercial	0.005 kW	36.44 kWh	291.52 kWh
Cold Storage	0.003 kW	81.56 kWh	652.48 kWh
Education	0.005 kW	25.36 kWh	202.88 kWh
Grocery	0.009 kW	67.61 kWh	540.88 kWh
Health	0.009 kW	72.62 kWh	580.96 kWh
Hotel/Motel	0.003 kW	17.66 kWh	141.28 kWh
Industrial	0.009 kW	32.52 kWh	260.16 kWh
Office	0.003 kW	29.64 kWh	237.12 kWh
Restaurant	0.007 kW	52.85 kWh	422.80 kWh
Retail	0.008 kW	52.55 kWh	420.40 kWh
Warehouse	0.001 kW	26.23 kWh	209.84 kWh

Semi-Prescriptive Savings Calculator (based on user input of P_{ctrl})

Enter total wattage controlled by sensor, P_{ctrl}

56.32

Building Type	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Avg. Commercial	0.005 kW	36.44 kWh	291.52 kWh
Cold Storage	0.003 kW	81.56 kWh	652.48 kWh
Education	0.005 kW	25.36 kWh	202.88 kWh
Grocery	0.009 kW	67.61 kWh	540.88 kWh
Health	0.009 kW	72.62 kWh	580.96 kWh
Hotel/Motel	0.003 kW	17.66 kWh	141.28 kWh
Industrial	0.009 kW	32.52 kWh	260.16 kWh
Office	0.003 kW	29.64 kWh	237.12 kWh
Restaurant	0.007 kW	52.85 kWh	422.80 kWh
Retail	0.008 kW	52.55 kWh	420.40 kWh
Warehouse	0.001 kW	26.23 kWh	209.84 kWh

RESOURCES

- ACEEE, "Lighting/HVAC Interactions and Their Effects on Annual and Peak HVAC Requirements in Commercial Buildings," Sezgen, A. O., Y. J. Huang, Lawrence Berkeley Laboratory, *ACEEE Summer Study* , 1994.
- AEG's 2018 Analysis File titled "AEG HPUC Update of Com-Lighting Measures - Analysis file."
- AEG's 2018 Analysis of U.S. Department of Energy's OpenEI Commercial Hourly Load Profiles using Hawaiʻi-specific data. OpenEI data files available here: https://openei.org/doe-opendata/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states.
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- Hawaiʻi Energy PY17 Program Data for Commercial Occupancy Sensor Projects. Filename: "EMV Extract UPDATED 20181015". Spreadsheet.
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- Mid-Atlantic Technical Reference Manual, Version 8, Final, May 2018.
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- Northwest Power Conservation Council (NWPCC). Commercial Interior Lighting Controls, Version 10 - Seventh Power Plan Conservation Supply Workbooks. February 25, 2016. Spreadsheet.
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- State of Minnesota, Technical Reference Manual for Energy Conservation Improvement Programs, Version 2.2, May 2, 2018.
- State of Pennsylvania Technical Reference Manual, Pennsylvania Public Utilities Commission, June 2016.
- Tennessee Valley Authority Technical Reference Manual, Version 6.0, Oct. 1, 2017.
- Vermont Energy Investment Corporation. Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 5.0. Illinois Energy Efficiency Stakeholder Advisory Group. February 11, 2016.

COMMERCIAL: Stairwell Bi-level Dimming Controls

Return to TOC

UPDATE STATUS

Updated in Fall 2018 for PY19 TRM.

MEASURE DETAILS

Description

Stairwell lighting typically operates continuously at full output despite very low, intermittent use. Bi-level stairwell dimming lights utilize either an ultrasonic or infrared motion sensor to detect motion in stairwells. Solid state controls are used to dim fixtures to lower light levels when a space is unoccupied. This measure may also include the installation of a new efficient fixture along with bi-level dimming controls.

Program Criteria

This measure applies to existing buildings. New construction is not eligible because the current ANSI/ASHRAE/IES Standard 90.1 requires that stairwell lighting be controlled so that lighting power can be reduced by at least 50% within 30 minutes of the stairwell space becoming unoccupied.

Ultrasonic and infrared sensors are eligible. Lighting must be ENERGY STAR labeled or Design Lights Consortium (DLC) listed and UL compliant.

Unit of Measure

Varies with scale of project.

Baseline Equipment

No bi-level dimming lights with occupancy sensors.

High Efficiency Equipment

Bi-level dimming lights with occupancy sensors.

ALGORITHMS

Peak Demand Reduction, kW

$$\Delta kW = \left(kW_{base} - \left(kW_{EE,dim} * \%_{time,dim} + kW_{EE,full} * \%_{time,full}\right)\right) * IE_{C,D} * ISR * CF * PF \qquad (1)$$

Annual Energy Savings, kWh/yr

$$\Delta kWh = \left(kW_{base} - \left(kW_{EE,dim} * \%_{time,dim} + kW_{EE,full} * \%_{time,full}\right)\right) * IE_{C,E} * ISR * HOU_{year} * PF \qquad (2)$$

$full$ $full$ $year$

Lifetime Energy Savings, kWh

$$\Delta kWh_{life} = \Delta kWh * EUL_{EE} \quad (3)$$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Source/Notes**
kW_{base}	Baseline kW load of continuous operation stairwell fixtures	User Input	kW	This is calculated based on user input of fixture wattages and fixture quantities
$kW_{EE,dim}$	kW load of stairwell fixtures in dim or low level mode when unoccupied	User Input	kW	This is calculated based on user input of fixture wattages in low power mode and fixture quantities
$kW_{EE,full}$	kW load of stairwell fixture in full power mode when occupied	User Input	kW	This is calculated based on user input of fixture wattages in full power mode and fixture quantities
$\%_{time,dim}$	Fraction of time stairwell fixture is in dim or low level mode when unoccupied	80%	%	AEG's Fall 2018 Benchmarking[1]
$\%_{time,full}$	Fraction of time stairwell fixture is in full power mode when occupied	20%	%	AEG's Fall 2018 Benchmarking[1]
$IE_{C,D}$	Interactive effects factor to account for cooling demand savings due to reducing waste heat with efficient lighting	1.00	-	Assumes negligible interaction with cooling equipment; conservative assumption, but reasonable since not all stairwells are conditioned
$IE_{C,E}$	Interactive effects factor to account for cooling energy savings due to reducing waste heat with efficient lighting	1.00	-	Assumes negligible interaction with cooling equipment; conservative assumption, but reasonable since not all stairwells are conditioned
ISR	Lifetime in-service rate	1.00		Assumes installations will be verified
CF	Coincidence factor	1.00	-	Assumes that occupancy patterns during peak hours of 5-9 PM are consistent (on average) with occupancy during the rest of the day
HOU_{year}	Hours of use per year	8,760	hrs	Assumes stairwell lighting must remain on 24 hr/day, 365 day/yr; value is consistent with AEG's Fall 2018 Benchmarking results

PF	Persistence factor	1.00	-	Assumes that savings persistence is accounted for in the EUL
EUL_{EE}	Effective useful life of measure	8	yrs	AEG's Fall 2018 Benchmarking

[1] Benchmarking yielded a median value of 79% for the percentage of time stairwells with bi-level occupancy control are in low power mode, and 21% for the percentage of time they are in full power mode. Values for low power mode varied from 62% to 97%, depending on the day of the week, building type, and stairwell type. AEG rounded to 80% and 20%.

SAVINGS

Semi-Prescriptive Savings Calculator (based on user input of fixture wattages and quantities)

1. Enter Baseline Fixture Wattage and Quantity (up to 3 types of fixtures)

Fixture Type	Full Power Mode Wattage, kW	Quantity
F32T8	0.031	10
F17T8	0.016	2

Note: Entries in red are for illustrative purposes only

kW_{base} = 0.342 kW

2. Enter Energy Efficient Fixture Wattages and Quantity (up to 3 types of fixtures)

Fixture Type	Full Power Mode Wattage, kW	Low Power Mode Wattage, kW	Quantity
F32T8	0.031	0.015	10
F17T8	0.016	0.008	2

Note: Entries in red are for illustrative purposes only

$kW_{EE,full}$ = 0.342 kW

$kW_{EE,dim}$ = 0.166 kW

Measure Name	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Stairwell Bi-Level Dimming	0.141 kW	1,233.41 kWh	9,867.26 kWh

Note: Savings in blue result from sample entries above. **They are for illustrative purposes only.**

RESOURCES

- AEG's 2018 Analysis File titled "AEG HPUC Update of Com-Lighting Measures - Analysis file."

- Connecticut's 2018 Program Savings Document, 13th Edition, filed December 15, 2017.
- Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 6.0, Volume 2: Commercial and Industrial Measures, FINAL, Feb. 8, 2017.
- Lighting Research Program, Project 5.1 Bi-Level Stairwell Fixture Performance, Final Report, prepared for California Energy Commission, Public Interest Energy Research Program, October 2015, CEC-500-2005-141-A16, Tables 2 and 3, https://www.energy.ca.gov/2005publications/CEC-500-2005-141/CEC-500-2005-141-A16.PDF
- Massachusetts Technical Reference Manual, 2013-2015 Program Years, October 2012.
- Michigan Energy Measure Database, v. 2018, https://www.michigan.gov/mpsc/0,4639,7-159-52495_55129---,00.html, filename: "mi_master_measure_database_2018-112917_609672_7"
- Public Service Company of Colorado. Xcel Energy. 2019/2020 Demand-Side Management Plan. Colorado Public Utilities Commission. August 31, 2018.
- Tennessee Valley Authority Technical Reference Manual, Version 6.0, Oct. 1, 2017.

COMMERCIAL: Energy Advantage

Return to TOC

UPDATE STATUS

The description was modified slightly for the PY19 TRM. Direct install or other early retirement projects that use pre-existing equipment for the baseline must use a dual baseline approach for lifetime savings to account for recent and forthcoming changes in federal codes and standards.

SAVINGS DESCRIPTION

The following documents how savings are calculated for the Energy Advantage projects within Amplify.

Each Energy Advantage application contains one or more Spaces, which represent different parts of a building affected by a project. Within each space the user selects the existing lighting equipment (e.g. base case) and the new lighting equipment (e.g. enhanced case) from the Amplify database, which has wattage values sourced from the product's specification. **Direct install or other early retirement projects that use pre-existing equipment for the baseline must use a dual baseline approach for lifetime savings to account for recent and forthcoming changes in federal codes and standards.**

In addition, Amplify does allow for the possibility that each space may have its own unique operating schedule.

The Equivalent Full Load Hours (EFLH)--which is often referred to as Hours of Use per year (HOU_{year}) for lighting projects--for each Space is calculated based on a user-entered start time and end time for each day of the week, modified by a user-entered set of holidays during which times the building is assumed to be inactive. The EFLH value can vary for different measures within the same Energy Advantage application due to various operating schedules entered per space. In the case where a user does not enter values for hours of operation, the default value used is 2,274 hours, which is based on an operating schedule of 8 AM to 5 PM Monday through Friday, with eight holidays per year. The eight holidays assumed include:

- New Year's Day,
- Martin Luther King Day,
- President's Day,
- Memorial Day,
- Independence Day,
- Labor Day,
- Thanksgiving Day, and
- Christmas Day

It is important to note that the specific holidays do not matter since it is simply a quantity (# Holidays * Hours/Day) that is used to adjust an annual total.

Formula:

EFLH = (Sum(Hours per Day of Week)*52.142857)–((Number of Holidays)*Avg. Operating Hours per Day)

Default: *EFLH = (9*5*52.142857) – (8*9) = 2,274.4 hours/year*

Where: Hours per Day of Week is evaluated for each day of the week and is equal to:

WHEN End Hours > Start Hours THEN End Hours - Start Hours

WHEN End Hours < Start Hours THEN End Hours - Start Hours + 24

WHEN End Hours = Start Hours THEN 24

COMMERCIAL: Anti-Sweat Heater Controls

Return to TOC

MEASURE DETAILS

Description

Anti-sweat heater controls sense the relative humidity in the air outside of a refrigerated display case and reduces or shuts off the glass door and/or frame anti-sweat heaters based on dew point temperature. Heat generated by an ASH is also load on the display case refrigeration system. Thus, reduction in ASH duty cycle will also have an interactive effect on the refrigeration energy. As a result, compressor run time and energy consumption are reduced.

Program Criteria

1. Pre-notification before project begins.
2. Controls must be installed on all doors of the refrigerator or freezer.
3. The following situations DO NOT qualify for this incentive:
   a. New refrigerators and freezers
   b. Refrigerators and freezers with existing controls being replaced with new controls
   c. Walk-in refrigerators and freezers manufactured after January 1, 2009
4. The rebate is awarded based on the total linear feet of the doors controlled by Anti-Sweat Heater Controls and incentivized at a rate of $40 per linear foot.

Unit of Measure

Linear feet

Baseline Equipment

No anti-sweat controls installed.

High Efficiency Equipment

Anti-sweat control installed.

ALGORITHMS

annual Peak kW savings from ASH per door =SVG_d,ash * W_b,door/1000 * CF

annual kWh savings from ASH =SVG_d,ash * W_b,door/1000 * HRS_ash

annual kW savings from Compressor =SVG_cooling / EER / 1000* CF

annual kWh savings from Compressor =SVG_cooling / EER / 1000 * HRS_comp

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes

SVG_d,ash	ASH demand savings factor	50%	-	SDG&E Statewide Express Efficiency Program - https://www.sdge.com/sites/default/files/regulatory/Express%20and%20SBS%20Workpapers.pdf
SVG_d,comp	Compressor demand savings factor	17.5%	-	SDG&E Statewide Express Efficiency Program - https://www.sdge.com/sites/default/files/regulatory/Express%20and%20SBS%20Workpapers.pdf
SVG_cooling	=BaseWatts/door*SVG_d_Comp	-	W	
Watt_b,door	Baseline door heater power	200	W	SDG&E Statewide Express Efficiency Program - https://www.sdge.com/sites/default/files/regulatory/Express%20and%20SBS%20Workpapers.pdf
Btu_b,door	Baseline door heater power (3.413 Btu/h per W)	682.6	Btu/hr	SDG&E Statewide Express Efficiency Program - https://www.sdge.com/sites/default/files/regulatory/Express%20and%20SBS%20Workpapers.pdf
EER	Compressor energy efficiency ratio	5.43	Btu/hr/W	SDG&E Statewide Express Efficiency Program - https://www.sdge.com/sites/default/files/regulatory/Express%20and%20SBS%20Workpapers.pdf
HRS_ash	Hours of base ASH operation per year	8,760	hrs	
HRS_comp	Compressor run time	5,700	hrs	SDG&E Statewide Express Efficiency Program - https://www.sdge.com/sites/default/files/regulatory/Express%20and%20SBS%20Workpapers.pdf
RH_avg	Typical Store relative humidity	45%	-	SDG&E Statewide Express Efficiency Program - https://www.sdge.com/sites/default/files/regulatory/Express%20and%20SBS%20Workpapers.pdf
CF	Coincidence factor	0.85	-	
Measure Life	Expected duration of savings	12	yrs	SDG&E Statewide Express Efficiency Program - https://www.sdge.com/sites/default/files/regulatory/Express%20and%20SBS%20Workpapers.pdf

SAVINGS

Annual Peak kW savings from ASH	0.085	kW

Annual kWh savings from ASH	876	kWh
SVG_cooling	119.455	Btu/hr/door
Annual Peak kW savings from Compressor	0.0187	kW
Annual kWh savings from Compressor	125.395	kWh
Total Cooling Savings:	119.455	Btu/hr/door
Total Peak Power Savings:	0.104	kW/door
Total Annual Energy Savings:	1001.39	kWh/door
Per Linear Foot calculation:		
Door width	35	inches
	12	inches/ft
Bottom door length	2.92	feet
Peak kW savings per linear foot	0.036	kW/ft
Annual kWh savings per linear foot	343.34	kWh/ft

Measure Name	Peak Demand Savings	Annual Energy Savings
ASH Control	0.036 kW	343.34 kWh

COMMERCIAL: Vending Miser

Return to TOC

MEASURE DETAILS

Description

Controls can significantly reduce the energy consumption of vending machine lighting and refrigeration systems. Qualifying controls must power down these systems during periods of inactivity but, in the case of refrigerated machines, must always maintain a cool product that meets customer expectations. This measure applies to refrigerated beverage vending machines, non-refrigerated snack vending machines, and glass front refrigerated coolers. This measure should not be applied to ENERGY STAR® qualified vending machines, as they already have built-in controls.

Program Criteria

Vending machine must be refrigerated and/or employ an active lamp.

Unit of Measure

One control unit

Baseline Equipment

The baseline efficiency case is a standard efficiency refrigerated beverage vending machine, non-refrigerated snack vending machine, or glass front refrigerated cooler without a control system capable of powering down lighting and refrigeration systems during periods of inactivity.

High Efficiency Equipment

The high efficiency case is a standard efficiency refrigerated beverage vending machine, non-refrigerated snack vending machine, or glass front refrigerated cooler with a control system capable of powering down lighting and refrigeration systems during periods of inactivity.

ALGORITHMS

$$\Delta E = P * HRS * SVG$$

$$\Delta P = \Delta E / HRS$$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Notes**
ΔE	Annual energy reduction	Calculated	kWh	
ΔP	Peak power demand reduction	Calculated	kW	
P	Rated power of connected equipment	Table	kW	
HRS	Annual operating hours	8760	hrs	24 hrs/day, 7 days/wk
SVG	Savings factor for connected equipment	Table	%	
Measure Life	Expected duration of savings	8	yrs	

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings
Refrigerated beverage vending maching (cans or bottles)	0.184 kW	1612 kWh
Refrigerated	0.124 kW	1086 kWh
Non-refrigerated snack vending machine	0.044 kW	387 kWh
All (Average)	0.117 kW	1028 kWh

COMMERCIAL: Water Cooler Timer

Return to TOC

MEASURE DETAILS

Description

Similar to the timers you might use to control lights in your home, plug-in appliance timers allow you to pre-program the times that various appliances in your business are turned on and drawing electricity. So you could pre-program the water cooler so it turns on one hour before the office opens and turns off again after everyone leaves.

Program Criteria

Timers must be digital, include an internal rechargeable battery, and 7 day programmable on/off settings.

Unit of Measure

One timer unit

Baseline Equipment

No timer

High Efficiency Equipment

Timer installed

ALGORITHMS

	Energy Usage	
Type of Water Cooler	Cold Only (kWh/day)	Hot/Cold (kWh/day)
ENERGY STAR	0.16	1.20
Conventional	0.29	2.19

Hours per Day	24
Days per year	365

Base Case Usage	Cold Only	Hot/Cold
ENERGY STAR USAGE (kWh/year)	58	438
Conventional (kWh/year)	106	799

Enhanced Case Usage	Cold Only	Hot/Cold
ENERGY STAR USAGE (kWh/year)	21	157
Conventional (kWh/year)	38	287

Energy Savings	Cold Only	Hot/Cold

ENERGY STAR USAGE (kWh/year)	37	281
Conventional (kWh/year)	68	512
Average Savings (kWh/year)	**53**	**397**

SAVINGS

It is assumed that half of all water coolers are ENERGY STAR and half are not:

- □□□□□□□ 50% ΕΝΕΡΓΨ ΣΤΑΡ
- 50% Conventional

It is assumed that half of all water coolers are cold only and half are hot + cold dispenser:

- 50% Cold Only
- 50% Hot + Cold

The energy savings figure will be based on the average of the above-mentioned percentages.

Persistence Factor = 90%

Energy Savings = 225 x 90% = 202.5 kWh/year

Taking a conservative approach, the demand savings will based on the following calculation and methodology:
Demand Savings = 225 kWh/year divided by 8760 hrs/year = 0.026 kW
Coincidence Factor = 75%

Note: Based on utilization of 3 of the 4 peak hours (6PM-9PM). 5PM-6PM is not counted since most offices close at 5PM and the timer should be set to turn off cooler 1 hour after office closes which is 6PM.

Coincidence Demand Savings = 0.026 kW x .75 = 0.020 kW
Persistence = 90% (10% of people will disconnect)

Peak Demand Savings = 0.020 kW x .90 = 0.018 kW

Measure Name	Peak Demand Savings	Annual Energy Savings
Water Cooler Timer	0.018 kW	202.50 kWh

COMMERCIAL: Case Night Cover

Return to TOC

MEASURE DETAILS

Description

Installation of night covers on existing, open-type refrigerated display cases to reduce extra cooling load caused by infiltration and radiation. Unit of measure is 1 foot of case opening width to be covered.

Program Criteria

Project pre-approval required.

Unit of Measure

Linear foot of cooler space

Baseline Equipment

The baseline efficiency case is the annual operation of open-display cooler cases

High Efficiency Equipment

The high-efficiency case is the use of night covers to protect the exposed areas of display cooler cases during unoccupied store hours.

ALGORITHMS

peak kW savings/ft = 0*

annual kWh savings/ft = SVG_kW * HRS

* Assumes covers are used during off peak hours--midnight to 6 am

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
SVG_kW	Reduced power use of refrigerated display case	Table 1	-	Original factors from Southern Cal Edison 1997 paper
HRS	Hours per year that cases are covered	2,407	hrs	8760 minus (average of 45 Hawaiʻi supermarkets open hours)
Measure Life	Expected duration of savings	5	yrs	DEER 2014

Table 1. Power Savings Factor for Refrigerated Cases	kW/ft[1]
Low Temp (less than 0 F)	0.03
Medium Temp (0F to 30 F)	0.02
High Temp (35 F to 55 F)	0.01
Average	**0.02**

Source: Pennsylvania Technical Reference Manual, Errata Update February 2017, p.403,

http://www.puc.pa.gov/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx

[1] Google search of refrigerated display cases yields a range of typical sizes--4', 5', 6', 6.5', 8'.

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings
Case Night Cover	0.000 kW/ft	48.14 kWh/ft

COMMERCIAL: VFD Booster Pump

Return to TOC

UPDATE STATUS

Updated in Fall 2018 for PY19 TRM.

MEASURE DETAILS

Description

The purpose of this measure is to reduce energy consumption through more efficient domestic water booster systems by installing a VFD with or without also reducing pump HP. Pump improvements can be done to optimize the design and control of water pumping systems.

Program Criteria

• Booster pump applications require pre-notification before equipment is purchased and installed.
• The new Booster Pump System's total horsepower must be equal to or less than that of the existing system.
• The system horsepower reduction must be between 0 to 129 hp. For projects with greater than 129 hp, please contact the program. Booster pump applications do not apply to new construction.

Unit of Measure

One pump.

Baseline Equipment

Assumed to be a non-optimized existing pumping system with a constant speed motor. Baseline pumps are assumed to run 60% of the time.

High Efficiency Equipment

Assumed to be an optimized pumping system meeting applicable program efficiency requirements. The proposed booster pump system must be a more efficient design than the existing system (i.e. Installed with VFD controls). All pump motors must meet NEMA Premium Efficiency standards. As in the base case, enhanced pumps are assumed to run 60% of the time. Savings result from two aspects: (1) reduced horsepower and (2) reduced speed on the motor due to VFD controls.

ALGORITHMS

Pump Horsepower Reduction

Annual Energy Savings, kWh/yr per hp

$$\Delta kWh\ per\ hp = 0.746\frac{kW}{hp} * Hours * LF * AF_{CS} \quad (1)$$

hp

Peak Demand Reduction, kW per hp

$$\Delta kW\ per\ hp = 0.746 \frac{kW}{hp} * CF * AF_{CS} \tag{2}$$

Lifetime Energy Savings, kWh per hp

$$\Delta kWh_{life}\ per\ hp = \Delta kWh\ per\ hp * EUL \tag{3}$$

VFD Installation

Annual Energy Savings, kWh/yr per hp

$$\Delta kWh\ per\ hp = 0.746 \frac{kW}{hp} * Hours * LF * (AF_{CS} - AF_{VS}) \tag{4}$$

Peak Demand Reduction, kW per hp

$$\Delta kW\ per\ hp = 0.746 \frac{kW}{hp} * CF * (AF_{CS} - AF_{VS}) \tag{5}$$

Lifetime Energy Savings, kWh per hp

$$\Delta kWh_{life}\ per\ hp = \Delta kWh\ per\ hp * EUL \tag{6}$$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Source/Notes**
ΔkWh per hp	Annual energy savings per horsepower	Calculated	kWh/yr/hp	
ΔkW per hp	Peak demand reduction per horsepower	Calculated	kW/hp	
Constant	Conversion from horsepower to kW	0.746	kW/hp	
Hours	Operating hours	8760	hrs	No change from PY18 TRM
LF	Loading factor - % of time pump actually operates	60%	-	No change from PY18 TRM
CF	Coincidence factor	0.50	-	No change from PY18 TRM
AF_{CS}	Adjustment factor for constant-speed pump - accounts for pumping system efficiency and load profile	0.90	-	AEG derived the value from the Regional Technical Forum's (RTF) original analysis contained in the unit energy savings measure workbook for Efficient Pumps
AF_{VS}	Adjustment factor for variable-speed pump - accounts for pumping system efficiency and load profile	0.67	-	AEG derived the value from the Regional Technical Forum's (RTF) original analysis contained in the unit energy savings measure workbook for Efficient Pumps

EUL	Effective useful life of measure	15	yrs	No change from PY18 TRM; EUL was verified during AEG's 2018 benchmarking

SAVINGS

Source of Savings	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
HP Reduction	0.335 kW/hp	3523.08 kWh/hp	52846.20 kWh/hp
VFD Installation	0.085 kW/hp	891.20 kWh/hp	13368.00 kWh/hp

RESOURCES

- AEG's 2018 Analysis File titled "AEG HPUC Update of Com Booster Pump VFD - Analysis File."
- DOE, Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Pumps, U.S. Department of Energy, Washington DC: December 2015. Available for download here: https://www.regulations.gov/document?D=EERE-2011-BT-STD-0031-0056.

- Regional Technical Forum. Efficient Pumps - Unit Energy Savings Measure Workbook, Version 1.1. Northwest Power and Conservation Council. June 14, 2017. Spreadsheet. Available online at: https://rtf.nwcouncil.org/measure/efficient-pumps.

COMMERCIAL: Electronically Commutated Motor

Return to TOC

MEASURE DETAILS

Description

Electronically Commutated Motor is a fractional horsepower DC motor often used in commercial refrigeration, replacing shaded pole motor. Typical motor size 10-140 W. ECM also used in fan coil units. **Note that condenser/evaporator fans less than 1 hp are required by code to be ECM in walk in

Program Criteria

1. New Construction projects and Retrofits from standard efficiency shaded pole motors to ECM in fan coil units (FCUs) are eligible
2. All ECMs replacing standard efficient shaded pole motors installed in existing refrigeration cases up to 1 HP in size may qualify for an incentive
3. ECM must be coupled with integrated controllers

Unit of Measure

One ECM motor

Baseline Equipment

4-pole (1800 RPM) demand of 107 W

High Efficiency Equipment

High efficiency DC/EC demand of 54 W

ALGORITHMS

peak kW savings per W	= (kW_bs - kW_ee)	refrigeration
annual kWh savings per W	= (kWh_bs - kWh_ee)	refrigeration
peak kW savings per motor	= (kW_bs - kW_ee) * CF	fan coil
annual kWh savings per motor	= (kW_bs - kW_ee) * HRS	fan coil

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
kW_bs	Demand of existing motor technology	Table	kW	The PY2015 Hawaiʻi TRM makes no adjustment for efficiency
kW_ee	Demand of new electronically commutated motor	Table	kW	
kWh_bs	Energy use of existing motor technology	Table	kWh	
kWh_ee	Energy use of new electronically commutated motor	Table	kWh	24 hrs/day, 7 days/wk
HRS	Annual operating hours	4380	hrs	
CF	Savings fact for connected equipment	0.5	-	
Measure Life	Expected duration of savings	15	yrs	

Table 1: Approved ECM- Values

Technology	kW_bs [1]	kW_ee	kWh_bs	kWh_ee
Shaded Pole motor for refrigeration	0.002	N/A	18.0	N/A
ECM motor for refrigeration	N/A	0.001	N/A	8.7
Baseline motor on AHU fan	0.107	N/A	N/A	N/A
ECM motor on AHU fan	N/A	0.054	N/A	N/A

Source: Hawai'i Energy Technical Reference Manual, PY 2015, July 1 2015-June 30, 2016. Measure Savings Calculations, pp.130-135

Notes: 1. For ECM in refrigeration, demand (W) and energy consumption values (kWh) are expressed per rated W. Presumably, this means for every rated W of ECM motor, an equivalent Shaded Pole motor draws 2 W.
For ECM in a fan coil unit, demand (W) and energy consumption (kWh) values are gross for an assumed motor.

SAVINGS

Table 2: Demand and Energy Savings for ECM motors

Measure Name	Peak Demand Savings	Annual Energy Savings
ECM motor-refrigeration [1]	0.001 kW	9.30 kWh
ECM motor on AHU fan	0.027 kW	232.14 kWh

Notes: 1. Refrigeration ECM values are savings per rated motor W

COMMERCIAL: Premium Efficiency Motor

Return to TOC

MEASURE DETAILS

Description

This measure relates to the installation of premium efficiency three phase Open Drip Proof (ODP) and Totally Enclosed Fan-Cooled (TEFC) motors less than or equal to 200 HP, meeting minimum qualifying efficiency for the following HVAC applications: supply fans, return fans, exhaust fans, chilled water pumps, and boiler feed water pumps.

Program Criteria

- Incentives apply to both ODP and TEFC enclosures with 1200 RPM, 1800 RPM or 3600 RPM motors.
- Motors must meet minimum efficiency requirements as shown in the Table below.
- Motors greater than 200 hp will be given consideration under the Hawai‘i Energy Customized Program.
- If motors are not listed, submit manufacturer specifications, motor curve and performance data to Hawai‘i Energy for consideration

Unit of Measure

Per horse power

Baseline Equipment

2007 EISA nominal efficiency (as defined in NEMA MG1 Table 12-12) motors.

High Efficiency Equipment

The qualified efficiency table includes motors that are 1-200 hp NEMA Design A/B, 460 volts, TEFC or ODP, and 1200 rpm, 1800 rpm, or 3600 rpm.

ALGORITHMS

peak kW savings per HP $= kW_{\_perHP} * [(1 / \eta_{\_base}) - (1 / \eta_{\_ee})]$

annual kWh savings per HP $= kW_{\_perHP} * [(1 / \eta_{\_base}) - (1 / \eta_{\_ee})] * LF * HRS$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Notes**
$kW_{\_perHP}$	kW equivalent of 1 horse power	0.746	kW/HP	
$\eta_{\_base}$	Efficiency of baseline motor	81.7%	-	EISA 2007, avg 1 HP
$\eta_{\_ee}$	Efficiency of energy efficient motor	84.3%	-	HE requirement, avg 1 HP
LF	Loading factor--% of time pump actually operates	75%	-	Hawai‘i Energy PY15 TRM

HRS	Annual operating hours	2190	hrs	Hawai'i Energy PY15 TRM, 6 hours per day
Measure Life	Expected duration of savings	15	yrs	

Table 1: Qualifying Motor Efficiency Table

Motor Size (hp)	3600 RPM (2-pole)		1800 RPM (4-pole)		1200 RPM (6-pole)	
	ODP	TEFC	ODP	TEFC	ODP	TEFC
1	80.0	84.0	86.4	87.5	83.8	84.0
1.5	86.5	87.5	87.3	88.5	87.5	89.2
2	86.5	88.5	87.3	88.5	88.5	90.1
7.5	90.2	91.7	91.7	93.0	91.7	92.4
10	91.7	91.7	92.3	93.0	92.4	92.4
15	91.6	92.4	93.6	93.6	92.4	93.0
20	92.4	93.0	93.6	94.1	93.0	93.0
25	93.0	93.6	94.1	94.5	93.6	94.1
30	92.4	93.6	94.6	94.5	94.1	94.1
40	93.6	94.1	94.5	95.0	94.5	95.0
50	94.1	94.5	95.0	95.4	94.5	95.0
60	94.5	95.0	95.4	95.8	95.0	95.4
75	95.0	95.4	95.4	95.8	95.4	95.4
100	95.4	95.4	95.8	96.2	95.4	95.8
125	95.4	95.8	95.8	96.2	95.8	95.8
150	95.8	96.2	96.2	96.5	95.8	96.2
200	95.8	96.2	96.2	96.8	95.8	96.2

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings
Premium Efficiency Motor	0.028 kW/hp	46.46 kWh/hp

COMMERCIAL: VFD Pool Pump

Return to TOC

UPDATE STATUS

Updated in Fall 2018 for PY19 TRM.

MEASURE DETAILS

Description

This measure is the replacement of a single-speed or dual-speed pool filter pump with a variable-speed pump of equivalent horsepower. This measure is only applicable to self-priming pool filter pumps which are typically used with permanent, in-ground pools in multi-family and commercial buildings (there is a separate measure for single-family residential settings). Non-self-priming pool filter pumps, which are typically used with rigid, above-ground pools, are not applicable.

Program Criteria

Pre-approval required. Pumps greater than 4 hp in size may be handled as a custom measure. The installed variable-speed self-priming pool filter pump's rated Weighted Energy Factor (WEF) should meet or exceed the ENERGY STAR v2.0 specifications. Any high-speed override capability should be for a temporary period not to exceed one 24-hour cycle without reverting to default settings.

Unit of Measure

One pump.

Baseline Equipment

The baseline efficiency equipment is a single-speed or dual-speed self-priming pool filter pump.

High Efficiency Equipment

The high efficiency equipment is a variable-speed self-priming pool filter pump.

ALGORITHMS

Annual Energy Savings, kWh/yr

$$\Delta kWh = \left(kWh_{Daily,Base} - kWh_{Daily,Eff}\right) * Days \quad (1)$$

Peak Demand Reduction, kW

$$\Delta kW = \left[\left(\frac{kWh_{Daily,Base}}{Hours_{Daily,Base}}\right) * CF_{Base}\right] - \left[\left(\frac{kWh_{Daily,Eff}}{Hours_{Daily,Eff}}\right) * CF_{Eff}\right] \quad (2)$$

Lifetime Energy Savings, kWh

$$\Delta kWh_{life} = \Delta kWh * EUL \quad (3)$$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Sources/Notes**
ΔkWh	Annual energy savings	Calculated	kWh/yr	
ΔkW	Peak demand reduction	Calculated	kW	
$kWh_{Daily,Base}$	Daily energy consumption of baseline pump (depends on pump horsepower) Single-Speed Pumps > 0 to ≤ 1 hp > 1 to ≤ 2 hp > 2 to ≤ 3 hp > 3 to ≤ 4 hp Dual-Speed Pumps > 0 to ≤ 1 hp > 1 to ≤ 2 hp > 2 to ≤ 3 hp > 3 to ≤ 4 hp	 20.0 29.3 43.7 51.8 19.0 30.3 39.2 49.4	 kWh/day kWh/day kWh/day kWh/day kWh/day kWh/day kWh/day kWh/day	AEG derived the values from the Regional Technical Forum's (RTF) original analysis contained in the unit energy savings measure workbook for Efficient Pool Pumps
$kWh_{Daily,Eff}$	Daily energy consumption of variable-speed pump (depends on pump horsepower) Variable-Speed Pumps > 0 to ≤ 1 hp > 1 to ≤ 2 hp > 2 to ≤ 3 hp > 3 to ≤ 4 hp	 9.2 13.9 21.6 27.0	 kWh/day kWh/day kWh/day kWh/day	AEG derived the values from the Regional Technical Forum's (RTF) original analysis contained in the unit energy savings measure workbook for Efficient Pool Pumps
Days	Number of days the pump operates in a year	365	Days/yr	No change from PY18 TRM
$Hours_{Daily,Base}$	Daily runtime of baseline pump (depends on pump horsepower) Single-Speed Pumps > 0 to ≤ 1 hp > 1 to ≤ 2 hp > 2 to ≤ 3 hp > 3 to ≤ 4 hp Dual-Speed Pumps > 0 to ≤ 1 hp > 1 to ≤ 2 hp > 2 to ≤ 3 hp > 3 to ≤ 4 hp	 17.6 17.2 17.8 18.9 24.0 24.0 24.0 24.0	 Hrs/day Hrs/day Hrs/day Hrs/day Hrs/day Hrs/day Hrs/day Hrs/day	AEG derived the values from the Regional Technical Forum's (RTF) original analysis contained in the unit energy savings measure workbook for Efficient Pool Pumps
$Hours_{Daily,Eff}$	Daily runtime of variable-speed pump (depends on pump horsepower) Variable-Speed Pumps > 0 to ≤ 1 hp	 22.7	 Hrs/day	AEG derived the values from the Regional Technical Forum's (RTF) original analysis contained in the unit energy savings

	> 1 to ≤ 2 hp > 2 to ≤ 3 hp > 3 to ≤ 4 hp	22.7 22.7 23.5	Hrs/day Hrs/day Hrs/day	in the unit energy savings measure workbook for Efficient Pool Pumps
CF_{Base}	Coincidence factor of baseline pump (depends on pump horsepower) Single-Speed Pumps > 0 to ≤ 1 hp > 1 to ≤ 2 hp > 2 to ≤ 3 hp > 3 to ≤ 4 hp Dual-Speed Pumps > 0 to ≤ 1 hp > 1 to ≤ 2 hp > 2 to ≤ 3 hp > 3 to ≤ 4 hp	 0.73 0.72 0.74 0.79 1.00 1.00 1.00 1.00		AEG's estimate, obtained by dividing the number of daily operation hours of pump by 24 hours
CF_{Eff}	Coincidence factor of variable-speed pump (depends on pump horsepower) Variable-Speed Pumps > 0 to ≤ 1 hp > 1 to ≤ 2 hp > 2 to ≤ 3 hp > 3 to ≤ 4 hp	 0.95 0.95 0.95 0.98		AEG's estimate, obtained by dividing the number of daily operation hours of pump by 24 hours
EUL	Effective useful life of measure	10	yrs	AEG's Fall 2018 Benchmarking

SAVINGS

Measure Name Com. VFD Pool Pump	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Single-speed to variable speed: > 0 to ≤ 1 hp	0.447 kW	3,912.62 kWh	39,126.20 kWh
Single-speed to variable speed: > 1 to ≤ 2 hp	0.639 kW	5,600.45 kWh	56,004.50 kWh
Single-speed to variable speed: > 2 to ≤ 3 hp	0.921 kW	8,067.84 kWh	80,678.40 kWh
Single-speed to variable speed: > 3 to ≤ 4 hp	1.032 kW	9,041.89 kWh	90,418.90 kWh
Dual-speed to variable speed: > 0 to ≤ 1 hp	0.406 kW	3,555.14 kWh	35,551.40 kWh

Dual-speed to variable speed: > 1 to ≤ 2 hp	0.683 kW	5,984.43 kWh	59,844.30 kWh
Dual-speed to variable speed: > 2 to ≤ 3 hp	0.734 kW	6,428.10 kWh	64,281.00 kWh
Dual-speed to variable speed: > 3 to ≤ 4 hp	0.931 kW	8,151.47 kWh	81,514.70 kWh

RESOURCES

- AEG's 2018 Analysis File titled "AEG HPUC Update of Com Pool Pump VFD - Analysis File."
- DOE National Impact Analysis (NIA) for Dedicated Purpose Pool Pumps ("NIA_PoolPumps_2016-12-19_ForPublication_v2.xlsm"), available online at: https://www.regulations.gov/document?D=EERE-2015-BT-STD-0008-0107.
- ENERGY STAR Product Specifications for Pool Pumps, Version 2.0, available online at: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%202.0%20Pool%20Pumps%20Specification.pdf.
- Regional Technical Forum. Efficient Pool Pumps - Unit Energy Savings Workbook, Version 2.1. Northwest Power and Conservation Council. February 27, 2018. Spreadsheet. Available online at: https://rtf.nwcouncil.org/measure/efficient-pool-pumps.

COMMERCIAL: Condominium Submetering

Return to TOC

MEASURE DETAILS

Description

This program is to assist master-metered condominiums and their Association of Apartment Owners (AOAO) efforts to reduce energy consumption and implement the current submetering proposal as one that will insure both equity and fairness in allocating energy costs as well as encouraging energy conservation through direct feedback of personal energy use to tenants.
The combination of billing submeters, along with education, peer group comparisons and special equipment offerings, will assist the tenant achieve significant energy conservation and efficiency.

Program Criteria

The manufacturer's submetering system model type to be installed (meter and CTs) must have been tested by an independent third party that is Nationally Rated Testing Laboratory certified for ANSI C12.1. The certification documentation must be provided to the Program prior to installation. Additionally, manufacturers must have a factory-quality compliance procedure in place to ensure meter accuracy. Documentation of this procedure must be available to the Program upon request. The submeter must be UL, CSA or ETL listed (Electrical Safety).

Requirements:
• The metering system must remain in place and billing to occur for a period of at least five (5) years or a pro-rated portion of the incentive will be recovered by Hawai'i Energy. Provide Hawai'i Energy with energy meter data for analysis purposes.
• A joint educational and monitoring program will be undertaken with AOAO to assist in the verification of savings and development of an ongoing energy incentive offering for other condominiums in Hawai'i.

Unit of Measure

Per tenant unit

Baseline Equipment

The base case is no submetering. Baseline Annual Energy Usage is the actual average usage (kWh/year) based on historical usage for past 24 months (or as appropriate) for entire condominium (master metered) divided by the number of condominium units. Baseline demand (kW) is the Average Historical Demand divided by the number of condominium units.

Building Types	Demand Baseline (kW)	Energy Baseline (kWh/year)
Condominium	1.42	7,200

High Efficiency Equipment

The high efficiency case is with submetering. It is expected there will be a 10% reduction in energy usage and 8% reduction in peak demand during (5PM – 9PM).

Building Types	Efficient Case (kW)	Efficient Case (kWh/year)
Condominium	1.30	6,480

ALGORITHMS

Building Types	Gross Customer Savings (kW)	Gross Customer Savings (kWh/year)
Condominium	0.113	720

Operational Factor	Adjustment Factor
Persistence Factor (pf)	1.00
Demand Coincidence Factor (cf)	1.00

Building Types	Net Customer Savings (kW)	Net Customer Savings (kWh/year)
Condominium	0.113	720

SAVINGS

Example Savings Calculation:

Submetering (Condominium)

Average Master Meter Energy Usage (kWh/month)		180,000	kWh per month
Number of tenant Units	÷	300	Units
Average Tenant Energy Usage (Example)		600	kWh per home per month
	x	12	month per year
Baseline Annual Household Energy Usage		7,200	kWh per Year
Average Master Meter Demand (kW)		425	
Number of tenant Units	÷	300	
Baseline Demand (kW)		1.42	kW
Energy Reduction		10.0%	
Actively Informed Household Energy Usage		6,480	kWh per Year
Baseline Annual Household Energy Usage		7,200	kWh per Year
Actively Informed Household Energy Usage		6,480	kWh per Year

Actively Informed Household Energy Usage	-	6,480	kWh per Year	
Gross Customer Level Energy Savings		720	kwh per Year	
Gross Customer Level Energy Savings		720	kwh per Year	
Persistance Factor	x	1.0		
Net Customer Level Savings		720	kwh per Year	
Submetering Energy Savings		720	kWh / Year Savings	
Baseline Household Demand		1.42	kW	HECO 2008 Load Study
Peak Demand Reduction		8.00%		
Actively Informed Household Demand		1.30	kW	
Baseline Household Demand		1.42	kW	
Actively Informed Household Demand	-	1.30	kW	
Gross Customer Demand Savings		0.113	kW	
Gross Customer Demand Savings		0.113	kW	
Persistance Factor	x	1.0		
Coincidence Factor	x	1.0		
		0.113	kW	
Condominium Sub-Metering Demand Savings		0.113	kW Savings	

COMMERCIAL: Small Business Submetering

Return to TOC

MEASURE DETAILS

Description

This program is to assist master-metered small businesses to reduce energy consumption that will insure both equity and fairness in allocating energy costs as well as encouraging energy conservation through direct feedback of personal energy use to business tenants.
The combination of billing submeters, along with education, peer group comparisons and special equipment offerings, will assist the tenant achieve significant energy conservation and efficiency.

Program Criteria

The manufacturer's submetering system model type to be installed (meter and CTs) must have been tested by an independent third party that is Nationally Rated Testing Laboratory certified for ANSI C12.1. The certification documentation must be provided to the Program prior to installation. Additionally, manufacturers must have a factory-quality compliance procedure in place to ensure meter accuracy. Documentation of this procedure must be available to the Program upon request. The submeter must be UL, CSA or ETL listed (Electrical Safety).

Requirements:

• The metering system must remain in place and billing to occur for a period of at least five (5) years or a pro-rated portion of the incentive will be recovered by Hawai'i Energy. Provide Hawai'i Energy with energy meter data for analysis purposes.

• A joint educational and monitoring program will be undertaken with the businesses to assist in the verification of savings and development of an ongoing energy incentive offering for other condominiums in Hawai'i.

Unit of Measure

Baseline Equipment

The base case is no submetering.

Building Types	Demand Baseline (kW)	Energy Baseline (kWh/year)
Small Business	3.00	10,800

High Efficiency Equipment

The high efficiency case is with submetering.

Building Types	Efficient Case (kW)	Efficient Case (kWh/year)
Small Business	2.76	9,720

ALGORITHMS

Building Type	Demand Savings (kW)	Annual Energy Savings (kWh/year)
Small Business	0.24	1080

Operational Factor	Adjustment Factor
Persistence Factor (PF)	1
Coincidence Factor (CF)	1

SAVINGS

Example Savings Calculation:

Small Business Submetering

Average Tenant Energy Usage		900	kWh per business per month (Schedule G)
	x	12	
Baseline Business Energy Usage		10,800	kWh per Year
Energy Reduction		10.0%	
Actively Informed Business Energy Usage		9,720	kWh per Year
Baseline Business Energy Usage		10,800	kWh per Year
Actively Informed Business Energy Usage	-	9,720	kWh per Year
Gross Customer Level Energy Savings		1,080	kwh per Year
	x	1,000	Watts per kW
	÷	8,760	Hours per Year
Average 24/7 Demand Reduction		123	Watts
Gross Customer Level Energy Savings		1,080	kwh per Year
Persistance Factor	x	1.0	
Net Customer Level Savings		1,080	kwh per Year
Submetering Energy Savings		1,080	kWh / Year Savings
Baseline Business Demand		3.00	kW
Peak Demand Reduction		8.00%	
Actively Informed Business Demand		2.76	kW
Baseline Business Demand		3.00	kW
Actively Informed Business Demand	-	2.76	kW
Gross Customer Demand Savings		0.240	kW
Gross Customer Demand Savings		0.240	kW
Persistance Factor	x	1.00	
Coincidence Factor	x	1.00	
		0.240	kW

0.240 kW

Small Business Demand Savings	0.24 kW Savings

COMMERCIAL: Solar Water Heater

Return to TOC

UPDATE STATUS

Updated in January 2019 for PY19 TRM.

MEASURE DETAILS

Description

Replacement of an Electric Storage Water Heater with a Solar Water Heater for Service Water Heating in an existing commercial building. Solar Water Heating systems use solar thermal energy to meet most of the water heating load and continue to utilize electricity to operate the circulation pump and provide heating through an electric resistance element when needed.

The semi-prescriptive approach presented here is reserved for smaller, simpler systems where the baseline Electric Storage Water Heater has an input rating of 12 kW (40,950 Btu/hr) or less and the square footage of the building or area served by the solar water heating system is known. ***A fully custom approach should be used for larger or more complex installations, and/or when the water heating load served by the solar water heater is more accurately known.***

Program Criteria

The Solar Water Heating collectors must meet the Solar Rating and Certification Corporation (SRCC™) OG-100 standard. OG-300 certification for the solar water heating system is not required.

Unit of Measure

One system.

Baseline Equipment

Baseline equipment for the semi-prescriptive approach is an Electric Storage Water Heater with an input rating of 12 kW (40,950 Btu/hr) or less that meets current Federal codes and standards, which were effective April 16, 2015. (Commercial water heaters with an input rating of ≤ 12 kW must meet the Residential standards per a ruling by the Department of Energy.)

High Efficiency Equipment

High efficiency equipment is a new Solar Water Heater with electric backup designed for a 90% Solar Fraction. The Solar Water Heating collectors must meet the Solar Rating and Certification Corporation (SRCC™) OG-100 standard. OG-300 certification for the solar water heating system is not required. Solar Water Heating systems use solar thermal energy to meet most of the water heating load and continue to utilize electricity to operate the circulation pump and provide heating through an electric resistance element when needed.

ALGORITHMS

Energy Factor of Baseline Equipment (Electric Storage Water Heater ≤ 55 gallons)

$$EF_{base,\leq 55} = 0.960 - (0.0003 * V) \quad (1)$$

Energy Factor of Baseline Equipment (Electric Storage Water Heater > 55 gallons)

$$EF_{base,>55} = 2.057 - (0.00113 * V) \quad (2)$$

Baseline Annual Energy Use, kWh/hr

$$kWh_{base} = \left(\frac{1}{EF_{base}}\right) * \frac{HW_{per\ SqFt} * A * \rho * c_p * (T_{out} - T_{in})}{3412 \frac{Btu}{kWh}} \quad (3)$$

Efficient Case Annual Energy Use, kWh/hr

$$kWh_{EE} = (1 - SF)\left(\frac{1}{EF_{SWH}}\right) * \frac{HW_{per\ SqFt} * A * \rho * c_p * (T_{out} - T_{in})}{3412 \frac{Btu}{kWh}} + (kW_{pump} * HOU_{pump}) * M \quad (4)$$

Annual Energy Savings, kWh/yr

$$\Delta kWh = (kWh_{base} - kWh_{EE}) * PF \quad (5)$$

Peak Demand Reduction, kW

$$\Delta kW = \frac{\Delta kWh}{EFLH} * CF \quad (6)$$

Lifetime Energy Savings, kWh

$$\Delta kWh_{life} = \Delta kWh * EUL_{EE} \quad (7)$$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Source/Notes
EF_{base}	Energy factor of the baseline equipment	See Eq'ns 1 or 2	-	Minimum federal requirements effective April 16, 2015[1]
V	Rated Storage Volume of baseline Electric Storage Water Heater tank	User input	gal	-
$HW_{per\ SqFt}$	Average annual hot water use per square foot of building space	See Table 1	gal/SqFt	DEER 2015 "DEER-WaterHeater-Calculator-v1.1.xlsm"[2]

A	Square footage of area served by new Solar Water Heater	User input	SqFt	-
ρ	Density of water	8.3	lb_m/gal	-
c_p	Specific heat capacity of water	1	Btu/lbm°F	-
T_{out}	Outlet temperature of the water heater	User input	°F	-
T_{in}	Incoming water temperature from the water main	User input	°F	-
SF	Solar fraction	User input	-	Program requirement of 0.9
EF_{SWH}	Energy factor of solar water heater when using back-up electric resistance heating	0.9	-	Typical value for electric resistance water heating; equal to efficiency assumption of 0.9 from PY18 TRM
kW_{pump}	Circulation pump demand	0.082	kW	Source: KEMA 2005-2007; consistent with residential solar water heating measure[3]
HOU_{pump}	Pump hours of operation	1,292	hr/yr	Source: KEMA 2005-2007; consistent with residential solar water heating measure[3]
PF	Persistence factor	0.93	-	Source: KEMA 2005-2007; consistent with residential solar water heating measure[3]
M	Multiplier to scale circulation pump energy use for medium-sized systems	1.0 for small; 1.5 for medium	-	Assumes small commercial systems have same circulation pump energy requirements as residential systems and medium commercial systems have greater (1.5X) circulation pump energy requirements[4]
EFLH	Equivalent full load hours of equipment operation	See Table 1	hrs	AEG's Hawaiʻi-specific analysis of U.S. DOE OpenEI Load shapes for Commercial Water Heating

CF	Peak demand coincidence factor	See Table 1	-	AEG's Hawaiʻi-specific analysis of U.S. DOE OpenEI Load shapes for Commercial Water Heating; peak period defined as non-holiday weekdays from 5-9 pm
EUL_{EE}	Effective useful life of measure	18	yrs	AEG's Fall 2018 Benchmarking

[1] Federal Register, Energy Conservation Program for Consumer Products: Definitions for Residential Water Heaters, Table I.2, April 8, 2015, available here: https://www.federalregister.gov/documents/2015/04/08/2015-07956/energy-conservation-program-for-consumer-products-definitions-for-residential-water-heaters. Applies to residential and non-residential water heaters that are ≤12 kW.

[2] AEG assumes average hot water use per square footage of commercial building space is similar in California and Hawaiʻi.

[3] See "R_WH_SWH" tab for more details. The kW_{pump}, HOU_{pump}, and PF values should be updated as better data specific to the commercial sector becomes available.

[4] Small systems are defined as those with a baseline electric storage water heater of ≤ 55 gal. Medium systems are defined as those with a baseline electric storage water heater of >55 gal and input rating ≤ 12 kW. Larger systems are to be treated with a custom approach. The approach to estimate circulation pump energy use for commercial applications should be updated as better data specific to the commercial sector becomes available.

Table 1. Key Parameters for Semi-Prescriptive Approach

Building Type	$HW_{per\ SqFt}$	EFLH	CF
Avg. Commercial	9.78	2,322	0.29
Cold Storage	0.23	Varies	Varies
Education	7.58	1,916	0.25
Grocery	10.60	4,406	0.60
Health	22.70	2,247	0.20
Hotel/Motel	12.61	3,008	0.35
Industrial	2.83	Varies	Varies
Office	2.07	2,632	0.30
Restaurant	74.91	3,947	0.74
Retail	1.49	Varies	Varies
Warehouse	0.23	Varies	Varies

Use custom approach for entries noted as "Varies."

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

SAVINGS

Semi-Prescriptive Savings Calculator (based on customer-specific values for key parameters)

Enter Equivalent Rated Storage Volume in gallons for Electric Storage Water Heater, V

50 EF= 0.945 M= 1.0

Enter Solar Fraction for new Solar Water Heater (default of 0.9), SF

0.9

Select Building Type from Dropdown List

Grocery	$HW_{per\ SqFt}$ =	10.60	EFLH =	4,406	CF =	0.60

Enter Square Footage of Area Served by Solar Water Heater, A

1,800 SqFt

Enter inlet temperature of the water heater, T_{in}

(default of 75°F for Honolulu and Hawaiʻi Counties, and 71°F for Maui County)

75 °F

Enter outlet temperature of the water heater (default of 130°F), T_{out}

130 °F

Measure Name	Peak	Annual	Lifetime
Commercial Solar Water Heater	0.293 kW	2,149.93 kWh	38,698.74 kWh

Note: Savings in blue result from sample entries above. **They are for illustrative purposes only.**

RESOURCES

- 2015 International Energy Conservation Code, Chapter 4: Commercial Energy Efficiency, Section C404: Service Water Heating (Mandatory), https://codes.iccsafe.org/content/IECC2015/chapter-4-ce-commercial-energy-efficiency.
- AEG's 2018 Analysis Files titled 1) "AEG HPUC Update of Com-Solar Water Heater - Analysis file" and 2) "R&C Solar Water Heater - v2 Solar Fraction."
- AEG's 2018 Analysis of U.S. DOE OpenEI Load shapes for Commercial Water Heating. Analyzed 16 commercial building types (based off the DOE commercial reference building models) for IECC Zone 1A and Hawaiʻi weather stations (Keahole-Kona.Intl.AP, Honolulu.Intl.AP, Kahului.AP). Prototype data available here: https://openei.org/doe-opendata/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states.
- A.O. Smith responses to ENERGY STAR 2.0 framework specification for water heaters, ENERGY STAR Water Heaters Product Specification Framework May 2011, Questions for Discussion, Q9: "9. How does the SEF metric compare to EF metric? Could they be considered equivalent compared?..." https://www.energystar.gov/sites/default/files/specs/AOSmith%20Comments_0.pdf.
- Baseline Energy Appliance, Equipment and Building Characteristics Study Report, Prepared for the State of Hawaii Public Utilities Commission, November 6, 2013, With errata February 26, 2014, Evergreen Economics, Figure 87.
- DEER 2015 Small Storage and Small Instantaneous Water Heater Energy Use Calculator. Filename: "DEER-WaterHeater-Calculator-v1.1.xlsm," "TechCalc" sheet. Spreadsheet dated 11/29/2014. AEG used for analysis of hot water usage (Gal/SqFt-yr) by building type.

- Energy and Peak Demand Impact Evaluation Report of the 2005-2007 Demand Management Programs – (KEMA 2005-07)
- ENERGY STAR Program Requirement for Residential Water Heaters, v3.0, April 2015. https://www.energystar.gov/products/water_heaters/residential_water_heaters_key_product_criteria.
- Federal Register, Energy Conservation Program for Consumer Products: Definitions for Residential Water Heaters, April 8, 2015, available here: https://www.federalregister.gov/documents/2015/04/08/2015-07956/energy-conservation-program-for-consumer-products-definitions-for-residential-water-heaters.
- Hawaiʻi Energy PY17 Program Data for BEEM. Filename: "EMV Extract UPDATED 20181015." Spreadsheet. AEG used data to develop shares of participant energy savings (kWh) by building type. The shares were then used to estimate weighted averages of key parameters (HWper SQFT, EFLH, and CF) for the average commercial building type ("Avg. Commercial").
- Hawaiʻi Energy Solar Water Heating Program Handbook: Design Guidelines, Volume 5, October 2018, available for download here: <https://hawaiienergy.com/files/for-homes/swh_handbook.pdf>.
- International Code Council (ICC) and Solar Rating & Certification Corporation (SRCC), 2015 ICC 900/SRCC 300-2015 Solar, Thermal System Standard, https://codes.iccsafe.org/content/ICC9002015/toc.
- Technical Reference Manual, State of Pennsylvania, Act 129 Energy Efficiency and Conservation Program & Act 213 Alternative Energy Portfolio Standards, June 2016.
- Title 10: Energy, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, Subpart B—Test Procedures, Appendix E to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Water Heaters, https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=ap10.3.430_127.e&rgn=div9.
- Title 10: Energy, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, Subpart C—Energy and Water Conservation Standards, §430.32 Energy and water conservation standards and their compliance dates, (d) Water heaters.

COMMERCIAL: Re/Retro-commissioning

Return to TOC

MEASURE DETAILS

Description

Hawaiʻi Energy incentivizes the actions of building owners to evaluate the effectiveness and efficiency of current building systems to optimize performance.

These actions will be documented in a Commissioning Report that shall include:

- Executive summary of all activities included in the commissioning process.
- Introduction section, including names and contact information for the Building Owner, Building Manager, RCx Trade Ally.
- Detailed building and energy systems description, including estimates of the equipment usage profiles.
- Detailed operational scheduling of the major systems.
- Detailed report of all optimization measures identified.
- Cost estimate, energy savings estimate and simple payback for all recommended operational actions, sequencing, and equipment enhancements.
- Pre- and post-data logging.
- Testing and Balancing (TAB) of HVAC system.
- Functional testing of the EMS, if equipped.
- Detailed operations and maintenance review.
- Documentation of O&M refresher training for facility staff.
- Assessment of existing equipment over-sizing and recommendations for right-sizing when HVAC equipment needs replacement, including, but not limited to recommended capital items.

Program Criteria

Program pre-approval is required prior to the start of any energy consumption analysis. Projects can be whole building or by system if determined cost-effective by Hawaiʻi Energy.

Eligible program participants must:

- Own or operate a high energy usage facility that has at least 50,000 square feet of conditioned space or that consumes at least 1,000,000 kWh/year.
- Receive electric service from Hawaiian Electric Companies (e.g., HECO, MECO or HELCO) and pay a Hawaiʻi public benefits fund surcharge on their electric bill.
- For retro-commissioning, building has been in service for at least 2 years and has never been commissioned before. For recommissioning, it has been at least 5 years since the last commissioning activity.
- Be willing to commit up to 100% of the incentive value to implement energy conservation measures (ECMs) found to have a 2- year or less payback. Any implemented ECMs are eligible for Hawaiʻi Energy's prescriptive and custom incentives.
- Grant Hawaiʻi Energy access to their facility's billing data and other required data to establish an initial benchmark rating via ENERGY STAR Portfolio Manager®.
- Grant Hawaiʻi Energy access to the facility itself for on-going program assessment, monitoring and measurement purposes.

- Be willing to invest facility management time, typically between 8-16 hours, to support multiple site visits and data requests from the RCx consultant.
- Perform at least two weeks of metering of all major building systems prior to the implementation of any ECMs and at least two weeks of post metering. The cost of “pre” and “post” metering may be included in the total project cost by the commissioning agent. The metering plan shall be included in the proposal.
- The participant’s commissioning specialist shall be certified by a nationally recognized building commissioning organization such as the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), AABC Commissioning Group (ACG), Building Commissioning Association (BCA), National Environmental Balancing Bureau (NEBB) or similar organization acceptable to Hawaiʻi Energy.
- If participant wishes to use a non-certified contractor to perform the Retro-Commissioning or Enhanced Commissioning project, an exception may be granted at Hawaiʻi Energy’s sole discretion if:

  1. The proposed contractor provides evidence of having completed similar commissioning projects for two or more buildings of at least 50,000 square feet (conditioned space) each, and

  2. The proposed contractor submits at least two verifiable and satisfactory references from customers or clients who used the contractor to complete the similar projects.
- All retro-commissioning work performed (to include, but not limited to, documentation and reporting) must follow guidelines recommended by an approved commissioning organization. The commissioning specialist must indicate in their report the organization’s guidelines which were followed for the retro-commissioning process.
- The cost of replacement of major end use items may be included in the total project cost from the commissioning agent. Cost of routine maintenance activities identified by the commissioning agent shall not be included in the total project.

Unit of Measure
Any kWh and kW savings brought about by and verified by the retro-commissioning study, such as process optimization, schedule or set-point changes, and routine maintenance.

Baseline Equipment
Pre-commissioning operating procedures.

High Efficiency Equipment
Post-commissioning operating procedures.

ALGORITHMS

(Custom)

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings
Re|Retro-Commissioning	Custom	Custom

RESIDENTIAL: Clothes Washer

Return to TOC

MEASURE DETAILS

Description
Energy Efficient Clothes Washer

Program Criteria
ENERGY STAR certified

Unit of Measure
One washer

Baseline Equipment
Clothes washer meeting minimum federal requirements as of March 2015.

High Efficiency Equipment
Three tiers of efficient equipment:
1) ENERGY STAR or CEE Tier 1 certified
2) ENERGY STAR Most Efficient, or CEE Tier 2 certified
3) CEE Tier 3 certified

ALGORITHMS

ΔE = [(CAP * (1 / IMEF_base) * CYCLES) * (%E_wash,base + (%E_heat,base * %HEATER_electric) + (%E_dry,base * %DRYER_electric))] - [(CAP * (1 / IMEF_he) * CYCLES) * (%E_wash,he + (%E_heat,he * %HEATER_electric) + (%E_dry,he * %DRYER_electric))]

ΔP = (ΔE / HRS) * CF

ΔE_lifetime = ΔE * (Measure Life)

DEFINITIONS & ASSUMPTIONS

Variable	Description	Tier 1	Tier 2	Tier 3	Unit	Notes
CAP	Average clothes washer capacity in ft3	3.45	3.45	3.45	ft^3	Based on analysis of all models meeting federal minimum standards in NEEP Mid-Atlantic TRM V6
IMEF_base	Integrated Modified Energy Factor of baseline unit	1.66	1.66	1.66	-	Based on analysis of all models meeting federal minimum standards in NEEP Mid-Atlantic TRM V6

IMEF_he	Integrated Modified Energy Factor of efficient unit	2.26	2.74	2.92	-	Minimum qualifying IMEF for various efficiency tiers; weighted average based on the relative number of front-loading vs. top-loading washers available in each tier. See NEEP Mid-Atlantic TRM V6.
CYCLES	Average number of washer cycles per washer per year	313	313	313	-	NEEA Dryer Field Study, 2014 (Table 45)[1]
%E_wash,base	Percentage of total energy consumption for clothes washer operation for a baseline model	8%	8%	8%	%	Based on analysis of all models meeting federal minimum standard in NEEP Mid-Atlantic TRM V6
%E_heat,base	Percentage of total energy consumption for water heating for a baseline model	31%	31%	31%	%	Based on analysis of all models meeting federal minimum standard in NEEP Mid-Atlantic TRM V6
%E_dry,base	Percentage of total energy consumption for clothes drying for a baseline model	61%	61%	61%	%	Based on analysis of all models meeting federal minimum standard in NEEP Mid-Atlantic TRM V6
%E_wash,he	Percentage of total energy consumption for clothes washer operation for efficient unit	8%	14%	14%	%	Based on analysis of all models meeting requirements for each tier in NEEP Mid-Atlantic TRM V6
%E_heat,he	Percentage of total energy consumption for water heating for efficient unit	23%	10%	10%	%	Based on analysis of all models meeting requirements for each tier in NEEP Mid-Atlantic TRM V6
%E_dry,he	Percentage of total energy consumption for clothes drying for efficient unit	69%	76%	76%	%	Based on analysis of all models meeting requirements for each tier in NEEP Mid-Atlantic TRM V6
%DRYER_electric	Percentage of dryers assumed to be electric	81%	81%	81%	%	Based on Evergreen Baseline Study (2014) on percentage of homes with secondary fuel sources (Figure 22)

%HEATER_electric	Percentage of water heating assumed to be electric	50%	50%	50%	%	Based on Evergreen Baseline Study (2014) on percentage of homes with electric water heaters (scaled down to account for likelihood that homes with electric water heating use less hot water than those with solar or gas water heating due to smaller home and household size)
HRS	Average number of run hours per washer per year	297	297	297	hrs	57 minutes/cycle based on NEEA Dryer Field Study, 2014[1]
CF	Coincidence Factor	5.7%	5.7%	5.7%	%	
Measure Life	Expected duration of savings	11	11	11	yrs	ENERGY STAR Market & Industry Scoping Report, 2011[3]

[1] https://www.neea.org/docs/default-source/reports/neea-clothes-dryer-field-study.pdf

[2] https://www.energystar.gov/sites/default/files/asset/document/ENERGY_STAR_Scoping_Report_Residential_Clothes_Dryers.pdf

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings
Clothes Washer Tier 1	0.022 kW	114.07 kWh
Clothes Washer Tier 2	0.030 kW	156.80 kWh
Clothes Washer Tier 3	0.034 kW	176.37 kWh

RESIDENTIAL: Clothes Dryer

Return to TOC

MEASURE DETAILS

Description

Energy efficient clothes dryer as specified below replacing a baseline clothes dryer.

Program Criteria

ENERGY STAR certified

Unit of Measure

One dryer

Baseline Equipment

Clothes dryer meeting minimum federal requirements (blended average of pre-1/1/15 and post-1/1/15 federal standards).

High Efficiency Equipment

ENERGY STAR certified electric clothes dryer ≥ 4.4 ft^3

ALGORITHMS

$$\Delta E = [(LOAD / CEF\_base) - (LOAD / CEF\_he)] * CYCLES$$
$$\Delta P = (\Delta E / HRS) * CF$$
$$\Delta E\_lifetime = \Delta E * (Measure\ Life)$$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
ΔE	Annual energy reduction	Calculated	kWh	
ΔP	Peak power demand reduction	Calculated	kW	
LOAD	Average total weight (lbs) of clothes per drying cycle	8.45	lbs	Based on ENERGY STAR product criteria testing.[1]
CEF_base	Combined Energy Factor (lbs/kWh) of the baseline unit	3.15	-	Blended average of early replacement (80%) and replace on burnout (20%) baselines, using federal minimum CEF. From 1994-2014, minimum CEF was 3.01 (early replacement baseline). Since 2015, minimum CEF has been 3.73 (replace on burnout baseline).
CEF_he	Combined Energy Factor (lbs/kWh) of the efficient unit	3.93	-	Based on ENERGY STAR product criteria testing.
CYCLES	Average number of dryer cycles per dryer	311	-	NEEA Dryer Field Study, 2014.[2]

HRS	Average run hours per dryer per year	290	hrs	56 minutes/cycle based on NEEA Dryer Field Study, 2014.[2]
CF	Coincidence factor	5.7%	-	Based on analysis of clothes dryer loadshape curve from DOE PNNL study. See Tab 2 for calculation.[3]
Measure Life	Expected duration of savings	14	yrs	ENERGY STAR Market & Industry Scoping Report, 2011.[4]

[1] https://www.energystar.gov/products/appliances/clothes_dryers/key_product_criteria

[2] https://www.neea.org/docs/default-source/reports/neea-clothes-dryer-field-study.pdf

[3] http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20110.pdf

[4] https://www.energystar.gov/sites/default/files/asset/document/ENERGY_STAR_Scoping_Report_Residential_Clothes_Dryers.pdf

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings
Clothes Dryer	0.033 kW	165.58 kWh

RESIDENTIAL: Refrigerator and Freezer

Return to TOC

UPDATE STATUS

Updated in Fall 2018 for PY19 TRM.

MEASURE DETAILS

Description

ENERGY STAR v5.0 certified refrigerator/freezer as specified below replacing a non-ENERGY STAR refrigerator/freezer and turning in the existing refrigerator/freezer to be recycled. Also, turn-in only refrigerator/freezer rebate available.

Program Criteria

ENERGY STAR v5.0 certified.

Unit of Measure

One refrigerator/freezer.

Baseline Equipment

The base case for the new unit is the current federal requirement (National Appliance Energy Conservation Act, or NAECA, 2011) for a refrigerator/freezer, effective as of September 15, 2014. The base case for a turned-in unit is the pre-existing refrigerator/freezer.

High Efficiency Equipment

The efficient case for the new unit is an ENERGY STAR v5.0 qualified refrigerator/freezer, which has an efficiency criteria of 10 percent less energy use than minimum federal requirements.

ALGORITHMS

The base case (minimum federal requirement) and efficient case (ENERGY STAR) for a new refrigerator/freezer are based on the adjusted volume (AV) in cubic feet of the unit. The adjusted volume is calculated as follows (see Equations 1 and 2):

Refrigerator Adjusted Volume (AV), cu ft

$$AV_R = Fresh\ Volume + 1.76 * Freezer\ Volume \tag{1}$$

Freezer Adjusted Volume (AV), cu ft

$$AV_F = 1.73 * Freezer\ Volume \tag{2}$$

Unit Replacement Annual Energy Savings, kWh/yr

$$\Delta kWh_{Replace} = (E_{Base} - E_{EE}) * PF \quad (3)$$

Unit Replacement Peak Demand Reduction, kW

$$\Delta kW_{Replace} = (\Delta kWh_{Replace} / HRS) * CF \quad (4)$$

Unit Replacement Lifetime Energy Savings, kWh

$$\Delta kWh_{Replace,Life} = \Delta kWh_{Replace} * EUL_{Replace} \quad (5)$$

Unit Replacement with Turn-In Annual Energy Savings, kWh/yr

$$\Delta kWh_{Replace+Turn-in} = (E_{Base} - E_{EE} + E_{Turn-in}) * PF \quad (6)$$

Unit Replacement with Turn-In Peak Demand Reduction, kW

$$\Delta kW_{Replace+Turn-in} = (\Delta kWh_{Replace+Turn-in} / HRS) * CF \quad (7)$$

Unit Replacement with Turn-In Lifetime Energy Savings, kWh

$$\Delta kWh_{Replace+Turn-in,Life} = \Delta kWh_{Replace,Life} + (E_{Turn-in} * PF * RUL_{Turn-in}) \quad (8)$$

2nd Unit Turn-In Only Annual Energy Savings, kWh/yr

$$\Delta kWh_{Turn-in\ Only} = (\%_{Pre'93} * E_{Pre'93} + \%_{Post'93} * E_{Post'93}) * PF \quad (9)$$

2nd Unit Turn-In Only Peak Demand Reduction, kW

$$\Delta kW_{Turn-in\ Only} = (\Delta kWh_{Turn-in\ Only} / HRS) * CF \quad (10)$$

2nd Unit Turn-In Only Lifetime Energy Savings, kWh

$$\Delta kWh_{Turn-in,Life} = \Delta kW_{Turn-in\ Only} * RUL_{Turn-in} \quad (11)$$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Source/Notes**
AV_R	Adjusted volume of refrigerator[1]	Default = 25.4	cu ft	See Footnote 2 for Default assumption
AV_F	Adjusted volume of freezer[1]	Default = 26.0	cu ft	See Footnote 3 for Default assumption
Fresh volume	Fresh volume of new refrigerator	User entry	cu ft	Based on actual unit; used to calculate AV in Equation 1
Freezer volume	Freezer volume of new refrigerator or freezer	User entry	cu ft	Based on actual unit; used to calculate AV in Equations 1 and 2
E_{Base}	Annual energy usage of baseline unit	See Tables 1 and 2	kWh	Federal requirements as of September 15, 2014

E_{EE}	Annual energy usage of new efficient unit	See Tables 1 and 2	kWh	ENERGY STAR as of September 15, 2014
$E_{Turn-in}$	Annual energy usage of unit turned-in with purchase of new replacement	717	kWh	No change from PY18 TRM [4]
$\%_{pre'93}$	Share of 2nd units that are of pre-1993 vintage	0.35	-	Estimate; updated from 44.6% in PY18 TRM [4]
$\%_{post'93}$	Share of 2nd units that are of post-1993 vintage	0.65	-	Estimate; updated from 54.4% in PY18 TRM [4]
$E_{pre'93}$	Annual energy usage of pre-1993 2nd unit turned-in without purchase of new replacement	1131	kWh	No change from PY18 TRM [4]
$E_{post'93}$	Annual energy usage of post-1993 2nd unit turned-in without purchase of new replacement	640	kWh	No change from PY18 TRM [4]
PF	Persistence factor	1.0	-	See Footnote 5
HRS	Annual operating hours	8760	hrs	Conservative assumption when used to estimate peak demand savings
CF	Coincidence factor	1.0	-	Acceptable if used along with 8760 hours
$EUL_{Replace,R}$	Effective useful life of new refrigerator	14	yrs	AEG's Fall 2018 Benchmarking [6]
$EUL_{Replace,F}$	Effective useful life of new freezer	17	yrs	AEG's Fall 2018 Benchmarking [6]
$RUL_{Turn-In,R}$	Remaining useful life of turned-in refrigerator	8	yrs	AEG's Fall 2018 Benchmarking [6]
$RUL_{Turn-In,F}$	Remaining useful life of turned-in freezer	7	yrs	AEG's Fall 2018 Benchmarking [6]

[1] Source of AV equations is ENERGY STAR, Savings Calculator for ENERGY STAR Appliances, available at: https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx, accessed December 15, 2018.

[2] Based on average of default values for Total Model Volume for refrigerators from ENERGY STAR calculator (20.5 cu ft), and assuming 68.6% of volume is refrigerator (fresh volume), which is default in ENERGY STAR calculator. Recommendation for future update: Determine average AV of units installed through Hawaiʻi program.

[3] Based on average of default values for Total Model Volume for freezers (non-compact) from ENERGY STAR calculator (15.0 cu ft). Recommendation for future update: Determine average AV of units installed through Hawaiʻi program.

[4] Recommend updating with Hawaiʻi-specific data on the types/ages of units turned-in through the program in future TRM update.

[5] Use value of PF=1 until more data is available on savings persistence of ENERGY STAR units relative to baseline units.

[6] See analysis file titled "AEG HPUC EUL Analysis."

Table 1. Base and Efficient Case Refrigerator Standards, Total Volume ≥ 7.75 cu ft and < 39 cu ft, Equation: E = a*AV + b

Product Category	E_{base}, Federal Standard, Maximum kWh/yr [1]		E_{EE}, ENERGY STAR, Maximum kWh/yr [2]	
Equation Term:	**a**	**b**	**a**	**b**
Manual Defrost w/ and w/o TDD, All Configurations	6.79	193.6	6.11	174.2
Auto Defrost w/o TDD, Top Freezer and Single Door Refrigerators	8.07	233.7	7.26	210.3
Auto Defrost w/o TDD, Side by Side	8.51	297.8	7.66	268.0
Auto Defrost w/o TDD, Bottom Freezer	8.85	317.0	7.97	285.3
Auto Defrost w/ TDD, Bottom Freezer	9.25	475.4	8.33	436.3
Auto Defrost w/ TDD, Top Freezer	8.40	385.4	7.56	355.3
Auto Defrost w/ TDD, Side by Side	8.54	432.8	7.69	397.9
"Average" Refrigerator [3]	8.34	333.7	7.51	303.9

[1] Electronic Code of Federal Regulations, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, Subpart C—Energy and Water Conservation Standards, §430.32 Energy and water conservation standards and their compliance dates. (a) Refrigerators/refrigerator-freezers/freezers, current as of December 13, 2018, accessed December 17, 2018.

[2] ENERGY STAR Program Requirements for Residential Refrigerators and Freezers. Eligibility Criteria, V5.0, https://www.energystar.gov/ia/partners/product_specs/program_reqs/Refrigerators_and_Freezers_Program_Requirements_V5.0.pdf, accessed December 17, 2018.

[3] Recommend updating with weighted average by type using program data or baseline data in future TRM update.

Table 2. Base and Efficient Case Freezer Standards, Total Volume ≥ 7.75 cu ft and < 39 cu ft, Equation: E = a*AV + b

Product Category	E_{base}, Federal Standard, Maximum kWh/yr [1]		E_{EE}, ENERGY STAR, Maximum kWh/yr [2]	
Equation Term:	**a**	**b**	**a**	**b**
Upright Freezers, Manual Defrost	5.57	193.7	5.01	174.3
Upright Freezers, Auto Defrost, w/o Auto Icemaker	8.62	228.3	7.76	205.5
Upright Freezers, Auto Defrost, w/ Auto Icemaker	8.62	312.3	7.76	289.5
Built-in Freezers, Auto Defrost, w/o Auto Icemaker	9.86	260.9	8.87	234.8
Built-in Freezers, Auto Defrost, w/ Auto Icemaker	9.86	344.9	8.87	318.8
Chest Freezers and All Other Freezers, except Compact Freezers	7.29	107.8	6.56	97.0
Chest Freezers with Auto Defrost	10.24	148.1	9.22	133.3
"Average" Freezer [3]	8.58	228.0	7.72	207.6

[1] Electronic Code of Federal Regulations, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, Subpart C—Energy and Water Conservation Standards, §430.32 Energy and water conservation standards and their compliance dates. (a) Refrigerators/refrigerator-freezers/freezers, current as of December 13, 2018, accessed December 17, 2018.

[2] ENERGY STAR Program Requirements for Residential Refrigerators and Freezers. Eligibility Criteria, V5.0, https://www.energystar.gov/ia/partners/product_specs/program_reqs/Refrigerators_and_Freezers_Program_Requirements_V5.0.pdf, accessed December 17, 2018.

[3] Recommend updating with weighted average by type using program data or baseline data in future TRM update.

SAVINGS - DEEMED

Deemed Savings (based on default value for Adjusted Volume, AV): Refrigerator w/o Turn-In

Refrigerator w/o Turn-In, AV = 25.4 cu ft Product Category	**Peak Demand Savings**	**Annual Energy Savings**	**Lifetime Energy Savings**
Manual Defrost w/ and w/o TDD, All Configurations	**0.004 kW**	**36.67 kWh**	**513.38 kWh**
Auto Defrost w/o TDD, Top Freezer and Single Door Refrigerators	**0.005 kW**	**43.97 kWh**	**615.58 kWh**
Auto Defrost w/o TDD, Side by Side	**0.006 kW**	**51.39 kWh**	**719.46 kWh**
Auto Defrost w/o TDD, Bottom Freezer	**0.006 kW**	**54.05 kWh**	**756.70 kWh**
Auto Defrost w/ TDD, Bottom Freezer	**0.007 kW**	**62.47 kWh**	**874.58 kWh**
Auto Defrost w/ TDD, Top Freezer	**0.006 kW**	**51.44 kWh**	**720.16 kWh**
Auto Defrost w/ TDD, Side by Side	**0.006 kW**	**56.49 kWh**	**790.86 kWh**
"Average" Refrigerator	**0.006 kW**	**50.93 kWh**	**713.02 kWh**

Deemed Savings (based on default value for Adjusted Volume, AV): Freezer w/o Turn-In

Freezer w/o Turn-In, AV = 26.0 cu ft Product Category	**Peak Demand Savings**	**Annual Energy Savings**	**Lifetime Energy Savings**
Upright Freezers, Manual Defrost	**0.004 kW**	**33.96 kWh**	**577.32 kWh**
Upright Freezers, Auto Defrost, w/o Auto Icemaker	**0.005 kW**	**45.16 kWh**	**767.72 kWh**
Upright Freezers, Auto Defrost, w/ Auto Icemaker	**0.005 kW**	**45.16 kWh**	**767.72 kWh**
Built-in Freezers, Auto Defrost, w/o Auto Icemaker	**0.006 kW**	**51.84 kWh**	**881.28 kWh**
Built-in Freezers, Auto Defrost, w/ Auto Icemaker	**0.006 kW**	**51.84 kWh**	**881.28 kWh**
Chest Freezers and All Other Freezers, except Compact Freezers	**0.003 kW**	**29.78 kWh**	**506.26 kWh**
Chest Freezers with Auto Defrost	**0.005 kW**	**41.32 kWh**	**702.44 kWh**
"Average" Freezer	**0.005 kW**	**42.72 kWh**	**726.24 kWh**

Deemed Savings (based on default value for Adjusted Volume, AV): Refrigerator w/ Turn-In

Refrigerator w/ Turn-In, AV = 25.4 cu ft Product Category	**Peak Demand Savings**	**Annual Energy Savings**	**Lifetime Energy Savings**
Manual Defrost w/ and w/o TDD, All Configurations	**0.086 kW**	**753.67 kWh**	**6,249.38 kWh**

Auto Defrost w/o TDD, Top Freezer and Single Door Refrigerators	**0.087 kW**	**760.97 kWh**	**6,351.58 kWh**
Auto Defrost w/o TDD, Side by Side	**0.088 kW**	**768.39 kWh**	**6,455.46 kWh**
Auto Defrost w/o TDD, Bottom Freezer	**0.088 kW**	**771.05 kWh**	**6,492.70 kWh**
Auto Defrost w/ TDD, Bottom Freezer	**0.089 kW**	**779.47 kWh**	**6,610.58 kWh**
Auto Defrost w/ TDD, Top Freezer	**0.088 kW**	**768.44 kWh**	**6,456.16 kWh**
Auto Defrost w/ TDD, Side by Side	**0.088 kW**	**773.49 kWh**	**6,526.86 kWh**
"Average" Refrigerator	**0.088 kW**	**767.93 kWh**	**6,449.02 kWh**

Deemed Savings (based on default value for Adjusted Volume, AV): Freezer w/ Turn-In

Freezer w/ Turn-In, AV = 26.0 cu ft Product Category	**Peak Demand Savings**	**Annual Energy Savings**	**Lifetime Energy Savings**
Upright Freezers, Manual Defrost	**0.086 kW**	**750.96 kWh**	**5,596.32 kWh**
Upright Freezers, Auto Defrost, w/o Auto Icemaker	**0.087 kW**	**762.16 kWh**	**5,786.72 kWh**
Upright Freezers, Auto Defrost, w/ Auto Icemaker	**0.087 kW**	**762.16 kWh**	**5,786.72 kWh**
Built-in Freezers, Auto Defrost, w/o Auto Icemaker	**0.088 kW**	**768.84 kWh**	**5,900.28 kWh**
Built-in Freezers, Auto Defrost, w/ Auto Icemaker	**0.088 kW**	**768.84 kWh**	**5,900.28 kWh**
Chest Freezers and All Other Freezers, except Compact Freezers	**0.085 kW**	**746.78 kWh**	**5,525.26 kWh**
Chest Freezers with Auto Defrost	**0.087 kW**	**758.32 kWh**	**5,721.44 kWh**
"Average" Freezer	**0.087 kW**	**759.72 kWh**	**5,745.24 kWh**

Deemed Savings: Refrigerator or Freezer Turn-In Only

Measure Name	**Peak Demand Savings**	**Annual Energy Savings**	**Lifetime Energy Savings**
Refrigerator Turn-In Only, AV = 25.4 cu ft	**0.093 kW**	**811.85 kWh**	**6,494.80 kWh**
Freezer Turn-In Only, AV = 26.0 cu ft	**0.093 kW**	**811.85 kWh**	**5,682.95 kWh**

SAVINGS - SEMI-PRESCRIPTIVE CALCULATOR

Refrigerator		***Freezer***	
Enter Fresh Volume	14.1	Enter Frozen Volume	15.0
Enter Frozen Volume	6.4		
AV_R = 25.4	per Equation 1	AV_F = 26.0	per Equation 2

Semi-Prescriptive Savings (based on user entry): Refrigerator w/o Turn-In

Refrigerator w/o Turn-In Product Category	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Manual Defrost w/ and w/o TDD, All Configurations	**0.004 kW**	**36.67 kWh**	**513.38 kWh**
Auto Defrost w/o TDD, Top Freezer and Single Door Refrigerators	**0.005 kW**	**43.97 kWh**	**615.58 kWh**
Auto Defrost w/o TDD, Side by Side	**0.006 kW**	**51.39 kWh**	**719.46 kWh**
Auto Defrost w/o TDD, Bottom Freezer	**0.006 kW**	**54.05 kWh**	**756.70 kWh**
Auto Defrost w/ TDD, Bottom Freezer	**0.007 kW**	**62.47 kWh**	**874.58 kWh**
Auto Defrost w/ TDD, Top Freezer	**0.006 kW**	**51.44 kWh**	**720.16 kWh**
Auto Defrost w/ TDD, Side by Side	**0.006 kW**	**56.49 kWh**	**790.86 kWh**
"Average" Refrigerator	**0.006 kW**	**50.93 kWh**	**713.02 kWh**

Semi-Prescriptive Savings (based on user entry): Freezer w/o Turn-In

Freezer w/o Turn-In Product Category	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Upright Freezers, Manual Defrost	**0.004 kW**	**33.96 kWh**	**577.32 kWh**
Upright Freezers, Auto Defrost, w/o Auto Icemaker	**0.005 kW**	**45.16 kWh**	**767.72 kWh**
Upright Freezers, Auto Defrost, w/ Auto Icemaker	**0.005 kW**	**45.16 kWh**	**767.72 kWh**
Built-in Freezers, Auto Defrost, w/o Auto Icemaker	**0.006 kW**	**51.84 kWh**	**881.28 kWh**
Built-in Freezers, Auto Defrost, w/ Auto Icemaker	**0.006 kW**	**51.84 kWh**	**881.28 kWh**
Chest Freezers and All Other Freezers, except Compact Freezers	**0.003 kW**	**29.78 kWh**	**506.26 kWh**
Chest Freezers with Auto Defrost	**0.005 kW**	**41.32 kWh**	**702.44 kWh**
"Average" Freezer	**0.005 kW**	**42.72 kWh**	**726.24 kWh**

Semi-Prescriptive Savings (based on user entry): Refrigerator w/ Turn-In

Refrigerator w/ Turn-In Product Category	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Manual Defrost w/ and w/o TDD, All Configurations	**0.086 kW**	**753.67 kWh**	**6,249.38 kWh**
Auto Defrost w/o TDD, Top Freezer and Single Door Refrigerators	**0.087 kW**	**760.97 kWh**	**6,351.58 kWh**
Auto Defrost w/o TDD, Side by Side	**0.088 kW**	**768.39 kWh**	**6,455.46 kWh**
Auto Defrost w/o TDD, Bottom Freezer	**0.088 kW**	**771.05 kWh**	**6,492.70 kWh**
Auto Defrost w/ TDD, Bottom Freezer	**0.089 kW**	**779.47 kWh**	**6,610.58 kWh**
Auto Defrost w/ TDD, Top Freezer	**0.088 kW**	**768.44 kWh**	**6,456.16 kWh**
Auto Defrost w/ TDD, Side by Side	**0.088 kW**	**773.49 kWh**	**6,526.86 kWh**
"Average" Refrigerator	**0.088 kW**	**767.93 kWh**	**6,449.02 kWh**

Semi-Prescriptive Savings (based on user entry): Freezer w/ Turn-In

Freezer w/ Turn-In Product Category	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Upright Freezers, Manual Defrost	**0.086 kW**	**750.96 kWh**	**5,596.32 kWh**
Upright Freezers, Auto Defrost, w/o Auto Icemaker	**0.087 kW**	**762.16 kWh**	**5,786.72 kWh**
Upright Freezers, Auto Defrost, w/ Auto Icemaker	**0.087 kW**	**762.16 kWh**	**5,786.72 kWh**
Built-in Freezers, Auto Defrost, w/o Auto Icemaker	**0.088 kW**	**768.84 kWh**	**5,900.28 kWh**
Built-in Freezers, Auto Defrost, w/ Auto Icemaker	**0.088 kW**	**768.84 kWh**	**5,900.28 kWh**
Chest Freezers and All Other Freezers, except Compact Freezers	**0.085 kW**	**746.78 kWh**	**5,525.26 kWh**
Chest Freezers with Auto Defrost	**0.087 kW**	**758.32 kWh**	**5,721.44 kWh**
"Average" Freezer	**0.087 kW**	**759.72 kWh**	**5,745.24 kWh**

RESOURCES

- AEG's 2018 Analysis File titled "AEG HPUC Update of Residential Measures - Analysis file."
- Electronic Code of Federal Regulations, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, Subpart C—Energy and Water Conservation Standards, §430.32 Energy and water conservation standards and their compliance dates. (a) Refrigerators/refrigerator-freezers/freezers, current as of December 13, 2018, accessed December 17, 2018.
- Energy Information Administration, Residential Energy Consumption Survey, 2015, Table CE3.5: Annual household site end-use consumption in the West--totals and averages, 2015, https://www.eia.gov/consumption/residential/data/2015/c&e/pdf/ce3.5.pdf, accessed December 17, 2018.
- ENERGY STAR, Key Product Criteria, https://www.energystar.gov/products/appliances/refrigerators/key_product_criteria.
- ENERGY STAR Program Requirements for Residential Refrigerators and Freezers. Eligibility Criteria, V5.0, https://www.energystar.gov/ia/partners/product_specs/program_reqs/ Refrigerators_and_Freezers_Program_Requirements_V5.0.pdf, accessed December 17, 2018.
- ENERGY STAR, Savings Calculator for ENERGY STAR Appliances, available at: https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx, accessed December 15, 2018.

RESIDENTIAL: Dishwasher

Return to TOC

UPDATE STATUS

Added in Spring 2019 for PY19 TRM.

MEASURE DETAILS

Description
An energy efficient, ENERGY STAR-certified dishwasher for use in residential applications.

Program Criteria
Must have ENERGY STAR certification.

Unit of Measure
One unit.

Baseline Equipment
Non-ENERGY STAR dishwasher that meets the federal standard.

High Efficiency Equipment
ENERGY STAR certified dishwasher that exceeds the federal standard.

ALGORITHMS

peak kW savings $= [\Delta kWh / (Cycles * HRS_{.cycle})] * CF$

annual kWh savings, ΔkWh $= (kWh_{.base,yr} - kWh_{.ee,yr}) * (\%kWh_{.Op} + \%kWh_{.heat} * \%DHW_{.electric})$

lifetime kWh savings $= \Delta kWh * EUL$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
$kWh_{.base,yr}$	Annual energy usage of standard non-ES dishwasher.	307	kWh/yr	DOE standard effective May 30, 2013.
$kWh_{.ee,yr}$	Annual energy usage of standard ES dishwasher.	270	kWh/yr	ENERGY STAR Residential Dishwasher Specification Version 6.0.
$\%kWh_{.Op}$	Percentage of dishwasher energy consumption used for unit operation.	44%	%	Assume default of 44% (0.44) per the ENERGY STAR Appliance Calculator.
$\%kWh_{.heat}$	Percentage of dishwasher energy consumption used for water heating.	56%	%	Assume default of 56% (0.56) per the ENERGY STAR Appliance Calculator.

$\%DHW_{.electric}$	Percentage of domestic hot water assumed to be electric.	57%	%	Assume 57% (0.57) per AEG's 2019 analysis, which is based on Evergreen Economics Baseline Study, 2014.
Cycles	Number of cycles per year.	215	cycle	Representative average dishwasher use in 10 CFR 430, Subpart B, Appendix C1 - Uniform Test Method for Measuring the Energy Consumption of Dishwashers.
$HRS_{.cycle}$	Hours per dishwashing cycle.	1.5	hrs / cycle	Efficiency Vermont TRM 2015.
CF	Coincidence factor	0.04	-	In the absence of a true region-specific system peak coincidence factor for the end-use, use a run-time average factor calculated as hours of use divided by 8,760 hours per year.
EUL	Effective useful life of measure	11	yrs	DEER2020.

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Dishwasher	0.003 kW	28.09 kWh	308.99 kWh

RESOURCES

- AEG's 2019 Analysis File titled "New Residential Measures Summary - AEG Analysis file."
- Baseline Energy Appliance, Equipment and Building Characteristics Study Report, Prepared for the State of Hawaii Public Utilities Commission, November 6, 2013, With errata February 26, 2014, Evergreen Economics.
- California Public Utilities Commission, Database of Energy Efficiency Resources, 2020 update, (DEER2020), READI v.2.5.0, Ex Ante Database Support Table Export, EUL_basis, created on 8/24/2018, available here: www.deeresources.com/index.php/homepage. Spreadsheet.
- Code of Federal Regulations, 10 CFR 430, Subpart B, Appendix C1 - Uniform Test Method for Measuring the Energy Consumption of Dishwashers.
- Efficiency Vermont Technical Reference User Manual, Measure Savings Algorithms and Cost Assumptions, 2015.
- ENERGY STAR, Appliance Calculator, available here: https://www.energystar.gov/sites/default/files/asset/.../appliance_calculator.xlsx.

- ENERGY STAR, Dishwashers, webpage, https://www.energystar.gov/products/appliances/dishwashers.
- ENERGY STAR, Residential Dishwasher Specification Version 6.0, available here: https://www.energystar.gov/products/spec/residential_dishwasher_specification_version_6_0_pd.

RESIDENTIAL: Air Purifier

Return to TOC

UPDATE STATUS

Updated in Spring 2019 for PY19 TRM.

MEASURE DETAILS

Description
Energy efficient domestic room air purifier.

Program Criteria
Air purifier must be ENERGY STAR certified.

Unit of Measure
One air purifier.

Baseline Equipment
Non-ENERGY STAR air purifier.

High Efficiency Equipment
ENERGY STAR certified air purifier.

ALGORITHMS

$$\Delta kW_{.peak} = \{CAP * [(1 / \eta_{.bs}) - (1 / \eta_{.he})]\} / 1000 * CF$$

$$\Delta kWh_{.annual} = \{HRS * CAP * [(1 / \eta_{.bs}) - (1 / \eta_{.he})] + (8760 - HRS) * (P_{.stdby,bs} - P_{.stdby,he})\} / 1000$$

$$\Delta kWh_{.lifetime} = \Delta kWh_{.annual} * EUL$$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Source/Notes
CAP	Capacity	100	CADR	Default capacity in ENERGY STAR Appliance Calculator.
$\eta_{.bs}$	Baseline efficiency rating	1.0	CADR/W	ENERGY STAR Appliance Calculator: EPA research on available models, 2011.
$\eta_{.he}$	High efficiency rating	3.0	CADR/W	ENERGY STAR Appliance Calculator: EPA research on available models, 2011.
$P_{.stdby,bs}$	Baseline standby power	1.0	W	ENERGY STAR Appliance Calculator.
$P_{.stdby,he}$	High efficiency standby power	0.6	W	ENERGY STAR Appliance Calculator.

CF	Coincidence factor, percent of time equipment load corresponds with utility peak load	0.67	-	Based on 16 hrs/day.
HRS	Equipment annual operating hours	5,840	hrs/yr	ENERGY STAR Appliance Calculator: 16 hrs/day, 365 days/year.
Constant	Watt/Kilowatts conversion	1,000	W/kW	
EUL	Effective useful life of measure	9	yrs	DEER 2020 for "Res-AirCleaner" measure.

SAVINGS

	Baseline	Enhanced	
Operating power	0.100	0.033	kW
Operating energy	584.00	194.67	kWh/yr
Standby energy	2.92	1.75	kWh/yr
Total energy	586.92	196.42	kWh/yr

Measure Name	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Room Air Purifier	0.045 kW	390.50 kWh	3,514.50 kWh

RESOURCES

- AEG's 2019 Analysis File titled "New Residential Measures Summary - AEG Analysis file."
- California Public Utilities Commission, Database of Energy Efficiency Resources, 2020 update, (DEER2020), READI v.2.5.0, Ex Ante Database Support Table Export, EUL_basis, created on 8/24/2018, available here: www.deeresources.com/index.php/homepage. Spreadsheet.
- ENERGY STAR, Appliance Calculator, available here: https://www.energystar.gov/sites/default/files/asset/.../appliance_calculator.xlsx.
- ENERGY STAR, Air Purifiers (Cleaners), webpage, https://www.energystar.gov/products/appliances/air_purifiers_cleaners.

RESIDENTIAL: Television

Return to TOC

MEASURE DETAILS

Description

ENERGY STAR V7.0 televisions. This measure is for a midstream incentive to retailers to stock, promote, and sell televisions which meet or exceed ENERGY STAR Version 7.0.

Program Criteria

ENERGY STAR certified

Unit of Measure

One television

Baseline Equipment

Non-ENERGY STAR 7.0 cetified television

High Efficiency Equipment

ENERGY STAR 7.0 certified television

ALGORITHMS

peak kW savings per TV = [(Watts_base -Watts_ee) /1000] x *CF*

annual kWh savings per TV = (Watts_base -Watts_ee) /1000 x HOURS_Active x 365

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Notes**
Watts_base	Baseline connected Watts (active)	User Input	W	Baseline power consumption is drawn from ENERGY STAR “Consumer Electronics Calculator”. [1]
Watts_ee	Energy efficient connected Watts (active)	User Input	W	ENERGY STAR V7.0 Program Requirements. [2]
CF	Demand Coincidence Factor	0.22	-	Based on Efficiency Vermont TRM, 2015 for coincident usage between 5-7PM.
HRS_Active	Average hours of use per day in Active Mode	5	hrs	Average television active power reported in ENERGY STAR “Consumer Electronics Calculator”.

Measure Life	Expected duration of energy savings	10	yrs	Average television lifetime estimated in ENERGY STAR "Consumer Electronics Calculator" referencing Appliance Magazine, Portrait of the U.S. Appliance Industry 2000.

Note: 1. https://www.energystar.gov/sites/default/files/asset/document/Consumer_Electronics_Calculator.xlsx
2. https://www.energystar.gov/sites/default/files/ FINAL%20Version%207.0%20Television%20Program%20Requirements%20%28Dec-2014%29.pdf

Non-4K

Screen size		Max Power			Demand Savings		TEC			Energy Savings	
(in)		(W)			(kW)		(kWh/yr)			(kWh/yr)	
Min	Max	Base	ES7	ME16	ES7	ME16	Base	ES7	ME16	ES7	ME 16
40	45	54	37	27	0.017	0.027	99	68	50	31	49
45	50	69	45	33	0.024	0.036	126	82	61	44	65
50	55	74	52	38	0.022	0.036	135	95	70	40	65
55	60	87	57	42	0.030	0.045	159	104	77	55	82
60	80	88	66	49	0.022	0.039	161	120	89	40	71
Average		74	51	38	0.023	0.036	136	94	69	42	66

4K

Screen size		Max Power			Demand Savings		TEC			Energy Savings	
(in)		(W)			(kW)		(kWh/yr)			(kWh/yr)	
Min	Max	Base	ES7	ME16	ES7	ME16	Base	ES7	ME16	ES7	ESME 16
40	45	81	37	27	0.044	0.054	148	68	50	80	98
45	50	104	45	33	0.059	0.070	189	82	61	107	128
50	55	111	52	38	0.059	0.073	203	95	70	108	132
55	60	131	57	42	0.074	0.088	238	104	77	134	161
60	80	132	66	49	0.066	0.083	241	120	89	120	152
Average		112	51	38	0.060	0.074	204	94	69	109.8	134

Non-4k	40%	0.0092	Non-4k	40%	16.80
4k	60%	0.036	4k	60%	65.88
	CF	0.220		ΔkWh	82.68
	ΔkW	0.00994			

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings

Television	0.010 kW	82.68 kWh

RESIDENTIAL: Soundbar

Return to TOC

MEASURE DETAILS

Description

This measure is for a midstream incentive to retailers to stock, promote, and sell soundbars which meet or exceed ENERGY STAR Version 3.0.

Program Criteria

ENERGY STAR certified

Unit of Measure

One soundbar

Baseline Equipment

Non-ENERGY STAR v3.0 cetified soundbar

High Efficiency Equipment

ENERGY STAR v3.0 certified soundbar

ALGORITHMS

Peak kW Savings/Soundbar $= PF \times [(Watts_{bs,active} - Watts_{ee,active}) /1000] \times CF$

Annual kWh Savings/Soundbar $= PF \times \{[(Watts_{bs,active} - Watts_{ee,active}) * HRS_{active}] + [Watts_{bs,idle} - Watts_{ee,idle}) * HRS_{idle}] + [Watts_{bs,sleep} - Watts_{ee,sleep}) * HRS_{sleep}]\}/1000$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
$Watts_{bs,active}$	Baseline Watts (active)	30	W	Fraunhofer Center for Sustainable Energy Systems. 2014.[1]
$Watts_{bs,idle}$	Baseline Watts (idle)	12	W	
$Watt_{bs,sleep}$	Baseline Watts (sleep)	4	W	
$Watt_{ee,active}$	Energy efficient watts (active)	20.2	W	Energy Solutions Report on RPP - Citing EPA Internal Analysis of ENERGY STAR V2.0 Soundbars.2
$Watt_{ee,idle}$	Energy efficient watts (idle)	3.5	W	
$Watt_{ee,sleep}$	Energy efficient watts (sleep)	0.5	W	
HRS_{active}	Hours per year in active mode	1,580	hrs	Fraunhofer Center for Sustainable Energy Systems. 2014.[3]
HRS_{idle}	Hours per year in idle mode	730	hrs	
HRS_{sleep}	Hours per year in sleep mode	6,450	hrs	

CF	Coincidence factor	0.220	-	Assuming same CF as Televisions. Based on Efficiency Vermont TRM, 2015 for coincident usage between 5-7PM.
PF	Persistence factor	100%	-	
Measure Life	Expected duration of energy savings	4	yrs	ENERGY STAR Assumption - Via NEEP Mid-Atlantic TRM Version 6

Note: 1.https://www.cta.tech/CTA/media/policyImages/Energy-Consumption-of-Consumer-Electronics.pdf
2.https://static1.squarespace.com/static/53c96e16e4b003bdba4f4fee/t/556d387fe4b0d8dc09b24c28/1433221247215/RPP+Methodology+for+Developing+UEC+Estimates_Final.pdf
3.https://www.cta.tech/CTA/media/policyImages/Energy-Consumption-of-Consumer-Electronics.pdf

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings
Soundbar	0.002 kW	44.26 kWh

RESIDENTIAL: Window AC

Return to TOC

UPDATE STATUS

Updated in Winter 2020 for PY19 TRM v2.1.

MEASURE DETAILS

Description

The early removal and recycling of a pre-existing inefficient window air conditioning unit and replacement with a new ENERGY STAR qualifying unit, or the installation of a new ENERGY STAR unit without recycling a previous unit through the program. This measure applies to ENERGY STAR dual inverter driven window AC systems.

Program Criteria

For early replacement with recycling projects, documentation must be provided to show that the pre-existing unit was operating and had a meaningful remaining useful life prior to replacement.

Unit of Measure

One window AC unit.

Baseline Equipment

Equipment is assumed to be a window AC unit without reverse cycle, with louvered sides, and a capacity range of less than 28,000 Btu/h. For window AC units not meeting this type or capacity range, confirm program eligibility with Hawai'i Energy and use a custom approach to calculate impacts.

For early replacement with recycling, a dual baseline is required to estimate impacts. The efficiency during the first baseline period corresponds to federal minimum requirements for units manufactured between Oct. 1, 2000 and May 31, 2014 and the efficiency during the second baseline period corresponds to federal minimum requirements for units manufactured as of Jun. 1, 2014. (See Table 1.)

For addition of new systems without recycling a previous unit, or for replacement on burnout of a pre-existing unit, a single baseline that corresponds to federal minimum requirements for units manufactured as of Jun. 1, 2014 is used. (See Table 1.)

High Efficiency Equipment

High efficiency equipment is a new window AC unit without reverse cycle, with louvered sides, and a capacity range of less than 28,000 Btu/h that meets or exceeds the minimum requirements per the ENERGY STAR Product Specification for Room Air Conditioners, Version 4.1. (See Table 1.) This measure includes dual inverter window AC units that are ENERGY STAR certified.

For PY19, all window AC units must meet or exceed the $CEER_{Min}$ ENERGY STAR qualifications.

For PY20 and later, standard window AC units that are not "Connected" (or, "Smart") must meet or exceed the $CEER_{Base}$ qualifications. Connected (Smart) window ACs must meet or exceed the $CEER_{Min}$ ENERGY STAR qualifications.

Table 1: Baseline and ENERGY STAR Specifications

Capacity Bin (Btu/h)	1st Baseline[1]		2nd Baseline[2]		ENERGY STAR[3]			
	$CEER_{BL,1}$	$EER_{BL,1}$	$CEER_{BL,2}$	$EER_{BL,2}$	$CEER_{Base}$	EER_{Base}	$CEER_{Min}$	EER_{Min}
< 8,000	9.6	9.7	11.0	11.1	12.1	12.2	11.5	11.6
8,000 to 13,999	9.7	9.8	10.9	11.0	12.0	12.1	11.4	11.5
14,000 to 19,999	9.6	9.7	10.7	10.8	11.8	11.9	11.2	11.3
20,000 to 27,999	8.4	8.5	9.4	9.5	10.3	10.4	9.8	9.9

[1] See federal minimum $EER_{BL,1}$ requirements for units manufactured between Oct. 1, 2000 to May 31, 2014 at <https://www.govinfo.gov/content/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf>, paragraph (b) on page 472. $CEER_{BL,1}$ is assumed to be $EER_{BL,1}$ / 1.01.

[2] See federal minimum $CEER_{BL,2}$ requirements for units manufactured as of Jun. 1, 2014 at <https://www.govinfo.gov/content/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf>, paragraph (b) on page 472. $EER_{BL,2}$ is assumed to be $CEER_{BL,2}$ * 1.01.

[3] See ENERGY STAR Version 4.1 Room Air Conditioners Program Requirements, available here: <https://www.energystar.gov/products/heating_cooling/air_conditioning_room/partners>. EER is assumed to be CEER * 1.01.

ALGORITHMS

First Baseline Peak Demand Reduction, kW (Early Replacement Only)

$$\Delta kW_{1st} = Capacity * ((1/EER_{BL,1} - 1/EER_{EE})/1000) * CF * PF \quad (1)$$

Second Baseline Peak Demand Reduction, kW (or, Single Baseline for Replace on Burnout)

$$\Delta kW_{2nd} = Capacity * ((1/EER_{BL,2} - 1/EER_{EE})/1000) * CF * PF \quad (2)$$

First Baseline Annual Energy Savings, kWh/yr (Early Replacement Only)

$$\Delta kWh_{1st} = Capacity * ((1/CEER_{BL,1} - 1/CEER_{EE})/1000) * EFLH * PF \quad (3)$$

Second Baseline Annual Energy Savings, kWh/yr (or, Single Baseline for Replace on Burnout)

$$\Delta kWh_{2nd} = Capacity * ((1/CEER_{BL,2} - 1/CEER_{EE})/1000) * EFLH * PF \quad (4)$$

Early Replacement Lifetime Energy Savings, kWh

$$\Delta kWh_{life,ER} = \Delta kWh_{1st} * RUL + \Delta kWh_{2nd} * (EUL - RUL) \quad (5)$$

Replace on Burnout Lifetime Energy Savings, kWh

$$\Delta kWh_{life,ROB} = \Delta kWh_{2nd} * EUL \quad (6)$$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Source/Notes**
Capacity	Cooling capacity of installed window AC unit	Based on installed unit	Btu/h	Assumes capacity of < 28,000 Btu/h.[1]
$EER_{BL,1}$	Energy efficiency ratio of baseline unit for first baseline period (early replacement)	See Table 1	Btu/Wh	Federal minimum requirement for units manufactured between Oct. 1, 2000 and May 31, 2014.
$EER_{BL,2}$	Energy efficiency ratio of baseline unit for second baseline period (early replacement) or for single baseline (replace on burnout)	See Table 1	Btu/Wh	Assumed to be $CEER_{BL,2}$ * 1.01 per ENERGY STAR data.[2]
EER_{EE}	Energy efficiency ratio of installed high efficiency unit	As installed	Btu/Wh	EER_{EE} is assumed to be $CEER_{EE}$ * 1.01 per ENERGY STAR data.[2]
$CEER_{BL,1}$	Combined energy efficiency ratio of baseline unit for first baseline period (early replacement)	See Table 1	Btu/Wh	Assumed to be $EER_{BL,1}$ / 1.01 per ENERGY STAR data.[2]
$CEER_{BL,2}$	Combined energy efficiency ratio of baseline unit for second baseline period (early replacement) or for single baseline (replace on burnout)	See Table 1	Btu/Wh	Federal minimum requirement for units manufactured as of Jun. 1, 2014.
$CEER_{EE}$	Combined energy efficiency ratio of installed high efficiency unit	As installed	Btu/Wh	Must meet ENERGY STAR Version 4.1 minimum. For PY19, $CEER_{EE} \geq CEER_{Min}$ for all systems. For PY20 and later, $CEER_{EE} \geq CEER_{Min}$ for connected systems and $CEER_{EE} \geq CEER_{Base}$ for standard systems.[3] See Table 1.
CF	Coincidence factor	0.36	-	CF corresponding with system peak of 5-9pm on non-holiday weekdays. Determined based on EnergyPlus prototype simulations with room AC systems.

EFLH	Equivalent full load cooling hours	2,528	hrs/yr	EFLH determined as average of residential EnergyPlus prototype simulations with room AC cooling system by dividing total cooling kWh by maximum kW (proxy for capacity, adjusted for oversizing).
PF	Persistence factor	1	-	
Constant	Watt/kilowatt conversion	1,000	W/kW	
RUL	Remaining useful life of measure	3	yrs	Assumed to be 1/3 EUL.
EUL	Effective useful life of measure	9	yrs	DEER 2020.

[1] For window AC units outside of this capacity range, use a custom approach to calculate impacts.

[2] ENERGY STAR specification provided equivalent EER and CEER ratings. For the most popular size band, the EER rating is approximately 1% higher than the CEER. See ENERGY STAR Version 3.0 Room Air Conditioners Program Requirements and 2020 Illinois Statewide Technical Reference Manual, v8.0, Vol. 3: Residential Measures, Oct. 17, 2019, pg. 37.

[3] ENERGY STAR has a CEER allowance for connected systems, where $CEER_{Min} = CEER_{Base} - 0.05 * CEER_{Base}$. Per ENERGY STAR, connected systems "shall include the appliance plus all elements (hardware, software) required to enable communication in response to consumer-authorized energy related commands (not including third-party remote management which may be made available solely at the discretion of the manufacturer). These elements may be resident inside or outside of the appliance. This capability shall be supported through one or more means, as identified in Section 4.B.2" of ENERGY STAR Version 4.1 Room Air Conditioners Program Requirements, available here: <https://www.energystar.gov/products/heating_cooling/air_conditioning_room/partners>.

SAVINGS

See the accompanying AC worksheet:

R_HVAC_AC_WKST

RESOURCES

- AEG's Analysis Files titled "AEG HPUC Res HVAC Calculator - Analysis File" and "AEG HPUC Mid-Year PY19 TRM Updates_Analysis File." In addition, the file titled "AEG HPUC Update - Ductless Systems - Analysis file," worksheet tab named "Res_HVAC Key Parameters," includes Hawaiʻi-specific simulation results for determining Room AC EFLH and CF.
- California Public Utilities Commission, Database of Energy Efficiency Resources, 2020 update, (DEER2020), READI v.2.5.0, Ex Ante Database Support Table Export, EUL_basis, created on 8/24/2018, available here: www.deeresources.com/index.php/homepage. Spreadsheet.

- Code of Federal Regulations, 10 CFR 430.32, Subpart C, Energy and Water Conservation Standards and Their Effective Dates, (b) Room Air Conditioners, page 472, available here: <https://www.govinfo.gov/content/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf>.
- ENERGY STAR Version 3.0 Room Air Conditioners Program Requirements, available here: <https://www.energystar.gov/products/spec/room_air_conditioners_specification_version_3_0_pd>.
- ENERGY STAR Version 4.1 Room Air Conditioners Program Requirements, available here: <https://www.energystar.gov/products/heating_cooling/air_conditioning_room/partners>.
- Hawaiʻi-specific energy simulations of single family home prototypes in BEopt™ with EnergyPlus v8.8 as the simulation engine.
- 2020 Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 8.0, Volume 3: Residential Measures, FINAL, Oct. 17, 2019, page 37.
- Oversizing of HVAC System: Signatures and Penalties, University of Idaho, Integrated Design Lab-Boise, available here: <http://www.idlboise.com/pdf/papers/ENB_3018_RTU_Measurement_accepted.pdf>. Used to determine correct HVAC oversizing adjustment for EFLH and CF analysis.

RESIDENTIAL: Ductless Split Systems

Return to TOC

UPDATE STATUS

Updated in Winter 2020 for PY19 TRM v2.1.

MEASURE DETAILS

Description

Ductless split systems are inverter-driven direct expansion AC and heat pump systems that use distributed refrigerant technology for cooling and heating. These systems consist of: an outdoor unit with a single variable speed compressor or multiple staged compressors, indoor evaporator unit(s) with variable speed fans designed for single zone air distribution, and zone temperature controls. Per the Air Conditioning, Heating, and Refrigeration Institute (AHRI), residential ductless split systems can be classified as:

- Ductless One-to-One (Single) Split Systems
- Space Constrained Ductless-Split Systems
- Ductless Multi-Split Systems
- Variable Refrigerant Flow (VRF) Ductless Split Systems
- Heat Recovery Multi-Split Systems

Heat pumps and heat recovery systems are not relevant to the residential sector in this climate zone; only cooling systems are evaluated.

Program Criteria

SEER rating of 16.0 or higher for ≥8,000 Btu/h and <65,000 Btu/h.

EER rating of 11.0 or higher for ≥8,000 Btu/h and <30,000 Btu/h. EER rating of 11.5 or higher for ≥30,000 Btu/h and <65,000 Btu/h.

Unit of Measure

Savings are calculated per split system unit.

Baseline Equipment

The baseline equipment meets the current State of Hawaiʻi code, which is IECC 2015 and is consistent with the national ASHRAE 90.1-2016 standard that manufacturers adhere to (See Table 1). All counties are expected to adopt IECC 2015 or better by March 2019.

Table 1: Baseline Efficiency Specifications[1]

Capacity Bin	Baseline	
	SEER	EER
≥8,000 Btu/h and <14,000 Btu/h	10.9	9.8
≥14,000 Btu/h and <20,000 Btu/h	9.7	8.7
≥20,000 Btu/h and <30,000 Btu/h	9.4	8.5
≥30,000 Btu/h and <65,000 Btu/h	14.0	11.5

[1] Baseline efficiencies for the lower capacity bins (up to 30 kBtu/h) are provided based on ASHRAE 90.1-2016 standards for louvered, non-reverse-cycle room AC. A standard baseline efficiency for larger units (≥ 30 kBtu/h) is specified based on an air-cooled split system central air conditioner installed in Hawaiʻi. Since the recommended savings algorithm uses both SEER and EER and only one or the other was specified in ASHRAE for these equipment types, a simple rule of thumb of EER = 0.9 * SEER was used to convert between the two (ASHRAE provides a minimum EER standard for 8-14 kBtu/h and 20-30 kBtu/h bins and provides a SEER standard for the 14-20 kBtu/h and >30 kBtu/h bins). For the larger central AC units (≥ 30 kBtu/h), AEG's research of the AHRI database (Oct 2018 extract) showed that 11.5 EER represents the 1st quartile of EER values corresponding to 14 SEER. Since it is reasonable to expect all high efficiency systems to be at least as efficient as the 1st quartile EER value, 11.5 EER was used for 14 SEER baseline units.

High Efficiency Equipment

The installed equipment is assumed to meet the 16 SEER / 11 EER (<30,000 Btu/h) or 16 SEER / 11.5 EER (≥30,000 Btu/h) minimum requirements and reflect the actual efficiency of the unit.

ALGORITHMS

Peak Demand Reduction, kW

$$\Delta kW = Capacity * ((1/EER_{BL} - 1/EER_{EE})/1000) * CF * PF \quad (1)$$

Annual Energy Savings, kWh/yr

$$\Delta kWh = Capacity * ((1/SEER_{BL} - 1/SEER_{EE})/1000) * EFLH * PF \quad (2)$$

Lifetime Energy Savings, kWh

$$\Delta kWh_{life} = \Delta kWh * EUL \quad (3)$$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Source/Notes
Capacity	Capacity, in Btu/h, of installed unit	Based on installed unit	Btu/h	As installed.
EER_{BL}	Full load energy efficiency ratio of baseline unit	See Table 1	Btu/Wh	ASHRAE 90.1-2016. Full load efficiency is used for demand calculations.
EER_{EE}	Full load energy efficiency ratio of installed high efficiency unit	As installed	Btu/Wh	Must meet 11 EER or 11.5 EER minimum, depending on capacity.
$SEER_{BL}$	Seasonal energy efficiency ratio of baseline unit	See Table 1	Btu/Wh	ASHRAE 90.1-2016.
$SEER_{EE}$	Seasonal energy efficiency ratio of installed high efficiency unit	As installed	Btu/Wh	Must meet 16 SEER minimum.

CF	Coincidence Factor for <30,000 Btu/h units	0.36	-	CF corresponding with system peak of 5-9pm on non-holiday weekdays. Determined based on EnergyPlus prototype simulations with Room AC systems.
	Coincidence Factor for ≥30,000 Btu/h units	0.27	-	CF corresponding with system peak of 5-9pm on non-holiday weekdays. Determined based on EnergyPlus prototype simulations with Central AC systems.
EFLH	Equivalent full load cooling hours for <30,000 Btu/h units	2,528	hrs/yr	EFLH determined as median of residential EnergyPlus prototype simulations with room AC systems by dividing total cooling kWh by maximum kW (proxy for capacity, adjusted for oversizing).
	Equivalent full load cooling hours for ≥30,000 Btu/h units	1,884	hrs/yr	EFLH determined as median of residential EnergyPlus prototype simulations with central AC systems by dividing total cooling kWh by maximum kW (proxy for capacity, adjusted for oversizing).
PF	Persistence Factor	1.0	-	
Constant	Watt/kilowatt conversion	1,000	W/kW	
EUL	Effective useful life of measure	15	yrs	No change from PY18 TRM; EUL was verified during AEG's 2018 benchmarking.

SAVINGS

See the accompanying AC worksheet:
R_HVAC_AC_WKST

RESOURCES

- AEG's Analysis Files titled "AEG HPUC Update - Ductless Systems - Analysis File" and "AEG HPUC Res HVAC Calculator - Analysis File."
- Air-Conditioning, Heating, & Refrigeration Institute (AHRI), Database of Certified Products, accessed Oct. 2018, available here: <http://www.ahrinet.org/Contractors-Specifiers/Certified-Products>.
- Code of Federal Regulations, 10 CFR 430.32, Subpart C, Energy and Water Conservation Standards and Their Effective Dates, (c) Central Air Conditioners and Heat Pumps, page 472, available here: <https://www.govinfo.gov/content/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf>.
- Hawaiʻi Energy. Code baseline specification based on Hawaiʻi Energy: <https://hawaiienergy.com/resources#hawaii-codes> and <http://energy.hawaii.gov/hawaii-energy-building-code/2015-iecc-update>.

  All equipment is expected to meet minimum ASHRAE standards. ASHRAE requires a subscription to see the standard in full; AEG used staff subscriptions to ASHRAE to obtain the latest 90.1-2016 standard. The minimum efficiency levels are also summarized in various publicly available sources, including this one from Trane: <https://www.trane.com/content/dam/Trane/Commercial/global/products-systems/education-training/engineers-newsletters/standards-codes/ADMAPN053EN_0315.pdf>.

- Hawaiʻi Energy. The IECC 2015 with Hawaiʻi Amendments Commercial Reviewer and Designer Checklist requires efficient HVAC equipment to be 10% better than the minimum efficiency. Available at: <https://hawaiienergy.com/files/resources/2015-IECC_CommercialReviewer_Checklist.pdf>.
- Hawaiʻi-specific energy simulations of single family home prototypes in BEopt™ with EnergyPlus v8.8 as the simulation engine.
- Oversizing of HVAC System: Signatures and Penalties, University of Idaho, Integrated Design Lab-Boise, available here: <http://www.idlboise.com/pdf/papers/ENB_3018_RTU_Measurement_accepted.pdf>. Used to determine correct HVAC oversizing adjustment for EFLH and CF analysis.

RESIDENTIAL: Central A/C Retrofit

Return to TOC

UPDATE STATUS

Updated in Fall 2019 for PY19 TRM v2.0.

MEASURE DETAILS

Description

Early removal of an existing inefficient central air conditioning unit from service, prior to its measure and natural end of life, and replacement with a higher efficiency unit.

Program Criteria

Contact Hawai'i Energy's residential team for more information. For early replacement, the pre-existing unit must be less than 20 years old and documentation must be provided to show that the pre-existing unit was operating and had a meaningful remaining useful life prior to replacement. Examples of acceptable documentation include a signed statement from the homeowner or a video showing the pre-existing unit in operation. In addition, a photo of the nameplate is required, even if it is corroded or otherwise illegible. In cases where the nameplate is missing, the age is unknown, and/or the unit is assumed to have been manufactured prior to Jan. 23, 2006, both a video of the pre-existing unit in operation and a signed statement from the homeowner verifying that it is operational are required.

Unit of Measure

One central AC unit.

Baseline Equipment

Baseline equipment is assumed to be a split-system or single-package central AC unit with capacity of <65,000 Btu/h. For early replacement, a dual baseline is required to estimate impacts. During the first baseline period, pre-existing equipment manufactured after Jan. 23, 2006 is assumed to be 13 SEER per the minimum federal requirement in effect between 2006 and 2015, while pre-existing equipment manufactured before Jan. 23, 2006 is assumed to be 11 SEER. In cases where the pre-existing AC unit's nameplate is corroded or otherwise illegible due to age, assume pre-2006 vintage as long as the system's age can reasonably be assumed to be less than 20 years old. After the end of the first baseline period, the baseline must meet or exceed the current federal and state minimum requirement of 14 SEER, which has been in effect since Jan. 1, 2015.

High Efficiency Equipment

High efficiency equipment is a new split-system or single-package central AC unit (<65,000 Btu/h) with at least 10% efficiency improvement over the current federal and state minimum requirement, which equates to 14 SEER plus 10% = 15.4 SEER for the high efficiency unit.

ALGORITHMS

First Baseline Peak Demand Reduction, kW

$$\Delta kW_{1st} = Capacity * ((1/EER_{BL,1} - 1/EER_{EE})/1000) * CF * PF \quad (1)$$

Second Baseline Peak Demand Reduction, kW

$$\Delta kW_{2nd} = Capacity * ((1/EER_{BL,2} - 1/EER_{EE})/1000) * CF * PF \quad (2)$$

First Baseline Annual Energy Savings, kWh/yr

$$\Delta kWh_{1st} = Capacity * ((1/SEER_{BL,1} - 1/SEER_{EE})/1000) * EFLH * PF \quad (3)$$

Second Baseline Annual Energy Savings, kWh/yr

$$\Delta kWh_{2nd} = Capacity * ((1/SEER_{BL,2} - 1/SEER_{EE})/1000) * EFLH * PF \quad (4)$$

Early Replacement Lifetime Energy Savings, kWh

$$\Delta kWh_{life,ER} = \Delta kWh_{1st} * RUL + \Delta kWh_{2nd} * (EUL - RUL) \quad (5)$$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Sources/Notes**
Capacity	Cooling capacity of installed central AC unit	Based on installed unit	Btu/h	As installed (< 65,000 Btu/h).
$EER_{BL,1}$	Energy efficiency ratio of baseline unit for first (early replacement) baseline period, Vintage = pre-2006	9.9	Btu/Wh	Assumed to be EER = 0.9 * SEER, for 11 SEER system.
	Energy efficiency ratio of baseline unit for first (early replacement) baseline period, Vintage = 2006 or later	11.0	Btu/Wh	See Note 1.
$EER_{BL,2}$	Energy efficiency ratio of baseline unit for second baseline period	11.5	Btu/Wh	See Note 2.
EER_{EE}	Energy efficiency ratio of installed high efficiency unit	As installed	Btu/Wh	Must meet 11.5 EER minimum.
$SEER_{BL,1}$	Seasonal energy efficiency ratio of baseline unit for first (early replacement) baseline period, Vintage = pre-2006	11.0	Btu/Wh	See Note 3.

$SEER_{BL,1}$	Seasonal energy efficiency ratio of baseline unit for first (early replacement) baseline period, Vintage = 2006 or later	13.0	Btu/Wh	See Note 4.
$SEER_{BL,2}$	Seasonal energy efficiency ratio of baseline unit for second baseline period	14.0	Btu/Wh	See Note 5.
$SEER_{EE}$	Seasonal energy efficiency ratio of installed high efficiency unit	As installed	Btu/Wh	Must meet 15.4 SEER minimum (≥10% improvement relative to $SEER_{BL,2}$).
CF	Coincidence factor	0.27	-	CF corresponding with system peak of 5-9pm on non-holiday weekdays. Determined based on EnergyPlus prototype simulations with Central AC systems.
EFLH	Equivalent full load cooling hours	1,884	hrs/yr	EFLH determined as average of residential EnergyPlus prototype simulations with central AC cooling system by dividing total cooling kWh by maximum kW (proxy for capacity, adjusted for oversizing).
PF	Persistence Factor	1.0	-	
Constant	Watt/kilowatt conversion	1,000	W/kW	
RUL	Remaining useful life of measure	5	yrs	Assumed to be 1/3 EUL.
EUL	Effective useful life of measure	15	yrs	DEER 2020.

1. AEG's research of the AHRI database (Oct 2018 extract) showed that 11.0 EER represents the 1st quartile (and median) of EER values corresponding to 13 SEER. Since it is reasonable to want all high efficiency systems to be more efficient than the 1st quartile (or median) EER value, 11.0 EER was used for 13 SEER baseline units.

2. AEG's research of the AHRI database (Oct 2018 extract) showed that 11.5 EER represents the 1st quartile of EER values corresponding to 14 SEER. Since it is reasonable to want all high efficiency systems to be more efficient than the 1st quartile EER value, 11.5 EER was used for 14 SEER baseline units.

3. 11.0 SEER is a conservative assumption since federal requirements for equipment manufactured after Jan. 1, 1993 and before Jan. 23, 2006 were 10.0 SEER for split-systems and 9.7 SEER for single-package systems. See <https://www.govinfo.gov/content/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf>, paragraph (c) (1) on page 472-473.

4. The minimum is 13.0 SEER for split-system central AC and single-package central AC systems manufactured after Jan. 23, 2006 and before Jan. 1, 2015 and installed in Hawai'i. See <https://www.govinfo.gov/content/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf>, paragraph (2) on page 473.

5. The minimum is 14.0 SEER for split-system central AC and single-package central AC systems manufactured on or after Jan. 1, 2015 and installed in Hawai'i. See <https://www.govinfo.gov/content/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf>, paragraphs (3) and (4) on page 473.

SAVINGS

See the accompanying AC worksheet:

R_HVAC_AC_WKST

RESOURCES

- AEG's Analysis Files titled "AEG HPUC Res HVAC Calculator - Analysis File" and "AEG HPUC Mid-Year PY19 TRM Updates_Analysis File." In addition, the file titled "AEG HPUC Update - Ductless Systems - Analysis file," worksheet tab named "Res_HVAC Key Parameters," includes Hawaiʻi-specific simulation results for determining Central AC EFLH and CF.
- Air-Conditioning, Heating, & Refrigeration Institute (AHRI), Database of Certified Products, accessed Oct. 2018, available here: <http://www.ahrinet.org/Contractors-Specifiers/Certified-Products>.
- California Public Utilities Commission, Database of Energy Efficiency Resources, 2020 update, (DEER2020), READI v.2.5.0, Ex Ante Database Support Table Export, EUL_basis, created on 8/24/2018, available here: www.deeresources.com/index.php/homepage. Spreadsheet.
- Code of Federal Regulations, 10 CFR 430.32, Subpart C, Energy and Water Conservation Standards and Their Effective Dates, (c) Central Air Conditioners and Heat Pumps, page 472, available here: <https://www.govinfo.gov/content/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf>.
- Hawaiʻi Energy. The IECC 2015 with Hawaiʻi Amendments Commercial Reviewer and Designer Checklist requires efficient HVAC equipment to be 10% better than the minimum efficiency. Available at: <https://hawaiienergy.com/files/resources/2015-IECC_CommercialReviewer_Checklist.pdf>.
- Hawaiʻi-specific energy simulations of single family home prototypes in BEopt™ with EnergyPlus v8.8 as the simulation engine.
- Oversizing of HVAC System: Signatures and Penalties, University of Idaho, Integrated Design Lab-Boise, available here: <http://www.idlboise.com/pdf/papers/ENB_3018_RTU_Measurement_accepted.pdf>. Used to determine correct HVAC oversizing adjustment for EFLH and CF analysis.

RESIDENTIAL: HVAC Savings Calculator

Return to TOC

Step 1: Enter AC nameplate data

Is Room AC a Connected (Smart) System?	NA	Only used for Room AC
Enter Vintage of Existing AC Unit	2006 and Later	Only used for Central AC early replacement
Enter AC type:	Central AC (<65,000 Btu/h)	
Enter AC size (Btu/h):	9,000	
Enter Full Load Efficiency:*	12.0 EER	
Enter Part-Load Efficiency:**	16.0 SEER or CEER	

* If EER is unknown, use EER = 0.9 * SEER or EER = 1.01 * CEER

**If SEER or CEER is unknown, use SEER = EER / 0.9 or CEER = EER / 1.01

Step 2: Determine if it qualifies

EER_EE_Min	11.5	Pass
SEER/CEER_EE_Min	15.4	Pass
$EER_{BL,2}$	11.5	
$SEER/CEER_{BL,2}$	14.0	
$EER_{BL,1}$	11.0	Only for early replacement
$SEER/CEER_{BL,1}$	13.0	Only for early replacement

Step 3: Calculate savings

CF:	0.27	
EFLH:	1,884	
PF:	1.0	
kW reduction:	0.009	
kW reduction (ER):	0.018	Only for early replacement; this is savings during first baseline period
kWh/yr savings:	151.39	
kWh/yr savings (ER):	244.56	Only for early replacement; this is savings during first baseline period
Lifetime kWh:	2,736.70	

Baseline Specifications

	Replace on Burnout (Single Baseline)	
Ductless Split System by Capacity Bin	**$SEER_{BL}$**	**EER_{BL}**
≥8,000 Btu/h and <14,000 Btu/h	10.9	9.8
≥14,000 Btu/h and <20,000 Btu/h	9.7	8.7
≥20,000 Btu/h and <30,000 Btu/h	9.4	8.5
≥30,000 Btu/h and <65,000 Btu/h	14.0	11.5

	Replace on Burnout (or, Second Baseline for Early Replacement)		2006 and Later: Early Replacement (First Baseline)		Pre-2006: Early Replacement (First Baseline)	
Central AC and Room AC	**$SEER/CEER_{BL,2}$**	**$EER_{BL,2}$**	**$SEER/CEER_{BL,1}$**	**$EER_{BL,1}$**	**$SEER/CEER_{BL,1}$**	**$EER_{BL,1}$**
Central AC Split and Single Package (<65,000 Btu/h)	14.0	11.5	13.0	11.0	11.0	9.9
Room AC w/ recycling (< 8,000 Btu/h)	11.0	11.1	9.6	9.7		
Room AC w/o recycling (< 8,000 Btu/h)	11.0	11.1				
Room AC w/ recycling (8,000-13,999 Btu/h)	10.9	11.0	9.7	9.8		
Room AC w/o recycling (8,000-13,999 Btu/h)	10.9	11.0				
Room AC w/ recycling (14,000-19,999 Btu/h)	10.7	10.8	9.6	9.7		
Room AC w/o recycling (14,000-19,999 Btu/h)	10.7	10.8				
Room AC w/ recycling (20,000-27,999 Btu/h)	9.4	9.5	8.4	8.5		
Room AC w/o recycling (20,000-27,999 Btu/h)	9.4	9.5				

Minimum EE Qualifications and Parameters Table

System Type	SEER/CEER_EE_Min	EER_EE_Min	SEER/CEER_EE_Base	EER_EE_Base	EFLH	CF	PF	EUL
Ductless (<30,000 Btu/h)	16.0	11.0	16.0	11.0	2,528	0.36	1.0	15
Ductless (≥30,000 Btu/h)	16.0	11.5	16.0	11.5	1,884	0.27	1.0	15
Room AC w/ recycling (< 8,000 Btu/h)	11.5	11.6	12.1	12.2	2,528	0.36	1.0	9
Room AC w/o recycling (< 8,000 Btu/h)	11.5	11.6	12.1	12.2	2,528	0.36	1.0	9
Room AC w/ recycling (8,000-13,999 Btu/h)	11.4	11.5	12.0	12.1	2,528	0.36	1.0	9
Room AC w/o recycling (8,000-13,999 Btu/h)	11.4	11.5	12.0	12.1	2,528	0.36	1.0	9
Room AC w/ recycling (14,000-19,999 Btu/h)	11.2	11.3	11.8	11.9	2,528	0.36	1.0	9
Room AC w/o recycling (14,000-19,999 Btu/h)	11.2	11.3	11.8	11.9	2,528	0.36	1.0	9
Room AC w/ recycling (20,000-27,999 Btu/h)	9.8	9.9	10.3	10.4	2,528	0.36	1.0	9
Room AC w/o recycling (20,000-27,999 Btu/h)	9.8	9.9	10.3	10.4	2,528	0.36	1.0	9
Central AC (<65,000 Btu/h)	15.4	11.5	15.4	11.5	1,884	0.27	1.0	15

Notes:

1. CEER applies to Room AC, while SEER applies to Ductless and Central AC.
2. SEER/CEER_EE_Base and EER_EE_Base only differ from SEER/CEER_EE_Min and EER_EE_Min for Room AC systems. SEER/CEER_EE_Base represents the minimum ENERGY STAR efficiency for standard Room AC systems, while SEER/CEER_EE_Min represents the minimum ENERGY STAR efficiency for "Connected" (Smart) Room AC systems. The stricter SEER/CEER_EE_Base requirements for standard Room AC systems will only apply for PY20 and later. For PY19, the SEER/CEER_EE_Min values will apply for both standard and "Connected" Room AC systems.

RESIDENTIAL: Central A/C Tune Up

Return to TOC

MEASURE DETAILS

Description
Maintenance of a residential central A/C system.

Program Criteria
Contact Hawai'i Energy's residential team for more information.

Unit of Measure
One tune up

Baseline Equipment
Pre-tune up central air conditioning unit

High Efficiency Equipment
Post-tune up central air conditioning unit

ALGORITHMS

$$\Delta E = [(CAP_{.avg} / \eta_{.avg}) * HRS * AF_{.op}] / 1000$$

$$\Delta P = (P_{.avg} * CF) - (P_{.avg} * CF * AF_{.rt})$$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
ΔE	Annual energy reduction	Calculated	kWh	
ΔP	Peak power demand reduction	Calculated	kW	
$CAP_{.avg}$	Average AC unit cooling capacity	36,000	BTU/hr	3 ton of cooling
$P_{.avg}$	Average AC unit power demand	2.77	kW	
$\eta_{.avg}$	Average AC unit EER	13	EER	
$AF_{.op}$	Adjustment factor for operational problems[1]	8%	-	
HRS	Annual hours of operation	1460	hrs	
$AF_{.rt}$	Adjustment factor for post tune-up run time[2]	92%	-	
Constant	Conversion from W to kW	1,000	-	
CF	Coincidence factor	33%	-	
Measure Life	Expected duration of savings	3	yrs	

[1] Accounts for impacts to performance due to incorrect refrigerant charge, clogged AHU filter, dirty condenser coil.

[2] A reduction in run time will occur once tune up is completed, lowering coincidence factor.

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings
Residential AC Tune Up	0.073 kW	323.45 kWh

RESIDENTIAL: Ceiling Fan

Return to TOC

MEASURE DETAILS

Description

ENERGY STAR ceiling fan with high efficiency motor and CFL bulbs, replacing fan with standard efficiency motor and (three) integral incandescent bulbs.

Program Criteria

Ceiling fan must have an ENERGY STAR label and include lighting.

Unit of Measure

One unit

Baseline Equipment

Standard efficiency motor with three integral incandescent bulbs.

High Efficiency Equipment

ENERGY STAR high efficiency motor with CFL bulbs.

ALGORITHMS

peak kW savings/fan $= [(\%_{.low} * (Low_{.kW,base} - Low_{.kW,ee}) + \%_{.med} * (Med_{.kW,base} - Med_{.kW,ee}) + \%_{.high} * (High_{.kW,base} - High_{.kW,ee})) + ((Inc_{.kW} - CFL_{.kW}) * WHF_{.d})] * CF$

annual kWh savings/fan $= [(\%_{.low} * (Low_{.kW,base} - Low_{.kW,ee}) + \%_{.med} * (Med_{.kW,base} - Med_{.kW,ee}) + \%_{.high} * (High_{.kW,base} - High_{.kW,ee})) * HRS_{.fan} + ((Inc_{.kW} - CFL_{.kW}) * WHF_{.e}) * HRS_{.light}] * CF$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
$\%_{.low}$	percent of time on low speed	40%	-	
$\%_{.med}$	percent of time on medium speed	40%	-	
$\%_{.high}$	percent of time on high speed	20%	-	
$Low_{.kW,base}$	low speed baseline fan motor wattage	0.0152	kW	
$Low_{.kW,ee}$	low speed efficient fan motor wattage	0.0117	kW	0.008 kW per current ENERGY STAR criteria and min air flow setting
$Med_{.kW,base}$	medium speed baseline fan motor wattage	0.0348	kW	
$Med_{.kW,ee}$	medium speed efficient fan motor wattage	0.0314	kW	0.030 kW per current criteria and min air flow setting
$High_{.kW,base}$	high speed baseline fan motor wattage	0.0725	kW	
$High_{.kW,ee}$	high speed efficient fan motor wattage	0.0715	kW	0.067 kW per current criteria and min air flow setting

$Inc_{.kW}$	baseline wattage of 3 incandescent bulbs	0.129	kW	EISA baseline effective 2014
$CFL_{.kW}$	wattage of 3 efficient CFL bulbs	0.060	kW	
CF	Coincidence factor	11%	-	
$HRS_{.fan}$	Hours of fan operation per year	1,022	hrs	2.8 hours per day, 365 days per year
$HRS_{.light}$	Hours of light operation per year	840	hrs	2.3 hours per day, 365 days per year
$WHF_{.d}$	Waste heat factor to account for cooling load savings from efficent lighting	1.21	-	
$WHF_{.e}$	Waste heat factor to account for cooling energy savings from efficent lighting	1.07	-	
Measure Life	Expected duration of energy savings	5	yrs	

Source: Hawai'i Energy Efficiency Program Technical Reference Manual, PY 2015. Measure Savings Calculations, pp. 43

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings
Ceiling Fan	0.010 kW	65.01 kWh

RESIDENTIAL: Smart Thermostat

Return to TOC

MEASURE DETAILS

Description

Thermostat controlling residential cooling loads during unoccupied and nighttime hours, replacing a manual thermostat serving a ducted central a/c system.

Program Criteria

Programmable thermostat with ENERGY STAR label

Unit of Measure

One thermostat

Baseline Equipment

Manual thermostat

High Efficiency Equipment

Programmable thermostat

ALGORITHMS

peak kW savings/thermostat = 0

annual kWh savings/thermostat = $[CAP_{.cool} / (1000\ W/kW)] * [1 / (SEER * EFF_{.duct})] * EFLH_{.cool} * ESF_{.cool}$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
$CAP_{.cool}$	Cooling capacity of a/c unit	36000	BTU/hr	
SEER	Seasonal Energy Efficiency Ratio	11.9	BTU/hr/W	
$EFF_{.duct}$	Duct system efficiency	0.8	-	
$ESF_{.cool}$	Energy savings factor for cooling	0.02	-	
PF	Persistence factor	1	-	
$EFLH_{.cool}$ [1]	Equivalent full load cooling hours	1825	hrs	
CF [1]	Coincidence factor	0.5	-	
Measure Life	Expected duration of savings	3	yrs	

Source: Pennsylvania 2016 Technical Reference Manual, p.79.

Note: 1. Values assumed for Residential HVAC measure by Hawaiʻi Energy .

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings
Smart Thermostat	0.000 kW	138.03 kWh

RESIDENTIAL: Solar Attic Fan

Return to TOC

MEASURE DETAILS

Description

Solar-powered attic fan assumed to reduce 10% of existing air conditioning load (non-peak) and energy usage.

Program Criteria

Contact Hawai'i Energy's residential team for more information.

Unit of Measure

One unit

Baseline Equipment

No attic fan.

High Efficiency Equipment

Solar-powered attic fan in air-conditioned home

ALGORITHMS

peak kW savings/fan $= AC_{.cap} / 1000 * (1 / EER) * \%_{.svgs,ac} * PF * CF$

annual kWh savings/fan $= AC_{.cap} / 1000 * (1 / EER) * EFLH * \%_{.svgs,ac} * PF$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
$\%_{.svgs,ac}$	Percentage of a/c load savings from solar attic fan	10%	-	
$AC_{.cap}$	Cooling capacity of existing air conditioner	8500	BTU	Average of PY14 window A/C units incentivized by Hawaiʻi Energy
EER	Full load cooling efficiency of existing air conditioner	9.8	BTU/hr/kW	
EFLH	Equivalent full load cooling hours for existing air conditioner	1825	hrs	
CF	Coincidence factor	0.000	-	
PF	Persistence factor	100%	-	
Measure Life	Expected duration of energy savings	20	yrs	

Source: Hawaiʻi Energy Efficiency Program Technical Reference Manual, PY 2015. Measure Savings Calculations, pp. 46

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings

Solar Attic Fan	0.000 kW	158.29 kWh

RESIDENTIAL: Whole-House Fan

Return to TOC

MEASURE DETAILS

Description

A fan that pulls hot air from the living space and exhausts through attic and roof or ductwork.

Program Criteria

Contact Hawai'i Energy's residential team for more information.

Unit of Measure

One fan.

Baseline Equipment

No fan installed.

High Efficiency Equipment

Fan installed.

ALGORITHMS

peak kW savings/fan $= AC_{.cap} / 1000 * (1 / EER) * \%_{.svgs,ac} * PF * CF$

annual kWh savings/fan $= AC_{.cap} / 1000 * (1 / EER) * EFLH * \%_{.svgs,ac} * PF$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Notes**
$\%_{.svgs,ac}$	Percent of a/c load savings from solar attic fan	20%	-	KEMA-Xenergy, Inc.[1]
$AC_{.cap}$	Cooling capacity of existing air conditioner	8500	BTU	Average of PY14 window A/C units incentivized by Hawai'i Energy
EER	Full load cooling efficiency of existing air conditioner	9.8	BTU/hr/kW	
EFLH	Equivalent full load cooling hours for existing air conditioner	1825	hrs	
CF	Coincidence factor	0.590	-	
PF	Persistence factor	1	-	
Measure Life	Expected duration of energy savings	20	yrs	

Source: Hawai'i Energy Efficiency Program Technical Reference Manual, PY 2015. Measure Savings Calculations, pp. 49-50

Note: 1. KEMA-Xenergy, Inc. Impact Evaluation of the 2001 Statewide Low Income Energy Efficiency (LIEE) Program. April 8, 2003. calmac.org/publications/2001_LIEE_Impact_Evaluation.pdf

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings
Whole House Fan	0.102 kW	316.58 kWh

RESIDENTIAL: Dehumidifier

Return to TOC

UPDATE STATUS

Updated in Spring 2019 for PY19 TRM.

MEASURE DETAILS

Description
The deployment of an energy efficient domestic dehumidifier.

Program Criteria
Dehumidifier must be ENERGY STAR certified.

Unit of Measure
One dehumidifier.

Baseline Equipment
Non-ENERGY STAR dehumidifier.

High Efficiency Equipment
ENERGY STAR certified dehumidifier.

ALGORITHMS

$$\Delta kW_{.peak} = [(CAP * 0.473) / 24] * (1 / \eta_{.bs} - 1 / \eta_{.he}) * CF$$

$$\Delta kWh_{.annual} = [(CAP * 0.473) / 24] * (1 / \eta_{.bs} - 1 / \eta_{.he}) * HRS$$

$$\Delta kWh_{.lifetime} = \Delta kWh_{.annual} * EUL$$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Source/Notes
CAP	Capacity	See Table	pints/day	
$\eta_{.bs}$	Baseline efficiency rating	See Table	L/kWh	ENERGY STAR: EPA research on available models, 2011.
$\eta_{.he}$	High efficiency rating	See Table	L/kWh	ENERGY STAR: EPA research on available models, 2011.
CF	Coincidence factor, percent of time equipment load corresponds with utility peak.	0.36	-	3,185 hrs / 8,760 hrs

HRS	Equipment annual operating hours	3,185	hrs/yr	NREL: Measure Guideline: Supplemental Dehumidification in Warm-Humid Climates. Miami (Climate Zone 1) hours at 60% set point.
Constant	Liters/pints conversion	0.473	L/pt	
EUL	Effective useful life of measure	12	yrs	ENERGY STAR Appliance Calculator: EPA Research, 2012.

SAVINGS

Capacity (pints/day)	Avg. Capacity [1] (pints/day)	ENERGY STAR Product % [2]	Baseline Efficiency [3] (≥ L/kWh)	Enhanced Efficiency [4] (≥ L/kWh)	Baseline kWh	Enhanced kWh	Savings kWh
≤25	25.00	0.55%	1.35	2	1,162.43	784.64	377.79
> 25 to ≤35	30.25	19.94%	1.35	2	1,406.54	949.41	457.12
> 35 to ≤45	44.47	5.26%	1.5	2	1,861.11	1,395.83	465.28
> 45 to ≤ 54	50.00	23.27%	1.6	2	1,961.60	1,569.28	392.32
> 54 to ≤ 75	68.78	39.89%	1.7	2	2,539.62	2,158.68	380.94
> 75 to ≤ 185	106.12	11.08%	2.5	2.8	2,664.46	2,378.98	285.48
Average	59.34		1.68	2.09	2,213.10	1,783.39	429.71

Notes: 1,2. Weighted average of capacities based on units listed in ENERGY STAR Certified Product List. Accessed 2018/09/21.
3. Federal minimum standard efficiency.
4. ENERGY STAR program criteria efficiency.

Measure Name	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Dehumidifier	0.049 kW	429.71 kWh	5,156.52 kWh

RESOURCES

- AEG's 2019 Analysis File titled "New Residential Measures Summary - AEG Analysis file."
- Code of Federal Regulations, Title 10, Part 430, Subpart C.
- ENERGY STAR, Appliance Calculator, available here: https://www.energystar.gov/sites/default/files/asset/.../appliance_calculator.xlsx.
- ENERGY STAR, Dehumidifiers, webpage, https://www.energystar.gov/products/appliances/dehumidifiers.
- U.S. Department of Energy, Energy Efficiency & Renewable Energy, Building Technologies Office, Measure Guideline: Supplemental Dehumidification in Warm-Humid Climates, Armin Rudd, Building Science Corporation, October 2014, available here: https://www.nrel.gov/docs/fy15osti/62677.pdf.

RESIDENTIAL: LED

Return to TOC

UPDATE STATUS

Updated in Fall 2018 for PY19 TRM.

MEASURE DETAILS

Description

The replacement of an EISA-compliant omni-directional, medium screw base lamp with an ENERGY STAR LED lamp of comparable brightness (lumens) in both Residential Single Family and Multifamily homes.

Program Criteria

This measure is applicable to both the REEM and RHTR programs.
The replacement LED lamp must have an ENERGY STAR label.

Unit of Measure

One lamp.

Baseline Equipment

This measure has a dual baseline for PY19. The first baseline is an omni-directional halogen-incandescent lamp that complies with Energy Independence and Securities Act (EISA) 2007 legislation that had 2012-2014 effective dates (EISA Tier 1). The second baseline is a lamp that complies with the EISA Tier 2 2020 Backstop requirement of 45 lumens per watt. For PY20 and later, there is a single baseline (EISA Tier 2).

High Efficiency Equipment

The high efficiency case is an ENERGY STAR omni-directional LED lamp.

ALGORITHMS

First Baseline Peak Demand Reduction, kW

$$\Delta kW_{1st} = \left(kW_{base,1} - kW_{LED}\right) * ISR * CF * \left(1 + WH_{C,D}\right) * PF \quad (1)$$

Second Baseline Peak Demand Reduction, kW

$$\Delta kW_{2nd} = \left(kW_{base,2} - kW_{LED}\right) * ISR * CF * \left(1 + WH_{C,D}\right) * PF \quad (2)$$

First Baseline Annual Energy Savings, kWh/yr

$$\Delta kWh_{1st} = \left(kW_{base,1} - kW_{LED}\right) * ISR * HOU * 365day/yr * \left(1 + WH_{C,E}\right) * PF \quad (3)$$

Second Baseline Annual Energy Savings, kWh/yr

$$\Delta kWh_{2nd} = \left(kW_{base,2} - kW_{LED}\right) * ISR * HOU * 365 day/yr * \left(1 + WH_{C,E}\right) * PF \quad (4)$$

Lifetime Energy Savings, kWh (Applicable to PY19)

$$\Delta kWh_{PY19} = \Delta kWh_{1st} * EUL_{1st} + \Delta kWh_{2nd} * (EUL_{LED} - EUL_{1st}) \quad (5)$$

Lifetime Energy Savings, kWh (Applicable to PY20 and later)

$$\Delta kWh_{PY20+} = \Delta kWh_{2nd} * EUL_{LED} \quad (6)$$

Waste Heat Factors due to Interaction with Space Cooling System

$$WH_{C,D} = \%_{Cool} * \%_{Int} * \left(IE_{C,D} - 1\right) \quad (7)$$

$$WH_{C,E} = \%_{Cool} * \%_{Int} * \left(IE_{C,E} - 1\right) \quad (8)$$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Source/Notes**
$kW_{base,1}$	First Baseline Wattage - EISA Tier 1	See Table 1	kW	EISA legislation, effective dates of 2012-2014
$kW_{base,2}$	Second Baseline Wattage - EISA Tier 2 (calculated for middle of lumen range)	See Table 1	kW	EISA legislation, effective date of Jan. 1, 2020
kW_{LED}	ENERGY STAR LED Wattage (typical values from Hawaiʻi Energy program data)	See Table 1	kW	No change from PY18 TRM
ISR	Lifetime in-service rate	0.97	-	AEG's Fall 2018 Benchmarking
CF	Peak demand coincidence factor	See Table 2	-	AEG's Hawaiʻi-specific simulation modeling
HOU	Average hours of use per day	See Table 2	hr/day	No change from PY18 TRM; values confirmed with AEG's Fall 2018 Benchmarking
$WH_{C,D}$	Waste heat factor due to lighting interaction with space cooling system demand	Varies	-	See Equation 7; applicable to lighting installed in locations with space cooling
$WH_{C,E}$	Waste heat factor due to lighting interaction with space cooling system energy use	Varies	-	See Equation 8; applicable to lighting installed in locations with space cooling
$\%_{Cool}$	Share of homes with electric cooling	See Table 2	-	Evergreen Economics Baseline Study, 2014

$\%_{Int}$	Share of interior light bulbs	0.85	-	DOE 2012 Residential Lighting End-Use Consumption Study[1]
$IE_{C,D}$	Interactive effects factor to account for cooling demand savings due to reducing waste heat with efficient lighting	1.30	-	AEG's Hawaiʻi-specific simulation modeling
$IE_{C,E}$	Interactive effects factor to account for cooling energy savings due to reducing waste heat with efficient lighting	1.35	-	AEG's Hawaiʻi-specific simulation modeling
PF	Persistence factor	1	-	Footnote 2
EUL_{1st}	Effective useful life of EISA Tier 1 baseline lamps	See Table 2	yrs	Based on average lamp life of 2,500 hours
EUL_{LED}	Effective useful life of LED	See Table 2	yrs	Based on average lamp life of 15,000 hours

[1] Residential Lighting End-Use Consumption Study: Estimation Framework and Initial Estimates, Prepared by DNV KEMA Energy and Sustainability, Pacific Northwest National Laboratory, Prepared for Solid-State Lighting Program, Building Technologies Program, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, December 2012. Table 4.4 shows that 15% of CFLs are installed in garages and exterior locations. AEG assumes CFLs are reasonable proxy for LEDs.

[2] Use value of PF=1 until more data is available on PF of LEDs relative to new EISA Tier 2 baseline (CFL).

Table 1. Baseline and Energy Efficient Wattages

Traditional Incandescent Equivalent (W)	EISA Lumen Bin	EISA Tier 1 Baseline ($kW_{base,1}$)	EISA Tier 2 Baseline[1] ($kW_{base,2}$)	Average Omni-directional LED[2] (kW_{LED})	% Breakdown by Wattage[2]
40	310 - 749 lm	0.029	0.012	0.006	6%
60	750 - 1049 lm	0.043	0.020	0.008	57%
75	1050 - 1489 lm	0.053	0.028	0.013	29%
100	1490 - 2600 lm	0.072	0.045	0.017	8%
Weighted average (default)		**0.047**	**0.024**	**0.010**	-

[1] EISA Tier 2 wattages area calculated based on 45 lumen/W and midpoint of lumen range

[2] LED wattages and % breakdowns by lighting type are from actual Hawaiʻi Energy Program Data (per description in PY15-PY18 TRMs)

Table 2. Key Parameters for Non-Military and Military Homes

	CF	$\%_{Cool}$	HOU[1]	EUL_{LED}	EUL_{1st}
Non-Military	0.16	0.41	2.3	18	3
Military	0.24	1	3.5	12	2

[1] Per the approach in previous versions of the Hawaiʻi TRM, the Non-Military HOU has been multiplied by a factor of 1.5 to obtain the Military HOU .

SAVINGS *(ONLY APPLICABLE FOR PY19)*

Deemed Savings (based on default values for wattages)

Measure Name	First Baseline Peak Demand Savings	First Baseline Annual Energy Savings	Lifetime Energy Savings
LED (non-military)	0.006 kW	34.11 kWh	291.32 kWh
LED (military)	0.011 kW	60.02 kWh	341.76 kWh

Semi-Prescriptive Savings Calculator (based on equivalent traditional incandescent wattage)

Enter Equivalent Incandescent Wattage

60

$kW_{base,1}$= 0.043 $kW_{base,2}$= 0.020 kW_{LED}= 0.008

Measure Name	First Baseline Peak Demand Savings	First Baseline Annual Energy Savings	Lifetime Energy Savings
LED (non-military)	0.006 kW	31.98 kWh	260.40 kWh
LED (military)	0.010 kW	56.27 kWh	305.48 kWh

SAVINGS *(APPLICABLE FOR PY20 AND LATER)*

Deemed Savings (based on default values for wattages)

Measure Name	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
LED (non-military)	0.002 kW	12.60 kWh	226.80 kWh
LED (military)	0.004 kW	22.17 kWh	266.04 kWh

Semi-Prescriptive Savings Calculator (based on equivalent traditional incandescent wattage)

Enter Equivalent Incandescent Wattage

60

kW_{base}= 0.020 kW_{LED}= 0.008

Measure Name	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
LED (non-military)	0.002 kW	10.96 kWh	197.28 kWh
LED (military)	0.004 kW	19.29 kWh	231.48 kWh

RESOURCES

- AEG's 2018 Analysis Files titled "AEG HPUC Update of Residential Measures - Analysis file" and "HI - Res Lighting IEF Analysis."

- AEG's 2018 Hawaiʻi-specific building energy simulations of single family home prototypes in BEopt™ with EnergyPlus v8.8 as the simulation engine. Used Hawaiʻi weather data and developed prototypes based on a mixture of assumptions from the 2014 State of Hawaiʻi Baseline Report, 2014 Building America House Simulation Protocols, and building characteristics from a survey of suburban homes in Google Maps. Homes were simulated with a variety of HVAC system types and four different lighting consumption levels. House leakage was also varied to vary the efficiency of the home. AEG used the analysis to determine coincidence factors (CFs), as well as interactive effects factors (IEFs) that account for cooling demand and energy savings due to reducing waste heat with efficient lighting.

- Arkansas Technical Reference Manual, Version 7.0, Arkansas Public Service Commission, 2017.
- Baseline Energy Appliance, Equipment and Building Characteristics Study Report, Prepared for the State of Hawaii Public Utilities Commission, November 6, 2013, With errata February 26, 2014, Evergreen Economics.
- Connecticut's 2018 Program Savings Document, 13th Edition, filed December 15, 2017.
- ENERGY STAR, https://www.energystar.gov/, https://www.energystar.gov/products/lighting_fans/light_bulbs, accessed 10/24/2018.
- Hawaiʻi PUC LED Baseline Memo, Opinion Dynamics, April 9, 2018.
- Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 6.0, Volume 3: Residential
- Lighting Research Center, Publications, 061Incandescent, page 114, Halogen A, https://www.lrc.rpi.edu/resources/publications/lpbh/061Incandescent.pdf, accessed 11/7/2018.

- Mid-Atlantic Technical Reference Manual, Version 8, Final, May 2018.
- National Renewable Energy Laboratory. Building Energy Optimization (BEopt) Software. Version 2.8.0.0. U.S. Department of Energy. January 2018. Available at: https://beopt.nrel.gov/.
- New Mexico Technical Resource Manual for the Calculation of Energy Efficiency Savings, 2016.
- Public Utility Commission of Texas, Texas Technical Reference Manual, Version 5.0, Volume 2: Residential Measures, Program Year (PY) 2018, October 2017.
- Regional Technical Forum. Residential Lighting - Unit Energy Savings Workbook, Version 6.1 (ResLighting_v6_1). Northwest Power and Conservation Council. April 4, 2018. Spreadsheet.
- Regulatory Advisory Appliance Efficiency Regulations for Lamps: Effective Dates, California Energy Commission, 2017.
- Residential Lighting End-Use Consumption Study: Estimation Framework and Initial Estimates, Prepared by DNV KEMA Energy and Sustainability, Pacific Northwest National Laboratory, Prepared for Solid-State Lighting Program, Building Technologies Program, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, December 2012, Table 4.4.
- Rhode Island Technical Reference Manual – 2018 Program Year, National Grid, 2017.
- RLPNC Study 17-9, 2017-18 Residential Lighting Market Assessment Study, Submitted to the Electric and Gas Program Administrators of Massachusetts, Submitted by NMR Group, March 28, 2018. Table 14, page 38.
- State of Minnesota, Technical Reference Manual for Energy Conservation Improvement Programs, Version 2.2, May 2, 2018.
- State of Pennsylvania Technical Reference Manual, Pennsylvania Public Utilities Commission, June 2016.

- Tennessee Valley Authority Technical Reference Manual, Version 6.0, Oct. 1, 2017.

- Uniform Methods Project, Chapter 6: Residential Lighting Evaluation Protocol, S. Dimetrosky, K. Parkinson, and N. Lieb, Apex Analytics, C. Kurnik, National Renewable Energy Laboratory, October 2017.

- Wilson, E. et. al., 2014 Building America House Simulation Protocols. National Renewable Energy Laboratory. March 2014. Available at: https://www.nrel.gov/docs/fy14osti/60988.pdf.

RESIDENTIAL: Lighting Occupancy Sensor

Return to TOC

UPDATE STATUS

Updated in Fall 2018 for PY19 TRM.

MEASURE DETAILS

Description

This measure is for wall switch sensors that control the use of lighting in areas around the home with variable use, such as laundry, storage, garage, bedrooms or spare areas. The default deemed savings approach assumes each occupancy sensor controls two omni-directional lamps in a non-military home. A semi-prescriptive savings calculator is also provided to allow custom entry of the controlled wattage.

Program Criteria

This measure is applicable to both the REEM and RHTR programs.
All types of wall switch sensors (e.g. infrared, ultrasonic) are eligible.
The occupancy sensors must be UL listed.

Unit of Measure

One unit.

Baseline Equipment

The default deemed base case is assumed to be two omni-directional lightbulbs in operation 2.3 hours per day. The default deemed measure has a dual baseline for PY19. The first baseline is two omni-directional halogen-incandescent lamps that comply with Energy Independence and Securities Act (EISA) 2007 legislation that had 2012-2014 effective dates (EISA Tier 1). The second baseline is two lamps that comply with the EISA Tier 2 2020 Backstop requirement of 45 lumens per watt. For PY20 and later, there is a single baseline (EISA Tier 2).

The semi-prescriptive calculator allows custom entry of the wattage controlled by the occupancy sensor. However, to use the semi-prescriptive calculator, the efficacy of the controlled lighting must meet or exceed the EISA Tier 2 2020 Backstop requirement of 45 lumens per Watt. For example, LEDs, CFLs, and T5 or T8 fluorescent lamps would all be eligible for the semi-prescriptive calculator, but incandescent and halogen bulbs would not be.

High Efficiency Equipment

The enhanced case is assumed to be the same base case lamps in operation with a 30% reduction in runtime.

ALGORITHMS

First Baseline Peak Demand Reduction, kW

$$\Delta kW_{1st} = kW_{ctrl,1} * RTR * ISR * CF * \left(1 + WH_{C,D}\right) * PF \quad (1)$$

Second Baseline Peak Demand Reduction, kW

$$\Delta kW_{2nd} = kW_{ctrl,2} * RTR * ISR * CF * \left(1 + WH_{C,D}\right) * PF \quad (2)$$

First Baseline Annual Energy Savings, kWh/yr

$$\Delta kWh_{1st} = kW_{ctrl,1} * RTR * ISR * HOU * 365day/yr * \left(1 + WH_{C,E}\right) * PF \quad (3)$$

Second Baseline Annual Energy Savings, kWh/yr

$$\Delta kWh_{2nd} = kW_{ctrl,2} * RTR * ISR * HOU * 365day/yr * \left(1 + WH_{C,E}\right) * PF \quad (4)$$

Lifetime Energy Savings, kWh (Applicable to PY19)

$$\Delta kWh_{PY19} = \Delta kWh_{1st} * RUL_{1st} + \Delta kWh_{2nd} * (EUL_{EE} - RUL_{1st}) \quad (5)$$

Lifetime Energy Savings, kWh (Applicable to PY20 and later)

$$\Delta kWh_{PY20+} = \Delta kWh_{2nd} * EUL_{EE} \quad (6)$$

Waste Heat Factors due to Interaction with Space Cooling System

$$WH_{C,D} = \%_{Cool} * \%_{Int} * \left(IE_{C,D} - 1\right) \quad (7)$$

$$WH_{C,E} = \%_{Cool} * \%_{Int} * \left(IE_{C,E} - 1\right) \quad (8)$$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Source/Notes**
$kW_{ctrl,1}$	EISA Tier 1 Wattage; two (2) 43W bulbs	0.086	kW	EISA legislation, effective dates of 2012-2014
$kW_{ctrl,2}$	EISA Tier 2 Wattage; two (2) 20W bulbs (Wattage calculated using middle of 750 - 1049 lm range)	0.040	kW	EISA legislation, effective date of Jan. 1, 2020
RTR	Runtime reduction factor from sensor	0.30	-	AEG's Fall 2018 Benchmarking; median of 6 sources
ISR	Lifetime in-service rate	0.97	-	AEG's Fall 2018 Benchmarking
CF	Peak demand coincidence factor	0.16	-	AEG's Hawai‘i-specific simulation modeling; non-military home [1]
HOU	Average hours of use per day	2.3	hr/day	No change from PY18 TRM; non-military home

$WH_{C,D}$	Waste heat factor due to lighting interaction with space cooling system demand	Varies	-	See Equation 7; applicable to lighting installed in locations with space cooling
$WH_{C,E}$	Waste heat factor due to lighting interaction with space cooling system energy use	Varies	-	See Equation 8; applicable to lighting installed in locations with space cooling
$\%_{Cool}$	Share of homes with electric cooling	0.41	-	Evergreen Economics Baseline Study, 2014; non-military home
$\%_{Int}$	Share of interior light bulbs	0.85	-	DOE 2012 Residential Lighting End-Use Consumption Study [2]
$IE_{C,D}$	Interactive effects factor to account for cooling demand savings due to reducing waste heat with efficient lighting	1.30	-	AEG's Hawaiʻi-specific simulation modeling
$IE_{C,E}$	Interactive effects factor to account for cooling energy savings due to reducing waste heat with efficient lighting	1.35	-	AEG's Hawaiʻi-specific simulation modeling
PF	Persistence factor	1	-	Assumes that savings persistence is accounted for in the EUL
RUL_{1st}	Remaining useful life of EISA Tier 1 baseline lamps	1	yrs	Based on average halogen lamp life of 2,500 hours and assumption that RUL_{1st} = $1/3*EUL_{1st}$
EUL_{EE}	Effective useful life of occupancy sensor	8	yrs	AEG's Fall 2018 Benchmarking

[1] This approach assumes that the occupancy pattern during 5-9 pm is consistent with rest of day.

[2] Residential Lighting End-Use Consumption Study: Estimation Framework and Initial Estimates, Prepared by DNV KEMA Energy and Sustainability, Pacific Northwest National Laboratory, Prepared for Solid-State Lighting Program, Building Technologies Program, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, December 2012. Table 4.4 shows that 15% of CFLs are installed in garages and exterior locations. AEG assumes CFLs are reasonable proxy for LEDs.

DEEMED SAVINGS *(ONLY APPLICABLE FOR PY19)*

Deemed Savings (based on default values for wattage)

Measure Name	First Baseline Peak Demand Savings	First Baseline Annual Energy Savings	Lifetime Energy Savings
Residential Lighting Occupancy Sensor	0.004 kW	23.57 kWh	100.32 kWh

DEEMED SAVINGS *(APPLICABLE FOR PY20 AND LATER)*

Deemed Savings (based on default values for wattage)

Measure Name	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Residential Lighting Occupancy Sensor	0.002 kW	10.96 kWh	87.68 kWh

SEMI-PRESCRIPTIVE SAVINGS

Semi-Prescriptive Savings Calculator (based on user input wattage for energy efficient lamps)

Does the efficacy of the lamps controlled by the occupancy sensor meet or exceed 45 lumen/W? (For example, are they LEDs, CFLs, T5 or T8 lamps?)

Yes

Enter Total Wattage Controlled by Occupancy Sensor in Watts

40

Are the lamps installed in an air-conditioned space?

No

Measure Name	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Residential Lighting Occupancy Sensor	0.002 kW	9.77 kWh	78.16 kWh

RESOURCES

- AEG's 2018 Analysis Files titled "AEG HPUC Update of Residential Measures - Analysis file" and "HI - Res Lighting IEF Analysis."
- AEG's 2018 Hawaiʻi-specific building energy simulations of single family home prototypes in BEopt™ with EnergyPlus v8.8 as the simulation engine. Used Hawaiʻi weather data and developed prototypes based on a mixture of assumptions from the 2014 State of Hawaiʻi Baseline Report, 2014 Building America House Simulation Protocols, and building characteristics from a survey of suburban homes in Google Maps. Homes were simulated with a variety of HVAC system types and four different lighting consumption levels. House leakage was also varied to vary the efficiency of the home. AEG used the analysis to determine coincidence factors (CFs), as well as interactive effects factors (IEFs) that account for cooling demand and energy savings due to reducing waste heat with efficient lighting.
- Arkansas Technical Reference Manual, Version 7.0, Arkansas Public Service Commission, 2017.
- Baseline Energy Appliance, Equipment and Building Characteristics Study Report, Prepared for the State of Hawaii Public Utilities Commission, November 6, 2013, With errata February 26, 2014, Evergreen Economics.

- Connecticut's 2018 Program Savings Document, 13th Edition, filed December 15, 2017.
- Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 6.0, Volume 3: Residential Measures, FINAL, Feb. 8, 2017.
- Lighting Research Center, Publications, 061Incandescent, page 114, Halogen A, https://www.lrc.rpi.edu/resources/publications/lpbh/061Incandescent.pdf, accessed 11/7/2018.
- Massachusetts Technical Reference Manual, 2016-2018 Program Years, October 2015.
- Mid-Atlantic Technical Reference Manual, Version 8, Final, May 2018.
- National Renewable Energy Laboratory. Building Energy Optimization (BEopt) Software. Version 2.8.0.0. U.S. Department of Energy. January 2018. Available at: https://beopt.nrel.gov/.
- New Mexico Technical Resource Manual for the Calculation of Energy Efficiency Savings, 2016.
- Public Utility Commission of Texas, Texas Technical Reference Manual, Version 5.0, Volume 2:
- Regional Technical Forum. Residential Lighting - Unit Energy Savings Workbook, Version 6.1
- Residential Lighting End-Use Consumption Study: Estimation Framework and Initial Estimates, Prepared by DNV KEMA Energy and Sustainability, Pacific Northwest National Laboratory, Prepared for Solid-State Lighting Program, Building Technologies Program, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, December 2012, Table 4.4.
- Rhode Island Technical Reference Manual – 2018 Program Year, National Grid, 2017.
- State of Minnesota, Technical Reference Manual for Energy Conservation Improvement Programs, Version 2.2, May 2, 2018.
- State of Pennsylvania Technical Reference Manual, Pennsylvania Public Utilities Commission, June 2016.
- Tennessee Valley Authority Technical Reference Manual, Version 6.0, Oct. 1, 2017.
- Wilson, E. et. al., 2014 Building America House Simulation Protocols. National Renewable Energy Laboratory. March 2014. Available at: https://www.nrel.gov/docs/fy14osti/60988.pdf.

RESIDENTIAL: Linear LED

Return to TOC

UPDATE STATUS

Introduced in Fall 2019 for PY19 TRM.

MEASURE DETAILS

Description

Replacement of linear 4-ft fluorescent lamps with linear LED lamps. Residential linear LEDs will be implemented through Hawai'i Energy's direct install program. Linear LEDs will also be a part of the upstream lighting program.

Program Criteria

Efficient equipment must be Design Light Consortium (DLC) listed.

Unit of Measure

One lamp.

Baseline Equipment

General service linear: One-lamp 4' F32T8 fixture with electronic ballast.
Shop light: Two-lamp 4' F32T8 fixture with electronic ballast.

High Efficiency Equipment

General service linear: One (1) 4' T8 LED with Type A, Type B, or Type C installation.*

- Type A installation: Ballast left in place; reduced savings due to losses and lifetime reduced to remaining useful life of existing ballast.
- Type B installation: Bypassing fluorescent ballast and utilizing internal LED driver.
- Type C installation: Removing fluorescent ballast and utilizing an external driver.

*Note: As of January 2020, Hawai'i Energy plans for installations through the direct install program to be Type A. In addition, the installation type for LEDs purchased through the upstream program will be unknown, with a default of Type A. However, deemed savings for all options are included to keep the measure entry as generally applicable as possible in case the delivery approach changes in the future.

Shop light: One (1) 4' Integrated LED light with equivalent lumen output to a two-lamp 4' F32T8 fixture.

ALGORITHMS

Peak Demand Reduction, kW

$$\Delta kW = \frac{(W_{base} - W_{LED})}{1{,}000\ W/kW} * ISR * CF * \left(1 + WH_{C,D}\right) * PF \qquad (1)$$

First Baseline Annual Energy Savings, kWh/yr

$$\Delta kWh = \frac{(W_{base} - W_{LED})}{1{,}000\, W/kW} * ISR * HOU * \left(1 + WH_{C,E}\right) * PF \quad (2)$$

Lifetime Energy Savings, kWh

$$\Delta kWh = \Delta kWh * EUL \quad (3)$$

Waste Heat Factors due to Interaction with Space Cooling System

$$WH_{C,D} = \%_{Cool} * \left(IE_{C,D} - 1\right) \quad (4)$$

$$WH_{C,E} = \%_{Cool} * \left(IE_{C,E} - 1\right) \quad (5)$$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Source/Notes**
W_{base}	Baseline Wattage	See Table 1	W	Appendix B SFW, per lamp averages across fixture types.
W_{LED}	LED Wattage	See Table 1	W	Typical values from retailers.
ISR	Lifetime in-service rate	0.97	-	AEG's Fall 2018 Benchmarking for Residential LED measure.[1]
$\%_{Cool}$	General service linear: Share of lamps installed in spaces with electric cooling	0.41	-	Share of homes with electric cooling, Evergreen Economics Baseline Study, 2014.
	Shop light: Share of lamps installed in spaces with electric cooling	0	-	Assumes shop lights are installed in unconditioned shops and garages.
$IE_{C,D}$	Interactive effects factor to account for cooling demand savings due to reducing waste heat with efficient lighting	1.30	-	AEG's Hawaiʻi-specific simulation modeling.
$IE_{C,E}$	Interactive effects factor to account for cooling energy savings due to reducing waste heat with efficient lighting	1.35	-	AEG's Hawaiʻi-specific simulation modeling.
CF	Peak demand coincidence factor	See Table 1	-	AEG's Hawaiʻi-specific simulation modeling.[2]
HOU	Annual hours of use	See Table 1	hrs	DOE 2012 Residential Lighting End-Use Consumption Study.
PF[3]	Persistence factor	1	-	
EUL_{LED}	Effective useful life of LED	See Table 1	yrs	Based on average lamp life, limited to 25 yrs.

[1] AEG's ISR benchmarking was done specifically for the Residential LED measure, which applies to omnidirectional LED bulbs. Until further research can be carried out for linear LEDs, assume the ISRs for both measures would be similar.

[2] CF for general service linear assumes non-military home (CF=0.16). CF for shop light measure was reduced by 25% relative to general lighting value as a conservative assumption (CF=0.12).

[3] Use value of PF=1 until more data is available on PF of LEDs.

Table 1: Baseline and Energy Efficient Wattages

Measure Name	W_{base}	W_{LED}	*HOU*	*CF*	*EUL*
Linear LED, Type A	31	18	803	0.16	10
Linear LED, Type B or Type C	31	16	803	0.16	25
Shop Light	62	32	402	0.12	25

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Linear LED, Type A *(Use if type is unknown)*	0.002 kW	11.58 kWh	115.80 kWh
Linear LED, Type B or C	0.003 kW	13.36 kWh	334.00 kWh
Shop Light	0.003 kW	11.70 kWh	292.50 kWh

RESOURCES

- AEG's 2019 Analysis File titled "PY19 TRM - Residential Additions - Draft_20191113 AEG reviewed."
- AEG's 2018 Analysis Files titled "AEG HPUC Update of Residential Measures - Analysis file" and "HI - Res Lighting IEF Analysis."
- AEG's 2018 Analysis File titled "AEG HPUC Update of Com-Lighting Measures - Analysis file."
- AEG's 2018 Hawai‘i-specific building energy simulations of single family home prototypes in BEopt™ with EnergyPlus v8.8 as the simulation engine. Used Hawai‘i weather data and developed prototypes based on a mixture of assumptions from the 2014 State of Hawai‘i Baseline Report, 2014 Building America House Simulation Protocols, and building characteristics from a survey of suburban homes in Google Maps. Homes were simulated with a variety of HVAC system types and four different lighting consumption levels. House leakage was also varied to vary the efficiency of the home. AEG used the analysis to determine coincidence factors (CFs), as well as interactive effects factors (IEFs) that account for cooling demand and energy savings due to reducing waste heat with efficient lighting.

- Baseline Energy Appliance, Equipment and Building Characteristics Study Report, Prepared for the State of Hawaii Public Utilities Commission, November 6, 2013, With errata February 26, 2014, Evergreen Economics.
- Residential Lighting End-Use Consumption Study: Estimation Framework and Initial Estimates, Prepared by DNV KEMA Energy and Sustainability, Pacific Northwest National Laboratory, Prepared for Solid-State Lighting Program, Building Technologies Program, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, December 2012, https://www1.eere.energy.gov/buildings/publications/pdfs/ssl/2012_residential-lighting-study.pdf, Table 4.4.
- 2016 Statewide Customized Offering Procedures Manual for Business. Appendix B: Table of Standard Fixture Wattages. July 2014, Version 6.0.

RESIDENTIAL: Security Light

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UPDATE STATUS

Introduced in Fall 2019 for PY19 TRM.

MEASURE DETAILS

Description
Replacement of halogen-based exterior security/porch light fixture with LED-based fixture. Both security and porch lights will be a part of Hawai'i Energy's upstream lighting program. The security lights will also be implemented through the direct install program.

Program Criteria
Efficient equipment must be ENERGY STAR certified.

Unit of Measure
One fixture.

Baseline Equipment
For PY19:

Security Lights: (2) PAR38 Halogen 60W lamps (Year 1 baseline, expiring in Jun 2020) and (2) PAR38 EISA-compliant lamps rated at 45 lumens/Watt (Year 2 through Year 6 baseline).

Porch Lights: (1) Omni-directional A19 Halogen 60W bulb (Year 1 baseline, expiring in Jun 2020) and (1) Omni-directional A19 EISA-compliant bulb rated at 45 lumens/Watt (Year 2 through Year 6 baseline).

For PY20 and Later (pending final ruling on EISA 2020 backstop):

Security Lights: (2) PAR38 EISA-compliant lamps rated at 45 lumens/Watt (Year 1 through Year 6 baseline).

Porch Lights: (1) Omni-directional A19 EISA-compliant bulb rated at 45 lumens/Watt (Year 2 through Year 6 baseline).

High Efficiency Equipment
Security Lights: (2) PAR38 ENERGY STAR LED
Porch Lights: (1) Omni-directional A19 ENERGY STAR LED

ALGORITHMS

First Baseline Peak Demand Reduction, kW

$$(W_{base1} - W_{LED})$$

$$\Delta kW_1 = \frac{(W_{base1} - W_{LED})}{1{,}000\ W/kW} * ISR * CF * PF \quad (1)$$

Second Baseline Peak Demand Reduction, kW

$$\Delta kW_2 = \frac{(W_{base2} - W_{LED})}{1{,}000\ W/kW} * ISR * CF * PF \quad (2)$$

First Baseline Annual Energy Savings, kWh/yr

$$\Delta kWh_1 = \frac{(W_{base1} - W_{LED})}{1{,}000\ W/kW} * ISR * HOU * PF \quad (3)$$

Second Baseline Annual Energy Savings, kWh/yr

$$\Delta kWh_2 = \frac{(W_{base2} - W_{LED})}{1{,}000\ W/kW} * ISR * HOU * PF \quad (4)$$

Lifetime Energy Savings, kWh

Dual baseline (PY19):

$$\Delta kWh_{dual} = \Delta kWh_1 * EUL_1 + \Delta kWh_2 * EUL_2 \quad (5)$$

Single baseline (PY20 and later):

$$\Delta kWh_{single} = \Delta kWh_2 * EUL_{LED} \quad (6)$$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Source/Notes**
W_{base}	Baseline Wattage	See Table 1	W	Typical values from retailers.
W_{LED}	LED Wattage	See Table 1	W	Typical values from retailers.
ISR	Lifetime in-service rate	0.97	-	AEG's Fall 2018 Benchmarking for Residential LED measure.[1]
CF	Peak demand coincidence factor	0.62	-	AEG's analysis of average annual sunset time in Honolulu (6:32 PM) and overlap with the 5-9 PM peak demand period.
HOU	Annual hours of use	2475	hrs	2020 Illinois Statewide TRM.
PF [2]	Persistence factor	1	-	
EUL_1	Effective useful life of first baseline lamp	See Table 1	yrs	Based on rated lamp life and HOU.
EUL_2	EUL_{LED} - EUL_1	See Table 1	yrs	Length of second baseline period.

EUL_{LED}	Effective useful life of LED	See Table 1	yrs	Based on rated lamp life and HOU.

[1] AEG's ISR benchmarking was done specifically for the Residential LED measure, which applies to omnidirectional LED bulbs. Until further research can be carried out for PAR38 LEDs, assume the ISRs for both measures would be similar.

[2] Use value of PF=1 until more data is available on PF of LEDs.

Table 1: Baseline and Energy Efficient Wattages

Measure Name	W_{base1}	W_{base2}	W_{LED}	EUL_1	EUL_2	EUL_{LED}
Security Light	120	48	26	1	5	6
Porch Light	47	24	10	1	5	6

SAVINGS

For PY19

Measure Name	**Peak Demand Savings**		**Annual Energy Savings**		**Lifetime Energy Savings**
	1st BL	**2nd BL**	**1st BL**	**2nd BL**	
Security Light	0.057 kW	0.013 kW	225.67 kWh	52.82 kWh	489.77 kWh
Porch Light	0.022 kW	0.008 kW	88.83 kWh	33.61 kWh	256.88 kWh

For PY20 and Later [1]

Measure Name	**Peak Demand Savings**	**Annual Energy Savings**	**Lifetime Energy Savings**
Security Light	0.013 kW	52.82 kWh	316.92 kWh
Porch Light	0.008 kW	33.61 kWh	201.66 kWh

[1] Pending final ruling on EISA 2020 backstop.

RESOURCES

- AEG's 2019 Analysis File titled "PY19 TRM - Residential Additions - Draft_20191113 AEG reviewed."
- AEG's 2018 Analysis Files titled "AEG HPUC Update of Residential Measures - Analysis file."
- 2020 Illinois Statewide Technical Reference Manual, v8.0, Vol. 3: Residential Measures, Oct. 17, 2019, pg. 241.

RESIDENTIAL: Holiday String Light

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UPDATE STATUS

Introduced in Fall 2019 for PY19 TRM.

MEASURE DETAILS

Description

The replacement of incandescent decorative holiday string lights with LED string lights .

Program Criteria

Efficient equipment must be Design Light Consortium (DLC) listed. Mini bulb count per string should be documented.

Unit of Measure

One bulb.

Baseline Equipment

String lighting with multiple incandescent mini bulbs.

High Efficiency Equipment

String lighting with LED mini bulbs.

ALGORITHMS

Peak Demand Reduction, kW

$$\Delta kW = \frac{(W_{base} - W_{LED})}{1{,}000\ W/kW} * ISR * CF * PF \qquad (1)$$

First Baseline Annual Energy Savings, kWh/yr

$$\Delta kWh = \frac{(W_{base} - W_{LED})}{1{,}000\ W/kW} * ISR * HOU * PF \qquad (2)$$

Lifetime Energy Savings, kWh

$$\Delta kWh = \Delta kWh * EUL \qquad (3)$$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Source/Notes
W_{base}	Baseline Wattage	0.39	W	Benchmark of incandescent string lights at retail.
W_{LED}	LED Wattage	0.07	W	Benchmark of LED string lights at retail.

ISR	Lifetime in-service rate	0.97	-	AEG's Fall 2018 Benchmarking for Residential LED measure.[1]
CF	Peak demand coincidence factor	0.78	-	Average percentage of hours after sunset within 5pm to 9pm peak period. (Assumes average sunset time of 5:54 pm during holiday season.)
HOU	Annual hours of use	210	hrs	Assume average of 6 hours per day for 5 weeks.
PF [2]	Persistence factor	1	-	
EUL_{LED}	Effective useful life of LED	5	yrs	Reasonable estimate of EUL based on typical use and storage.

[1] AEG's ISR benchmarking was done specifically for the Residential LED measure, which applies to omnidirectional LED bulbs. Until further research can be carried out for string lights, assume the ISRs for both measures would be similar.

[2] Use value of PF=1 until more data is available on PF of LEDs.

SAVINGS

Deemed Savings (per mini bulb)

Measure Name	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Holiday String Light, per bulb	0.000242 kW/bulb	0.065184 kWh/bulb	0.325920 kWh/bulb

Semi-Prescriptive Savings Calculator (based on count of mini bulbs per string)

Number of bulbs/string

100 *Example only. Hawai'i Energy to fill in based on bulbs in incented strings.*

Measure Name	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Holiday String Light, per string	0.024	6.52	32.59

RESOURCES

- AEG's 2019 Analysis File titled "PY19 TRM - Residential Additions - Draft_20191113 AEG reviewed."
- AEG's 2018 Analysis Files titled "AEG HPUC Update of Residential Measures - Analysis file."

RESIDENTIAL: Advanced Power Strips

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MEASURE DETAILS

Description

Load sensing advanced power strips. This measure involves the purchase and installation of a new Tier 1 or Tier 2 load sensing advanced power strip in place of a power strip with no automated power shutoff function.

Program Criteria

Tier 1 or Tier 2 qualified power strip with automated power shutoff capability

Unit of Measure

One power strip

Baseline Equipment

Code-compliant or standard efficiency power strip.

High Efficiency Equipment

Tier 1: The high efficiency equipment is an advanced power strip. If the exact number of plugs in the strip is unknown, savings is based on a 6-plug strip, as shown below. If the exact number of plugs in the strip is known, such as part of the Hawaiʻi Energy online kit promotions, then the respective savings value may be used based on the actual size of the advanced power strip.

Tier 2: Savings is based on an IR-OS Tier 2 APS product.

ALGORITHMS

$$\text{peak kW savings/smart strip} = [(KWH_{.plug} * NUM_{.plug}) / HRS] * CF * PF$$

$$\text{annual kWh savings/smart strip} = KWH_{.plug} * NUM_{.plug} * PF$$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
$KWH_{.plug}$	Average deemed kWh per receptacle ("outlet") on the strip	See Table 1	kWh	
$NUM_{.plug}$	Number of plug outlets per power strip	6	-	Average of 5 and 7-plug strips
PF	Persistence factor	80%	-	Hawaiʻi Energy estimate
HOURS	Annual hours of equipment operation	8760	hrs	Assumes no manual shutoff of equipment
CF	Coincidence factor	100%	-	% of maximum hourly Watt savings on average that were realized from 5-9 pm for residential A/V equipment (see Valmiki and Corradini).

Measure Life	Expected duration of energy savings	5	yrs	

Source: Hawaiʻi Energy Efficiency Program Technical Reference Manual, PY 2015. Measure Savings Calculations, pp. 55 for Measure Life, PF, #plugs

Table 1. Deemed Savings Values for Advanced Power Strips

	Tier 1-5 plug[1]	Tier 1-7 plug[1]	Tier 2- 8 plug[2]	Average Tier 1
kWh/unit savings	56.50	102.80	149.00	79.65
Number of plugs/unit	5	7	6	6
Calculated kWh/plug savings	11.30	14.69	24.83	12.99

Note: 1. Refer to "Akamai Power Strips" unit savings calculations noted in the PY2015 Hawaiʻi TRM, citing "NYSERDA Measure Characterization for Advanced Power Strips". The original source for these values cannot be identified, although NYSERDA's 2011 "Advanced Power Strips Research Report" is available on their website https://www.nyserda.ny.gov/Residents-and-Homeowners/Your-Home/Power-Management.
2. Values are derived from Valmiki and Corradini, 2015.

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings
Tier 1	0.007 kW	62.37 kWh
Tier 2	0.014 kW	119.20 kWh

SOURCES

Evergreen Economics. Baseline Energy Appliance,Equipment and Building Characteristics Study Report. Prepared for the State of Hawaii Public Utilities Commission. November 6, 2013.

Valmiki, M. and A. Corradini. Tier 2 Advanced Power Strips in Residential and Commercial Applications. San Diego Gas & Electric Emerging Technologies Program, Technology Assessment Report. April 2015. The test APS used in the study is shown with 6 controlled receptacles.

RESIDENTIAL: Switch Plug

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UPDATE STATUS

Updated in Spring 2019 for PY19 TRM.

MEASURE DETAILS

Description

A power switch that acts as the interface between the wall outlet and the appliance. It prevents phantom energy drain by disconnecting the attached appliance without having to remove the power cord.

Program Criteria

Unit of Measure

One switch.

Baseline Equipment

No switch installed.

High Efficiency Equipment

Switch plug installed.

ALGORITHMS

peak kW savings = $(W_{.stby} * CF) / 1000$

annual kWh savings = $kWh_{.stby}$

lifetime kWh savings = $kWh_{.stby} * EUL$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
$W_{.stby}$	Standby power draw of attached load	3.073	W	Determined based on probability of attached equipment type. [1]
$kWh_{.stby}$	Annual standby energy consumption of attached load	26.85	kWh	Determined based on probability of attached equipment type. [1]
Constant	Conversion constant	1,000	W/kW	

CF	Coincidence factor	0.82	-	AEG's analysis of DOE's OpenEI load shapes using Hawaiʻi-specific prototypes, weather data, and peak demand period.
EUL	Effective useful life of measure	5	yrs	DEER 2020 for "Res-Plug-AdvPwrStrip" measure.

Note: 1. Based on data from Lawrence Berkeley National Laboratory: Low-Power Mode Energy Consumption in California Homes, 2008. See accompanying Power Switch Calculation (R_PlugProcess_Power Switch_CALC).

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Switch Plug	0.003 kW	26.85 kWh	134.25 kWh

RESOURCES

- AEG's 2019 Analysis File titled "New Residential Measures Summary - AEG Analysis file."
- AEG's 2018 Analysis of U.S. Department of Energy's OpenEI Commercial Hourly Load Profiles using Hawaiʻi-specific data. OpenEI data files available here: https://openei.org/doe-opendata/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states. AEG used the residential end-use load profile data for "Miscellaneous" interior equipment for this Switch Plug measure. (See file named "AEG HPUC EFLH and CF Analysis - Non-Holiday Weekdays" for results.)
- Lawrence Berkeley National Laboratory: Low-Power Mode Energy Consumption in California Homes, 2008.

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Category	Product	Standby Devices per Household	Power (W)	Energy (kWh/yr)	Probability		Averages:	3.073 W	26.85 kWh/yr
Appliance	Cooktop,electric	0.02	1.0	9	0.07%				
Appliance	Dishwasher	0.15	1.5	13	0.53%				
Audio	Amplifier	0.12	6.8	59	0.42%				
Audio	AudioMinisystem	0.50	8.7	76	1.75%				
Audio	CDPlayer	0.75	3.2	28	2.63%				
Audio	CDPlayer,portable	0.25	1.4	12	0.88%				
Audio	Charger,digitalmusicplayer	0.34	0.3	2	1.19%				
Audio	Equalizer(audio)	0.01	1.6	14	0.04%				
Audio	Hometheatersystem	0.05	4.0	35	0.18%				
Audio	Karaokemachine	0.03	1.1	10	0.11%				
Audio	Musicalkeyboard	0.20	2.9	25	0.70%				
Audio	Radio,table	0.23	1.3	11	0.81%				
Audio	Receiver(audio)	0.35	10.8	94	1.23%				
Audio	Speakers,powered	0.05	3.8	33	0.18%				
Audio	Speakers,wireless(basestation)	0.03	3.8	33	0.11%				
Audio	Speakers,wireless(speakers)	0.03	3.8	33	0.11%				
Audio	Stereo,portable	0.48	1.3	12	1.68%				
Audio	Subwoofer	0.22	8.9	78	0.77%				
Audio	Tuner	0.14	1.0	8	0.49%				
Audio	Turntable(audio)	0.14	1.0	9	0.49%				
Computer	Computer,desktop	0.95	4.5	39	3.33%				
Computer	Computer,integrated(all)	0.02	5.2	45	0.07%				
Computer	Computer,notebook	0.41	4.0	35	1.44%				
Computer	Dock,notebook	0.02	1.0	9	0.07%				
Display	Computerdisplay,LCD	0.53	0.9	8	1.86%				
Display	Projector,video	0.01	1.6	14	0.04%				
Display	Television,LCD	2.07	1.5	13	7.26%				
Display	Television,plasma	0.02	1.9	16	0.07%				
Display	Television,rearprojection	0.09	2.4	21	0.32%				
ElectricHousewares	Clock,alarm	0.50	1.0	9	1.75%				
ElectricHousewares	Clock,radio	1.13	2.2	19	3.96%				
ElectricHousewares	Coffeemaker,residential	0.21	1.1	9	0.74%				
ElectricHousewares	Oven,microwave	1.01	3.0	26	3.54%				
ElectricHousewares	Ricecooker	0.06	0.5	4	0.21%				
ElectricHousewares	Toaster	0.02	0.9	8	0.07%				
ElectricHousewares	Toasteroven	0.12	0.9	8	0.42%				
ElectricHousewares	Vacuum,central	0.07	3.0	26	0.25%				
ElectricHousewares	Vacuum,rechargeable	0.16	2.1	19	0.56%				
Hobby/leisure	Exerciseequipment	0.05	1.8	15	0.18%				
Hobby/leisure	Ride-ontoycar	0.02	1.9	17	0.07%				
Hobby/leisure	Spa/hottub	0.07	2.4	21	0.25%				
HVAC	Aircleaner,portable	0.06	0.2	2	0.21%				

HVAC	Airconditioner,room/wall	0.03	1.9	17	0.11%
HVAC	Ceilingfan	0.20	0.7	6	0.70%
HVAC	Fan,portable	0.03	0.4	3	0.11%
Imaging	Copier	0.07	4.8	42	0.25%
Imaging	Fax,inkjet	0.13	6.0	52	0.46%
Imaging	Fax,laser	0.02	4.0	35	0.07%
Imaging	Fax,thermal	0.01	5.0	43	0.04%
Imaging	Multi-functiondevice,inkjet	0.35	7.9	69	1.23%
Imaging	Multi-functiondevice,laser	0.06	5.8	51	0.21%
Imaging	Printer,inkjet	0.43	5.4	47	1.51%
Imaging	Printer,laser	0.07	5.0	44	0.25%
Imaging	Printer,photo	0.18	1.4	12	0.63%
Imaging	Scanner,flatbed	0.15	3.5	31	0.53%
Infrastructure	Garagedooropener	0.44	4.9	43	1.54%
Lighting	Motionsensor,interior	0.05	0.8	7	0.18%
Lighting	Nightlight,interior	1.20	0.2	2	4.21%
Lighting	Timer,interior	0.13	0.3	2	0.46%
Networking	Hub,ethernet	0.08	3.8	33	0.28%
Networking	Hub,USB	0.25	1.3	11	0.88%
Networking	Modem,cable	0.25	8.3	73	0.88%
Networking	Modem,DSL	0.30	6.0	52	1.05%
Networking	Modem,POTS	0.17	5.6	49	0.60%
Networking	Modem,satellite	0.02	9.5	83	0.07%
Networking	Router,ethernet	0.22	5.9	52	0.77%
Networking	Wirelessaccesspoint	0.23	4.7	41	0.81%
OutdoorAppliances	Charger,hedgetrimmer	0.04	1.0	9	0.14%
OutdoorAppliances	Charger,weedtrimmer	0.08	1.9	17	0.28%
OutdoorAppliances	Lawnmower	0.06	1.8	16	0.21%
OutdoorAppliances	Timer,irrigation	0.24	2.7	24	0.84%
Peripherals	Dock,PDA	0.13	1.4	12	0.46%
Peripherals	Externaldrive	0.06	1.0	9	0.21%
Peripherals	Speakers,computer	0.63	2.6	23	2.21%
PersonalCare	Massager	0.05	1.7	15	0.18%
PersonalCare	Shaver,men's	0.25	0.1	1	0.88%
PersonalCare	Shaver,women's	0.15	0.1	1	0.53%
PersonalCare	Toothbrush	0.51	1.6	14	1.79%
Power	UninterruptiblePowerSupply(UPS)	0.03	4.5	39	0.11%
Security	Securitysystem	0.20	4.0	35	0.70%
Set-top	Set-topbox,analogcable	0.10	8.7	76	0.35%
Set-top	Set-topbox,digitalcable	0.30	19.2	168	1.05%
Set-top	Set-topbox,digitalcablewithPVR	0.05	34.3	301	0.18%
Set-top	Set-topbox,gameconsolewithinternetconnectivity	0.04	7.4	64	0.14%
Set-top	Set-topbox,internet	0.06	10.8	94	0.21%
Set-top	Set-topbox,satellite	0.48	13.7	120	1.68%
Set-top	Set-topbox,satellitewithPVR	0.04	20.8	182	0.14%
Telephony	CallerIDunit	0.05	1.3	11	0.18%

Telephony	Charger,cordlessphonehandset	0.28	1.6	14	0.98%
Telephony	Charger,mobilephone	1.68	0.4	4	5.89%
Telephony	Phone,conference	0.03	2.0	18	0.11%
Telephony	Phone,cordless	1.70	2.2	19	5.96%
Transportation	Golfcart	0.02	11.0	96	0.07%
Transportation	Wheelchair	0.02	9.5	83	0.07%
Utility	Charger,battery	0.26	0.2	2	0.91%
Utility	Powertool,cordless	1.72	0.6	5	6.03%
Video	Charger,stillcamera	0.67	0.1	1	2.35%
Video	Charger,videocamera	0.35	0.1	1	1.23%
Video	DVDplayer	1.00	2.2	19	3.51%
Video	Gameconsole	0.29	3.5	31	1.02%
Video	Video,PVR(nomultifunctionality)	0.19	22.8	200	0.67%

Source: Lawrence Berkeley National Laboratory: Low-Power Mode Energy Consumption in California Homes, 2008.

RESIDENTIAL: VFD Pool Pump

Return to TOC

UPDATE STATUS

Updated in Fall 2018 for PY19 TRM.

MEASURE DETAILS

Description

This measure is the replacement of a single-speed or dual-speed pool filter pump with a variable-speed pump of equivalent horsepower. This measure is only applicable to self-priming pool filter pumps which are typically used with permanent, in-ground pools in single-family homes (there is a separate measure for multi-family and commercial settings). Non-self-priming pool filter pumps, which are typically used with rigid, above-ground pools, are not applicable.

Program Criteria

New construction homes do not qualify. The installed variable-speed self-priming pool filter pump's rated Weighted Energy Factor (WEF) should meet or exceed the ENERGY STAR v2.0 specifications. Any high-speed override capability should be for a temporary period not to exceed one 24-hour cycle without reverting to default settings.

Unit of Measure

One pump.

Baseline Equipment

The baseline efficiency equipment is a single-speed or dual-speed self-priming pool filter pump.

High Efficiency Equipment

The high efficiency equipment is a variable-speed self-priming pool filter pump.

ALGORITHMS

Annual Energy Savings, kWh/yr

$$\Delta kWh = \left(kWh_{Daily,Base} - kWh_{Daily,Eff}\right) * Days \quad (1)$$

Peak Demand Reduction, kW

$$\Delta kW = \left[\left(\frac{kWh_{Daily,Base}}{Hours_{Daily,Base}}\right) * CF_{Base}\right] - \left[\left(\frac{kWh_{Daily,Eff}}{Hours_{Daily,Eff}}\right) * CF_{Eff}\right] \quad (2)$$

Lifetime Energy Savings, kWh

$$\Delta kWh_{life} = \Delta kWh * EUL \quad (3)$$

life

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Sources/Notes**
ΔkWh	Annual energy savings	Calculated	kWh/yr	
ΔkW	Peak demand reduction	Calculated	kW	
$kWh_{Daily,Base}$	Daily energy consumption of baseline pump (depends on pump horsepower) Single-Speed Pumps > 0 to ≤ 1 hp > 1 to ≤ 2 hp > 2 to ≤ 3 hp > 3 to ≤ 4 hp Dual-Speed Pumps > 0 to ≤ 1 hp > 1 to ≤ 2 hp > 2 to ≤ 3 hp > 3 to ≤ 4 hp	 6.4 11.5 15.0 16.0 4.1 7.1 8.2 9.1	 kWh/day kWh/day kWh/day kWh/day kWh/day kWh/day kWh/day kWh/day	AEG derived the values from the Regional Technical Forum's (RTF) original analysis contained in the unit energy savings measure workbook for Efficient Pool Pumps.
$kWh_{Daily,Eff}$	Daily energy consumption of variable-speed pump (depends on pump horsepower) Variable-Speed Pumps > 0 to ≤ 1 hp > 1 to ≤ 2 hp > 2 to ≤ 3 hp > 3 to ≤ 4 hp	 1.7 2.9 4.1 4.4	 kWh/day kWh/day kWh/day kWh/day	AEG derived the values from the Regional Technical Forum's (RTF) original analysis contained in the unit energy savings measure workbook for Efficient Pool Pumps.
Days	Number of days the pump operates in a year	365	Days/yr	No change from PY18 TRM.
$Hours_{Daily,Base}$	Daily runtime of baseline pump (depends on pump horsepower) Single-Speed Pumps > 0 to ≤ 1 hp > 1 to ≤ 2 hp > 2 to ≤ 3 hp > 3 to ≤ 4 hp Dual-Speed Pumps > 0 to ≤ 1 hp > 1 to ≤ 2 hp > 2 to ≤ 3 hp > 3 to ≤ 4 hp	 5.6 6.8 6.1 5.8 11.0 13.3 12.1 11.9	 Hrs/day Hrs/day Hrs/day Hrs/day Hrs/day Hrs/day Hrs/day Hrs/day	AEG derived the values from the Regional Technical Forum's (RTF) original analysis contained in the unit energy savings measure workbook for Efficient Pool Pumps.
$Hours_{Daily,Eff}$	Daily runtime of variable-speed pump (depends on pump horsepower) Variable-Speed Pumps > 0 to ≤ 1 hp > 1 to ≤ 2 hp > 2 to ≤ 3 hp	 13.3 16.3 17.1	 Hrs/day Hrs/day Hrs/day	AEG derived the values from the Regional Technical Forum's (RTF) original analysis contained in the unit energy savings measure workbook for Efficient Pool Pumps.

	> 3 to ≤ 4 hp	17.9	Hrs/day	
CF_{Base}	Coincidence factor of baseline pump (depends on pump horsepower) Single-Speed Pumps > 0 to ≤ 1 hp > 1 to ≤ 2 hp > 2 to ≤ 3 hp > 3 to ≤ 4 hp Dual-Speed Pumps > 0 to ≤ 1 hp > 1 to ≤ 2 hp > 2 to ≤ 3 hp > 3 to ≤ 4 hp	 0.23 0.28 0.26 0.24 0.46 0.56 0.50 0.50		AEG's estimate, obtained by dividing the number of daily operation hours of pump by 24 hours.
CF_{Eff}	Coincidence factor of variable-speed pump (depends on pump horsepower) Variable-Speed Pumps > 0 to ≤ 1 hp > 1 to ≤ 2 hp > 2 to ≤ 3 hp > 3 to ≤ 4 hp	 0.56 0.68 0.71 0.75		AEG's estimate, obtained by dividing the number of daily operation hours of pump by 24 hours.
EUL	Effective useful life of measure	10	yrs	No change from PY18 TRM; EUL was verified during AEG's 2018 benchmarking.

SAVINGS

Measure Name Res. VFD Pool Pump	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Single-speed to variable speed: > 0 to ≤ 1 hp	0.192 kW	1,682.10 kWh	16,821.00 kWh
Single-speed to variable speed: > 1 to ≤ 2 hp	0.357 kW	3,124.18 kWh	31,241.80 kWh
Single-speed to variable speed: > 2 to ≤ 3 hp	0.456 kW	3,992.90 kWh	39,929.00 kWh
Single-speed to variable speed: > 3 to ≤ 4 hp	0.484 kW	4,240.06 kWh	42,400.60 kWh
Dual-speed to variable speed: > 0 to ≤ 1 hp	0.099 kW	867.21 kWh	8,672.10 kWh

Dual-speed to variable speed: > 1 to ≤ 2 hp	0.176 kW	1,539.54 kWh	15,395.40 kWh
Dual-speed to variable speed: > 2 to ≤ 3 hp	0.174 kW	1,522.09 kWh	15,220.90 kWh
Dual-speed to variable speed: > 3 to ≤ 4 hp	0.196 kW	1,714.60 kWh	17,146.00 kWh

RESOURCES

- AEG's 2018 Analysis File titled "AEG HPUC Update of Res Pool Pump VFD - Analysis File."
- DOE National Impact Analysis (NIA) for Dedicated Purpose Pool Pumps ("NIA_PoolPumps_2016-12-19_ForPublication_v2.xlsm"), available online at: https://www.regulations.gov/document?D=EERE-2015-BT-STD-0008-0107.
- ENERGY STAR Product Specifications for Pool Pumps, Version 2.0, available online at: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%202.0%20Pool%20Pumps%20Specification.pdf.
- Regional Technical Forum. Efficient Pool Pumps - Unit Energy Savings Workbook, Version 2.1. Northwest Power and Conservation Council. February 27, 2018. Spreadsheet. Available online at: https://rtf.nwcouncil.org/measure/efficient-pool-pumps.

RESIDENTIAL: Heat Pump Water Heater

Return to TOC

MEASURE DETAILS

Description

The installation of a heat pump water heater in place of a standard electric water heater.

Program Criteria

Rebate applications for water heaters are provided by the retailers at the time of purchase or a customer can visit our website and download the form. Rebate applications must include an original purchase receipt showing brand and model number.

Unit of Measure

One unit

Baseline Equipment

The base case is a standard electric resistance water heater (SERWH), COP 0.90.

High Efficiency Equipment

The high efficiency case is the installation of a heat pump water heater, COP 2.26.

ALGORITHMS

(see below)

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
ΔE	Annual energy reduction	Calculated	kWh	
ΔP	Peak power demand reduction	Calculated	kW	
P_base	Power demand of baseline equipment	0.7	kW	
SVG_e	Saving factor for energy reduction	55%	-	
SVG_d	Saving factor for demand reduction	90%	-	
HRS	Annual hours of operation	1551.25	hrs	4.25 hrs/day, 365 days/yr
CF	Coincidence factor	14.3%	-	8.6 min/hr for 4 hours
Measure Life	Expected duration of savings	15	yrs	

Energy per Day (BTU) = (Gallons per Day) x (lbs. per Gal.) x (Temp Rise) x (Energy to Raise Water Temp)

Hot Water needed per Person		13.3	gallons / day / person	HE
Average Occupants	x	3.77	persons	KEMA 2008
Household Hot Water Usage		50.1	gallons / day	
Mass of Water Conversion		8.34	lbs / gallon	
Finish Temperature of Water		130	deg. F Finish Temp	

Initial Temperature of Water	-	75	deg. F Initial Temp	
Temperature Rise		55	deg. F Temperature Rise	
Energy to Raise Water Temp		1.0	BTU / deg. F / lbs.	
Energy per Day (BTU) Needed in Tank		23,000	BTU / day	

Energy per Day (BTU) Needed in Tank		23,000	BTU / day	
BTU to kWh Energy Conversion	÷	3,412	BTU / kWh	
Energy per Day		6.74	kWh / day	
Days per Month	x	30.4	days / month	
Energy per Month		204.92	kWh / month	
Months per Year	x	12	months	
Energy Needed to Heat Water per Year		2,459.05	kWh / year	
Elec. Res. Water Heater Efficiency	÷	0.90	COP	
Base SERWH Energy Usage per Year		2,732.28	kWh / Year	KEMA 2008 - HECO
Energy Needed to Heat Water per Year		2,459.05	kWh / year	
Heat Pump Water Heater Efficiency	÷	2.26	COP	
Heat Pump Energy Usage per Year		1,088.08	kWh / Year	KEMA 2008 - HECO
Base SERWH Energy Usage per Year		2,732.28	kWh / Year	
Heat Pump Energy Usage per Year	-	1,088.08	kWh / Year	
Residential Heat Pump Energy Savings		1,644.20	kWh / Year	

Base SERWH Element Power Consumption		4.000	kW	
Coincidence Factor	x	0.143		8.6 minutes per hour
Base SERWH On Peak Demand		0.572	kW On Peak	KEMA 2008
Heat Pump Power Consumption		4.500	kW	
Coincidence Factor	x	0.080		4.8 minutes per hour
Heat Pump On Peak Demand		0.360	kW On Peak	
Base SERWH On Peak Demand		0.572	kW On Peak	
Heat Pump On Peak Demand	-	0.360	kW On Peak	
Residential Heat Pump Demand Savings		0.212	kW On Peak	

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings
Heat Pump WH	0.212 kW	1644.20 kWh

RESIDENTIAL: Solar Water Heater

Return to TOC

UPDATE STATUS

Updated in January 2019 for PY19 TRM.

MEASURE DETAILS

Description

Replacement of Electric Resistance Storage Water Heater with a Solar Water Heater designed for a 90% Solar Fraction. The new Solar Water Heating systems most often include an upgrade of the hot water storage tank sized at 80 or 120 gallons.

Program Criteria

Rebate applications for water heaters are provided by the retailers at the time of purchase or a customer can visit the Hawaiʻi Energy website and download the form. Rebate applications must include an original purchase receipt showing brand and model number.

Existing Homes: The rated storage volume of the baseline equipment (Electric Resistance Storage Water Heater) is limited to 55 gallons or less. For homes with a pre-existing Solar Water Heater, the tank size required to meet water heating demand with an Electric Resistance Storage Water Heater must be determined and limited to a storage volume of 55 gallons or less. Therefore, homes requiring water heating capacity greater than the equivalent of a 55 gallon electric resistance water heater do not qualify. (It is important to clarify that the 55 gallon or less requirement only applies to the baseline Electric Resistance Storage Water Heater, and not to the new Solar Water Heater tank; Solar Water Heater tanks would be 80-120 gallons to meet the equivalent water heating demand.)

New Construction: New construction single-family homes do not qualify. Per legislation, new homes in Hawaiʻi are required to have Solar Water Heaters as of 2010, with a few exceptions.

Unit of Measure

One system.

Baseline Equipment

Baseline equipment is an Electric Resistance Storage Water Heater that meets current Federal codes and standards, which were effective April 16, 2015.

High Efficiency Equipment

High efficiency equipment is a new Solar Water Heater with electric backup designed for a 90% Solar Fraction. The Solar Water Heating collectors must meet the Solar Rating and Certification Corporation (SRCC™) OG-100 standard. OG-300 certification for the solar water heating system is not required. Solar Water Heating systems use solar thermal energy to meet most of the water heating load and continue to utilize electricity to operate the circulation pump and provide heating through an electric resistance element when needed.

ALGORITHMS

Energy Factor of Baseline Equipment (Electric Storage Water Heater ≤ 55 gallons)

$$EF_{base} = 0.960 - (0.0003 * Rated\ Storage\ Volume\ in\ gallons) \quad (1)$$

Baseline Annual Energy Use, kWh/hr

$$kWh_{base} = \left(\frac{1}{EF_{base}}\right) * \frac{GPD_{Occ} * \#Occ * 365\ days * \rho * c_p * (T_{out} - T_{in})}{3412 \frac{Btu}{kWh}} \quad (2)$$

Efficient Case Annual Energy Use, kWh/hr

$$kWh_{EE} = (1 - SF)\left(\frac{1}{EF_{SWH}}\right) * \frac{GPD_{Occ} * \#Occ * 365\ days * \rho * c_p * (T_{out} - T_{in})}{3412 \frac{Btu}{kWh}} + (kW_{pump} * HOU_{pump}) \quad (3)$$

Annual Energy Savings, kWh/yr

$$\Delta kWh = (kWh_{base} - kWh_{EE}) * PF \quad (4)$$

Peak Demand Reduction, kW

$$\Delta kW = \frac{\Delta kWh}{EFLH} * CF \quad (5)$$

Lifetime Energy Savings, kWh

$$\Delta kWh_{life} = \Delta kWh * EUL_{EE} \quad (6)$$

DEFINITIONS & ASSUMPTIONS				
Variable	**Description**	**Value**	**Unit**	**Source/Notes**
EF_{base}	Energy factor of the baseline equipment[1]	See Eq'n 1 (default = 0.945)	-	Default EF assumes 50 gallon Electric Storage Water Heater
GPD_{Occ}	Daily hot water use per occupant	15	gal/day-person	AEG's Fall 2018 Benchmarking

#Occ	Average number of occupants per Home	Actual or Table 1 (default = 3.24)	persons	Evergreen Economics Baseline Study, 2014; default is occupancy for non-military single family homes
ρ	Density of water	8.3	lb_m/gal	-
c_p	Specific heat capacity of water	1	Btu/lbm°F	-
T_{out}	Outlet temperature of the water heater	130	°F	No change from PY18 TRM
T_{in}	Incoming water temperature from the water main	See Table 2 (default = 75)	°F	Hawaiʻi Energy[2]
SF	Solar fraction	User input (default = 0.9)	-	Program requirement is 0.9
EF_{SWH}	Energy factor of solar water heater when using back-up electric resistance heating	0.9	-	Typical value for electric resistance water heating; equal to efficiency assumption of 0.9 from PY18 TRM
kW_{pump}	Circulation pump demand	0.082	kW	No change from PY18 TRM; Source: KEMA 2005-2007[3]
HOU_{pump}	Pump hours of operation	1,292	hr/yr	No change from PY18 TRM; Source: KEMA 2005-2007[3]
PF	Persistence factor	0.93	-	KEMA 2005-2007 report found 7% of solar water heating systems evaluated to be "inoperable"[4]
EFLH	Equivalent full load hours of equipment operation	See Table 2 (default = 3,564)	hrs	AEG's Hawaiʻi-specific analysis of U.S. DOE OpenEI Load shapes for Residential Electric Water Heating
CF	Peak demand coincidence factor	See Table 2 (default = 0.53)	-	AEG's Hawaiʻi-specific analysis of U.S. DOE OpenEI Load shapes for Residential Electric Water Heating; peak period defined as non-holiday weekdays from 5-9 pm
EUL_{EE}	Effective useful life of measure	18	yrs	AEG's Fall 2018 Benchmarking

[1] Source for EF equation: Federal Register, Energy Conservation Program for Consumer Products: Definitions for Residential Water Heaters, Table I.2, April 8, 2015, available here: https://www.federalregister.gov/documents/2015/04/08/2015-07956/energy-conservation-program-for-consumer-products-definitions-for-residential-water-heaters.

[2] Hawaiʻi Energy Solar Water Heating Program Handbook, Table 2. Maui value is average across 19 locations in Maui County (Range: 64-74°F). Primary source of data is the Maui Board of Water Supply.

[3] This KEMA report has been referenced in Hawai'i Energy's TRM algorithms for solar water heating since the PY11 TRM, and may have been in use to estimate savings prior to PY11. The report is cited as "KEMA 2005-2007 Energy and Peak Demand Impact Evaluation Report" and appears to describe a water heating study conducted by KEMA. AEG and the EEM were unable to locate the original KEMA evaluation report, despite inquiring directly with DNV GL (KEMA is now a part of DNV GL). From what AEG can ascertain from the past Hawai'i Energy TRMs, the circulation pump demand and pump hours of operation were determined from metering a sample of systems. AEG recommends collecting new data to update these values in a future TRM update.

[4] From what AEG can ascertain from the past Hawai'i Energy TRMs, "inoperable" was defined by KEMA as solar water heating systems that use more than an average of 5 kWh per day. The reference for the definition of "inoperable" is cited in past Hawai'i Energy TRMs as: "Impact Evaluation Report of the 2001-2003 Demand Side Management Programs," KEMA, page 2-36, 2004.

KEMA's solar water heating study involved metering energy and peak demand for a sample of 260 solar water heaters. Of these, 18 (7%) were considered to be in a state of disrepair that made them essentially "inoperable" as solar water heaters. In this "inoperable" state, they used an average of 3,925 kWh/yr, which is more than the current baseline energy use. Additional details about the study, including characteristics of the units tested (age, capacity, maintenance history, etc.) and the metering approach (equipment used, time of year, measurement period, etc.) were not provided in the past TRMs, so these details about the approach could not be verified by AEG. In addition, due to the general lack of published data on solar water heater savings persistence, AEG was unable to find benchmarking information to help validate KEMA's findings. As such, the persistence factor was reviewed, but not updated, for the PY19 TRM. As more data becomes available on savings degradation of solar water heating systems relative to baseline equipment, the persistence factor should be reevaluated for future TRMs.

Table 1. Average Occupancy in Homes

Type of Home	No. of Occupants
Unspecified	3.24
Hawai'i Non-Military (SF or MF)	2.28
Honolulu Non-Military (SF or MF)	3.18
Maui Non-Military (SF or MF)	2.58
SF Non-Military (Any County)	3.24
MF Non-Military (Any County)	2.60
Military (SF or MF)	3.82

SF = single family home

MF = multifamily home

Source: Evergreen Economics Baseline Study, 2014

Table 2. EFLH, CF, and T_{in}

Factor	County			
	Hawai'i	Honolulu	Maui	Unspecified
EFLH [1]	3,569	3,564	3,567	3,564
CF [1]	0.53	0.53	0.53	0.53
T_{in} [2]	75	75	71	75

[1]Source of EFLH and CF: AEG 2018 analysis of U.S. DOE OpenEI Load shape for Residential Electric Water Heating

[2]Source of T_{in}: Hawai'i Energy Solar Water Heating Program Handbook, Table 2; Maui value is average across 19 locations in Maui County (Range: 64-74°F)

1 2 3 4 5 6 7 8 9 10 11 12

SAVINGS

Deemed Savings (based on default values for key parameters)

Measure Name	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Residential Solar Water Heater	0.296 kW	1,991.90 kWh	35,854.20 kWh

Semi-Prescriptive Savings Calculator (based on customer-specific values for key parameters)

Enter Equivalent Rated Storage Volume in gallons for Electric Water Heater (default of 50 gal)

50 EF= 0.945

Enter Solar Fraction for new Solar Water Heater (default of 0.9)

0.9

Enter Occupancy of Home (default of 3.24 people)

3.24

Enter County (default of Honolulu)

Honolulu EFLH = 3,564 CF = 0.53 T_{in} = 75

Measure Name	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Residential Solar Water Heater	0.296 kW	1,991.90 kWh	35,854.20 kWh

RESOURCES

- AEG's 2018 Analysis Files titled 1) "AEG HPUC Update of Residential Measures - Analysis file" and 2) "R&C Solar Water Heater - v2 Solar Fraction."
- AEG's 2018 analysis of U.S. DOE OpenEI Load shapes for Residential Electric Water Heating. Used B10 Benchmark, Base Load prototype for IECC Zone 1A and Hawaiʻi weather stations (Keahole-Kona.Intl.AP, Honolulu.Intl.AP, Kahului.AP). Prototype data available here: https://openei.org/doe-opendata/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states.
- Baseline Energy Appliance, Equipment and Building Characteristics Study Report, Prepared for the State of Hawaii Public Utilities Commission, November 6, 2013, With errata February 26, 2014, Evergreen Economics.
- Connecticut's 2018 Program Savings Document, 13th Edition, filed December 15, 2017. https://www.energizect.com/sites/default/files/2018-PSD-FINAL-121217.pdf.
- Energy and Peak Demand Impact Evaluation Report of the 2005-2007 Demand Management Programs – (KEMA 2005-07)

- ENERGY STAR Program Requirement for Residential Water Heaters, v3.0, April 2015, https://www.energystar.gov/products/water_heaters/residential_water_heaters_key_product_criteria.
- ENERGY STAR websites and resources: https://www.energy.gov/energysaver/water-heating/solar-water-heaters, https://www.energy.gov/energysaver/estimating-cost-and-energy-efficiency-solar-water-heater, https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/WaterHeaterAnalysis_Final.pdf
- Energy.gov, Solar Water Heating Requirement for New Residential Construction, State of Hawaiʻi, https://www.energy.gov/savings/solar-water-heating-requirement-new-residential-construction.
- Federal Register, Energy Conservation Program for Consumer Products: Definitions for Residential Water Heaters, Table I.2, April 8, 2015, available here: https://www.federalregister.gov/documents/2015/04/08/2015-07956/energy-conservation-program-for-consumer-products-definitions-for-residential-water-heaters.
- Hawaiʻi Energy Solar Water Heating Program Handbook: Design Guidelines, Volume 5, October 2018, available for download here: <https://hawaiienergy.com/files/for-homes/swh_handbook.pdf>.
- International Code Council (ICC) and Solar Rating & Certification Corporation (SRCC), 2015 ICC 900/SRCC 300-2015 Solar, Thermal System Standard, https://codes.iccsafe.org/content/ICC9002015/toc.
- Public Utility Commission of Texas, Texas Technical Reference Manual, Version 5.0, Volume 2: Residential Measures, Program Year (PY) 2018, October 2017.
- Regional Technical Forum. Residential Heat Pump Water Heater - Unit Energy Savings Workbook, Version 4.1. Northwest Power and Conservation Council. April 19, 2018. Spreadsheet. "ResHPWH_v4_1.xlsm." Uses SEEM Simulation Model Version 0.98 build May 29 2015 13:41:19.
- Saying Mahalo to Solar Savings: A Billing Analysis of Solar Water Heaters in Hawaiʻi, Jenny Yaillen, Evergreen Economics, Chris Ann Dickerson, CAD Consulting, Wendy Takanish and John Cole, Hawaii Public Utilities Commission, ©2012 ACEEE Summer Study on Energy Efficiency in Buildings.
- STATE OF HAWAIʻI SOLAR WATER HEATING IMPACT ASSESSMENT (1992 - 2011) Prepared For: Department of Business and Economic Development and Tourism (DBEDT) State of Hawaiʻi FINAL December 18, 2012 Prepared by: InSynergy Engineering, Inc. Honolulu, HI.
- System Advisor Model (SAM) is a performance and financial model designed to facilitate decision making for people involved in the renewable energy industry, https://sam.nrel.gov/.
- Technical Reference Manual, State of Pennsylvania, Act 129 Energy Efficiency and Conservation Program & Act 213 Alternative Energy Portfolio Standards, June 2016.
- Tennessee Valley Authority Technical Reference Manual, Version 6.0, Oct. 1, 2017.

- Title 10: Energy, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, Subpart B—Test Procedures, Appendix E to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Water Heaters, https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=ap10.3.430_127.e&rgn=div9
- Title 10: Energy, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, Subpart C—Energy and Water Conservation Standards, §430.32 Energy and water conservation standards and their compliance dates, (d) Water heaters.
- United Nations Framework Convention of Climate Change, Small-scale Methodology: Solar water heating systems, Version 02.0, Sectoral scope(s): 01, Clean Development Mechanism, AMS-I.J, Aug. 31, 2018, available for download here: <https://cdm.unfccc.int/methodologies/DB/7FWC9VI15EMP2EOCF44OUZH9XHLL5W>.

RESIDENTIAL: Solar Water Heater Tune Up

Return to TOC

UPDATE STATUS

Updated in Fall 2018 for PY19 TRM.

MEASURE DETAILS

Description

Maintenance and repair of residential solar water heating systems for optimum performance.

Program Criteria

Systems must be more than 3 years old and can only receive a tune-up incentive once every 5 years.

Unit of Measure

One system.

Baseline Equipment

Average per unit energy use (kWh) and on-peak demand (kW) for the baseline solar water heater was estimated by KEMA using field measurements on a sample of 260 solar water heaters. The baseline values represent a blend of 242 "operable" and 18 "inoperable" systems, where "inoperable" refers to systems requiring maintenance and repair. Inoperable systems are defined as systems that use more than an average of 5 kWh per day.

High Efficiency Equipment

Average per unit energy use (kWh) and on-peak demand (kW) for the high efficiency solar water heater was estimated by KEMA using field measurements on the 242 "operable" systems within the sample of 260 solar water heaters tested.

ALGORITHMS

Peak Demand Reduction, kW

$$\Delta kW = \left(P_{base} - P_{op}\right) * PF \quad (1)$$

Annual Energy Savings, kWh/yr

$$\Delta kWh = \left(E_{base} - E_{op}\right) * PF \quad (2)$$

Lifetime Energy Savings, kWh

$$\Delta kWh_{life} = \Delta kWh * EUL_{EE} \quad (3)$$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Source/Notes

P_{base}	On Peak Demand, group "All"	0.079	kW	KEMA 2005-2007 report[1]
P_{op}	On Peak Demand, group "Operating"	0.05	kW	KEMA 2005-2007 report
E_{base}	kWh per Unit, group "All"	577	kWh	KEMA 2005-2007 report
E_{op}	kWh per Unit, group "Operating"	328	kWh	KEMA 2005-2007 report
PF	Persistence factor	0.5	-	Factor accounts for savings degradation between tune-ups; the value of 0.5 assumes linear degradation of savings across measure life.
EUL_{EE}	Effective useful life of measure	5	yrs	

[1] This KEMA report has been referenced in Hawaiʻi Energy's TRM algorithms for solar water heating since the PY11 TRM, and may have been in use to estimate savings prior to PY11. The report is cited as "KEMA 2005-2007 Energy and Peak Demand Impact Evaluation Report" and appears to describe a water heating study conducted by KEMA. AEG and the EEM were unable to locate the original KEMA evaluation report, despite inquiring directly with DNV GL (KEMA is now a part of DNV GL). From what AEG can ascertain from the past Hawaiʻi Energy TRMs, "inoperable" was defined by KEMA as solar water heating systems that use more than an average of 5 kWh per day. The reference for the definition of "inoperable" is cited in past Hawaiʻi Energy TRMs as: "Impact Evaluation Report of the 2001-2003 Demand Side Management Programs," KEMA, page 2-36, 2004.

KEMA's solar water heating study involved metering energy and peak demand for a sample of 260 solar water heaters. Of these, 18 (7%) were considered to be in a state of disrepair that made them essentially "inoperable" as solar water heaters. Additional details about the study, including characteristics of the units tested (age, capacity, maintenance history, etc.) and the metering approach (equipment used, time of year, measurement period, etc.) were not provided in the past TRMs, so these details about the approach could not be verified by AEG. In addition, due to the general lack of published data on savings from solar water heater maintenance and repair measures, AEG was unable to find benchmarking information to help validate KEMA's findings. As such, the energy and peak demand values for the baseline and high efficiency cases were reviewed, but not updated, for the PY19 TRM. However, AEG did add a persistence factor to the algorithms to account for gradual degradation of savings between tune-ups. As new data becomes available on savings from tune-ups, this measure entry should be reevaluated for future TRMs.

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings	Lifetime Energy Savings
Solar WH Tune Up	0.015 kW	124.50 kWh	622.50 kWh

RESOURCES

- AEG's 2018 Analysis File titled "AEG HPUC Update of Residential Measures - Analysis file."
- Hawaiʻi Energy Efficiency Program, Program Year 3, July 2011 through June 2012, Technical Reference Manual, No. 2011, Measure Savings Calculations.
- Solar Hot Water System Specifications and Requirements, Form: SHW102, Environmental Protection Agency, https://www.epa.gov/sites/production/files/2016-01/documents/webinar_20140416_systemspecifications.pdf.
- Solar Water Heating System Maintenance and Repair, Energy Saver webpage, Department of Energy, accessed 11/21/2018, https://www.energy.gov/energysaver/solar-water-heating-system-maintenance-and-repair.

RESIDENTIAL: Faucet Aerator

Return to TOC

UPDATE STATUS

Online Marketplace Blended Savings Added in Fall 2019 for PY19 TRM v2.0.

MEASURE DETAILS

Description
Efficient Low-Flow Aerators (bathroom and kitchen).

Program Criteria
Qualified low-flow bathroom aerators and kitchen swivel aerators are provided directly by Hawaiʻi Energy via online store or direct-install program.

Unit of Measure
One aerator.

Baseline Equipment
2.2 GPM aerator.

High Efficiency Equipment
1.5 GPM aerator.

ALGORITHMS

annual kWh savings $= (gpm_{\_base} - gpm_{\_low}) * MPD * (PH / FH) * S * (T_{\_mix} - T_{\_inlet}) * 365 * (RE * 3412)^{\wedge(-1)}$

peak kW savings $= (gpm_{\_base} - gpm_{\_low}) * 60 * S * (T_{\_mix} - T_{\_inlet}) * (RE * 3412)^{\wedge(-1)} * CF$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Bathroom	Kitchen	Unit	Sources/Notes
$gpm_{\_base}$	Baseline flow rate	2.2		gal/min	
$gpm_{\_low}$	Efficient flow rate	1.5		gal/min	
MPD	Usage time	1.6	4.5	min/day	Cadmus and Opinion Dynamics. Showerhead and Faucet Aerator Meter Study. Memorandum prepared for Michigan Evaluation Working Group. 2013.
PH	People per household, multi-family	2.6		people/ house	Evergreen Baseline Study (2014) – Appendix C; Average number of occupants – Table C.3 (total average) Table C.4 (MF and SF averages). [1]
	People per household, single-family	3.24			
FH	Fixtures per household, multi-family	1.66	1	fixtures/	Evergreen Baseline Study (2014) –Appendix C; Average number of

	Fixtures per household, single-family	2.13	1	house	bathrooms –Table C.3 (total average) Table C.4 (MF and SF averages). [1,2]
S	Conversion factor	8.3		Btu/gal/˚F	Engineering constant.
$T_{\_mix}$	Temperature at end use	86	93	˚F	Cadmus and Opinion Dynamics. Showerhead and Faucet Aerator Meter Study. Memorandum prepared for Michigan Evaluation Working Group. 2013.
$T_{\_inlet}$	Average ground water temperature	75		˚F	Honolulu Board of Water Supply.
RE	Recovery efficiency, electric resistance	0.98		-	Electric Resistance ER from AHRI.
	Recovery efficiency, heat pump water heater	2		-	Heat Pump WH and Solar WH from ENERGYSTAR
	Recovery efficiency, solar water heater	1.8		-	
Constant	Conversion factor	3412		Btu/kWh	Engineering constant.
CF	Coincidence factor	0.022		-	Illinois TRM v6. Volume 3.
PF	Persistence factor, MFDI	1		-	
	Persistence factor, online retail	0.51		-	Illume: Overview of Energy Savings "Kit" Programs, 2015.
EUL	Effective useful life of measure	10		yrs	AEG 2018 Analysis.

Notes: 1. The Evergreen Baseline Study includes Hawaii specific data.

2. Added 1 to qty of faucet aerators to include kitchen sink.

Table 1: Heating Type Distribution, Online Marketplace

Electric Resistance	56%
Electric On-Demand	3%
Heat Pump	0%
Solar	31%
Gas	10%

Source: Baseline Energy Appliance, Equipment and Building Characteristics Study Report, Prepared for the State of Hawaii Public Utilities Commission, November 6, 2013, With errata February 26, 2014, Evergreen Economics, page 54. Values in table reflect minor adjustments made based on historical program data in order to have all types sum to 100%.

SAVINGS

Table 2: Detailed Savings by Category

			kWh	kW
SERWH	Multi-family	Bathroom	17.48	0.025
		Kitchen	133.56	0.041
	Single-family	Bathroom	16.98	0.025
		Kitchen	166.44	0.041
HPWH	Multi-family	Bathroom	8.57	0.012
		Kitchen	65.45	0.020

HPWH	Single-family	Bathroom	8.32	0.012
		Kitchen	81.56	0.020
SWH	Multi-family	Bathroom	9.52	0.014
		Kitchen	72.72	0.022
	Single-family	Bathroom	9.24	0.014
		Kitchen	90.62	0.022

Table 3: Online Marketplace Blended Savings

	kWh	kW
Bathroom	6.40	0.018
Kitchen	55.75	0.030

RESIDENTIAL: Low-Flow Showerhead

Return to TOC

UPDATE STATUS

Online Marketplace Blended Savings Added in Fall 2019 for PY19 TRM v2.0.

MEASURE DETAILS

Description
Efficient Low-Flow Showerheads (fixed or handheld).

Program Criteria

Qualified showerheads are provided directly by Hawaiʻi Energy via online store or direct-install program.

Unit of Measure
One showerhead.

Baseline Equipment
2.5 GPM showerhead.

High Efficiency Equipment
1.5 GPM showerhead.

ALGORITHMS

annual kWh savings $= (gpm_{\_base} - gpm_{\_low}) * MPS * SPD * (PH / FH) * S * (T_{\_mix} - T_{\_inlet}) * 365 * (RE * 3412)^{\wedge(-1)}$

peak kW savings $= (gpm_{\_base} - gpm_{\_low}) * 60 * S * (T_{\_mix} - T_{\_inlet}) * (RE * 3412)^{\wedge(-1)} * CF$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Source/Notes
$gpm_{\_base}$	Baseline flow rate	2.5	gal / min	
$gpm_{\_low}$	Efficient flow rate	1.5	gal / min	
MPS	Minutes per shower	7.8	min / shower	Cadmus and Opinion Dynamics. Showerhead and Faucet Aerator Meter Study. Memorandum prepared for Michigan Evaluation Working Group. 2013.
SPD	Average showers per day, per person	0.6	shower / day / person	
PH	People per household, multi-family	2.60	people /	Evergreen Baseline Study (2014) – Appendix C; Average number of occupants – Table C.3 (total

PH	People per household, single-family	3.24	house	of occupants – Table C.3 (total average) Table C.4 (MF and SF averages). [1]
FH	Shower fixtures per household, multi-family	1.66	fixtures / house	Evergreen Baseline Study (2014) – Appendix C; Average number of bathrooms – Table C.3 (total average) Table C.4 (MF and SF averages). [1]
	Shower fixtures per household, single-family	2.13		
S	Conversion factor	8.3	Btu / gal / ˚F	Engineering constant.
$T_{\_mix}$	Temperature at end use	101	˚F	Cadmus and Opinion Dynamics. Showerhead and Faucet Aerator Meter Study. Memorandum prepared for Michigan Evaluation Working Group. 2013.
$T_{\_inlet}$	Average ground water temperature	75	˚F	Honolulu Board of Water Supply.
RE	Recovery efficiency, SERWH	0.98	-	Electric Resistance ER from AHRI.
	Recovery efficiency, HPWH	2	-	Heat Pump WH and Solar WH from ENERGYSTAR.
	Recovery efficiency, SWH	1.8	-	
Constant	Conversion factor	3412	Btu/kWh	Engineering constant.
PF	Persistence factor, MFDI	1	-	
	Persistence factor, online retail	0.59	-	Illume: Overview of Energy Savings "Kit" Programs, 2015.
CF	Coincidence factor	0.0278	-	Illinois TRM v6. Volume 3.
EUL	Effective useful life of measure	10	yrs	DEER 2020.

Notes: 1. The Evergreen Baseline Study includes Hawaii specific data.

2. Added 1 to qty of faucet aerators to include kitchen sink.

Table 1: Heating Type Distribution, Online Marketplace

Electric Resistance	56%
Electric On-Demand	3%
Heat Pump	0%
Solar	31%
Gas	10%

Source: Baseline Energy Appliance, Equipment and Building Characteristics Study Report, Prepared for the State of Hawaii Public Utilities Commission, November 6, 2013, With errata February 26, 2014, Evergreen Economics, page 54. Values in table reflect minor adjustments made based on historical program data in order to have all types sum to 100%.

SAVINGS

Table 2: Detailed Savings by Category

Annual Energy Savings	Peak Demand Savings

SERWH, MF	172.67 kWh	0.108 kW
SERWH, SF	167.70 kWh	0.108 kW
HPWH, MF	84.61 kWh	0.053 kW
HPWH, SF	82.17 kWh	0.053 kW
SWH, MF	94.01 kWh	0.059 kW
SWH, SF	91.30 kWh	0.059 kW

Table 3: Online Marketplace Blended Savings

	kWh	**kW**
LF Showerhead	73.18	0.079

RESIDENTIAL: Peer Group Comparison

Return to TOC

UPDATE STATUS

Description and Program Criteria updated in Fall 2018 for PY19 TRM. Savings approach will be updated in PY20 TRM to reflect preliminary findings from stoppage of treatment study.

MEASURE DETAILS

Description
Reports mailed periodically to participants educating and encouraging residents to reduce energy consumption. Comparing residents' energy usage to other similar homes is the driving factor in motivating energy reduction habits. Reports also have personalized savings tips.

Program Criteria
Program eligibility is based on household energy use.

Unit of Measure
Per residential unit.

Baseline Equipment
A residential unit that does not receive peer comparison reports.

High Efficiency Equipment
A residential unit that does receive regular peer comparison reports.

ALGORITHMS

$$\Delta E = SVG\_deemed * E\_avg,year$$
$$\Delta P = \Delta E / HRS\_deemed$$

DEFINITIONS & ASSUMPTIONS

Variable	Description	Value	Unit	Notes
ΔE	Annual energy reduction	Calculated	kWh	
ΔP	Peak power demand reduction	Calculated	kW	
E_avg,year	kWh per Unit, group "All"	6,633	kWh	Utility billing data
SVG_deemed	kWh per Unit, group "Operating"	0.80%	-	
HRS_deemed	On Peak Demand, group "All"	3,000	hrs	Hawai'i Energy PY15 TRM
Measure Life	Expected duration of savings	1	yrs	

SAVINGS

Measure Name	Peak Demand Savings	Annual Energy Savings

Peer Group Comparison	0.018 kW	53.06 kWh