Tennessee Valley Authority

Technical Resource Manual

Version 4

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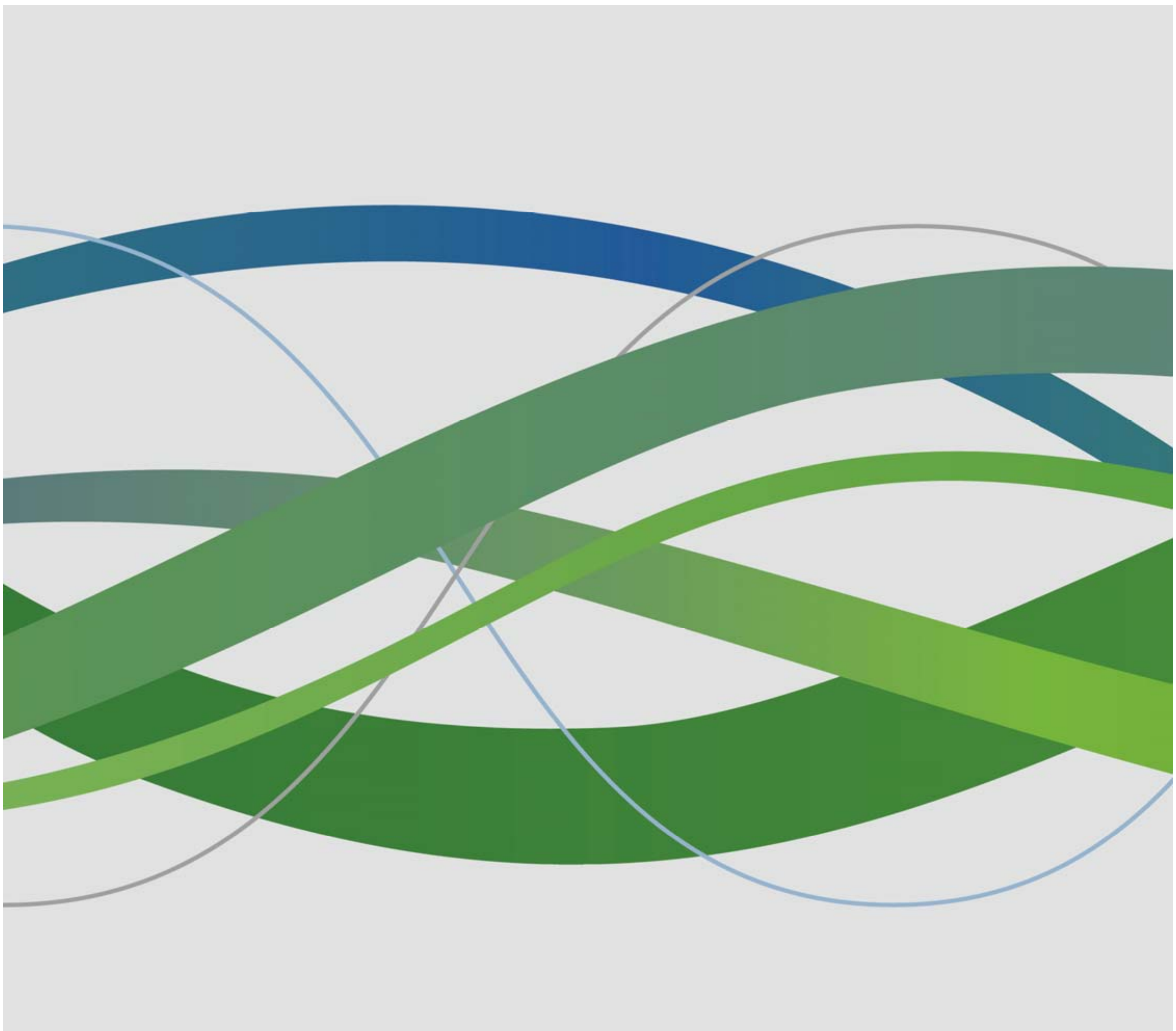

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1. Overview

The Tennessee Valley Authority (TVA) Technical Resource Manual (referred to as TRM or "manual") documents energy-efficiency program savings and methodologies for specific energy-efficiency measures. The manual supplies unit savings estimates, calculation algorithms, and methods for addressing specific measures. For each measure type, the recommended savings and verification processes are outlined as well as assumptions and resources used to measure and/or calculate the savings impacts. The manual also defines the minimum acceptable documentation for an implementer to provide TVA in order to claim the savings achieved by a local power company.

The manual provides a summary of deemed values for annual kilowatt-hour (kWh), summer peak kilowatt (kW), and winter peak kW savings, as well as the ability to calculate the hourly load profile impacts for most measures.[1] A Microsoft Excel-based database is available with the manual that contains all documented deemed values. General methods for assessing custom (non-deemed savings) measures provide guidance on how to quantify annual kWh, summer peak kW, and winter peak kW savings estimates. The manual is to be used with its associated tools, spreadsheets, and building prototype models.

This is version 4.0 of the manual. The original manual was completed in 2010 and was called the TVA Measurement Manual. This version includes new measures, removal of measures that have become standard practice or part of code, revisions based on updates to baseline or retrofit conditions, and results from evaluation studies nationally, and those within the Tennessee Valley.

1.1 Purpose

This manual provides a framework for TVA program implementers and program evaluators to document program impacts. Implementers, which include TVA, TVA contractors, and local power companies, are the entity or people that administer a program, review project applications, and process an incentive. Implementers should use this manual to properly document their program savings; the manual is intended to assist implementers to report accurate and consistent savings estimates and to minimize any evaluation risk. Measurement and verification (M&V) evaluators may reference this manual to understand implementer documentation source and methodology. Additionally, evaluators can use this manual as guidance for minimum guidelines for verifying program savings; however, additional effort may be required.

[1] "Deemed" refers to savings assumed that on average will be achieved by the population implementing the measure.

This manual provides tools to estimate annual energy and peak demand savings in order to assist TVA to report aggregated program savings. This manual should be updated on a periodic basis. Manual authors recommend that implementers and TVA stakeholders welcome input from all available sources, including white papers, publications, and evaluation reports outside of the TVA service area, to update this manual. As a result, the manual's documentation, including its associated databases and tools, is designed for users to easily refer to a source document for information and the methods for updates or changes. Accordingly, a user can recalculate program impacts if there are code changes to appliances, a change in peak demand definition, additional data provided on TVA building practices, or any other possible variable.[2] This manual provides the methods for customizing or updating the default deemed savings values, as well as providing a framework for custom measure project reviews.

1.2 Manual Content

This manual provides the following content:

- Load shapes and description of their development
  - Residential and commercial DOE-2 building models
  - Residential models calibrated to system load for TVA FY2007. There are plans to update these with evaluation research data
  - Industrial load shapes available from TVA's study conducted in 2000 by EPRI and DNV KEMA (then XENERGY)[3]
- Deemed non-weather and weather-sensitive measure savings
- Calculated/custom measure savings methodology (includes non-residential new construction)
- Strategies for program implementers to successfully verify, collect data for, and report accurate savings

[2] Building prototype models can be updated. The update process is not completely explained here since it requires a knowledgeable eQUEST/DOE-2.2 user (see Appendix Section 5). The model assumptions in TVA Modeling Assumptions.xls provide the variables and their associated values used in the model prototypes.

[3] This study was provided to TVA in its original format.

1.3 Revision Log

Revisions to the TVA TRM occur on a regular basis as new program evaluation data becomes available or as new energy efficiency codes or minimum equipment efficiency standards are adopted.

1.3.1 Revisions due to National Appliance Efficiency Standards

The TVA TRM baseline efficiency assumptions are periodically changed in response to increased standards for minimum efficiency of appliances that are implemented by the Department of Energy (DOE). The most recent example of this is the new federal minimum efficiency standards that went into effect on January 1, 2015, which effectively raised the minimum efficiency from 13.0 SEER to 14.0 SEER for most residential heat pumps and air conditioning equipment. Although the minimum efficiency standard went into effect on January 1, 2015, TVA will not be raising baseline program baseline efficiency values until October 1, 2015 to coincide with the start of its fiscal year 2016.

As a general rule TVA will allow some lag time after adoption of a new minimum efficiency standard to allow for existing equipment to work through the distribution system. The lag time will be determined on a case-by-case basis, but will generally be about nine months.

1.3.2 Revisions to Version Four

The following updates to the TRM were made for the Fiscal Year 2016 manual:

- Revision of the Residential, Non-Weather-Sensitive Measure Baseline and Quantifying Criteria table
- Elimination of high efficiency electric storage water heater measure
- Elimination of storage water heater (domestic) measure section
- Revision of the Residential, Weather-Sensitive Measure Baselines and Qualifying Criteria table
- Revision of the Annual Operating Hours by Building Types table
- Elimination of the Non-Residential Lighting Peak Load Shape Factors table
- Revision of the Non-Residential Lighting Peak Coincidence Factors table
- Update of single-family AC unit (central or split system) measure baseline
- Update of single-family heat pump unit measure baseline
- Update of residential (manufactured home and multifamily) AC units (central or split measure) measure baseline
- Update of residential (manufactured home and multifamily) heat pump unit measure baseline
- Elimination of EIR Equivalency to Air Conditioner SEER/EER table
- Elimination of Model Equivalent to Heat Pump SEER/EER/HSPF table

- Elimination of Cooling EIR eQUEST Efficiency table
- Revision of Baseline and Energy Efficiency Model Assumptions table
- Elimination of Cooling And Heating EIR eQUEST Efficiency Inputs < 65,000 kBtuh table
- Revision of Lighting Peak Coincidence Factor table
- Revision of Lighting Energy Interactive Effect table
- Revision of Summer Demand Interactive Effect table

1.3.3 Revisions to Version Three

The following changes to the TRM were made for the 2015 manual from the 2013 manual.

- Addition of section 1.5 Deemed Measure Baselines and Qualifying Criteria
- Revision of Table of Non-Weather-Sensitive, Load Shape End Uses
- Alignment of measure names in summary tables with measure section title
- Update of residential indoor CFL daily average hours based on TVA specific estimate
- Update of non-residential lighting annual operating hours for the retail, storage, and warehouse building types
- Correction of energy and demand savings values for linear fluorescent, LED, and metal-halide lighting measures
- Addition of the "LED, 4-foot Linear Replacement Lamps," measure within non-residential lighting
- Correction of energy (cooler and freezer cases) and demand savings (freezer cases) values for the refrigeration-case lighting controller measure
- Elimination of columns for cooler walk-in door ASH control savings for which the calculated energy or demand savings was zero
- Update of residential single-family heat pump measure baseline and savings values
- Addition of the following sections to the Non-Residential Custom/ Calculated Measure Analysis
    - Proposed Energy Savings Calculation Methodology
    - Plan for Capturing Operational Diversity
    - Data Accuracy Review

1.3.4 Revisions to Version Two

The following tables provide the list of measures added, updated, or removed from the 2010 manual. Measures with no changes are not listed in the following tables.

Table 1. Residential Measures

End Use	Measure Description	Status/Updates Made
HVAC	Packaged/Split AC	Existing - no change to manufactured home and multifamily;[4] Single-family revised with savings from the In-Home Energy Evaluation (IHEE) evaluation results
HVAC	Heat Pump	Existing - no change to manufactured home and multifamily; Single-family revised with savings from IHEE evaluation results
HVAC	Ductless Heat Pump	New
HVAC	Ground Source Heat Pump	New
HVAC	Refrigerant Charge	Revised to HVAC Tune-up and no change to multifamily; Single-family revised with savings from IHEE evaluation results
HVAC	Duct Sealing	Existing - no change to multifamily; Single-family revised with savings from IHEE evaluation results
HVAC	Duct Insulation	New
Envelope	Weatherization	Existing - no change to manufactured home and multifamily; Single-family revised with savings from IHEE evaluation results
Envelope	Insulation - Attic	Existing - no change to manufactured home and multifamily; Single-family revised with savings from IHEE evaluation results
Envelope	Insulation – Kneewall	New
Envelope	Windows - Primary and Storm	Existing - no change to manufactured home and multifamily; Single-family revised with savings from IHEE evaluation results
Lighting	Outdoor Integral (Screw-in) CFL, Switch or Photocell Control	Existing - revised with updated baseline wattages
Lighting	Indoor Integral (Screw-in) CFL	Existing - revised with updated baseline wattages
Lighting	Outdoor Compact Fluorescent Fixture, Switch or Photocell Control	Existing - revised with updated baseline wattages
Lighting	Indoor Compact Fluorescent Fixture	Existing - revised with updated baseline wattages
Lighting	ENERGY STAR® LED	New
Lighting	LED Night Light	Existing - revised in-service rate

[4] An update to the assumed unit size was made for multifamily, gas heat measures. Savings were updated accordingly.

End Use	Measure Description	Status/Updates Made
Lighting	Multifamily Lighting Measure	Existing- revised with updated baseline wattages
Lighting	Fluorescent Replacement-Garage/Kitchen	New
Lighting	CFL Table Lamp	Existing - revised with updated baseline wattages
Appliance	ENERGY STAR Residential Clothes Washer	Existing - updated retrofit
Appliance	Energy-Efficient Clothes Dryer	Existing - updated baseline and retrofit
Appliance	ENERGY STAR Residential Dishwashers	Existing - updated retrofit and added compact dishwashers
Appliance	ENERGY STAR Residential Refrigerator	Existing - updated baseline and retrofit
Appliance	ENERGY STAR Residential Freezer	Existing - updated baseline and retrofit
Appliance	Residential Refrigerator Recycling	Updated savings and source
Appliance	Residential Freezer Recycling	Updated savings and source
Appliance	ENERGY STAR Televisions	Removed
Appliance	ENERGY STAR Room AC	New
Domestic Hot Water	High-Efficiency Water Heater - Electric Storage	Existing - updated baseline
Domestic Hot Water	High-Efficiency Water Heater - Solar with electric backup	Existing - updated baseline
Domestic Hot Water	High-Efficiency Water Heater - Heat Pump	Existing - updated baseline
Domestic Hot Water	Faucet Aerator	Existing - updated inputs from updated sources
Domestic Hot Water	Low-Flow Showerhead	Existing - updated inputs from updated sources
Domestic Hot Water	Water Pipe Insulation Wrap	Existing - revised and savings from IHEE evaluation results
Domestic Hot Water	Water Heater Tank Insulation Wrap	Existing - revised and savings from IHEE evaluation results
New Construction	Manufactured Home New Construction	Existing - updated per E&RS reported value

Table 2. Non-Residential Measures

End Use	Measure Description	Status/ Updates Made
HVAC	Packaged AC, 35 ton	Existing - updated retrofit EER
Lighting	Screw-in CFL (1-13W)	Existing - updated baseline and retrofit wattage
Lighting	Screw-in CFL (14-26W)	Existing - updated baseline and retrofit wattage
Lighting	Screw-in CFL (27-40W)	Existing - updated baseline and retrofit wattage
Lighting	Hardwired CF Fixture (5-13W)	Existing - updated baseline and retrofit wattage

End Use	Measure Description	Status/ Updates Made
Lighting	Hardwired CF Fixture (14-26W)	Existing - updated baseline wattage
Lighting	Cold Cathode	Existing - updated baseline wattage
Lighting	T12 to T8 Lamp/Ballast Retrofit (2-foot)	Removed
Lighting	T12 to T8 Lamp/Ballast Retrofit (3-foot)	Removed
Lighting	T12 to T8 Lamp/Ballast Retrofit (4-foot)	Removed
Lighting	T12 to T8 Lamp/Ballast Retrofit (8-foot)	Removed
Lighting	De-lamping (2-foot)	Existing - updated baseline wattage
Lighting	De-lamping (3-foot)	Existing - updated baseline wattage
Lighting	De-lamping (4-foot)	Existing - updated baseline wattage
Lighting	De-lamping (8-foot)	Existing - updated baseline wattage
Lighting	High Performance 4-foot T8 Retrofit	Existing - updated baseline and retrofit wattage
Lighting	Reduced Wattage 4-foot T8 Retrofit	Existing - updated baseline and retrofit wattage
Lighting	Standard T8 to Reduced Wattage 4-foot T8 (lamp only)	Existing - updated baseline and retrofit wattage
Lighting	Screw-in LED Lamp	Existing - updated baseline and retrofit wattages, added categories based on ENERGY STAR
Lighting	Integrated Ballast Ceramic Metal-Halide (MH) Fixture	Existing - updated baseline wattage
Lighting	LED Traffic and Pedestrian Signal	Existing - updated baseline and retrofit
Motors	NEMA Premium-Efficiency Motors	Removed
Water Heating	Storage Water Heater	Existing - updated size used for efficiency calculation, for both baseline and retrofit
Water Heating	Low-Flow Pre-Rinse Sprayer	Existing - updated baseline and retrofit
Miscellaneous	High-Efficiency Office Copier	Removed
Miscellaneous	Plug Load Occupancy Sensor	Removed
Cooking	ENERGY STAR Convection Oven	Existing - updated baseline and retrofit
Cooking	ENERGY STAR Griddle	Existing - updated retrofit
Cooking	ENERGY STAR Fryer	Existing - updated baseline and retrofit
Cooking	ENERGY STAR Hot Food Holding Cabinets	Existing - updated baseline and retrofit
Cooking	ENERGY STAR Steam Cookers	Existing - updated retrofit
Cooking	Large Vat Fryers (18-inch commercial large vat)	Existing - updated baseline and retrofit
Cooking	Combination Oven	Existing - updated baseline and retrofit
Refrigeration	LED Refrigeration Case Lighting	Existing - updated retrofit, operating hours, and interactive effects
Refrigeration	Electronically Commutated (EC) Motor: Walk-ins	Existing - updated calculation inputs
Refrigeration	Evaporator Fan Controller	Existing - updated calculation inputs
Refrigeration	Strip Curtains	Existing - updated calculation inputs
Refrigeration	Door Gaskets	Existing - updated calculation inputs

End Use	Measure Description	Status/ Updates Made
Refrigeration	Anti-Sweat Heater (ASH) Controls	Existing - updated calculation inputs
Refrigeration	Door Auto Closers: Walk-ins	Existing - updated calculation inputs
Refrigeration	Door Auto Closers: Glass Reach-in Cooler or Freezer Doors	Existing - updated calculation inputs
HVAC	Variable Speed Drives (VSD)	New
HVAC	Hotel Guest Room Energy Management	New
Agriculture	Engine Block Heater Timer	New
Agriculture	Low Pressure Nozzles (Portable)	New
Agriculture	Low Pressure Nozzles (Solid-Set)	New
Agriculture	VSD on Dairy Vacuum Pump	New
Agriculture	VSD on Dairy Transfer Pump	New
Refrigeration	ENERGY STAR Reach-in Cooler/Freezer Solid & Glass Door	New
Refrigeration	Freezer and Refrigerated Case Door	New
Refrigeration	Night Curtains for Open Display Case Coolers	New
Refrigeration	High Efficiency Open and Reach-in Display Cases	New
Refrigeration	Electronically Commutated Motor (ECM) – Reach-in Cases	New
Refrigeration	Floating Head Pressure Controls	New
Refrigeration	Case Lighting Controls	New
Envelope	Cool Roof	New
Envelope	High Efficiency Windows	New
Envelope	Reflective Window Film	New
Miscellaneous	High Efficiency Transformers	New
Miscellaneous	Battery Chargers	New
Miscellaneous	VSD on Air Compressor	New

The following sections have been updated with additional items to further supplement and clarify language from the previous version:

- Definitions for building types (Section 5.2.1)
- Additional lighting building types - religious, other, service, municipal, 1-shift industrial, 2-shift industrial, and 3-shift industrial/warehouse (Section 5.2.1)
- Ineligible Custom Non-residential Measures (Section 8.2.2)
- General Guidelines for Custom Measure Analysis (Section 8.2.3)

- In Appendix Section 8 titled Refrigeration Calculator Assumptions, there is a new section called Interactive Factor Calculation
- In Appendix Section 8.2.8 Reviewing and Developing a Measurement (MFS) Plan Elements, subsections were added for Proposed Energy savings Calculation Methodology, Plan for Capturing Operational Diversity and, Data Adequacy Review

1.4 How to Use the Manual

This manual serves as a single-point value reference source for annual energy savings and summer and winter peak demand savings. However, users should be familiar with the tools utilized to develop the end-use and measure-level load shapes that are the source of the point value. The tools include:

- eQUEST/DOE-2.2 commercial and residential prototype models.
- Spreadsheets used to calculate deemed measure savings.
- Custom-measure calculation spreadsheets and/or methodologies.

Each tool catalogs documented measure inputs with source reference information provided by measure. Within each tool, 8,760 hourly load shape outputs or some other output format (e.g., point values or a set of values), used to calculate the manual's point values, are stored. These outputs can range from documenting the library of load shapes by end-use by building type by weather zone to the savings value for duct sealing or lighting energy interactive effect by building type by weather zone.

Because this manual supplies details and assumptions that underlie many of these calculation tools, manual authors recommend that users review the appropriate measure tool if referenced in this document. Similarly, users should review this manual when working with a tool provided as part of this manual. It may be difficult to use one without understanding or being comfortable navigating the other.

This manual is organized by subject matter sections to facilitate easy user review. Hyperlinks aid section-to-section references made within the manual.

1.5 Deemed Measure Baselines and Qualifying Criteria

This section contains tables that identify the baseline or qualifying criteria for the deemed energy efficiency measures. The intent of providing these tables in the beginning of the report is to make it easier to determine eligibility criteria on a measure basis. Residential, non-weather-sensitive measures are presented in Table 3.

Table 3. Residential, Non-Weather-Sensitive Measure Baselines and Qualifying Criteria

Measure Name	Sub-Measure Description	End Use	Baseline Value	Baseline Variable
Indoor/Outdoor Screw-in CFL		Lighting	25 - 150	Adjusted incandescent (EISA)[5] wattage
Indoor/Outdoor Pin-based Hardwire Fixtures		Lighting	250 - 600	Lumens
LED Lamps		Lighting	43 - 500	Incandescent table lamp wattage
CFL Table Lamp		Lighting	43 - 500	Incandescent table lamp wattage
LED Night Light (3W)		Lighting	7	Base wattage
Single-Family Linear Fluorescent	T12 and T8: 2-foot, 3-foot, and 8-foot	Lighting	33 - 109	Base lamp wattage
Single-Family Linear Fluorescent	Permanent lamp removal	Lighting	33 - 109	Base lamp wattage
Single-Family Linear Fluorescent	High-performance, 4-foot T8	Lighting	31 - 112	Base fixture wattage
Single-Family Linear Fluorescent	Reduced-wattage, 4-foot T12/T8 to T8 retrofit	Lighting	31 - 112	Base fixture wattage
Single-Family Linear Fluorescent	Reduced-wattage, 4-foot lamp used with existing ballast	Lighting	31 - 112	Base fixture wattage
Multifamily Lighting (exit signs, T8, or controls)	Exit signs: one incandescent lamp	Lighting	25	Base fixture wattage
Multifamily Lighting (exit signs, T8, or controls)	Exit signs: two incandescent lamps	Lighting	40	Base fixture wattage
Multifamily Lighting (exit signs, T8, or controls)	Occupancy sensors and photocells	Lighting	208	Base fixture wattage
Clothes Washer		Appliances	≥ 1.26	Modified energy factor (MEF) (ft3/kWh/cycle)
Clothes Washer		Appliances	≤ 9.5	Water factor (gal/ft3)
Clothes Dryer		Appliances	3.01	Energy factor (lb/kWh)

[5] Energy Independence and Security Act (EISA) of 2007.

Measure Name	Sub-Measure Description	End Use	Baseline Value	Baseline Variable
Dish Washer	Standard	Appliances	≤ 307	Unit electricity consumption (kWh/Year)
Dish Washer	Compact	Appliances	≤ 222	Unit electricity consumption (kWh/Year)
Refrigerators	Standard: bottom freezer	Appliances	610	Unit electricity consumption (kWh/Year)
Refrigerators	Standard: refrigerator only - single door	Appliances	441	Unit electricity consumption (kWh/Year)
Refrigerators	Standard: refrigerator/freezer - single door	Appliances	450	Unit electricity consumption (kWh/year)
Refrigerators	Standard: side-by-side	Appliances	710	Unit electricity consumption (kWh/year)
Refrigerators	Standard: top freezer	Appliances	476	Unit electricity consumption (kWh/year)
Refrigerators	Compact: bottom freezer	Appliances	452	Unit electricity consumption (kWh/year)
Refrigerators	Compact: refrigerator only - single door	Appliances	371	Unit electricity consumption (kWh/year)
Refrigerators	Compact: side-by-side	Appliances	446	Unit electricity consumption (kWh/year)
Refrigerators	Compact: top freezer	Appliances	417	Unit electricity consumption (kWh/year)
Freezers	Standard: upright freezer with manual defrost	Appliances	443	Unit electricity consumption (kWh/year)
Freezers	Standard: upright freezer with auto defrost	Appliances	686	Unit electricity consumption (kWh/year)
Freezers	Standard: chest freezer/all other freezers	Appliances	392	Unit electricity consumption (kWh/year)
Freezers	Compact: compact upright freezers with manual defrost	Appliances	306	Unit electricity consumption (kWh/year)
Freezers	Compact: compact upright freezers with auto defrost	Appliances	495	Unit electricity consumption (kWh/year)
Freezers	Compact: compact chest freezers	Appliances	257	Unit electricity consumption (kWh/year)

Measure Name	Sub-Measure Description	End Use	Baseline Value	Baseline Variable
Refrigerator & Freezer Recycling	Refrigerator	Appliances	1145	Unit Electricity Consumption (kWh/year)
Refrigerator & Freezer Recycling	Freezer	Appliances	1192	Unit electricity consumption (kWh/year)
Heat Pump Hot Water Heater		Water Heater	0.904	Energy factor (50 gallon volume)
Faucet Aerator	Domestic hot water (DHW) systems fueled by electrical water heaters	Water Heater	2.2	Maximum flow rate - gallons per minute (GPM)
Low-Flow Showerhead	DHW systems fueled by electrical water heaters	Water Heater	2.5	Maximum flow rate (GPM)
Pipe Wrap	Electric domestic hot water heater	Water Heater	0 (bare piping)	Insulation R-value
Tank Wrap	Electric domestic hot water heater	Water Heater	0 (no tank wrap)	Insulation R-value
Pool Pump (Pump and Motor Replacement)	Pre-existing or new in-ground pool	Miscellaneous	single or dual	Pump speed

Non-residential, non-weather-sensitive measure baselines and qualifying criteria are presented below in Table 4.

Table 4. Non-Residential, Non-Weather-Sensitive Measure Baselines and Qualifying Criteria

Measure Name	Sub-Measure Description	End Use	Baseline Value	Baseline Variable
Screw-in CFL	Baseline incandescent lamp	Lighting	29 - 150	Adjusted incandescent EISA wattage
Hardwired CFL	Baseline incandescent lamp	Lighting	43 - 500	Adjusted incandescent EISA wattage
Hardwired CFL	Baseline mercury vapor lamp	Lighting	125 - 285	Existing fixture wattage

Measure Name	Sub-Measure Description	End Use	Baseline Value	Baseline Variable
Cold Cathode	Baseline incandescent lamp	Lighting	15 - 29	Existing fixture wattage
T8 Lamps with Electronic Ballasts	2-foot, 3-foot, and 8-foot T12/standard T8	Lighting	33 - 109	Base lamp wattage
Linear Fluorescent Lamp Removal	2-foot, 3-foot, and 8-foot lamp removal	Lighting	33 - 109	Base lamp wattage
Linear Fluorescent Lamp Removal	4-foot lamp removal	Lighting	59 - 112	Base lamp wattage
High Performance T8	Baseline standard T8 lamps and electronic ballasts	Lighting	31 - 112	Standard T8 lamps with electronic ballast
Reduced Wattage T8	4-foot T12 to T8 retrofit	Lighting	31 - 112	Standard T8 lamps with electronic ballast
Reduced Wattage T8	Baseline 4-foot lamp used with existing ballast	Lighting	31 - 112	Standard T8 lamps with electronic ballast
LED Open Sign	Baseline neon fixture	Lighting	Neon	Baseline fixture type
LED Lighting	Recessed down or screw-in lamps	Lighting	29 - 125	Base lamp wattage
LED Exit Sign	Exit Signs: one incandescent lamp	Lighting	25	Base fixture wattage
LED Exit Sign	Exit Signs: two incandescent lamps	Lighting	40	Base fixture wattage
High Bay Lighting, T5 High-Output Fixtures	Baseline high-intensity discharge (HID), high-bay fixture	Lighting	365 - 780	Base fixture wattage
Pulse Start or Ceramic MH Fixtures	Baseline HID, high-bay fixture	Lighting	57 - 458	Base fixture wattage
Integrated Ballast Ceramic MH	Baseline Non-MH Lamp	Lighting	32 - 72	Base lamp wattage
Parking Garage – HID	Baseline HID Fixture	Lighting	208 - 458	Base fixture wattage
Parking Garage - High Wattage CFL	Baseline incandescent or HID lamps	Lighting	85 - 400	Base lamp wattage
Bi-Level Fixture	Baseline 2-lamp, T8 fixture	Lighting	60	Base lamp wattage
LED Traffic Signal	Baseline incandescent traffic lamps	Lighting	69 - 116	Base lamp wattage
Interior Lighting Controls: Occupancy Sensor	Occupancy sensor controlling T8 fixtures	Lighting	174	Base lamp wattage
Exterior Lighting Controls: Photocell	Baseline time clock controller	Lighting	380	Base lamp wattage

Measure Name	Sub-Measure Description	End Use	Baseline Value	Baseline Variable
Freezer/Cooler Fixtures With LED Lighting	Baseline fluorescent fixtures	Refrigeration	63 - 120	Existing fixture wattage
Freezer/Cooler Case-Lighting Controls	Baseline T12 fluorescent fixtures	Refrigeration	63 - 120	Existing fixture wattage
Freezer/Cooler Case-Lighting Controls	Baseline LED fixtures	Refrigeration	21.6	Existing fixture wattage
Electronic Commutated Motor in Walk-Ins	Baseline evaporator fan shaded-pole motor	Refrigeration	135.5	Existing motor wattage
Evaporator Fan Controller	Baseline operation: evaporator motors continuously running at full speed	Refrigeration	135.5	Existing shaded-pole motor wattage
Evaporator Fan Controller	Baseline operation: evaporator motors continuously running at full speed	Refrigeration	44	Existing EC motor wattage
Electronic Commutated (EC) Motor in Open and Reach-In Display Cases	Baseline evaporator fan shaded-pole motor	Refrigeration	0.33	Baseline motor load (Amps/linear foot)
Strip Curtains	Baseline condition: no strip curtains	Refrigeration	0	Coefficient of effectiveness
Door Gaskets	Baseline condition: weak, worn-out gaskets	Refrigeration	309	Baseline closed door infiltration rate
Night Curtains on Open Display Cases	Baseline condition: existing open display cases without night covers	Refrigeration	6	Minimum hours of deployment per 24 hour period
Anti-sweat heater controls	Baseline condition: anti-sweat heater runs continuously at full power	Refrigeration	0.04255	Existing anti-sweat heater strip watts/ linear foot
Door Auto Closers: Walk-Ins		Refrigeration	No auto closer	Existing condition
Door Auto Closers: Glass Reach-In Cooler or Freezer Doors		Refrigeration	No auto closer	Existing condition
High Efficiency Open and Reach-In Display Cases		Refrigeration	T-12 lamps, shaded-pole evaporator-fan motors, and standard glass doors with anti-sweat heaters	Existing equipment
High Efficiency Door Retrofit				

Measure Name	Sub-Measure Description	End Use	Baseline Value	Baseline Variable
Reach-In Refrigeration Case-Door Retrofit		Refrigeration	Continually-operating door heaters	Existing door heater operation
Floating Head Pressure Controls		Refrigeration	Fixed head pressure	Existing condition
ENERGY STAR Cooler	Standard-efficiency refrigerator	Refrigeration	2.95 - 11.36	Federal maximum daily energy consumption kWh per day
ENERGY STAR Freezer	Standard-efficiency freezer	Refrigeration	4.28 - 55.15	Federal maximum daily energy consumption kWh per day
Pre-Rinse Sprayer	Baseline condition: standard pre-rinse sprayer	Water Heater	1.9	Sprayer flow GPM
Vending Machine Controller - cold drinks	Base case: beverage vending machine w/no controls	Miscellaneous	variable	Existing vending machine kWh
Vending Machine Controller - snacks	Base case: beverage vending machine w/no controls	Miscellaneous	variable	Existing vending machine kWh
ENERGY STAR Convection Oven		Miscellaneous	65%	Cooking energy efficiency
ENERGY STAR Convection Oven		Miscellaneous	1.5	Idle energy rate (kW)
ENERGY STAR Griddle		Miscellaneous	60%	Cooking energy efficiency
ENERGY STAR Griddle		Miscellaneous	2.4	Idle energy rate (kW)
ENERGY STAR Fryer and Large Vat Fryers		Miscellaneous	75%	Cooking energy efficiency
ENERGY STAR Fryer and Large Vat Fryers		Miscellaneous	1.2 - 1.35	Idle energy rate (kW)
ENERGY STAR Hot Food Holding Cabinets	Full-size	Miscellaneous	9.6	daily energy consumption (kWh/day)
ENERGY STAR Hot Food Holding Cabinets	Three-quarter size	Miscellaneous	5.8	Daily energy consumption (kWh/day)
ENERGY STAR Hot Food Holding Cabinets	Half-size	Miscellaneous	3.8	Daily energy consumption (kWh/day)

Measure Name	Sub-Measure Description	End Use	Baseline Value	Baseline Variable
ENERGY STAR Steam Cookers		Miscellaneous	23.7	Cooking energy efficiency
ENERGY STAR Steam Cookers		Miscellaneous	1	Idle energy rate (kW)
Combination Oven		Miscellaneous	40%	Steam cooking energy efficiency
Combination Oven		Miscellaneous	65%	Convection cooking energy efficiency
High Efficiency Icemakers		Miscellaneous	6.0 - 12	kWh per 100 lb ice
Hotel Guest Room Energy Management (GREM) System		Miscellaneous	No occupancy HVAC controls	Existing condition
Variable Speed Drive on Air Compressor		Miscellaneous	Constant speed compressor	Existing equipment
Battery Chargers		Miscellaneous	High frequency chargers	Type
High Efficiency Transformer		Miscellaneous	0.97 - 0.989	Existing motor efficiency
Engine Block Heater Timer		Agricultural	Manual heater control	Existing condition
Low Pressure Sprinkler Nozzles		Agricultural	> 50 PSI	Existing sprinkler head pressure
VSD on Dairy Vacuum/Transfer Pump		Agricultural	Constant speed	Existing pump controls

The residential, weather-sensitive measure baselines and qualifying criteria are presented in Table 5.

Table 5. Residential, Weather-Sensitive Measure Baselines and Qualifying Criteria

Measure Name	Sub-Measure Description	Category	Baseline Value	Baseline Variable
Split system Air Conditioners	Baseline condition: current federal minimum standard	HVAC	14	SEER
Single package Air Conditioner	Baseline condition: current federal minimum standard	HVAC	14	SEER
Heat Pump	Baseline condition: current federal minimum standard	HVAC	14	SEER
Duct Leakage Reduction	Single-family duct sealing	HVAC	14%	% leakage to outside
Single-Family Refrigerant Charge		HVAC	12.17	SEER
Single-Family Window Replacement	Residential single-pane window replacement	Envelope	1.09	U-value
Single-Family Window Replacement	Residential single-pane window replacement	Envelope	0.81	Solar heat-gain coefficient (SHGC)
Single-Family Insulation (Attic, Floor, Wall)		Envelope	10.5	Existing insulation R-values
Single-Family Weatherization		Envelope	0.46 - 0.58	Air changes per hour
Single-Family Duct Repair/Replacement		HVAC	0.7"	Existing insulation level
Ground Source Heat Pump	Baseline condition: existing ground source heat pump	HVAC	13.0, 3.2	EER, COP
Ground Source Heat Pump	Baseline condition: existing AC with strip heat	HVAC	13.0, 1.0	EER, COP
Ductless Heat Pump	Baseline condition: typical existing efficiency	HVAC	10.5	EER
Multifamily and Manufactured Home Air Conditioning	Baseline condition: current federal minimum standard	HVAC	14	SEER

Measure Name	Sub-Measure Description	Category	Baseline Value	Baseline Variable
Multifamily and Manufactured Home Heat Pump	Baseline condition: current federal minimum standard	HVAC	14	SEER
ENERGY STAR Room AC	Baseline condition: current federal minimum standard	HVAC	10.9	SEER
Multifamily Duct Sealing		HVAC	28%	Baseline Leakage %
Refrigerant Charge Correction	Multifamily and manufactured home	HVAC	12.6	% change in Annual kWh
Multifamily Window Replacement	Residential single-pane window replacement	Envelope	1.25	U-value
Multifamily Window Replacement	Residential single-pane window replacement	Envelope	0.82	SHGC
Multifamily Insulation (Attic, Floor, Wall)		Envelope	10.5	Existing insulation R-values
Multifamily and Manufactured Home Weatherization		Envelope	0.7	Air changes per hour
Whole House Fans		HVAC	Central HVAC, no whole house fan	Existing condition

Non-residential, weather-sensitive measure baselines and qualifying criteria are presented in Table 6.

Table 6. Non-residential, Weather-Sensitive Measure Baselines and Qualifying Criteria

Measure Name	Sub-Measure Description	Category	Baseline Value	Baseline Variable
Package and split-system air conditioning	5.4 tons or less	HVAC	14	SEER
Package and split-system air conditioning	5.4 - 11.25 tons	HVAC	11	EER
Package and split-system air conditioning	5.4 - 11.25 tons	HVAC	11.2	IEER
Package and split-system air conditioning	11.25 - 20 tons	HVAC	10.8	EER
Package and split-system air conditioning	11.25 - 20 tons	HVAC	11	IEER

Measure Name	Sub-Measure Description	Category	Baseline Value	Baseline Variable
Package and split-system air conditioning	20 - 63.3 tons	HVAC	9.8	EER
Package and split-system air conditioning	20 - 63.3 tons	HVAC	9.9	IEER
Package and split-system air conditioning	≥ 63.3 tons	HVAC	9.5	EER
Package and split-system air conditioning	≥ 63.3 tons	HVAC	9.6	IEER
Package and split-system heat pump	5.4 tons or less	HVAC	12	SEER
Package and split-system heat pump	5.4 tons or less	HVAC	7.7	HSPF
Package and split-system heat pump	5.4 - 11.25 tons	HVAC	10.8	EER
Package and split-system heat pump	5.4 - 11.25 tons	HVAC	3.3	COP
Package and split-system heat pump	11.25 - 20 tons	HVAC	10.4	EER
Package and split-system heat pump	11.25 - 20 tons	HVAC	3.2	COP
Package and split-system heat pump	20 - 63.3 tons	HVAC	9.3	EER
Package and split-system heat pump	20 - 63.3 tons	HVAC	3.1	COP
Package terminal air conditioning/ heat pump	0.5 - 2 tons	HVAC	5.8 - 9.6	EER
Package terminal heat pump	0.5 - 2 tons	HVAC	2.3 - 2.7	COP
Variable speed drives on HVAC motors		HVAC	Constant speed drive	Baseline operation
Refrigerant charge correction		HVAC	N/A	N/A
Duct sealing		HVAC	28%	% leakage to outside
Economizer repair		HVAC	60%	Outside air fraction
Economizer retrofit		HVAC	55 °F	Maximum dry bulb temperature
Cool Roof		Envelope	.60 - 0.88	Existing roof absorbance
Window Film	Single-pane window	Envelope	1.82	U-factor
Window Film	Single-pane window	Envelope	0.82	SHGC

Measure Name	Sub-Measure Description	Category	Baseline Value	Baseline Variable
Window Film	Single-pane window	Envelope	0.9	Visible transmittance (VT)
Window Film	Double-pane window	Envelope	0.55	U-factor
Window Film	Double-pane window	Envelope	0.76	SHGC
Window Film	Double-pane window	Envelope	0.81	VT
High Efficiency Windows	Single-pane window	Envelope	1.23	U-factor
High Efficiency Windows	Single-pane window	Envelope	0.82	SHGC
High Efficiency Windows	Single-pane window	Envelope	0.9	VT
High Efficiency Windows	Double-pane window	Envelope	0.55	U-factor
High Efficiency Windows	Double-pane window	Envelope	0.76	SHGC
High Efficiency Windows	Double-pane window	Envelope	0.81	VT

2. Background on Load Shapes and Building Models

This manual refers to the TVA Model Development and Calibration document that supplies explanations about the data and procedures used to develop TVA's DOE-2 prototype models, which are broadly classified as either residential or commercial models. These models were used to develop measure-level savings profiles for TVA's demand side management (DSM) programs by the use of end-use load shapes, as well as annual estimated energy and peak demand savings for weather sensitive measures. Load shapes provide the hourly load profile for end-use energy consumption. Load shapes are an important part of the life-cycle cost analysis of any energy efficiency program portfolio. The net benefits associated with a measure are based on the amount of energy saved and the avoided cost per unit of energy saved. For electricity, the avoided cost varies hourly over an entire year, and thus, the total annual energy savings (kWh) of a measure and the distribution of those savings over the year are important factors in calculating avoided cost.

The distribution of savings over the year is represented by the measure's load shape. The measure's load shape indicates what fraction of annual energy savings occurs in each time period of the year. An hourly load shape indicates what fraction of annual savings occurs for each hour of the year.

In a study done for the Northwest Power and Conservation Council and Northeast Energy Efficiency Partnership,[6] KEMA summarized that most end-use load data are collected through one of three categories:

- **Compilation Studies** - studies that compiled primary interval data from other studies and used either DOE-2 modeling or statistical modeling techniques to produce average end-use load shapes.
- **Load Research Studies** - studies that utilized long-term, end-use power metering to develop average end-use load shapes. Study samples that were typically selected defined end uses at the tariff-class level with little or no customer-specific data collected other than interval power data.
- **Evaluation Studies** - studies that primarily focused on evaluating savings impacts for energy efficiency measures or demand response programs. These studies are characterized by shorter-term program participant monitoring and data collected for only the specific program measures being evaluated.

[6] "End-Use Load Data Update Project Final Report." Prepared for the Northwest Power and Conservation Council and Northeast Energy Efficiency Partnership, KEMA, 2009.

TVA does not have data from recent load research studies; however, it does have data from recent evaluation studies that will be used to update load shapes. These data will not be available for this version of the manual. Additionally, this manual leverages industry-accepted California modeling data to create prototype models that can later be updated with primary interval data from program evaluation efforts.[7] These data can then be used to update residential and commercial models to determine measure-level savings profiles.

Detailed explanations describing TVA load shape development and its application are provided later in this section. Load shape factors help determine winter and summer peak demand savings for commercial and residential measures. They are normalized hourly load profiles that are applied to measure-level savings. For this manual, KEMA has utilized data from existing TVA work and external sources to develop load impact estimates specific to TVA service area.

2.1 DOE-2 Models

The data and procedures used to develop TVA's DOE-2 prototype models, which were used to develop measure-level savings profiles for TVA's DSM programs, are discussed in this section. DOE-2 is a building energy analysis program that can predict energy use of a building by modeling the building characteristics such as layout, orientation, construction of walls, ceiling, and windows, as well as details on the energy using equipment including schedules. DOE-2 is a DOS-Box user interface. The eQUEST software, used here, is the graphical user interface for DOE-2.

DOE-2 prototype models are classified broadly as either residential or commercial models. Residential models consist of single-family, multifamily, and manufactured home models, all of which vary based upon heating, ventilation, and air-conditioning (HVAC), and water heating system types. Prototypical commercial models were developed for the following classifications:

[7] The models are based on the Database on Energy Efficiency Resources (DEER), which is a California Energy Commission and California Public Utilities Commission (CPUC) sponsored database designed to provide well-documented estimates of energy and peak demand savings values, measure costs, and effective useful life (EUL) all with one data source.

- Large office
- Small office
- Small retail
- Retail - Single-Story, Large
- Mall department store, retail
- Grocery store
- Hotel
- Motel
- Assembly
- Primary school
- High school/College
- University
- Fast-food restaurant
- Sit-down restaurant
- Hospital/medical
- Warehouse
- Refrigerated warehouse

The DOE-2 models were customized to accurately represent current TVA building stock so that energy-efficiency measure load shapes could be developed for buildings within TVA service area. It is critical that TVA estimates the demand impacts of energy-efficiency measures with a high level of precision so that system planners can rely on these numbers when looking at future generation and transmission needs. TVA serves a unique role of generating, transmitting, and selling wholesale electric power.

2.1.1 Residential Models

Report authors developed prototypical residential models using all available TVA-specific data sources. The residential model development process used base models from the Database for Energy Efficient Resources (DEER)[8] to provide a starting point for the TVA-specific prototypical model. However, where there are updated models from TVA-specific evaluations and other studies, those are used for savings presented in this manual. The residential sector accounts for approximately 45% of TVA's system load and had a substantial amount of TVA data available, including the following:

- Residential Saturation Survey data from 2007 and 2012
- Residential audit data from recent program activity and evaluation reports

[8] www.deeresources.com

- Residential Energy Efficiency Market Potential Study by Electric Power Research Institute (EPRI)[9]
- Residential DOE model inputs from TVA's EnergyRight® Solutions Program
- Residential sector annual energy consumption data for each local power company
- Residential load shapes developed by EPRI from TVA load research data[10]

Survey data from TVA's 2007 and 2012 Residential Saturation Surveys provided general frequency data about HVAC equipment, water heating, major appliances, housing, and occupant characteristics. Residential audit data provided additional detailed information such as insulation levels and HVAC equipment type, age, and efficiency. EPRI's 2010 Residential Energy Efficiency Market Potential Study provided information on major appliance (e.g., refrigerators, clothes dryers, and dishwashers) vintage distribution that was used to calculate unit energy consumption (UEC) of these appliances. The TVA EnergyRight Solutions program, U.S. Department of Energy (DOE) model inputs provided window type as well as air infiltration assumptions for the models. The model inputs are provided in TVA_ModelingAssumptions.xls. However, many measure impacts were also taken from the IHEE program report and not from the 2010 manual models. Actual source data is referenced for each measure.

Report authors developed an hourly estimate of TVA's residential system load from residential annual energy consumption data and 8,760-hour residential load profiles developed from load research data. These hourly load data were used to calibrate residential prototype models to provide an accurate estimate of typical residential load on the TVA system.

2.1.2 Commercial Models

To develop commercial models, authors used base model data from DEER.[11] As C&I evaluations are completed, the prototype building models will be updated with TVA-specific data. Modeling assumptions are summarized in a spreadsheet format under the following general categories:

- General building characteristics like floor area, number of stories, and floor-to-floor height

[9] There is an updated potential study from Global Energy Partners; however, the model prototypes were not updated for the current version of the manual and hence an updated study did not influence the savings presented here that are based on prototypical models.

[10] These data were developed from interval, whole-premise, metered data only. There was no end-use level, interval-meter data available.

[11] www.deeresources.com

- Envelope characteristics such as wall construction type, insulation, and window U-values
- Electrical loads such as lighting power density and equipment power density
- HVAC and domestic hot water (DHW) system features such as HVAC system type, HVAC fuel type, heating capacity, and cooling capacity
- Schedules such as those for occupancy, lighting, and HVAC

Initial commercial modeling assumptions were developed based on a combination of data sources, including 2005 DEER Measure Energy Analysis data, the 2008 DEER Update—Summary of Measure Energy Analysis revisions, and the DEER eQUEST energy models.[12] These models utilized inputs for 1978-1992 vintage data to represent average TVA-region commercial building stock.[13] Commercial prototype model inputs were organized in a spreadsheet template format and reviewed by TVA staff to evaluate how representative they were of TVA-region building stock. Modifications were made to the models as needed, and the sources of all inputs were recorded. These modifications included building constructions, occupancy densities, internal loads, schedules, different HVAC systems and cycling fans at night. Commercial model assumptions, used to produce DOE-2 models, are provided as a separate spreadsheet titled TVA_ModelingAssumptions.xls.

2.2 Industrial Sector

Industrial measures and load shapes need to be calculated on a case-by-case basis, since many industrial facilities are unique in their operation. However, TVA has a set of industrial load shapes that could be used as references. In 2000, KEMA and EPRI developed these industrial load shapes, including disaggregating non-heating and non-cooling load shape components into several manufacturing and facility end-uses for 14 two-digit SIC code groups. For each of the SIC groups, the team produced load shapes for the end uses shown in the following table. The dataset has been resubmitted to TVA.

[12] The team did not revise efforts based on DEER 2011 results, due to the fact that many TVA-specific efforts are underway to provide TVA-specific data. Additionally, DEER prototypical models were mostly established previously and not under the 2011 effort.

[13] Although California-based data may be significantly different than the southeastern U.S., California has extensive and robust data sets from different sources including online or mail surveys, in-home and telephone data collection, and evaluation and market research studies. The results of these studies were incorporated into the building models. This includes the schedule of equipment, lighting and equipment power density, and building layout. The major differences between TVA territory and California are the building stock mix, average building size, and standard building practices. California has had an energy code since 1978, which was revised in 1992, 2002, 2005, and 2008. The 1978-1992 California building vintage was selected as a starting point for the models developed in this study.

Table 7. Industrial End Uses

End Use
Space Heating
Space Cooling
Process Heating
Process Cooling
Machine Drive
Electro-Chemical
Other Process Uses
Lighting
Facility Support
Other Non-process Use

2.3 Other Load Shape Data

For some non-weather-sensitive loads (those not detailed in TVA's eQUEST models), the manual authors relied on load shapes borrowed from other geographic areas, which are relatively consistent across geographic regions for residential and commercial measures. Variations by building type are generally more important than variation by geography. KEMA conducted two major reviews of available end-use load data sources: one for the State of California and one for the Northwest Energy Efficiency Alliance and the Northeast Energy Efficiency Partnerships. The latter study defines the transferability of end-use load data from one region to another. The study notes that transferability for the C&I sector should be limited by building type. The results of the study[14] are summarized in the two following tables.

Table 8. Residential Analysis Groups Transferability Ratings

Analysis Group	Schedule Variability	Weather Variability	Transferability Rating
Appliances - Kitchen	Medium	Low	High
Appliances - Laundry	Medium	Low	High
Appliances - Refrigerator	Low	Medium	High
Domestic Hot Water	Low	Medium	Medium
HVAC - Cooling	Medium	High	Low
HVAC - Fan Energy	Medium	High	Low
HVAC - Heating	Medium	High	Low

[14] "End-Use Load Data Update Project Final Report." Prepared for Northwest Power and Conservation Council and Northeast Energy Efficiency Partnership, KEMA, 2009.

HVAC - Ventilation	Medium	Medium	Low
HVAC - Other	Medium	High	Low
Lighting - Exterior	Medium	Low	High
Lighting - Interior	Low	Low	High
Plug Load	Low	Low	High
Pool Pump	Low	Medium	Medium

Table 9. Non-Residential Analysis Groups Transferability Ratings

Analysis Group	Schedule Variability	Weather Variability	Transferability Rating
Agricultural - Process	Medium	Medium	Medium
Agricultural - Pumping	Medium	Medium	Medium
Appliances - Laundry	Low	Low	High
Clean Room	Low	High	Low
Compressed Air	Low	Low	High
Data Center Equipment	Low	Low	High
Data Center Cooling	Medium	High	Low
Food Service Equipment	Low	Low	High
HVAC - Cooling	Low	High	Low
HVAC - Fan Energy	Low	High	Low
HVAC - Heating	Low	High	Low
HVAC - Other	Low	High	Low
HVAC - Reheat	Medium	High	Low
HVAC - Ventilation Only	Low	High	Low
Industrial - Process	Medium	Medium	Medium
Lighting - Exterior	Low	Low	High
Lighting - Interior	Low	Low	High
Motors - Drives	Medium	Medium	Medium
Plug Load (Electronics)	Low	Medium	Medium
Pump	Low	Medium	Medium
Refrigeration	Low	High	Low
Water Heating	Low	Medium	Medium

Authors use available load shapes from California data (when not available from TVA prototypes) to maintain consistency, rather than using multiple load shape databases. The end use load shapes available from California are presented in the following table. End uses in the table that cite TVA as the source were developed from the TVA building model prototypes, consistent with the transferability recommendations provided above. Therefore measure groups with high transferability used California-based load shapes if none were available from the TVA building model prototypes.

Table 10. Non-Weather-Sensitive, Load Shape End Uses

Commercial	
End Uses	**Source**
Cooking	California
Air Compressors	California
Process	California
Miscellaneous	California
Hot Water	TVA
Motor	California
Office	California
Refrigeration	California
Ventilation	TVA
Interior Lighting	TVA
Exterior Lighting	California
Residential	
End Uses	**Source**
Dryer	California
Freezer	California
Microwave	California
Pool Pump	California
Refrigerator	California
Stove & Oven	California
Spa	California
Stove	California
Domestic Hot Water	TVA
Clothes Washer	California
Lighting	TVA

Initially TVA results were targeted to provide load shapes for the end uses identified in the previous table for the commercial and residential sectors; however, a simplification of the end-use categories is provided, due to the lack of TVA-specific load and measure data. Additionally, eQUEST end-use 8,760 output data are limited to the simplified end-use categories. Therefore, the list of TVA-specific end-use load shapes for each sector is summarized in the following table. However, other sources are used for 8,760 load shapes for end uses not specified in the following table.

Table 11. TVA Load Shape End Uses

Commercial	Residential
Cooling	Cooling
Heating	Heating (HP, resistance)
Ventilation	Ventilation
Interior Lighting	Interior Lighting
Water Heating	Water Heating
Equipment Loads	Plug Loads

One to three DOE-2 models were developed to represent each of the listed commercial building types (in Section 2.1). Up to seven models were developed for the residential sector for each of the three building types summarized in the following table. If other models are used for the savings estimates provided, then those are presented separately and described as such (for example, savings as a result of the IHEE program evaluation). These models represent differences in summer and winter savings for different cooling- or heating-system types. For example, a small office building was simulated using three different models: one model with non-electric heat, another with electric-strip heat, and the third with electric heat-pump heat (with electric-strip-heat backup).

Table 12. Residential Building Models

Model Name	System Combination	Heating	Cooling	Water Heating
EH1	HP/Central/E-DHW	Heat Pump	Central/Both AC	Electric
EH2	Strip/WW/E-DHW	Electric Strip	Window Wall	Electric
EH3	Strip/No AC/E-DHW	Electric Strip	No AC	Electric
GH1	NE-Heat/Central/NE-DHW	Non-Electric	Central/Both AC	Non-Electric
GH2	NE-Heat/Central/E-DHW	Non-Electric	Central/Both AC	Electric
GH3	NE-Heat/WW/E-DHW	Non-Electric	Window Wall	Electric
GH4	NE-Heat/No AC/E-DHW	Non-Electric	No AC	Electric

These DOE-2 models utilized available load shapes for non-weather-sensitive loads (lighting, water heating, etc.) to help define a building's internal heat gains. Then, the models generate the distinctive cooling and heating 8,760 hourly load shapes for TVA, based on TVA-territory typical meteorological year (TMY)[15] weather data.

Most non-weather-sensitive end-uses depend mostly on end-user behavior, which is independent of location in most cases, as explained previously in reference to the end-use load shape study. The following table lists specific California end-use measure load shapes that were utilized to determine peak factors that would otherwise be imbedded in an aggregate DOE-2 output channel. For non-weather-sensitive measures, peak load factors were developed from two different sources: TVA weather-specific DOE-2 models and California end-use meter data. The California end-use metered-data types offer smaller end-use granularity compared to the TVA models that were developed using eQUEST. This finer load resolution allows for a straightforward calculation of peak demand factors for certain measures, like cooking or residential appliances, whose end-use demand would have otherwise been grouped together into a non-specific category, like miscellaneous equipment end use.

Table 13. California End-Use Load Shapes

End Use	California End-Use Load Shape	Measures
Non-Residential Cooking	Cooking	ENERGY STAR Convection Ovens ENERGY STAR Griddles ENERGY STAR Fryers ENERGY STAR Hot Holding Cabinets ENERGY STAR Steam Cookers Large Vat Fryers Combination Ovens
Residential Appliances	Clothes Dryer Clothes Washer Freezer Refrigerator	Clothes Dryer Clothes Washer Freezer Refrigerator

[15] TMY is hourly weather data for a specific location. TMY refers to a characteristic weather condition. The weather files are created by selecting "typical" months of actual weather data to create a "typical" year. This weather data file is available from http://www1.eere.energy.gov/buildings/.

2.4 Calculating Load Shape Factors from Prototypical Building Models

This section describes the method for calculating load shape factors. Each end-use load shape is shown as a set of 8,760 hourly load (kW) values. Each kW's value per hour is the total kWh consumption for that particular hour and end use. To normalize and calculate the hourly load shape factor, each hourly kW is divided by the total kWh for its end use.

$$\text{Load shape factor}_{\text{hour,n}} = \frac{\text{kW}_{\text{hour,n}}}{\sum_{n=1}^{8760} \text{kW}_{\text{hour,n}}}$$

Load shapes were developed using five different typical meteorological year (TMY3)[16] weather files for the TVA region as follows:

- Chattanooga, Tennessee (Eastern Time Zone)
- Knoxville, Tennessee (Eastern Time Zone)
- Huntsville, Alabama (Central Time Zone)
- Memphis, Tennessee (Central Time Zone)
- Nashville, Tennessee (Central Time Zone)

System peak load hours for the summer and winter periods were defined using TVA's definitions as follows:

- Winter peak: December - March, weekdays 6 a.m. - 8 a.m. (central prevailing time [CPT])
- Summer peak: June - September, weekdays 2 p.m. - 5 p.m. (CPT).

For non-weather dependent measures, peak load factors were calculated as the simple average across all system peak hours (258 hours for summer, 170 hours for winter). For weather-sensitive measures, peak load factors were calculated as the average of the normalized load shape factors from the ten hottest (summer) or ten coldest (winter) hours that occurred during the respective summer and winter system

[16] TMY3 is derived from the 1961-1990 and 1991-2005 National Solar Radiation Data Base (NSRDB) archives.

peak hours in each of the five TMY weather files.[17] The top ten hours were chosen to represent the peak period after the team conducted analysis for different options and sensitivities to ensure the peak reduction value is representative of the impact during the system peak. Since the timing of the TVA system peak is variable from year to year, the ten-hour period was selected to increase the probability of including the peak without including too many lower probability hours.

System peak hours for the two Eastern Time Zone weather files (Chattanooga and Knoxville) were adjusted to CPT before either the weather-sensitive or the non-weather-sensitive load shape factors were calculated. These adjustments involved simply shifting the system peak window one hour later, so that all impacts would be evaluated during the same hours.

To calculate the average hourly demand expected for a given end-use variable-of-interest during the system peak window, the (average) peak load shape factors of that particular end-use are multiplied by the annual energy consumption (kWh) of the variable-of-interest. End-use peak demand (kW) can be estimated with these end-use specific peak load factors and corresponding annual end-use energy consumption.

$$\text{Average Peak Hourly Demand}_{\text{End-Use}} = \text{Peak Load Shape Factor}_{\text{End-Use}} \times \text{Annual kWh}_{\text{End-Use}}$$

In Appendix Section 9 titled LPC's by climate zones, there is a list of tables of LPC's categorized by climate zones.

[17] There are other ways to calculate peak savings. However, for this manual, this method was chosen.

3. Energy and Demand Savings Documentation

The measures covered under the programs implemented within Tennessee Valley Authority (TVA) service area fall under two categories:

1. Prescriptive measures with deemed savings: This manual includes work papers for prescriptive measures that provide the measure specification (e.g., equipment size and efficiency rating), assumptions, methodology, calculation spreadsheets or model inputs and outputs, and energy savings that are claimed per measure.
2. Custom/Calculated measures with simple calculated savings:
   - **Calculated savings:** The manual provides the calculation methodologies and/or tools and inputs needed per measure to calculate energy savings for the simplified calculated measures. These measures include some types of lighting, chillers, demand-control ventilation, and early retirement of equipment. Measures are classified as prescriptive or non-prescriptive, and savings algorithms are specified, along with some input parameters such as, operating hours or capacity.
   - **Customized savings calculations**: This manual provides the process and methodologies for custom measures that require a full-detailed analysis. These measures include air compressor system upgrades, energy management system installation, and process improvements.

For prescriptive measures with deemed savings, the manual provides the associated on-peak kW savings (for summer and winter peak periods), connected demand reduction (if appropriate), annual energy savings, and measure life. For the custom/calculated measures (non-deemed measures), the manual provides the load shape category or method to assess the on-peak summer and winter savings, and measure life. Calculation algorithms, parameter values, and required inputs for non-deemed measures are also provided.

Savings reported in this manual are customer-level savings and do not include any savings associated to transmission or distribution. Savings include interactive effects (mostly for lighting measures).[18]

[18] Interactive effects represent energy impacts on other end uses from installation of an efficient measure. For instance, there may be heat/cool interaction for efficient lighting measures and other measures in conditioned spaces that reduce internal heat gains. Interactive effects are provided for lighting and refrigeration measures, as appropriate.

Savings Examples

This manual provides the ability for an implementer to classify a measure as prescriptive, calculated, or custom (requiring measurements). Section 3.2 provides the user guidance on this classification process. Typically, measures that are commonly installed within a program have been studied by TVA (or a recognized third party with publicly available data) or can be calculated based on standardized engineering principles with justifiable and verifiable assumptions can be made deemed. For calculated measures, especially any lighting retrofits not already covered by deemed measures; a calculation can be made using simple equations. Other examples are a bin analysis and industry-accepted tools, such as the Cool Roof Calculator.[19] For custom measures, typically project-specific measurements must be conducted in conjunction with engineering calculations, regression analysis, billing analysis, modeling, or other techniques.

There may be exceptions in the above situations. For example, not all custom or calculated projects will require building models or project-specific measurements. And the Cool Roof Calculator, because of its lack of precision, may not be appropriate for a large project/incentive. Balancing savings risk and costs is a challenge for most implementers. Therefore, the manual provides guidance on the calculation and/or MFS rigor. More details on selecting a method for calculating energy and peak demand savings are provided throughout the manual.

Demand Reduction

The demand reduction per measure is defined as the non-coincident demand reduction associated with the measure. This definition varies by measure: it might be the full-load difference between package air conditioning units or the difference in fixture lighting wattages. The following illustrates the different definitions.

$$\text{Demand Reduction} = \text{Base case kW} - \text{Retrofit kW}$$

$$\text{Base case kW} = \text{Base case fixture wattage}$$

OR

$$\text{Base case kW} = \text{Rated Unit Capacity (MBTUh)} \times 1/\text{EER}_{\text{Base case}}$$

[19] http://www.ornl.gov/sci/roofs+walls/facts/CoolCalcEnergy.htm

Peak Demand Savings

The on-peak period is defined for winter and summer peak in Section 2.4. All peak periods are defined as CPT. The power system operators run on Central Time and all other time zones are adjusted accordingly. For example, the Eastern Time district cities (Chattanooga and Knoxville) use the hours 7 a.m. to 9 a.m. Eastern, coinciding with 6 a.m. to 8 a.m. Central.[20] From the standpoint of the TVA system load, this time zone adjustment insures that the factors are being calculated across the actual peak hours.

Winter and summer peak savings values are provided for the deemed savings measures provided in this report, except for the industrial sector. The industrial-sector population has unique characteristics on a per-site basis. Therefore, it is recommended that peak savings are calculated (or measured) on a case-by-case basis for the industrial sector except for lighting and HVAC measures that will clearly respond like a commercial building if the operating profile is similar. Peak savings for all sectors can be determined by the following methods resulting in average peak kW, not a maximum at peak hours:

1. **Calculated Method** where Peak kW Savings = kWh savings during the peak period divided by hours of operation during the peak period
2. **Measured Method** where the value can be measured during the peak period over a number of days or during a typical day, depending on the application
3. **Load Shape Method** where the value is looked up using the reference library of load shapes provided with this manual and described in Section 2.0. The load shapes were developed using TVA-specific building prototype eQUEST models that include 8,760 hourly outputs of end-use load shapes for each of the models

These load shapes were normalized into load shape factors. The average load shape factor during the two peak periods was calculated and used to calculate peak savings for non-weather-sensitive measures using the following equation:

Peak kW Savings = Average load factor during peak period x Annual energy savings

Load shape factors are calculated using the following steps:

1. Normalize each hour's load (kW or kWh consumed for the hour) with the total annual energy consumption (kWh per year) for each end use.
2. Extract the hourly load data that occurs during the peak hours.

[20] It is important to note that the hourly outputs from eQUEST models are stamped for the "hour ending." So, if the hour is stamped as 6, it is the hour of 5 to 6.

3. Average the data during the respective peak period.
4. Use California-based load shape data as an alternate for approach 3 described above, if TVA-specific end-use is not provided in the TVA specific building prototypes.
5. For weather-sensitive measures modeled in eQUEST or another platform that provides data for 8,760 hours, a different method is used. The top ten hottest or coldest hours during the specified peak period are determined. The difference in the average kW of the base case and retrofit models during those ten hours is the peak demand savings. These hours in the TMY3 files using the calendar year 2007 are summarized in the tables below.

Table 14. Chattanooga Ten Hottest Summer and Coldest Winter Peak Hours

	Summer		Winter	
Rank	**Date and Time (EST)**	**Temperature, °F**	**Date and Time (EST)**	**Temperature, °F**
1	June 28, 4-5 p.m.	98.1	December 20, 7-8 a.m.	16.0
2	June 28, 3-4 p.m.	97.0	February 7, 7-8 a.m.	18.0
3	July 14, 3-4 p.m.	97.0	December 20, 8-9 a.m.	18.0
4	July 12, 4-5 p.m.	97.0	January 25, 7-8 a.m.	19.9
5	July 14, 4-5 p.m.	97.0	January 26, 7-8 a.m.	19.9
6	June 28, 5-6 p.m.	97.0	January 27, 7-8 a.m.	19.9
7	July 14, 5-6 p.m.	97.0	February 10, 7-8 a.m.	21.9
8	June 29, 3-4 p.m.	96.1	February 14, 7-8 a.m.	21.9
9	July 10, 3-4 p.m.	96.1	January 26, 8-9 a.m.	21.9
10	July 12, 3-4 p.m.	96.1	January 27, 8-9 a.m.	21.9

Table 15. Knoxville Ten Hottest Summer and Coldest Winter Peak Hours

	Summer		Winter	
Rank	**Date and Time (EST)**	**Temperature, °F**	**Date and Time (EST)**	**Temperature, °F**
1	July 10, 3-4 p.m.	98.1	February 16, 7-8 a.m.	7.0
2	July 10, 4-5 p.m.	96.1	January 9, 7-8 a.m.	9.0
3	July 10, 5-6 p.m.	96.1	January 9, 8-9 a.m.	10.9
4	July 7, 4-5 p.m.	95.0	February 8, 7-8 a.m.	12.0
5	July 7, 5-6 p.m.	95.0	January 18, 7-8 a.m.	12.4
6	July 7, 3-4 p.m.	93.9	February 15, 7-8 a.m.	12.9
7	July 17, 3-4 p.m.	93.9	January 19, 7-8 a.m.	13.1
8	July 18, 3-4 p.m.	93.9	December 20, 7-8 a.m.	13.1
9	July 17, 4-5 p.m.	93.9	December 20, 8-9 a.m.	13.1
10	July 17, 5-6 p.m.	93.9	January 18, 8-9 a.m.	13.6

Table 16. Huntsville Ten Hottest Summer and Coldest Winter Peak Hours

	Summer		Winter	
Rank	Date and Time (CST)	Temperature, °F	Date and Time (CST)	Temperature, °F
1	July 7, 3-4 p.m.	98.1	February 3, 6-7 a.m.	8.1
2	July 7, 4-5 p.m.	98.1	February 3, 7-8 a.m.	8.1
3	July 7, 2-3 p.m.	96.1	January 11, 6-7 a.m.	9.0
4	July 6, 3-4 p.m.	96.1	January 11, 7-8 a.m.	10.9
5	September 4, 3-4 p.m.	96.1	January 10, 6-7 a.m.	12.9
6	September 4, 2-3 p.m.	95.0	January 10, 7-8 a.m.	16.0
7	July 6, 4-5 p.m.	95.0	December 18, 6-7 a.m.	17.1
8	July 6, 2-3 p.m.	93.9	January 6, 6-7 a.m.	19.0
9	July 3, 3-4 p.m.	93.9	January 9, 6-7 a.m.	19.0
10	September 11, 3-4 p.m.	93.9	January 27, 6-7 a.m.	19.0

Table 17. Memphis Ten Hottest Summer and Coldest Winter Peak Hours

	Summer		Winter	
Rank	Date and Time (CST)	Temperature, °F	Date and Time (CST)	Temperature, °F
1	August 29, 2-3 p.m.	100.9	January 31, 6-7 a.m.	12.9
2	August 29, 3-4 p.m.	100.0	January 31, 7-8 a.m.	14.0
3	August 29, 4-5 p.m.	99.0	January 19, 7-8 a.m.	15.1
4	August 28, 2-3 p.m.	98.1	January 19, 6-7 a.m.	16.0
5	August 28, 3-4 p.m.	98.1	February 8, 6-7 a.m.	19.0
6	July 12, 2-3 p.m.	97.0	January 20, 6-7 a.m.	19.9
7	August 18, 2-3 p.m.	97.0	February 8, 7-8 a.m.	21.0
8	July 12, 4-5 p.m.	97.0	January 20, 7-8 a.m.	21.9
9	August 28, 4-5 p.m.	97.0	February 9, 6-7 a.m.	23.0
10	June 5, 2-3 p.m.	96.1	January 27, 6-7 a.m.	25.0

Table 18. Nashville Ten Hottest Summer and Coldest Winter Peak Hours

	Summer		Winter	
Rank	Date and Time (CST)	Temperature, °F	Date and Time (CST)	Temperature, °F
1	June 28, 3-4 p.m.	98.1	January 27, 6-7 a.m.	6.1
2	June 28, 4-5 p.m.	97.0	February 3, 6-7 a.m.	7.0
3	June 28, 2-3 p.m.	96.1	February 3, 7-8 a.m.	9.0
4	June 29, 3-4 p.m.	96.1	February 8, 6-7 a.m.	10.9
5	June 29, 2-3 p.m.	95.0	January 27, 7-8 a.m.	12.9
6	August 3, 2-3 p.m.	95.0	January 26, 6-7 a.m.	14.0
7	August 4, 2-3 p.m.	95.0	January 26, 7-8 a.m.	14.0
8	June 26, 3-4 p.m.	95.0	February 8, 7-8 a.m.	14.0
9	June 27, 3-4 p.m.	95.0	February 2, 6-7 a.m.	15.1
10	August 3, 3-4 p.m.	95.0	February 1, 7-8 a.m.	15.1

The load shape factors described in load shape method 3 above can be found in the following five documents. All the prototypes and measure models discussed in the manual are based on calendar year 2007 for calculating peak factors (analysis however uses TMY weather).

- The non-weather-sensitive factors are the average of all hours in the peak period.
  - TVA 2010 NWS Res Load Shape Factors (Prototype Models).xls
  - TVA 2010 NWS NR Load Shape Factors (Prototype Models).xls
- The weather-sensitive factors are the average of the top ten hottest or coldest hours in the peak period.
  - TVA 2010 WS Res Load Shape Factors (Prototype Models).xls
  - TVA 2010 WS NR Load Shape Factors (Prototype Models).xls
- Load shape factors from California data can be found in CA Peak Load Shape Factors Summary.xls.

A sample calculation for calculating load shape factors from eQUEST output is provided (Peak Load Shape Factors Calculation.xls).

It is important to note that the peak period may vary year to year. Therefore the process described may need to be used to update the load shape factors and, subsequently, the peak demand savings. Additionally, the determination of what are peak demand savings may also change.

Annual Energy Savings

Annual energy savings can be broadly defined as the maximum demand reduction multiplied by the full-load operating hours per year. This definition varies by measure. These savings are the first-year savings. Full-load operating hours are simply defined as the equipment operating hours if operating at full load.

Annual kWh Savings = Base Case kWh - Retrofit kWh

Annual kWh Savings = Maximum Demand Reduction x Full load hours

Measure Life

The measure life or effective useful life (EUL) is the standard assumption used to determine the life-cycle savings (first-year savings multiplied by measure life). The EUL is an estimate of the average number of years that the measure is installed and operable. In some cases, the actual life of the equipment may be longer, but the EUL indicates the industry average life the measure provides savings. The lifetime savings estimate considers the baseline equipment and factors in the performance degradation by the use of the EUL value. Many measures have a degradation factor of one.[21] Measure retention studies have been used to estimate EULs, accounting for time- and use- related changes in the energy savings of a high efficiency measure or practice relative to a standard efficiency measure or practice. Typically, the standard EUL referenced in the manual takes any potential degradation into account.

3.1 Accurate Program Reporting

It is the responsibility of a program implementer to ensure the accurate representation of program savings. This manual, as described in Section 3, provides guidelines on using industry data to document savings associated with specific measures. However, in addition to validating the program measure definition with those included in this manual, the program must ensure proper reporting and documentation of incentive applications to finalize any savings claims. At a minimum, the following items should be considered by program implementers to document measure impacts, as well as provide the necessary data to program evaluators for verification.

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[21] CADMAC Report #2030P. *Summary Report of Persistence Studies: Assessments of Technical Degradation Factors, Final Report*, February 1999; CPUC. "Attachment to Review of Retention and Persistence Studies for the California Public Utilities Commission, Attachment G- Assessment of Technical Degradation Factor (TDF) Study." October 2004.

- **Program application form**: The form should include customer contact information, location where a measure was installed, material and labor installation costs, installation date, and a signed customer/utility agreement, which at a minimum should indicate what eligible measures were installed by the applicant.

- **Application worksheets**: The application form should also include measure worksheets. These worksheets should have at a minimum measure quantity, calculated incentive amount, and measure description. The measure description, particularly for prescriptive measures should be clearly specified. If the implementer uses the manual savings values then the measure specification should be compliant with the manual definition. Calculated savings should be included for non-prescriptive measures.

- **Invoices and specification sheets**: Most programs do not conduct 100% onsite verification, so as a substitute it is important to have measure installation invoices for verification. Additionally, some measures have specifications that can limit the availability of products and their efficiency level. Manufacturer specifications for measures can provide verification that the equipment installed meets the program requirements.

- **Program tracking system**: Overall program impacts can be verified via a tracking system. Tracking system best practices should be implemented for every program, such as including all information indicated on application forms, a contact log by program applicant (including contractor/customer/account representative or contact for each application), submitted and approved incentive amounts, and all important dates, such as application received and incentive paid dates. The tracking system would also ideally be designed for quality control of input variables (e.g., telephone field only allows numerical entry). Additionally, the tracking system should capture measure level information.

- To help clarify what is entailed in this process, the definitions of the major stakeholder roles that are affected by the manual are provided here:

- **Applicant** - This refers to the end-user/customer or the third party applying on behalf of the end-user. If the program does not use the traditional route of achieving savings through an application process, then the applicant refers to the end-user (or its representative). The end-user is the entity who is either a TVA direct-served customer or a local power company customer.

- **Implementer** - This is the entity (TVA, local power company, or a third party) who administers the incentive program. The implementer is responsible for documenting proper savings in a cost-effective manner for the program (and utility). Documenting program savings could include pre/post metering for custom measures, which could consist of directly metering the measure or utilizing interval metering for the whole premise when applicable. Implementer review for each project must be thorough but consider the cost-effectiveness of the analysis (balancing the accuracy of the savings estimate with the cost of achieving high accuracy).

- **Evaluator** - The evaluator in most cases conducts an independent impact evaluation of the total program savings developed by the implementer after the measures have been installed. The impact evaluation will typically utilize a stratified sample of the program participants that is developed using program savings estimates as the stratification variable and designed to achieve a target relative precision at a desired confidence interval. The evaluator will then draw the sample sites, conduct a file review, and determine the measurement plan that can use metering, onsite visits, or other methods to verify program savings. These methods may be more thorough than the implementer since the evaluator is sampling across a program.[22]

3.2 Measure Categories

The manual divides the measures in the following categories:

1. Non-weather-sensitive deemed savings
   a. Residential
   b. Non-residential
2. Weather-sensitive deemed savings
   a. Residential
   b. Non-residential
3. Residential new construction
4. Residential custom
5. Non-residential custom

These categories help the user navigate the manual. Additionally, these categories group market segment and methodology. Non-weather-sensitive measures typically rely on secondary sources for stipulated values, or research, and/or standard engineering calculations. Weather-sensitive measure savings rely on building models (described in Section 2.1) to simulate energy usage that is dependent on weather conditions. Both deemed categories depend on the 8,760 hourly load profile generated by building models for defining the peak demand savings. Residential new construction can be assessed with a deemed approach, but should have the flexibility to handle variations depending on the approach the builder uses to meet program minimum requirements. The residential custom category mostly provides

[22] Please reference the National Action Plan for Energy Efficiency website for additional resources. http://www.epa.gov/cleanenergy/energy-programs/suca/resources.html

guidance to develop a new deemed measure, if appropriate. Finally, the last category is non-residential custom. This manual provides guidelines for the user to use for evaluating the savings on custom measures and to help the user to decide on a method to use and the rigor to apply.

3.3 How to Use Manual for Measure Savings Documentation

This section provides guidance on how to use the manual to document energy savings for measures installed in programs implemented within the TVA service territory. The user should:

1. Determine if a measure is included in the deemed savings section.
2. If it is listed, make sure the program measure in question has similar specifications as indicated in the section describing the measure baseline and retrofit assumptions and the unit definition should be compared. If it is different, a conversion factor must be determined, if applicable.
3. If the measure does match, make sure the building type referred to in the program documentation is mapped to a building type modeled in this manual. In most cases, the building type can be matched. Use the values provided in this document or the “Measure Summary” workbooks, Nonres measure summary.xlsx and Res measure summary.xlsx, for non-weather-sensitive and weather-sensitive savings. However, there may be cases where some adjustments need to be made to redefine the building type.[23] The adjustments can be a new building model or other analysis must be included in the program documentation.
4. If the measure specifications do not match, the user must determine if a revised savings estimate can be calculated using the information provided within the manual and its documentation. If so, for non-weather-sensitive savings, follow the methodology provided for that measure (worksheets are provided for most measures and should be helpful in the re-calculation) and replace with program-specific assumptions and specifications. For weather-sensitive measures, follow Appendix Section 5 for varying the building prototype in wizard mode, and/or vary the baseline, and/or retrofit assumptions in the eQUEST models based on the measure specifications.
5. If not a deemed measure, review the calculated/custom Section 8.
    a. Select appropriate category for the measure.
    b. Assess the cost-effectiveness for varying levels of effort to review the measure.
    c. Select appropriate method and follow guidelines provided.

[23] Many school districts in the TVA territory have varying schedules. The model building prototype includes a standard schedule (summer vacation). Alternate schedules would need to be modeled. Description of varying building prototype model inputs in wizard mode is described in Appendix Section 5.

d. If measure category is not provided, establish a method and provide documentation of assumptions.[24] The documentation provided for the measure savings impacts must be sufficient to allow a third party to replicate and review any references from industry-accepted agencies.

[24] Share the new/revised method with TVA for future manual revisions.

4. Deemed Savings

This manual provides deemed savings for a variety of measures. Users should consider several factors before using savings values provided in this manual. Deemed savings estimates are practical for many reasons, but there are limitations to their use. Deemed savings are practical for measures that are common practice and have been measured/evaluated and allow for simplified assumptions and specifications. This approach allows the cost-effective implementation of programs on behalf of the program implementer and the participant. Documenting savings on a case-by-case basis can require extensive resources. The values quoted here are the savings that, on average, the participating population within TVA service area will gain. Because deemed savings should be based on the best available industry data or standards, they should be updated annually using metered or measured data specific to the TVA service area.

Some limitations of using deemed savings include:

- The savings may or may not be appropriate for the measure described. (Are the measure specifications in the manual the same as those described in the program requirements?)
- The savings are not appropriate for a specific application/project/customer, which needs to be custom-calculated on a site-specific basis. (Are there unique characteristics associated with the customer site?)
- Accuracy may be sacrificed due to oversimplification.

Given these limitations, the manual provides deemed savings estimates for a wide set of measures.

4.1 Verification of Deemed Savings Measures - Due Diligence

When applications are received, it is important for the implementer to ensure that measures are installed as reported by the applicant and that the measures do have verifiable savings. Basic checks should be completed to verify that the measure is operating, the quantity installed is as indicated by the applicant, and specifications of the installation meet program requirements. One hundred percent verification of all measured savings quantified for TVA should occur.[25] Specific steps that are relevant to all project types (residential and non-residential) include:[26]

[25] Verification could mean a paper review of the application. It does not require onsite visits in every case.
[26] It is recommended that the implementer develop a checklist to ensure proper and complete verification.

- Review invoices and manufacturer specifications submitted with application
  - Check that the invoice quantities match the claimed measure quantity on the application form
  - Check that the invoices include the make and model number
  - Check that the specifications match the measure requirements
- Decide if the project requires an inspection
  - Pre-inspection should be conducted, if applicable:
    - To verify that the measure is not yet installed and that existing equipment is operational (if applicable)
    - To verify that the incentive is not paying for replacing burned out equipment of the same efficiency
  - Post-inspection should be conducted on a random basis, especially for high volume participants:
    - To verify installation of proper equipment size, quantity, and efficiency
    - To verify large projects to ensure program savings

These are also steps that are conducted by an evaluation team. It is important for the implementer to do this verification for ensuring a high realization rate of savings and prevent surprises associated with evaluation findings. The following sections provide details, in addition to the steps provided above, to help guide the implementer in verifying energy savings for specific end uses.

4.2 Lighting (Non-Residential)

Lighting projects should be inspected on a random basis using a stratified sampling approach that over-samples the larger projects.[27] Inspections should be conducted if invoices, lighting survey, and specification sheets are not matching. Inspections should be conducted if there is a concern that there is a misunderstanding by the applicant.

If new construction is considered deemed based on the improvement in lighting power density, make sure to verify the equipment is installed is as indicated, and note space usage. The verification may be completed through a phone or a site visit.

[27] Simple random sampling is appropriate if the projects in the population do not vary too much in size (e.g., some residential programs). Otherwise, a stratified sample is typically more appropriate, where inspection quotas are defined for different measure types or business types or project sizes.

4.3 High Efficiency HVAC Equipment, Appliances, Cooking Equipment, and Water Heaters (Residential and Non-Residential)

These measures are broadly applicable for replacement on burnout, retrofit, and new construction. The baseline is federal minimum or building code standard. To ensure savings are realized, programs may require sizing calculations and other quality installation features such as checking airflow and refrigerant charge for air conditioning measures. Double-checking the specification sheets and the model number(s) indicated on the invoice is the recommended verification. However, inspections should be conducted randomly to reduce the potential of fraud, especially for high volume vendors.

4.4 Refrigerant Charge and Duct Sealing (Residential and Non-residential)

There are published protocols[28] for contractors to follow when providing refrigerant charge and/or duct sealing. The implementer should select a method or develop a method to publish and share with contractors participating in this program. This method should include a quality control process that can be incorporated in any program implemented within the TVA service area.

4.5 Other Retrofit Measures

A process should be established to ensure a consistent approach for implementers to maintain quality control in all measures that are part of a program. These guidelines described above should apply in every case. Specific details will vary, but the implementer should ensure the measure specification recorded by the program matches the installed measure at the customer site. Equipment operating assumptions recorded by the program (e.g., operating hours) should also match the actual installation parameters.

5. Deemed Non-Weather-Sensitive Savings

Deemed savings refer to savings for measures that are typically covered under a prescriptive (or standard) program. Prescriptive programs typically pay for the installation of measures per unit (such as per linear foot, per unit, or per ton). This section discusses the measures included in this report that are non-weather-sensitive. Non-weather-sensitive refers to measures that operate independently of outside air

[28] Air Conditioning Contractors of America (ACCA) publishes protocols recommended to program implementers to use.

temperature and humidity. However, this document does include commercial refrigeration in this category, since the variations across TVA weather zones and building types do not significantly affect the energy savings estimate, compared to other variables that affect those measures.

Secondary sources were used to document savings for deemed non-weather-sensitive measures. Adjustments were made to baseline assumptions to correspond with TVA existing equipment baselines (if data were available to make the adjustments), or used secondary sources for baseline definition, as necessary. The sources referenced are industry-accepted standards, California DEER,[29] ENERGY STAR, other technical resource manuals (TRMs), American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), International Energy Conservation Code (IECC), and others provided for each measure.

For many measures covered under this category, there are discussions on the methods and algorithms used from secondary and primary sources to determine savings. Many of the sections reference Microsoft Excel attachments that provide details on the analysis and assumptions.

5.1 Residential Non-Weather-Sensitive Measures

The following table is the residential non-weather-sensitive measures discussed here.

Table 19. Residential Non-Weather-Sensitive Measures

Measure Name	End Use
Indoor/Outdoor Screw-in CFL	Lighting
Indoor/Outdoor Pin-based Hardwire Fixtures	Lighting
CFL Table Lamp	Lighting
LED Lamps	Lighting
LED Night Light (Plug-in)	Lighting
Multifamily (Common Areas) and Single-Family Residential T-8 Interior Fixtures	Lighting
Multifamily Lighting Residential Exit Signs	Lighting
Photocells	Lighting
Clothes Washer	Appliances

[29] The California DEER is the country's most comprehensive database of deemed savings. This study is ongoing for more than a decade. The current version uses comprehensive, statewide survey data of residential and non-residential buildings. The data is then modeled as building prototypes in eQUEST. The models are calibrated and then used to establish weather sensitive savings. Non-weather sensitive savings for 2005 were completed in a similar manner determined in this manual. For 2008, they considered the non-weather sensitive measures as weather sensitive due to interactive effects with HVAC. This manual references the 2005 and 2008 DEER Studies.

Measure Name	End Use
Clothes Dryer	Appliances
Dish Washer	Appliances
Refrigerators	Appliances
Freezers	Appliances
Refrigerator & Freezer Recycling	Appliances
High Efficiency Water Heater[30]	Water Heater
Faucet Aerator	Water Heater
Low-Flow Showerhead	Water Heater
Hot Water Pipe Insulation	Water Heater
Electric Water Heater Insulation	Water Heater
Pool Pump (Pump and Motor Replacement)	Miscellaneous

All the calculations of the measure savings are provided in savings calculators referenced in each section, as applicable.

5.1.1 Residential Lighting

5.1.1.1 Indoor/Outdoor Integral (Screw-in) and Pin-Based (Hardwired) Compact Fluorescent Lamps (CFL)

Sources:

Illinois TRM, 2013, Illinois Statewide Technical Resource Manual

California DEER, 2008 and 2011. www.deeresources.com

DNV GL. *Residential Lighting End-Use Consumption Study*. Prepared for the U.S. Department of Energy, 2012

KEMA. *Evaluation of the 2004-2005 Statewide Multifamily Rebate Program - Volume 1, Final Report*. Prepared for the California Public Utilities Commission, March 2007.

[30] The measures with an asterisk are also applicable to new construction applications (as a single, stand-alone measure).

KEMA. *CFL Metering Study – Final Report*. Prepared for the Pacific Gas & Electric Company, San Diego Gas & Electric Company, and Southern California Edison Company, February 2005.

KEMA. *Final Evaluation Report: Upstream Lighting Program - Volume 1.* Prepared for the California Public Utilities Commission, 2010.

Heschong Mahone Group. *Lighting Efficiency Technology Report*. Prepared for the California Energy Commission, September 1999, pages 37-41.

Measure Description:

This section discusses the possible annual energy savings gained by replacing an interior or exterior non-CFL with a CFL. CFL bulbs are more efficient (lumens per Watt) than incandescent bulbs at converting electricity into visible light, and their lifetimes range between 6,000 and 15,000 hours. Pin-based CFL fixtures are pin-based sockets with integrated ballasts that use compatible modular CFL bulbs only, as opposed to incandescent fixtures (often screw-based) that use integral (self-included ballast) CFLs only. Interior fixtures have switch controls, and exterior fixtures have one of two cases: a switch control or a photocell control.

It is important to note that the Energy Independence and Security Act of 2007 (EISA) has dictated the federal standards which adjusts the baseline conditions for incandescent lamps. All general-purpose lamps between 40 W and 100 W must be more efficient. This process was phased with each new baseline based on lumen ranges changes once annually. The 100 W lamp baseline changed in 2012, 75 W in 2013, and 60 W and 40 W in 2014. The savings below include an adjusted baseline for all categories.

Assumptions:

The 2008 DEER update uses an incandescent: CFL wattage equivalency ratio of 3.53;[31] this manual uses this equivalency ratio to determine demand reduction between base and measure cases. DEER 2011 found the wattage ratio of 4.07 for exterior lighting; however, the 3.53 ratio was used for both indoor and outdoor lighting. The following table lists a range of incandescent lamp wattages and their equivalent CFL wattages. The CFL wattage equivalency ratio may be adjusted based on the program delivery method.

[31] DEER 2011 found the ratio to be 3.5, so no adjustments were made at this time.

Table 20. Wattage Lamp Assumptions

Lumen Range	Pre-EISA Watts Base	Post-EISA Watts Base	CFL Equivalent
2601-3300	150	150	42
1490-2600	100	72	25
1050-1489	75	53	20
750-1049	60	43	14
310-749	40	29	11

A selection of base case incandescent lamp sizes and their measure-case CFL equivalency was chosen from the Illinois TRM to establish a demand difference from which energy savings could be calculated. These lamps wattages and measure-case equivalency are in line with the average reduction found in the *Final Evaluation Report: Upstream Lighting Program - Volume 1* report (which is also referenced by ENERGY STAR) at approximately 40 W reduced. The following table shows the incandescent baseline, EISA adjusted baseline, retrofit wattages, and demand (wattage) reduction.

Table 21. Compact Fluorescent Wattage Assumptions[32]

Incandescent Wattage (W)	Adjusted Incandescent (EISA) Wattage (W)	"Equivalent" CFL Wattage (W)	Demand Reduction (W)
25	25	7	18
40	29	11	18
60	43	17	26
75	53	21	32
100	72	28	44
150	150	42	108

Daily operating hours for indoor and outdoor lamps can vary significantly, based on room type, fixture type, function, and fixture control type (e.g., switch, motion, and photocell). A DNV GL[33] metering study completed for DOE was leveraged to produce a TVA-specific estimate of 2.46 hours per day average *indoor* CFL use, and an earlier KEMA[34] metering study determined *outdoor* CFL use was 3.1 hours per day. The outdoor CFL hours-of-use estimate from the DOE study was based on a small number of sites,

[32] It is important to note that the demand reduction for the 40 W (29 W adjusted) incandescent baseline is on par with a 25 W baseline. This is a result of the Energy Independence and Security Act of 2007, EISA.

[33] DNV GL *TVA DOE Residential Lighting End-Use Consumption Study*. 2014.

[34] *KEMA CFL Metering Study. 2005, Section 4.1, p.45*

so the KEMA study estimate of outdoor CFL hours will be retained until the TRM can be updated with more robust TVA-specific metering data.[35]

The type of fixture control, either switch or photocell, used on outdoor fixtures can cause differences in energy savings.[36] Because a photocell control extends a fixture's daily operating hours, researchers used a multiplier factor of 3.94, which was obtained from a lighting report done for the California Energy Commission (CEC).[37] Using this multiplier, a photocell-controlled outdoor fixture yields 12.2 hours of operation daily.

$$\text{Hours of Operation}_{\text{Photocell}} = 3.94 \times \text{Hours of Operation}_{\text{Outdoor Switch}}$$

The research team assumed that both base case incandescent and measure-case bulbs are used 365 days per year. A summary of assumptions used to calculate energy savings is presented in the following table.

Table 22. Indoor/Outdoor CFL Variable Assumptions

Variable Name	Value	Source
Incandescent to CFL Wattage Ratio	3.53	DEER 2008
Daily Hours of Operation (Indoor)	2.46 hours per day	TVA DOE Residential Lighting End-Use Consumption Study (DNV GL 2014)
Daily Hours of Operation (Outdoor w/ Switch)	3.1 hours per day	CFL Metering Study (KEMA 2005)
Photocell Control Usage Multiplier	3.94	Lighting Efficiency Technology Report (CEC 1999)
Daily Hours of Operation (Outdoor w/ Photocell)	3.94 x 3.1 = 12.2 hours per day	Calculated

[35] There have been other studies since the referenced one for residential operation hours. However, these hours may still be relevant since the CFL penetration in TVA territory may still be dominated by high use sockets.

[36] CFL Metering Study (KEMA 2005), Table 3-14, shows 94% of metered fixtures were on switch control, only 2% on other (e.g., photocells, timers, and motion). Also, the study showed insignificant differences between CFL usage in a single-family and a multifamily building. This legitimizes the use of the photocell multiplier, a factor developed with a multifamily approach.

[37] Heschong Mahone Group. *Lighting Efficiency Technology Report*. Prepared for the CEC, September 1999.

Savings:

The tables below summarize energy and peak demand[38] savings realized by replacing an indoor/outdoor incandescent bulb with a CFL bulb of equivalent size, as discussed earlier in the assumptions section. Peak load shape factors are from the TVA-specific building prototype models.

Table 23. CFL Energy Savings (per Bulb)

CFL Wattage Range (W)	Demand Reduction (W)	Indoor Annual kWh Savings	Outdoor Annual kWh Savings (Switch)	Outdoor Annual kWh Savings (Photocell)
< 14	18	16	20	79
14 – 20	26	23	29	116
> 20	61	55	69	272

Table 24. Indoor CFL Peak Demand Savings (kW, per Bulb)

CFL Wattage Range (W)	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
< 14	0.0016	0.0013	0.0018	0.0015
14 – 20	0.0023	0.0019	0.0027	0.0022
> 20	0.0055	0.0044	0.0062	0.0051

Measure Life:

Based on the DEER,[39] CFL life span is rated based on lamp life and hours of use. The indoor lighting also includes a switching degradation factor of 0.523. Therefore the useful life is rated hours divided by annual usage multiplied by the switching degradation factor.

Table 25. Effective Useful Life

Lamp Life	Indoor	Outdoor
6,000	3.5	5.3
10,000	5.8	8.8
15,000	8.7	13.3

[38] Outdoor lighting is assumed to have zero summer and winter peak demand savings.

[39] SERA Inc. and Quantec LLC. *Revised/Updated EUL's Based on Retention and Persistence Studies Results, Revised Report*, July 8, 2005, Table 3.1, page 6.

Attachment:

TVA - Residential Lighting.xlsx

5.1.1.2 Light Emitting Diode (LED) Lamps

Sources:

Illinois Statewide TRM, May 2012

ENERGY STAR, www.energystar.gov, list of qualified LED lamps (September 2013)

KEMA. *Evaluation of the 2004-2005 Statewide Multifamily Rebate Program - Volume 1, Final Report*. Prepared for the California Public Utilities Commission, March 2007.

KEMA. *CFL Metering Study – Final Report*. Prepared for the Pacific Gas & Electric Company, San Diego Gas & Electric Company, and Southern California Edison Company, February 2005.

Heschong Mahone Group. *Lighting Efficiency Technology Report*. Prepared for the California Energy Commission, September 1999, pages 37-41.

Regional Technical Forum (RTF), rtf.nwcouncil.org, ResLEDLighting_v2_12.xlsm

Measure Description:

This measure consists of replacing non-LED lamps with LED recessed down or screw-in lamps that are ENERGY STAR qualifying products.

Assumptions:

The assumptions used to calculate measure energy savings are provided in the following tables. Baseline and retrofit wattages are based on lumen output and whether the lamp is decorative, directional, or omnidirectional. Baseline wattages use data provided by the RTF and the IL TRM (for those where EISA adjustments are required), and are the averages across the LED lamp types and lumen ranges. The retrofit wattages are from the average by across lumen ranges from the qualified product list provided by ENERGY STAR. The following table provides these assumed wattages.

Table 26. Baseline and Retrofit Wattages for LED Lamps[40]

Lumens	Retrofit Lamp Wattage	Base Lamp Wattage	Wattage Reduction
250	4.3	19.8	15.5
251-490	7	29.0	22.0
491-840	11.5	43.0	31.5
841-1190	15.6	44.8	29.2
1191-1690	19.5	62.5	43.0
1691-2600	22	144.0	122.0

The following table provides the assumptions from the *CFL Metering Study* (KEMA 2005) of operating hours per day by area type.

Table 27. Residential Lighting Hours (per Day)

Location	Hours per Day
All Exterior	3.9
All Interior	1.7
Bathroom	1.4
Bedroom	1.7
Dining	1.9
Garage	1.2
Hall	1.2
Kitchen	2.5
Living	2.3
Office	1.6
Other	1.4

Savings:

The following table provides the energy savings by area type.

[40] It is important to note that the demand reduction for the 491-840 lumens range is on par or higher than the 841-1190 lumens due to the 2007 Energy Independence and Security Act (EISA) regulations that require more efficient lamps than the standard incandescent lamp for these lumen ranges.

Table 28. LED Lamp kWh Savings (per Lamp)

Lumens	All Exterior	All Interior	Bath-room	Bed-room	Dining	Garage	Hall	Kitchen	Living	Office	Other
0-250	22.0	9.6	7.9	9.6	10.7	6.8	6.8	14.1	13.0	9.0	7.9
251-490	31.3	13.7	11.2	13.7	15.3	9.6	9.6	20.1	18.5	12.8	11.2
491-840	44.8	19.5	16.1	19.5	21.8	13.8	13.8	28.7	26.4	18.4	16.1
841-1190	41.6	18.1	14.9	18.1	20.3	12.8	12.8	26.6	24.5	17.1	14.9
1191-1690	61.2	26.7	22.0	26.7	29.8	18.8	18.8	39.2	36.1	25.1	22.0
1691-2600	173.6	75.7	62.3	75.7	84.6	53.4	53.4	111.3	102.4	71.2	62.3

Peak demand savings are provided in TVA - Residential Lighting.xlsx.

Life:

12 years (RTF)

Attachment:

TVA - Residential Lighting.xlsx

5.1.1.3 CFL Table Lamp

Sources:

Southern California Edison (SCE). "CFL Desk and Table Lamps (Exchange) - Residential." Work paper WPSCRELG0027, December 2008.

KEMA. *CFL Metering Study – Final Report*. Prepared for the Pacific Gas & Electric Company, San Diego Gas & Electric Company, and Southern California Edison Company, February 2005.

DEER, 2008. www.deeresources.com.

GDS, "Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures," for the New England State Program Working Group, by GDS Associates, Inc., March 2007.

Measure Description:

This measure covers energy savings related to replacing incandescent table lamp bulbs with CFLs. CFL fixtures use only modular type CFL bulbs in which the miniature electronic ballast is a part of the fixture, and the phosphor-coated lamp tube is independent of the ballast and replaceable. Even though modular systems have advantages, integral CFLs are much more common (no fixture retrofitting necessary) and are the only CFL lamp type currently included in the ENERGY STAR labeling program.[41]

Assumptions:

A range of base case incandescent table lamp wattages was selected from an SCE work paper. Incandescent wattages ranged between 60 W and 500 W; the SCE work paper matched each incandescent wattage size to the CFL equivalent, leading to a broad range of savings for each base case replacement.

The 2008 DEER update study uses an equivalency ratio of 3.53 incandescent watts to 1 CFL W; this manual uses this equivalency ratio for determining replacement CFL wattage. The following table shows incandescent (EISA-adjusted) table lamp wattages and their assumed CFL replacements.

Table 29. Equivalent CFL Wattages

Incandescent Table Lamp Wattage (W)	Equivalent CFL Table Lamp Wattage (W)	Demand Reduction (W)
43	17	26
53	21	32
72	28	44
150	42	108
200	57	143
250	71	179
300	85	215
400	113	287
450	127	323
500	142	358

The hours of use per day are assumed to be the same as the value used for screw-in compact fluorescent lamps from the *CFL Metering Study* (KEMA 2005) at 2.28 hours per day, 365 days per year.

Savings:

Annual energy savings from CFL table lamps in this manual were calculated as follows.

[41] Modular bulbs are not included, but CFL *fixtures* are included in the ENERGY STAR program.

$$\text{kWh Savings} = \Delta\text{Watts} \times \text{Usage/day} \times \text{Days/year}$$

The following table shows annual energy and peak demand savings, using the calculation and the assumptions above, for each lamp by wattage range. Peak load shape factors are from the TVA-specific building prototype models.

Table 30. Table Lamp Savings (per Table Lamp)

CFL Table Lamp Wattage Range (W)	Demand Reduction (W)	Annual kWh Savings
< 25	29	24
25 - 49	76	63
50 - 99	179	149
> 100	323	268

Table 31. Table Lamp Peak Demand Savings (kW, per Table Lamp)

CFL Table Lamp Wattage Range (W)	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
< 25	0.0024	0.0020	0.0027	0.0022
25 – 49	0.0063	0.0051	0.0071	0.0058
50 – 99	0.0150	0.0121	0.0169	0.0138
> 100	0.0270	0.0218	0.0305	0.0249

Measure Life:

8 years (GDS Associates, Inc.)

Attachment:

TVA - Residential Lighting.xlsx

5.1.1.4 LED Night Lights (Plug-In)

Sources:

Southern California Edison (SCE) work paper (WPSCRELG0029), 2007

2004-2005 Database for Energy Efficient Resources (DEER) Update Study, Final Report," December 2005

www.nolico.com and www.lightbulbs.com

Pennsylvania Technical Reference Manual, 2013

Measure Description:

This measure covers the replacement of an existing incandescent plug-in night light with an LED (or fluorescent and electroluminescent) night light. A LED is a semiconductor that emits incoherent light when electrically charged. Major advantages to LED-based lighting include high light output per unit of power input and the solid-state technology of semiconductors, which results in longer life expectancy than incandescent bulbs.

Assumptions:

The measure base case is a photocell-controlled night light using an incandescent light bulb. Base and measure cases are assumed to operate the same number of hours. The base case wattage assumption was drawn from an SCE work paper that used three major lamp manufacturers' bulb specifications to determine average incandescent bulb wattage of 7 W that was used as the base case wattage.

Night-lights are typically controlled by a photocell, which turns on the light when insufficient light illuminates the photocell. A residential night light program evaluation study conducted by SCE estimated that night-lights are on 12 hours per day, 365 days per year. Below, we list a sample of available measure night-lights that were used to estimate energy savings.

Table 32. Night Light Measure Case Wattage

Measure Type	Description	Wattage (W)
LED	White LED w/ Photosensor	1
LED	White LED w/ Photosensor	0.8
LED	Multidirectional w/ Photosensor	0.8
LED	Sleeping Moon Night Light	0.3
LED	Blue LED Night Light w/ Photosensor	0.03
Electroluminescent (EL)	EL Night Light	0.05
Fluorescent	Automatic Fluorescent Night Light	1.5

Savings:

Energy savings were estimated using a simple methodology with an in-service rate (ISR) of 84% from the Pennsylvania TRM.

$$\text{Demand Reduction (kW/unit)} = \frac{(\text{Watts}_{\text{Base}} - \text{Watts}_{\text{LED}})}{1000\text{W/kW}} \times \text{ISR}$$

$$\text{EnergySavings (kWh/unit/year)} = \frac{(\text{Watts}_{\text{Base}} - \text{Watts}_{\text{LED}}) \times (\text{hours/day}) \times (\text{days/year})}{1000\text{Wh/kWh}} \times \text{ISR}$$

Using the assumptions above, annual energy savings were calculated for various measure types (LED, fluorescent (FL), and electroluminescent (EL)) as shown in the following table. The average savings value is 0.0053 kW demand reduction and 23 kWh per year.

Table 33. Night Light Savings

Measure Type	Base Wattage	Average Measure Wattage	Demand Reduction (W)	Average Annual kWh savings
LED	7	0.586	5.39	24
Fluorescent	7	1.5	4.62	20
Electroluminescent	7	0.05	5.84	26

Peak demand savings for night-lights are assumed to be negligible because they are typically not on during either summer or winter peak times.

Measure Life:

The 2004-2005 DEER Update Study, Final Report does not provide specific EUL values for plug-in LED night-lights; however, the DEER has an integrated photocell measure that has an 8-year EUL. Manufacturer data suggest that LED night-lights last as long as 100,000 hours (approximately 22 years life based on 12-hour per day usage) before burning out, but it is assumed the photocell would burn out before the LED. Thus, the measure life is eight years for plug-in LED night-lights.

Attachment:

TVA - Residential Lighting.xlsx

5.1.1.5 Multifamily (Common Areas) and Single-Family Residential T8 Interior Fixtures

Sources:

DEER, 2008. www.deeresources.com

DEER, 2011. www.deeresources.com

Pennsylvania TRM lighting worksheet

Consortium for Energy Efficiency (CEE), http://www.cee1.org/

GDS, "Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures," for the New England State Program Working Group, by GDS Associates, Inc., March 2007.

Measure Description:
It is important to note that new federal standards have eliminated the manufacturing and importing of magnetic ballasts and T12 lamps. Hence, it is important to redefine baseline. Subsequently, the TVA has adopted a standard T8 baseline for all linear fluorescent fixtures. Retrofitting T12 fixtures to T8 fixtures is a recommended measure; however, the adjusted baseline for this measure is T8 lamps and electronic ballasts.

2-foot, 3-foot, and 8-foot

This measure consists of replacing existing T12 or standard T8 lamps and magnetic/electronic ballasts with efficient T8 lamps and electronic ballasts. The T8 lamps must have a color-rendering index (CRI) ≥80. The electronic ballast must be high frequency (≥20 kHz), UL-listed, and warranted against defects for 5 years. Ballasts must have a power factor (PF) ≥0.90. For 2- and 3-foot lamps, ballasts must have THD ≤32% at full light output.

Permanent Lamp Removal

This measure consists of permanently removing existing fluorescent lamps, which results in a net reduction of the overall installed number of foot lamps (total number of linear feet). This measure is applicable for retrofits from T12 lamps to T8 lamps or standard T8 lamps to high-performanceT8 lamps. This measure requires the removal of all unused lamps, ballasts, and tombstones to ensure it is permanent.

High-Performance, 4-foot T8

This measure consists of replacing existing T12 lamps and magnetic ballasts or standard T8 lamps and electronic ballasts with high-performance 4-foot T8 lamps and ballasts. This measure is based on CEE's high performance T8 specifications, which are in the multi-family and linear fluorescent lighting excel workbook and can also be accessed at www.cee1.org. Additionally, a list of qualified lamps and ballasts can be found in the workbook and a regularly updated list can be accessed at www.cee1.org. These fixtures typically have a higher lumen per watt than standard T8 and electronic ballast fixtures.

Reduced-Wattage, 4-foot T12 to T8 Retrofit

This measure consists of replacing existing T12 lamps and magnetic ballasts or standard T8 lamps and electronic ballasts with reduced-wattage (28 W or 25 W) and 4-foot T8 lamps with electronic ballasts. This measure is based on CEE's reduced wattage specification, which are in the multi-family and linear fluorescent lighting excel workbook and can be accessed at www.cee1.org. A list of qualified lamps and ballasts can be found in the workbook and a regularly updated list can be accessed at www.cee1.org.

Reduced-Wattage, 4-foot Lamp used with Existing Ballast

This measure consists of replacing standard 32 W T8 lamps with reduced-wattage T8 lamps (28 W or 25 W) when an electronic ballast is already present. The lamps must be reduced wattage in accordance with the CEE's specification.[42] The measure assumes replacement lamps have a nominal wattage of 28 W (≥ 2,585 lumens) or 25 W (≥ 2,400 lumens). Mean system efficacy must be ≥ 90 mean lumens per Watt (MLPW) and CRI ≥ 80 with lumen maintenance at 94%.

Assumptions:

2-foot, 3-foot, and 8-foot

The assumptions used to calculate measure energy savings are listed in the following table. Baseline and retrofit wattages use standard industry values per lamp linear length. The fixture wattage used is representative of the fixture category and not meant to illustrate an absolute baseline and retrofit fixture. For calculation purposes, the demand savings per lamp is calculated to produce a single demand reduction value for all retrofit opportunities in the measure category. It is recommended that retrofits of 8-foot T12 HO (HO=high output) or 8-foot VHO (VHO=very high output) fixtures be covered as a custom measure.

[42] Qualified products can be found at http://www.cee1.org/com/com-lt/com-lt-main.php3.

Table 34. Baseline and Retrofit Wattage Assumptions for 2-foot, 3-foot, and 8-foot Lamps

Measure Description	Base Lamp Wattage	Retrofit Lamp Wattage	Demand Savings per Lamp (kW)	Baseline Description	Retrofit Description
2-foot T8	33	29	0.0020	Fluorescent, (2) 24", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Fluorescent, (2) 24", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)
3-foot T8	46	42	0.0020	Fluorescent, (2) 36", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Fluorescent, (2) 36", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)
8-foot T8	109	98	0.0055	Fluorescent, (2) 96", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Fluorescent, (2) 96", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)

Delamping (Permanent Lamp Removal)

The fixture wattage used is representative of the fixture category and not meant to illustrate an absolute baseline fixture. For calculation purposes, the demand savings per lamp is calculated to produce a single demand reduction value for all retrofit opportunities in the measure category. Lamp wattage assumptions are presented in the following two tables.

Table 35. Wattages for 2-foot, 3-foot, and 8-foot Lamp Removal

Measure Description	Base Lamp Wattage	Demand Savings per Lamp (kW)	Baseline Description
2-foot	33	0.0165	Fluorescent, (2) 24", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)
3-foot	46	0.0230	Fluorescent, (2) 36", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)
8-foot	109	0.0545	Fluorescent, (2) 96", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)

Table 36. Wattages for 4-foot Lamps

Retrofit	Baseline Fixture Wattage	Removed Lamp Wattage	Weight Percentages
Four 4' T12/T8 > Three 4' T8 (32W)	112	28.0	10%
Three 4' T12/T8 > Two 4' T8 (32W)	89	29.7	25%
Two 4' T12/T8 > One 4' T8 (32W)	59	29.5	10%
Four 4' T12/T8 > Two 4' T8 (32W)	112	28.0	49%
Three 4' T12/T8 > One 4' T8 (32W)	89	29.7	5%
Total Weighted Average		**28.7**	

High-Performance, 4-foot T8

The assumptions used to calculate measure energy savings are listed in the following table. Baseline and retrofit wattages use standard industry values. The fixture wattage used is representative of the fixture category. For calculation purposes, the demand reduction per lamp for various configurations are weighted (based on KEMA assumptions), and then are averaged to produce a single demand reduction value.

Table 37. Baseline and Retrofit Wattages for High-Performance Fixture Retrofits

T8, 4-foot Configuration	Base Fixture Wattage	Retrofit Lamp Wattage	Retrofit Fixture Wattage	Demand Reduction per Fixture (kW)	Demand Reduction per Lamp (kW)	Weight Percentages
4-lamp	112	32	107	0.0050	0.0012	36%
3-lamp	89	32	87	0.0025	0.0008	16%
2-lamp	59	32	57	0.0016	0.0008	32%
1-lamp	31	32	31	0.0001	0.0001	16%
Weighted Average					0.0008	

Reduced-Wattage, 4-foot T12/T8 to T8 Retrofit

The assumptions used to calculate measure energy savings are listed in the following table. Baseline and retrofit wattages use standard industry values. For calculation purposes, the demand savings per lamp for various configurations are weighted (based on KEMA assumptions), and are then averaged to produce a single demand reduction value.

Table 38. Baseline and Retrofit Wattages for Reduced-Wattage Fixture Retrofits

T8, 4-foot Configuration	Base Fixture Wattage	Retrofit Lamp Wattage	Retrofit Fixture Wattage	Demand Savings per Fixture (kW)	Demand Savings per Lamp (kW)	Weight Percentages
4-lamp	112	28	94	0.0181	0.0045	13%
3-lamp	89	28	75	0.0140	0.0047	20%
2-lamp	59	28	50	0.0092	0.0046	13%
1-lamp	31	28	27	0.0037	0.0037	12%
4-lamp	112	25	85	0.0267	0.0067	5%
3-lamp	89	25	67	0.0221	0.0074	11%
2-lamp	59	25	45	0.0143	0.0072	5%
1-lamp	31	25	25	0.0070	0.0070	4%
Weighted Average					**0.0044**	

Reduced-Wattage, 4-foot Lamp used with Existing Ballast

The following table provides assumptions used to calculate measure energy savings. Baseline and retrofit wattages use standard industry values. For calculation purposes, the demand savings per lamp for various configurations are weighted (based on KEMA assumptions), and are then averaged to produce a single demand reduction value.

Table 39. Baseline and Retrofit Wattages for 4-foot T8 Lamp with Existing Ballast

T8, 4-foot Configuration	Base Fixture Wattage	Retrofit Lamp Wattage	Retrofit Fixture Wattage	Demand Savings per Fixture (kW)	Demand Savings per Lamp (kW)	Weights
4-lamp	112	28	94	0.0181	0.0045	36%
3-lamp	89	28	75	0.0140	0.0047	16%
2-lamp	59	28	50	0.0092	0.0046	32%
1-lamp	31	28	27	0.0037	0.0037	16%
Weighted Average					**0.0044**	

In the following table, operating hours for linear fluorescent lamps used in indoor common areas are shown (from ADM Associates, Inc. and TecMarket Works paper). The operating hours are 1.2 hours per day for garage and 2.5 hours per day for the kitchen (CFL Metering Study). The operating hours for compact fluorescent lamps are assumed to be the same for linear fluorescents.

Table 40. Multifamily Common Area Operating Hours

Indoor Common Area	Operating Hours
Athletic/Exercise Facility	3143
Club House	5066
Hallway	8526
Kitchen	4796
Laundry Room/Facility	4460
Office Areas	3555

Savings:

The following table shows average savings by building type, location, and retrofit type.

Table 41. Standard T12 to T8 Lamp and Ballast Retrofit kWh Savings (per Lamp)

Retrofit Type	Athletic/ Exercise Facility	Club House	Hallway	Kitchen	Laundry Room/Facility	Office Areas	Single Family Garage	Single Family Kitchen
2-foot Lamp Removal	51.9	83.6	140.7	79.1	73.6	58.7	7.2	15.1
2-foot T8	6.3	10.1	17.1	9.6	8.9	7.1	0.9	1.8
3-foot Lamp Removal	72.3	116.5	196.1	110.3	102.6	81.8	10.1	21.0
3-foot T8	6.3	10.1	17.1	9.6	8.9	7.1	0.9	1.8
4-foot Lamp Removal	90.1	145.2	244.3	137.4	127.8	101.9	12.6	26.1
8-foot Lamp Removal	171.3	276.1	464.7	261.4	243.1	193.7	23.9	49.7
8-foot T8	17.3	27.9	46.9	26.4	24.5	19.6	2.4	5.0
T12 to High-Performance T8	2.7	4.3	7.2	4.1	3.8	3.0	0.4	0.8
T12 to Reduced Wattage T8	13.8	22.3	37.5	21.1	19.6	15.6	1.9	4.0
T8 to Reduced Wattage T8	14.0	22.5	37.9	21.3	19.8	15.8	1.9	4.1

Peak demand savings can be found in the referenced attachment for this measure.

Measure Life:

15 years maximum (GDS)

Attachment:

TVA - Ltg Multifamily and LinFluor SF.xlsx [43]

5.1.1.6 Multifamily Residential Exit Signs

Sources:

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Measure Description:

This measure consists of retrofitting an incandescent exit sign with a more efficient LED unit, using either a new exit sign or retrofit kit. Advantages to updating to LED alternatives include reduced energy consumption and longer lamp life, which can reduce maintenance costs.

Assumptions:

Wattage assumptions for this measure were derived from the 2008 DEER, as shown in the following table. Operating hours are assumed at 8,760 hours per year.

Table 42. Exit Sign Wattage Assumptions

Existing Description	Retrofit Description	Retrofit Fixture Wattage
One 25 W Incandescent	One 2 W LED	2
Two 20 W Incandescent	Two 2 W LED	4

Using information from the table above, base case fixture options were averaged by retrofit wattage to calculate wattage reduction savings. Savings are based on the average savings across all retrofit and base case options.

Table 43. Exit Sign Average Wattage Assumptions

	Existing Wattage	Retrofit Wattage	Wattage Reduction
LED Exit Sign	32.5	3	29.5

[43] This document also includes savings compact fluorescent lamps, fixtures, and LED lamps.

Savings:

The annual energy savings is 258 kWh based on 8,760 annual operating hours. The peak demand savings is equal to the instantaneous demand reduction of 0.0295 kW because the measure is continuously running, 8,760 hours per year.

Life:

16 years (DEER 2008).

Attachment:

TVA - Ltg Multifamily and LinFluor SF.xlsx

5.1.1.7 Multifamily Residential Occupancy Sensors and Photocells

Sources:

SCE. "Wall Mounted Occupancy Sensors - Multifamily and Hospitality." Work paper SCE13LG020, Revision 0, April 2012.

DEER. *Update Study Final Report - Residential and Commercial Non-Weather Sensitive Measures.* 2005

DEER. 2008. www.deeresources.com

ADM and TecMarket Works. *Statewide Survey of Multifamily Common Area Building Owners Market: Volume I: Apartment Complexes,* June 2000.

Measure Description:

In residential use, occupancy sensors and photocells are most prevalent in multifamily common areas, since they turn lighting off and on as needed. Occupancy sensors detect motion or occupancy in a room or area. Photocells turn outside lighting on when no other lighting source is available, such as daylight.

Assumptions:

To calculate energy savings, the SCE work papers assumed an occupancy sensor controls four 2-lamp T8 fixtures with 32 W electronic ballast (for a total of 52 W per fixture), which is a total of 208 W controlled. The assumed measure operating hours for indoor common areas are shown in the following table.

Table 44. Multifamily Common Area Operating Hours

Indoor Common Area	Operating Hours
Club House	5,066
Laundry Room/Facility	4,460
Athletic/Exercise Facility	3,143
Kitchen	4,796
Hallway	8,526
Office Areas	3,555

Occupancy sensor savings assume a 20% non-usage value for all controlled spaces.[44] Savings were calculated using the following equation:

$$\text{Energy Savings (kWh)} = \frac{(\text{controlled wattage}) \times (\text{annual operating hours}) \times (20\%)}{1{,}000}$$

The research team assumed that existing exterior lights were controlled by a timed clock; a measure retrofit saw the clock replaced with a new photocell. Using a photocell, exterior lights operate approximately 4,100 hours per year. Without the photocell, the lights operate an additional 280 hours per year (approximately 3 months at 3 hours per day). To calculate savings, KEMA assumed photocell controlled four 70 W high-pressure sodium exterior lamps with an effective 95 W including the ballast.

Savings:

Occupancy sensor savings in multifamily common areas are shown in the following table.

Table 45. Multifamily Occupancy Sensor kWh Savings (per Sensor)

Indoor Common Area	Savings
Club House	211
Laundry Room/Facility	186
Athletic/Exercise Facility	131
Kitchen	200
Hallway	355

[44] SCE work paper that references DEER 2005.

Indoor Common Area	Savings
Office Areas	148

Savings for a photocell are 106 kWh per year. Due to the nature of occupancy sensors, peak demand savings cannot be sufficiently determined without case-by-case metering.

Life:

8 years for occupancy sensors (2008 DEER) and for photocells (2005 DEER).

Attachment:

TVA - Ltg Multifamily and LinFluor SF.xlsx

5.1.2 Appliances

5.1.2.1 ENERGY STAR Residential Clothes Washer

Sources:

ENERGY STAR Program, www.energystar.gov

U.S. Department of Energy, Energy Efficiency & Renewable Energy, Building Technologies Office, http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43

U.S. Department of Energy, Federal Energy Management Program, Life Cycle Calculator

TVA 2012 Residential Saturation Survey, February 2013

Energy Right Program Model Assumptions, August 2008

Measure Description:

This measure applies to the replacement of a standard clothes washer with an ENERGY STAR-qualified clothes washer. ENERGY STAR-qualified residential clothes washers wash more clothing per load than standard machines while using less water and energy.

Assumptions:

The baseline clothes washer meets the minimum federal standard,[45] while the efficient clothes washer meets the minimum ENERGY STAR[46] specification. The criteria for clothes washer performance are the modified energy factor (MEF) and the water factor. The MEF is defined as the volume of laundry, in cubic feet, that can be washed and dried in one cycle using 1 kWh of electricity. The water factor is defined as the volume of water, in gallons, needed to wash a cubic foot of laundry. The following table lists the MEF and water factor requirements for the federal standard and ENERGY STAR qualification.

Table 46. Standards for Residential Clothes Washers

Specification	Federal Standard	ENERGY STAR
MEF (ft^3/kWh/cycle)	≥ 1.26	≥ 2.0
Water Factor (gallons/ ft^3)	≤ 9.5	≤ 6.0

Savings calculations are based on industry data assembled by the U.S. Department of Energy Life Cycle Calculator, as well as TVA's saturation study data. These measure calculation assumptions are presented in the following table:

Table 47. Calculation Assumptions

Parameter	Value	Source
Average Laundry Load Cycles per Year	392	ENERGY STAR
TVA Water Heating Source - Electricity	70.2%	TVA Saturation Survey (2012)
TVA Water Heating Source - Gas	29.8%	TVA Saturation Survey (2012)
TVA Clothes Dryer Energy Source - Electricity	95.3%	TVA Saturation Survey (2012)
TVA Clothes Dryer Energy Source - Gas	4.7%	TVA Saturation Survey (2012)
Average Gas Water Heater Energy Factor	0.89	Energy Right program model
Water Heating Temperature Increase	75°F	Federal test method[47]

Savings:

45 http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/39 Accessed January 13, 2015.

46 http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/commercial_clothes_washers/Clothes_Washers_Program_Requirements_Version_6_1.pdf?9e1f-40a9 Accessed January 13, 2015.

47 10 CFR 430, Subpart B, Appendix J1.

Annual electrical energy savings were calculated as the difference in annual energy consumption between the baseline and ENERGY STAR clothes washers. The annual energy consumption includes washing machine energy, electric water heating energy, and reduced electric dryer energy (due to more moisture being extracted during the spin cycle in more efficient clothes washer). For clothes washer installations with gas water heating source or gas fueled dryers, the water heating or dryer term becomes zero and the therm energy savings is accounted for in the therm savings equations. The energy savings equation and annual energy consumption equation are shown below.

$$\text{Annual kWh Savings} = \text{Annual kWh}_{\text{baseline}} - \text{Annual kWh}_{\text{ENERGY STAR}}$$

$$\text{Annual kWh} = \left[\text{machine energy}\frac{\text{kWh}}{\text{cycle}} + \text{elec water heating}\frac{\text{kWh}}{\text{cycle}} + \text{elec dryer}\frac{\text{kWh}}{\text{cycle}}\right] \times \frac{\text{cycles}}{\text{year}}$$

Annual therm savings were calculated as the difference in annual therm consumption between the baseline and ENERGY STAR clothes washers. For clothes washer installations with electric water heating sources or electrically fueled dryers, the water heating or dryer therm becomes zero and the kWh energy savings is accounted for in the kWh savings equations. The annual therm consumption includes gas water heating energy and reduced gas dryer energy, as shown in the two equations below.

$$\text{Annual Therm Savings} = \text{Annual Therm}_{\text{Baseline}} - \text{Annual Therm}_{\text{ENERGY STAR}}$$

$$\text{Annual Therm} = \left[\text{gas water heating}\frac{\text{therms}}{\text{cycle}} + \text{gas dryer}\frac{\text{therms}}{\text{cycle}}\right] \times \frac{\text{cycles}}{\text{year}}$$

The following table shows energy savings for ENERGY STAR clothes washers by water heating source and dryer fuel type.

Table 48. Annual Energy Savings by Water Heating Source and Dryer Fuel Type

Water Heating Source and Dryer Fuel	Electric Savings (kWh)	Gas Savings (therms)
Electric Water Heater and Electric Dryer	261	-
Electric Water Heater and Gas Dryer	177	3.2
Gas Water Heater and Electric Dryer	92	6.5
Gas Water Heater and Gas Dryer	7	9.7

These annual energy savings values were used in conjunction with the TVA water-heating source and TVA dryer fuel type saturation data to produce TVA weighted annual energy savings. The weighted savings values are presented in the following table.

Table 49. Weighted Annual Energy Savings

Water Heating Source	kWh	therms
Electric Water Heater	257	3.2
Gas Water Heater	88	6.6
TVA Weighted Average	207	4.2

Peak demand savings were determined by applying a clothes washer-specific end-use peak factor developed from California load shapes for residential buildings to the TVA weighted average annual kWh savings for an a ENERGY STAR clothes washer. The peak demand savings in TVA's eastern district for summer is 0.055 kW in the summer and 0.027 kW in the winter. For its central district, summer peak demand savings are 0.054 kW, and winter peak savings are 0.013 kW.

Measure Life:

11 years (ENERGY STAR)

Attachment:

TVA - Res Clothes Washer.xls

5.1.2.2 Residential Electric Clothes Dryers

Sources:

California Energy Commission Appliance Database, http://www.appliances.energy.ca.gov/

Consumer Energy Center, www.consumerenergycenter.org

U.S. Department of Energy, Energy Efficiency & Renewable Energy, Building Technologies Office, http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/36

Measure Description:

This measure applies to the installation of a new energy-efficient electric clothes dryer that exceeds the federal minimum efficiency standard for electric clothes dryers.

A standard clothes dryer uses various temperatures and drying durations to dry clothes depending on clothing type and laundry load size. In most cases, the dryer cylinder is spun to rotate the wet clothes, as hot air is injected into the drying cylinder; wet moist air is then exhausted from the dryer. With non-efficient dryers, the drying cycle's duration is manually set. An energy-efficient clothes dryer uses a moisture-sensing device to terminate the drying cycle, rather than using a timer. In addition, an energy-efficient motor is used for spinning the dryer tub.

ENERGY STAR does not rate clothes dryers since they use approximately the same amount of energy regardless of the type or model. However, it recommends using a clothes dryer that is equipped with moisture-sensing technology, which saves up to 15% according to the Consumer Energy Center and that a qualifying clothes dryer should have an energy factor (EF) (lb/kWh) ≥ 3.07.

New federal standard and test procedures for dryers will become effective on January 1, 2015.

Assumptions:

Savings calculations are based on DOE test procedures and industry data gathered in the California Energy Commission (CEC) Appliance Database, as of June 2013. Key calculation assumptions are shown in the following table.

Table 50. Clothes Dryer Calculation Assumptions

Parameter	Value	Source
Average Federal Minimum EF	3.01	DOE Minimum EF Applied to CEC Appliance Database Models
Average Market EF	3.12	CEC Appliance Database, 2013
Pounds per Load	7.0	DOE Test Procedure, 2008
Loads per Year	416	DOE Test Procedure, 2008

Savings:

Savings were calculated using the average market and federal minimum Energy Factor (EF) values and the DOE test procedure assumptions. The average market EF was calculated from all listed electric dryers in the CEC Appliance Database as of June 2013. The federal minimum EF was calculated as the average based on the characteristics of the dryers in the CEC Appliance Database. Using these average EF values, the annual kWh savings were calculated using the following equation.

$$\text{Annual kWh savings} = \left[\frac{1}{\text{EF}_{\text{standard}}} - \frac{1}{\text{EF}_{\text{efficient}}}\right] \times \frac{\text{lb}}{\text{load}} \times \frac{\text{loads}}{\text{year}}$$

The following table lists the clothes dryer energy use and annual energy savings.

Table 51. Clothes Dryer Energy Use and Annual Savings (kWh/Year)

Dryer Type	Standard Dryer	Efficient Dryer
Energy Use (kWh/Load)	2.33	2.25
Annual Energy Use (kWh/Year)	967	935
Annual Energy Savings (kWh/Year)		**32.7**

The peak demand savings were determined by applying a clothes dryer-specific end-use peak factor developed from California load shapes for residential buildings to the annual kWh savings for efficient clothes dryers. The following table lists the peak demand savings for summer and winter in TVA's districts.

Table 52. Peak Demand Savings (kW)

Appliance Type	Summer		Winter	
	Eastern	Central	Eastern	Central
Clothes Dryer	0.0040	0.0040	0.0037	0.0022

Measure Life:

11 years (assumed to be similar to clothes washers)

Attachment:

TVA - Res Clothes Dryer.xls

5.1.2.3 ENERGY STAR Residential Dishwashers

Sources:

ENERGY STAR Program, www.energystar.gov

U.S. Department of Energy, Energy Efficiency & Renewable Energy, Building Technologies Office, http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/67

TVA 2012 Residential Saturation Survey, February 2013

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Measure Description:

This measure applies to the installation of an ENERGY STAR-qualified model in place of a federally minimum-compliant dishwasher.

Assumptions:

Savings calculations were based on methodology derived from the current ENERGY STAR appliance calculator[48] and product data from the ENERGY STAR qualified dishwasher list.[49] The federal standard[50] became effective May 30, 2013. Since January 20, 2012, the ENERGY STAR standard[51] requires that standard dishwashers have an annual energy consumption of 295 kWh or less, and compact dishwashers have an annual energy consumption of 222 kWh or less. The baseline dishwasher annual energy consumption is the federal maximum. The energy-efficient dishwasher annual energy consumption is the average ENERGY STAR-qualified model available on the market, as of May 29, 2013. These annual unit energy consumption (UEC) values are presented in the following table.

Table 53. Dishwasher Rated Unit Electricity Consumption (kWh/Year)

Dishwasher Size	Federal Standard	ENERGY STAR
Standard	≤ 307	≤ 272
Compact	≤ 222	≤ 211

Additional measure calculation assumptions are presented in the following table.

Table 54. Dishwasher Calculation Assumptions

Parameter	Value	Source
Dishwasher Cycles per Year	215	DOE Federal Test Procedure
Percent of Dishwasher Energy Used for Water Heating	56%	ENERGY STAR Program
Gas Water Heater Efficiency	75%	DOE Federal Test Procedure
TVA Water Heating Source - Electricity	70 %	TVA Saturation Survey (2012)
TVA Water Heating Source - Gas	30 %	TVA Saturation Survey (2012)

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48 www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx Accessed January 14, 2015.
49 https://data.energystar.gov/Government/ENERGY-STAR-Certified-Residential-Dishwashers/58b3-559d Accessed 1/13/2015.
50 http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/67 Accessed January 13, 2015.
51 https://www.energystar.gov/index.cfm?c=dishwash.pr_crit_dishwashers Accessed January 13, 2015.

Savings:

Savings were calculated, for each dishwasher size and water heating type combination, as the difference in annual kWh and therm consumption based on the federal standard and ENERGY STAR UEC. For electric water heating, the calculation of annual kWh savings included machine energy and water heating energy components. The following equations illustrate the calculation of annual kWh savings for dishwashers using electric water heating.

$$\text{Annual kWh Savings} = \text{Annual kWh}_{\text{baseline}} - \text{Annual kWh}_{\text{ENERGY STAR}}$$

$$\text{Annual kWh} = \text{Machine}\frac{\text{kWh}}{\text{year}} + \text{Water Heating}\frac{\text{kWh}}{\text{year}}$$

$$\text{Annual kWh} = \text{UEC gas}\left(\frac{\text{kWh}}{\text{year}}\right) \times (1 - \%\text{ Elec Water Heating}) + \text{UEC Electric}\left(\frac{\text{kWh}}{\text{year}}\right) \times (\%\text{ Elec Water Heating})$$

For natural gas water heating, the annual kWh savings calculation only considered the machine energy component,[52] while the annual therms savings calculation accounted for the water-heating component. The following equations show the calculation of therms saving component for dishwashers using natural gas water heating.

$$\text{Annual Therm Savings} = \text{Annual Therm}_{\text{Baseline}} - \text{Annual Therm}_{\text{ENERGY STAR}} = \frac{\text{UEC}\left(\frac{\text{kWh}}{\text{year}}\right) \times \%\text{ Water Heating}}{\text{Gas Heating Efficiency }(\%)} \times .0.341\frac{\text{therms}}{\text{kWh}}$$

The annual kWh and therms savings for each water heating type were multiplied by the TVA saturation percentage of water heating types to arrive at TVA weighted average annual kWh and therms savings values. The unweighted and TVA weighted annual kWh and therms savings values for standard and compact dishwashers are presented in the following table.

[52] For natural gas water heating, the water heating term in the annual kWh equation was omitted.

Table 55. Dishwasher Annual Energy Savings (kWh/Year)

Water Heating Source	Electricity Savings (kWh/Year)	Gas Savings (therms/Year)
Standard Dishwashers		
Electric Water Heating	35	0.0
Gas Water Heating	15	0.9
TVA Weighted Average	29	0.3
Compact Dishwashers		
Electric Water Heating	11	0.0
Gas Water Heating	4.8	0.3
TVA Weighted Average	9.0	0.1

The peak demand savings were determined by applying a clothes washer-specific[53] end-use peak factor developed from California load shapes for residential buildings to the annual kWh savings for an ENERGY STAR dishwasher. The following table lists the peak demand savings for TVA's districts.

Table 56. Dishwasher Peak Demand Savings (kW)

Dishwasher Size	Summer		Winter	
	Eastern	Central	Eastern	Central
Standard	0.008	0.008	0.004	0.002
Compact	0.002	0.002	0.001	0.001

Measure Life:

10 years (ENERY STAR)

Attachment:

TVA - ES Dishwashers.xlsx

5.1.2.4 ENERGY STAR Residential Refrigerator

Sources:

ENERGY STAR program, www.energystar.gov, accessed January 2015

[53] No dishwasher-specific end-use peak factor from California was available. The clothes washer end-use peak factor was used as a proxy peak factor in place of a dishwasher-specific peak factor.

U.S. Department of Energy, Energy Efficiency & Renewable Energy, Building Technologies Office, http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43

Measure Description:

This measure applies to the replacement of an old refrigerator with a new ENERGY STAR-qualified residential refrigerator.

Assumptions:

Since April 28, 2008, ENERGY STAR criteria require that all refrigerators must be at least 20% more efficient than the federal standard, which is based on the National Appliance Energy Conservation Act (NAECA). The following table lists the federal and ENERGY STAR efficiency requirements for different standard and compact refrigerator-freezer categories. The federal maximum unit energy consumption (UEC) was updated September 15, 2014.

Table 57. Refrigerator Maximum Energy Consumption (kWh/Year)

Refrigerator-Freezer Category	Federal Standard[54]	ENERGY STAR[55]
Standard Refrigerators		
Partial Automatic Defrost	8.82*AV + 248.4	7.056*AV + 198.72
Automatic Defrost with Top-Mounted Freezer without Through-The-Door Ice Service and All-Refrigerators--Automatic Defrost	9.80*AV + 276	7.84*AV + 220.8
Automatic Defrost with Side-Mounted Freezer without Through-The-Door Ice Service	4.91*AV + 507.5	3.928*AV + 406
Automatic Defrost with Bottom-Mounted Freezer without Through-The-Door Ice Service	4.60*AV + 459	3.68*AV + 367.2
Automatic Defrost with Top-Mounted Freezer with Through-The-Door Ice Service	10.20*AV + 356	8.16*AV + 284.8
Automatic Defrost with Side-Mounted Freezer with Through-The-Door Ice Service	10.10*AV + 406	8.08*AV + 324.8
Compact Refrigerators		
Compact Refrigerator and Refrigerator-Freezer with Partial Automatic Defrost	7.01*AV + 398	5.60*AV + 318.4
Compact Refrigerator-Freezer-Automatic Defrost with Top Freezer	12.70*AV + 355	10.16*AV + 284

[54] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43 Accessed 1/13/2015.

[55] http://www.energystar.gov/ia/partners/product_specs/program_reqs/Refrigerators_and_Freezers_Program_Requirements.pdf?d37a-d459 Accessed 1/13/2015.

Compact Refrigerator-Side Mounted Freezer with Automatic Defrost	7.60*AV + 501	6.08*AC + 400.8
Compact Refrigerator-Bottom Mount Freezer with Automatic Defrost	13.10*AV + 367	10.48*AV + 293.6

Savings:

The ENERGY STAR database catalogs energy use for federal standard- and ENERGY STAR-rated refrigerators. KEMA calculated average federal standard and ENERGY STAR UEC for each refrigerator type category, using data from the ENERGY STAR database[56] (last modified 5/27/2013). The kWh difference between the two standards equals expected energy savings.[57] The following table presents the annual energy consumption and savings values of standard and compact refrigerator categories.

Table 58. Refrigerator UEC and Annual Savings (kWh/Year)

Refrigerator Class Category	Federal Standard (kWh/Year)	ENERGY STAR (kWh/Year)	Savings (kWh/Year)
Standard Refrigerators			
Bottom Freezer	610	477	133
Refrigerator Only - Single Door	441	337	104
Refrigerator/Freezer - Single Door	450	348	102
Side-by-Side	710	555	155
Top Freezer	476	370	107
Compact Refrigerators			
Bottom Freezer	452	362	90
Refrigerator Only - Single Door	371	284	86
Refrigerator Only - Single Door	371	284	86
Side-by-Side	446	330	116
Top Freezer	417	307	110

Since there is limited TVA refrigerator saturation data indicating construction class, a straight average of unit energy consumption for all available ENERGY STAR models was used to calculate the ENERGY STAR refrigerator energy savings. The average savings values are presented in the following table.

[56] http://downloads.energystar.gov/bi/qplist/refrigerators.xls Accessed 1/13/2015.

[57] Actual refrigerator energy consumption varies on a variety of usage factors, such as door opening and closing frequency, surrounding room temperature, type of food stored, and amount of food stored.

Table 59. Average Refrigerator UEC and Energy Savings (kWh/Year)

Refrigerator Size	Federal Standard (kWh/Year)	ENERGY STAR (kWh/Year)	Savings (kWh/Year)
Standard	594	463	131
Compact	378	288	90

Peak demand savings were determined by applying a refrigerator-specific end-use peak factor developed from California load shapes for residential buildings to the annual kWh savings for an ENERGY STAR refrigerator. The following table lists the peak demands savings for summer and winter periods in TVA's districts.

Table 60. Refrigerator Peak Demand Savings (kW)

Refrigerator Size	Summer		Winter	
	Eastern	Central	Eastern	Central
Standard	0.020	0.019	0.013	0.012
Compact	0.014	0.013	0.009	0.009

Measure Life:

12 years (ENERGY STAR appliance savings calculator)

Attachment:

TVA - ES Res Refrigerator.xls

5.1.2.5 ENERGY STAR Residential Freezer

Sources:

ENERGY STAR Program, www.energystar.gov, accessed January 20155

U.S. Department of Energy, Energy Efficiency & Renewable Energy, Building Technologies Office, http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43

Measure Description:

This measure applies to the replacement of an older freezer with a new ENERGY STAR residential freezer.

Assumptions:

ENERGY STAR requires that freezers with a volume of 7.75 cubic ft. or larger must use at least 10% less energy than the current federal standard, and freezers with a volume less than 7.75 cubic ft. must use at least 20% less energy than the current federal standard, which is based on the National Appliance Energy Conservation Act (NAECA).[58] The following table lists standards for different freezer categories. Federal maximum UEC was updated September 15, 2014.

Table 61. Freezer Maximum UEC (kWh/Year)

Freezer Class Category	Federal Standard[59]	ENERGY STAR[60]
Standard Freezers		
Upright Freezer with Manual Defrost	7.55*AV + 258.3	6.80*AV + 232.5
Upright Freezer with Auto Defrost	12.43*AV + 326.1	11.19*AV + 293.5
Chest Freezer/All Other Freezers	9.88*AV + 143.7	8.89*AV + 139.3
Compact Freezers		
Compact Upright Freezers with Manual Defrost	9.78*AV + 250.8	7.82*AV + 200.6
Compact Upright Freezers with Auto Defrost	11.40*AV + 391	9.12*AV + 312.8
Compact Chest Freezers	10.45*AV + 152	8.36*AV +121.6

Savings:

The ENERGY STAR database catalogs energy use for federal maximum and ENERGY STAR-rated upright or chest freezers (last modified 5/27/2013). Upright freezers are divided into manual or automatic defrost subcategories. The following table presents the average federal standard and ENERGY STAR-qualified UEC for each freezer category; the difference in kWh/year between the federal maximum and ENERGY STAR unit energy consumption equals the expected annual kWh savings.

[58] http://www.energystar.gov/index.cfm?c=refrig.pr_crit_refrigerators Accessed 1/13/2015.

[59] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43 Accessed 1/13/2015.

[60] http://www.energystar.gov/ia/partners/product_specs/program_reqs/Refrigerators_and_Freezers_Program_Requirements.pdf?ecda-b134 Accessed 1/13/2015.

Table 62. Freezer UEC and Annual Savings (kWh/Year)[61]

Freezer Class Category	Federal Standard (kWh/Year)	ENERGY STAR (kWh/Year)	Savings (kWh/Year)
Standard Freezers			
Upright Freezer with Manual Defrost	443	388	54
Upright Freezer with Auto Defrost	686	606	81
Chest Freezer/All Other Freezers	392	351	41
Compact Freezers			
Compact Upright Freezers with Manual Defrost	306	238	69
Compact Upright Freezers with Auto Defrost	495	355	140
Compact Chest Freezers	257	204	54

Since there are no current TVA freezer saturation data indicating construction type, a straight average of unit energy consumption for all available ENERGY STAR models was used to calculate an ENERGY STAR freezer energy savings. The average savings values are presented in the following table.

Table 63. Average Freezer UEC and Energy Savings (kWh/Year)

Refrigerator Size	Federal Standard (kWh/Year)	ENERGY STAR (kWh/Year)	Savings (kWh/Year)
Standard	597	527	69
Compact	299	231	68
All	562	493	69

Peak demand savings were determined by applying a freezer-specific end-use peak factor developed from California load shaped for residential buildings to the annual kWh savings for an ENERGY STAR freezer. The following table lists the peak demand savings for summer and winter periods in TVA districts.

Table 64. Freezer Peak Demand Savings (kW)

Freezer Size	Summer		Winter	
	Eastern	Central	Eastern	Central
Standard	0.011	0.011	0.006	0.006
Compact	0.011	0.011	0.006	0.006

[61] Actual energy consumption varies upon ambient temperature, frequency of use, density of storage, and food types being stored.

Measure Life:

12 years (ENERGY STAR appliance savings calculator)

Attachment:

TVA - ES Res Freezer.xls

5.1.2.6 Residential Refrigerator and Freezer Recycling

Sources:

Regional Technical Forum, ResFridgeFreezeDecommissioning_v2_5.xlsm, 12/11/2012

Measure Description:

Appliance recycling programs target residential customers who remove inefficient yet operable refrigerators or freezers of any vintage. These programs reduce overall energy consumption by removing inefficient refrigerators or freezers, which otherwise would have stayed in use. Replacement options are either no replacement (i.e., removal of secondary unit) or replace with an ENERGY STAR unit. The programs may also offer free appliance pickup and/or financial incentives to motivate residents to recycle.

Assumptions:

Energy savings were calculated by multiplying refrigerator and freezer UEC values with factors that account for differences in UEC performance due to in situ conditions, part-use factor, and if the unit was left on-grid without the program or not (identified as a net-to-gross value). Additionally, the savings assume three replacement scenarios: (1) recycle and replace with ENERGY STAR unit; (2) recycle only; and (3) a weighted average of all scenarios as referenced in in the Regional Technical Forum (RTF)[62] workbook. The unit replacement scenarios in this analysis were based on results from various evaluation reports and other studies as referenced in the RTF workbook. The input parameters are summarized below and provided in the summary tab of the RTF workbook.

[62] The RTF is an advisory committee for the Pacific Northwest Electric Power and Conservation Planning Council. As part of this role, the RTF develops and maintains a list of eligible conservation resources including unit energy savings for qualified measures. They maintain operative guidelines for requirements to establish these savings, costs and benefits, and lifetime for the measures.

Table 65. Refrigerator and Freezer UEC Values (kWh/Year)

Parameter	Possible Values	Further Explanation[63]
Part-use Factor	Refrigerator - 93% Freezer - 90%	Weighted average from impact evaluation studies.
Base Year	2011	This year is used to define profile of age of recycled units.
Annual Degradation Factor	1%	UEC of recycled unit is expected to increase by this percentage of the rated UEC every year from manufacture to the base year.
In-situ Factor	81%	This factor is used to adjust to actual UES from lab/rated UEC.
Left On Grid Factor	Refrigerator - 66% Freezer - 67%	Fraction of units which would have been left on the grid without the program. Program evaluation results of what would have happened without the program. Net-to-gross studies are used to account for normal (end-of-life) replacement or decommissioning of appliances.
Kept Factor	Refrigerator- 8% Freezer- 12%	Fraction of units left on grid without the program that would have been kept and used by participants without the program.
Induced Replacement (R1)	2%	Fraction of recycled appliances where the program caused the participant to acquire a unit.
Replacement by Would-be Owner (R2)	50%	Fraction of recycled appliances which with the program are "replaced" by the would-be owner. This parameter only applies to appliances which without the program would have been sold or donated by program participant and ultimately used by a would-be owner (left on grid).
Fraction of New Replacement Units	R1 case: 85% R2 case: 59%	Applies to refrigerators only.
C-Factor	Refrigerator: -5% Freezer: -4%	The purpose of this factor is to account for the shift in the age and energy consumption of units being recycled over time (newer, less consuming units are being recycled each year). This is necessary because the refrigerator/freezer vintage data are historical, whereas the measure UES applies to future measure deliveries.

The baseline is the UEC (1,145 kWh/unit for refrigerators and 1,192 kWh/unit for freezers) if the unit would have remained in use. ENERGY STAR UEC as provided in the RTF workbook is 495 kWh/unit for refrigerators and 500 kWh/unit for freezers. To calculate annual energy savings, refrigerator and freezer units' full annual energy consumption was multiplied and weighted by the factors provided in the above table. The replacement UEC is based on the unit that replaces the recycled unit and noted by the fraction of new or used replacement units or if there is no replacement. The Logic Model tab of this workbook provides the calculation methodology of the savings.

[63] Sources can be found in the RTF workbook.

Savings:

Annual energy savings were calculated by all the factors above including the UEC for multiplying the baseline UEC and the various replacement UEC values by the three adjustment factor values (part-use, in-situ, and net-to-gross) for each refrigeration unit type and summarized in the following table.

Table 66. Adjustment Factors for Refrigerator and Freezer Recycling Savings Calculation

Factor	Refrigerator	Freezer
In-Situ Performance Adjustment Factor	81.0%	81.0%
Part Use Factor	93.0%	90.0%
NTG (percent left off-grid or not used)	66.0%	67.0%

$$\text{Energy Savings}\left(\frac{\text{kWh}}{\text{yr}}\right) = \left[\text{Average Replaced Unit UEC}\left(\frac{\text{kWh}}{\text{yr}}\right) - \text{New } \textbf{or} \text{ no New Unit UEC}\left(\frac{\text{kWh}}{\text{yr}}\right)\right] \times \text{In Situ Adjustment Factor} \times \text{Part} - \text{Use Factor} \times \text{NTG}$$

The measure annual energy savings for the three recycle/replacement options are presented in the following table.

Table 67. Refrigerator and Freezer Recycling Energy Savings (kWh/Year)

Replacement Scenario	Refrigerator	Freezer
Recycled and Replaced	323.2	338.0
Recycled and Not Replaced	569.3	582.2
Weighted Average (Recycled, Replaced, Sold/Donated)[64]	424.0	478.0

Peak demand savings were determined by applying refrigerator-specific and freezer-specific end-use peak factors developed from California load shapes for residential buildings to the annual kWh savings for recycling a refrigerator or freezer, respectively. The tables below list the peak demand savings for summer and winter periods in TVA's districts.

[64] The baseline is the removed and/or replaced unit consumption if they would have continued to be in use without the program. This baseline is adjusted to indicate if it was not-used (by the NTG factor) or if it would have remained in use by either selling/donating or keeping it. The post-retrofit consumption is the equipment that replaces the recycled unit which varies under the following scenarios: (1) Used replacement unit (e.g., moving a primary refrigerator to secondary usage); (2) New unit is installed; and (3) No replacement.

Table 68. Refrigerator Recycling Peak Demand Savings (kW)

Unit Type	Summer		Winter	
	Eastern	Central	Eastern	Central
Recycled and Replaced	0.048	0.048	0.031	0.030
Recycled and Not Replaced	0.085	0.084	0.055	0.054
Weighted Average (Recycled, Replaced, Sold/Donated)	0.064	0.063	0.041	0.040

Table 69. Freezer Recycling Peak Demand Savings (kW)

Unit Type	Summer		Winter	
	Eastern	Central	Eastern	Central
Recycled and Replaced	0.055	0.054	0.028	0.028
Recycled and Not Replaced	0.094	0.093	0.049	0.049
Weighted Average (Recycled, Replaced, Sold/Donated)	0.077	0.076	0.040	0.040

Measure Life:

The recycling measure life is 6.5 years for refrigerators and 5 years for freezers per the RTF workbook. The original source data of the survival curves to calculate the remaining useful life of the baseline equipment average is DOE Technical Support Document 2009 (http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/ref_frz_prenopr_prelim_tsd.pdf).

Attachment:

TVA - Refrig and Freezer Recycling.xlsx and ResFridgeFreezeDecommissioning_v2_5.xls

5.1.3 Water Heating

5.1.3.1 Heat Pump or Solar Assisted Water Heater

Sources:

U.S. Department of Energy, Energy Efficiency & Renewable Energy, Building Technologies Office, http://www1.eere.energy.gov/femp/technologies/eep_waterheaters_calc.html

TVA 2012 Residential Saturation Survey, 2007.

Labs, Kenneth. "Underground Building Climate." Solar Age. October, p. 44. 1979.

U.S. Department of Energy, Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters; Final Rule. 1998.

U.S. Department of Energy, Energy Efficiency & Renewable Energy, Building Technologies Office, http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/27

ENERGY STAR Residential Water Heaters: Final Criteria Analysis," April 1, 2008

ENERGY STAR Program Requirements for Residential Water Heaters v2.0, July 2013, http://www.energystar.gov/index.cfm?c=water_heat.pr_crit_water_heaters

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Measure Description:

This measure applies to the replacement of a standard efficiency domestic water heater with a new heat pump water heater or solar assisted water heater with electrical backup heating. Water heater measures compare energy consumption of a standard storage water heater (EF=0.904) to the following types of water heaters:

- ENERGY STAR-qualified solar with electric backup
- ENERGY STAR-qualified electric heat pump

Heat pumps use technology similar to air conditioners and refrigerators to move heat from one source (ambient air) to another (water), instead of using heat from resistive electric load. Solar water heaters use collected energy from the sun to heat water. In almost all cases, solar water heaters are backed up by a conventional water heater. However, solar water heaters offset the amount of conventional energy required to heat water.

Assumptions:

Energy savings are calculated using the energy usage differences between a base water heater that meets federal standards and an ENERGY STAR-qualified water heater or other high-efficiency water heater.[65] The following table shows electric water heater federal minimum efficiency standards as of January 2004. Overall efficiency is measured by EF, which is a ratio of useful energy output to total energy consumed

[65] Due to technological limitations (U.S. DOE, 2008), ENERGY STAR does not qualify any electric water heaters, except heat pumps.

by the water heater. In this case, useful energy output equals the amount of heat transferred to the water.[66]

Table 70. Federal Minimum Energy Factor for Residential Electric Water Heaters

Heater Type	Federal Standard EF Rating Formula	EF with 50 Gal Volume
Baseline Electric Storage	0.97 - (0.00132 x Rated Storage Volume in gallons)	0.904

ENERGY STAR water heater criteria, as of September 2013, are listed in the following table.

Table 71. ENERGY STAR Water Heater Energy Factor Values

Heater Type	ENERGY STAR Qualified EF	High Efficiency EF	Source
Heat Pump Storage	≥ 2.0	N/A	ENERGY STAR Program Requirements for Residential Water Heaters v2.0, July 2013
Solar (with Electric Backup)	SEF ≥ 1.8	N/A	ENERGY STAR Program Requirements for Residential Water Heaters v2.0, July 2013

The following assumptions were used to calculate water-heater savings.

Table 72. Water Heater Variable Assumptions

Variable	Value	Units	Source
Average Gallons of Hot Water Used Per Household per Day	64.0	Gal	U.S. DOE, EERE. Assumption for Energy Cost Calculator for Electric and Gas Water Heaters
Average Rated Storage Volume	50.0	gal/ unit	TVA Saturation Survey 2007 (Assumptions)
Temperature of Water Entering Water Heater	60	°F	Water temperature represents a rough annual US average adopted from data in Labs (1979)
Temperature of Hot Water	135	°F	DOE, Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters; Final Rule, 1998
Water Density	8.33	lb/gal	
Specific Heat of Water	1	Btu/lb-F	
Number Btu per kWh	3413	Btu/kWh	

[66] The amount of heat transferred is based on three main factors for water heaters: (1) how efficiently energy (heat) is transferred to the water by the heating element, (2) what percentage of energy is lost during storage times, and (3) how much energy is used when cycling between active and standby modes

Savings:

Water heater savings were calculated from the difference in annual energy consumption between the 50-gallon baseline electrical storage water heater and the high efficiency water heaters. Annual energy consumption was calculated for each water heater type according to the following equations.

$$\text{Annual kWh Consumption} = \frac{\frac{\text{Avg gallons}}{\text{household} \cdot \text{day}} \times \Delta T \times \rho_{\text{Water}} \times \text{Specific Heat}_{\text{Water}} \times 365 \frac{\text{days}}{\text{year}}}{3413 \frac{\text{Btu}}{\text{kWh}} \times \text{EF}_{\text{Baseline or Measure}}}$$

Where,

$$\Delta T = \text{Temp}_{\text{Hot}} - \text{Temp}_{\text{Entering}}$$

The annual energy consumption, annual energy savings, and annual savings as a percent of baseline energy consumption values are presented in the following table.

Table 73. Water Heater Annual Energy Consumption and Savings[67]

Heater Type	Annual Energy Consumption (kWh/Year)	Annual Energy Savings (kWh/ Year)	Annual Energy Savings as a Percentage of Baseline Consumption
Baseline Electric Storage Water Heater	4730	0	0%
Solar (with Electric Backup)	2376	2355	50%
Heat Pump Storage	2138	2592	55%

Peak demand savings were determined depending on the type of water heater. TVA based model prototypes using standard water heaters are used as a proxy for peak demand savings for the heat pump and solar w/electric backup. It is assumed that solar water heating does not save during the winter peak.

Table 74. Water Heater Peak Demand Savings (kW)

Heater Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Solar (w/Electric Backup)	0.13	0.000	0.159	0.000
Heat Pump	0.143	0.558	0.175	0.583

[67] New standards are in effect in 2015 and baseline and high efficiency unit energy consumption values will need to be updated.

Measure Life:

Solar (w/ electric backup): 15 (DEER 2008)

Heat Pump: 10 (DEER 2008)

Attachment:

TVA - Res Water Heater.xlsx

5.1.3.2 Residential Faucet Aerator

Sources:

U.S. Department of Energy, Energy Efficiency & Renewable Energy, Building Technologies Office, http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/64

US Environmental Protection Agency, WaterSense Program 2012, http://www.epa.gov/watersense/products/bathroom_sink_faucets.html

TVA 2012 Residential Saturation Survey, February 2013

Aquacraft, Inc. Water Engineering 2003 Residential Indoor Water Conservation Study, Prepared for East Bay Municipal Utility District and the US EPA, Mayer and DeOreo

Aquacraft, Inc. Water Engineering 2011 Analysis of Water Use in New Single-Family Homes, Prepared for Salt Lake City Corporation and U.S. EPA, Mayer and DeOreo

ACEEE 2008 Energy Related Water Fixture Measurements: Securing the Baseline for Northwest Single-Family Homes, Schuldt

TVA EnergyRight® Program Model Assumptions, August 2008

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Measure Description:

This measure applies to the installation of low-water flow aerators on residential faucets which provide hot water. Low-flow aerators are inexpensive and provide lasting water and energy conservation by reducing the amount of water used at the faucet. The energy savings result from the reduction in heating load on the electric DHW heater. This measure compares annual energy savings between a standard domestic sink aerator with a maximum flow rate of 2.2 gallons per minute[68] (gpm) and a low-flow aerator with a maximum flow rate of 1.5 gpm.[69] Aerators may be installed on kitchen or bathroom faucets, but the faucet must provide hot water to the user. Only DHW systems fueled by electrical water heaters are eligible for this measure.

Assumptions:

The end-use consumption of water and the portion ultimately heated by a water heater can affect energy savings from a low-flow faucet aerator; end-use considerations include the number of occupants in a home, occupant age, occupant income level, duration of use, and water-temperature preference. The following table summarizes assumptions engineers made to estimate water and energy savings.

Table 75. Aerator Calculation Assumptions

Variable	Value	Units	Source
Average TVA occupancy	2.8	Number	2012 TVA Residential Saturation Survey
Average Hot Water Faucet Use	7.9	Min/ cd	Mean calculated from various sources, see following table
Number of Faucets per Household	3.0	Number	Assumed one kitchen and 2 bathroom faucets per household
Temperature of Water Entering Water Heater	60	°F	Water temperature represents a rough annual US average adopted from data in Labs (1979)
Temperature of Hot Water Leaving Faucet	105	°F	Based on surveys cited in Brown and Caldwell 1984
Water Heater Efficiency	0.89	EF	Based on Energy Right Program Model Assumptions
Water Density	8.33	Lb/gal	
Specific Heat of Water	1	Btu/lb-F	
Number Btu per kWh	3413	Btu/kWh	
Base In Situ Flow Rate	1.5	GPM	Mean calculated from various sources, see next table
Aerator In-Situ Flow Rate	1.0	GPM	Mean calculated from various sources, see next table

The mean daily hot water faucet use and in-situ metered faucet flow rates were calculated from the three water conservation studies shown in the following table.

[68] Federal Maximum faucet flow rate, DOE, EPAct 1992 http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/64

[69] EPA WaterSense 2012 http://www.epa.gov/watersense/products/bathroom_sink_faucets.html

Table 76. Faucet Usage and Flow Rate Values

Mean Daily Use (min/day)	Base Flow Rate (GPM)	Aerator Flow Rate (GPM)	Source
7.2	1.2		2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study[70]
8.6	1.0		2011, DeOreo, William. Analysis of Water Use in New Single-Family Homes[71]
	2.2	1.0	2008 Schuldt. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single-Family Homes[72]
7.9	1.5	1.0	Calculated Mean

Savings:

The annual energy savings were determined by calculating the annual hot water use for the baseline and low-flow aerator faucets, then converting the annual hot water use into annual water heater energy (kWh), and finally by taking the difference in annual water heater energy between the baseline and low-flow aerator faucets. This calculation methodology is shown in the following series of equations:

$$\text{Hot Water Use (gal/year)} = \text{Flow rate (gpm)} \times \text{Avg Occ.} \times \text{Hot Water Faucet Use (min/cd)} \times 365$$

$$\text{Annual kWh per faucet} = \frac{\text{Hot Water Use (gal/year)} \times \Delta T^{73} \times \text{Water Density} \times \text{Specific Heat of Water}}{3413\ \frac{\text{Btu}}{\text{kWh}} \times EF_{\text{water heater}} \times \text{\# of Faucets per Household}}$$

$$\text{Annual kWh savings} = \text{Annual kWh per faucet}_{\text{baseline}} - \text{Annual kWh per faucet}_{\text{aerator}}$$

The calculated annual consumption and savings of hot water and electrical energy are presented in the following table.

[70] 2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study. Aquacraft, Inc. Water Engineering and Management. Prepared for East Bay Municipal Utility District and the US EPA. July 2003. Table 3.4, Pg 29.

[71] 2011, DeOreo, William. Analysis of Water Use in New Single-Family Homes. By Aquacraft. For Salt Lake City Corporation and US EPA. July 20, 2011.Table 4-2, Pg 59 and Table 4-24, Pg 87.

[72] 2008 Schuldt. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single-Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. ACEEE 2008 Summer Study. Table 2, pg 1-260.

[73] ΔT is the difference in temperature between the hot water leaving the faucet and the temperature of the water entering the water heater.

Table 77. Aerator Consumption and Savings of Hot Water and Electrical Energy

Calculation	Baseline Consumption	Aerator Consumption	Savings
Annual Hot Water Use per Household (gallons/year)	11,675	7,924	3,751
Annual kWh per Faucet	360	244	116

Peak demand savings were determined by using a DHW-specific end-use load profile developed in eQuest for the TVA region residential baseline prototype. Peak load factors were extracted from the load profile using TVA's peak period times and then applied to the annual savings of 116 kWh. Listed in the following table are the summer and winter demand reduction values for TVA's time districts.

Table 78. Aerator Peak Demand Savings (kW)

TVA Time District	Summer	Winter
Central	0.006	0.024
Easters	0.008	0.026

Measure Life:

10 years (DEER 2008)

Attachment:

TVA - Faucet Aerator.xlsx

5.1.3.3 Residential Low-Flow Showerhead

Sources:

U.S. Department of Energy, Energy Efficiency & Renewable Energy, Building Technologies Office, http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/37

US Environmental Protection Agency, WaterSense Program 2012, http://www.epa.gov/watersense/products/showerheads.html

TVA 2012 Residential Saturation Survey, February 2013

Aquacraft 1999 Residential End Uses of Water, Prepared for AWWA by Mayer and DeOreo

Aquacraft, Inc. Water Engineering 2003 Residential Indoor Water Conservation Study, Prepared for East Bay Municipal Utility District and the US EPA, Mayer and DeOreo

Aquacraft, Inc. Water Engineering 2011 Analysis of Water Use in New Single-Family Homes, Prepared for Salt Lake City Corporation and US EPA, Mayer and DeOreo

ACEEE 2008 Energy Related Water Fixture Measurements: Securing the Baseline for Northwest Single-Family Homes, Schuldt

Energy Right Program Model Assumptions, August 2008

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Measure Description:

This measure applies to the installation of low water showerheads in residential hot water showers. Low flow showerheads are inexpensive and provide lasting water and energy conservation by reducing the amount of water used when showering. The energy savings result from the reduction in heating load on the DHW heater. This measure compares annual energy savings between a standard domestic showerhead with a maximum flow rate of 2.5 gpm [74] and a low-flow showerhead with a maximum flow rate of 2.0 gpm.[75]

Installed showerheads must provide hot water to the user. Only DHW systems fueled by electrical water heaters are eligible for this measure.

Assumptions:

The end-use consumption of water and the portion ultimately heated by a water heater can affect energy savings from a low-flow showerhead; end-use considerations include the number of occupants in a home, occupant age, occupant income level, duration of use, and water-temperature preference. The following table summarizes assumptions engineers made to estimate water and energy savings.

[74] Federal Maximum showerhead flow rate, DOE, EPAct 1992 http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/64

[75] EPA WaterSense 2012 http://www.epa.gov/watersense/products/showerheads.html

Table 79. Showerhead Calculation Assumptions

Variable	Value	Units	Source
Average Duration of Single Shower	8.4	Minutes	2012 TVA Residential Saturation Survey, see table
Average # People/Household	2.8	Number	Mean calculated from various sources, see Table
Average # Showers/Person/Day	0.8	Number	1999 Mayer, DeOreo
Average # Showers/Home	2.4	Number	2011, DeOreo, William. Table 4-9, Pg. 65.
Temperature of Water Entering Water Heater	60	°F	Water temperature represents a rough annual US average adopted from data in Labs (1979)
Temperature of Hot Shower Water	105	°F	Based on surveys cited in Brown and Caldwell 1984
Water Heater Efficiency	0.89	EF	Based on Energy Right Program Model Assumptions
Water Density	8.33	lb/gal	
Specific Heat of Water	1	Btu/lb-F	
Number Btu per kWh	3413	Btu/kWh	
Base Showerhead Flow Rate	2.3	GPM	Mean calculated from various sources, see Table
Efficient Showerhead Flow Rate	1.9	GPM	Mean calculated from various sources, see Table

The mean shower duration and showerhead flow rates were calculated from the three water conservation studies shown in the following table.

Table 80. Showerhead Usage and Flow Rate Values

Mean Shower Duration (min/day)	Base Flow Rate (GPM)	Retrofit Flow Rate (GPM)	Source
8.9	2.0		2003, Mayer, Peter, William DeOreo. Page 38.
8.2		2.0	2011, DeOreo, William. Table 4-22, Page 81.
8.2	2.5	1.8	2008 Schuldt. Table 3, Page 1-260.
8.4	**2.3**	**1.9**	**Calculated Mean**

Savings:

The annual energy savings were determined by calculating the annual hot water use for the baseline and low flow showerheads, then converting the annual hot water use into annual water heater energy (kWh), and finally by taking the difference in annual water heater energy between the baseline and low flow showerheads. This calculation methodology is shown in the following series of equations:

$$\text{Hot Water Use (gal/year)} = \text{Flow Rate (gpm)} \times \frac{\text{avg min}}{\text{shower}} \times \frac{\text{avg \# showers}}{\text{person day}} \times \frac{\text{Avg Occ.}}{\text{Household}} \times 365$$

Annual kWh per showerhead

$$= \frac{\text{Hot Water Use (gal/year)} \times \Delta T^{76} \times \text{Water Density} \times \text{Specific Heat of Water}}{3413\ \frac{\text{Btu}}{\text{kWh}} \times EF_{\text{water heater}} \times \text{\# of Showers per Household}}$$

Annual kWh savings

$$= \textbf{Annual kWh per showerhead}_{\textbf{baseline}} - \textbf{Annual kWh per showerhead}_{\textbf{low flow}}$$

The calculated annual consumption and savings of hot water and electrical energy are presented in the following table.

Table 81. Showerhead Consumption and Savings of Hot Water and Electrical Energy

Calculation	Baseline Consumption	Aerator Consumption	Savings
Annual Hot Water Use per Household (Gallons/Year)	14,295	12,071	2,224
Annual kWh per Showerhead	738	623	115

Peak demand savings were determined by using a DHW-specific end-use load profile developed in eQuest for the TVA region residential baseline prototype. Peak load factors were extracted from the load profile using TVA's peak period times and then applied to the annual kWh savings of 115 kWh. Listed in the following table are the summer and winter demand reduction values for TVA's time districts.

Table 82. Showerhead Peak Demand Savings (kW)

TVA Time District	Summer	Winter
Central	0.006	0.024
Eastern	0.008	0.025

Measure Life:

10 years (DEER 2008)

Attachment:

TVA - Low Flow Showerheads.xlsx

[76] ΔT is the difference in temperature between the hot water leaving the showerhead and the temperature of the water entering the water heater.

5.1.3.4 Hot Water Pipe Insulation

Sources:

"In-Home Energy Evaluation FY10 Program Impact and Process Evaluation Final Report," Tennessee Valley Authority, KEMA, Inc., July 2012

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Measure Description:

This measure applies to the addition of insulating wrap on bare hot-water piping. Hot-water pipe insulation increases the efficiency of a hot-water heating system by reducing the rate at which hot water heat is lost to the surrounding materials (e.g., framing, ambient air). Insulation also provides occupant safety by covering the hot water pipe, which can cause burns if touched. Additionally, some types of insulation also act as a corrosion inhibitor.

Under this measure, bare pipe size must be at least 1/2" or larger in bore diameter. The pipe wrap must provide at least R-3 insulation and a minimum of five feet of insulating pipe wrap, beginning at the water heater output, must be added to the hot-water heating system's existing bare pipe. Only electric water heating systems qualify for this measure.

Assumptions:

Baseline and retrofit insulation levels are based off the IHEE evaluation findings. IHEE participant data were used to develop DOE-2 building prototypes. The pipe insulation measure was modeled within these model prototypes. The baseline (R-0) and retrofit (R-3.43) values are used in the modeling.

Savings:

These savings can be found in TVA TRM Savings from IHEE.xlsx and per linear foot of pipe, by heating type for Nashville weather.

Table 83. Pipe Insulation Savings (per Linear Foot)

Heating Type	kWh Savings	Summer peak kW	Winter peak kW
Heat Pump	9.60	0.002	0.000
Gas Heat	10.20	0.002	0.002
Strip Heat	2.80	0.000	0.000

Life:

13 years (DEER 2008)

5.1.3.5 Electric Water Heater Insulation

Sources:

"In-Home Energy Evaluation FY10 Program Impact and Process Evaluation Final Report," Tennessee Valley Authority, KEMA, Inc., July 2012.

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Measure Description:

This measure applies to the addition of insulating wrap on an electric domestic hot water heater where no insulation exists.

Assumptions:

Baseline and retrofit insulation levels are based off the IHEE evaluation findings. IHEE participant data were used to develop DOE-2 building prototypes. The water heater insulation measure was modeled and savings determined from these model prototypes.

Savings:

These savings can be found in TVA TRM Savings from IHEE.xlsx and per hot water tank, by heating type for Nashville weather.

Table 84. Electric Water Heater Insulation Savings (per Unit)

Heating Type	kWh Savings	Summer peak kW	Winter peak kW
Heat Pump	159.00	0.020	0.010
Gas Heat	169.00	0.020	0.020
Strip Heat	47.00	0.010	0.000

Life:

7 years (DEER 2008)

5.1.4 Miscellaneous Measures

5.1.4.1 Residential Variable-Speed Pool Pumps

Sources:

ENERGY STAR Program, www.energystar.gov

2012 SCE "Residential Variable Speed Swimming Pool Pump." Work paper SCE13WP001.0.

California Energy Commission Appliance Database, www.appliances.energy.ca.gov /[77]

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Measure Description:

This measure applies to the replacement of an older single-speed or two-speed pool pump with a variable-speed pool pump. Residential swimming pool pumps circulate and filter swimming pool water to maintain clarity and purity. Residential pool pumps range in size from one-half to three horsepower. They average four hours of operation per day, but sometimes can be operational up to 10 hours per day. These pump motors typically draw approximately 1 kW per nominal horsepower.

Pool pumps must meet the ENERGY STAR requirement of an EF greater than or equal to 3.8 at their most efficient operating speed.[78] Variable-speed pool pumps and motors must be a new product installed in a pre-existing or new in-ground pool. Spa or Jacuzzi applications do not qualify.

Assumptions:

The baseline is either a single-speed or two-speed pool pump. Savings calculations assume an average pool capacity is 20,341 gallons that requires one full water turnover per day. A single-speed pump motor's baseline horsepower is 1.73 horsepower, which is based on SCE's program data.[79] A two-speed motor's baseline pump horsepower is also 1.73 horsepower, which is near the 1.70 horsepower average

[77] Updated March 2009. Accessed June, 2013.

[78] http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/pool_pumps/Pool_Pumps_Version1.0_Program_Requirements.pdf?c8d6-f8db

[79] SCE "Residential Variable Speed Swimming Pool Pump." Work paper SCE13WP001.0.

two-speed pool pump listed in the CEC database.[80] Variable speed pumps are 3.0 horsepower, since most variable-speed pumps available are rated at 3.0 horsepower.[81]

Savings:

This savings approach, from SCE's work paper, is based on field measurements and analysis of data taken from single- and variable-speed pool pump installations and two-speed pump test results from the CEC appliance database. These savings results are assumed applicable to swimming pools located in the TVA service area.

Annual energy savings are taken as the difference in annual energy use of the baseline and retrofit pool-pumps. Annual energy use was calculated using the following formula.

$$\text{Annual kWh} = \frac{\text{pool volume} \times \frac{\text{turnover}}{\text{day}} \times 365\,\frac{\text{days}}{\text{year}}}{\text{Energy Factor} \times 1000\,\frac{\text{W}}{\text{kW}}}$$

The energy factor values were calculated from field data of flow, pressure, and pump power draw for variable-speed and base case pool pump installations. Using this information, pump curves were plotted to determine the operating characteristics at different flow rates. The flow rates, energy factors, turnover rates, and annual energy consumption values are presented in the following table.

Table 85. Pool-Pump Calculation Variables and Annual Energy Use[82]

Configuration	Relative Frequency (Weights, %)	Pump Description	Turnovers per Day	Daily Gallons Pumped	Hours of Pumping	Energy Factor (Gal/Watt-hr)	Annual Energy Use (kWh/Yr)
Single-speed Pump: Baseline	100%	1.73 hp, Single Speed	1	20,341	5.2	2.18	3,406
Two-speed Pump: All pumping At Low Speed (20.7 GPM)	94.40%	1.73 hp, Two Speed	0.98	19,934	15.8	3.39	2,146
Two-speed Pump: (0.86/ 0.37 Turnover At Low/High Capacities)	5.60%	1.73 hp, Two Speed	0.86 0.37	17,493 at 21 gpm 7,526 at 65 gpm	14.1 filtering 1.9 pool sweeps	3.4 (low speed) 2.1 (high speed)	3,217

80 http://www.energy.ca.gov/appliances/database/historical_excel_files/Pool_Products/ Accessed Jan. 2015.

81 SCE "Residential Variable Speed Swimming Pool Pump." Work paper SCE13WP001.0.

82 SCE "Residential Variable Speed Swimming Pool Pump." Work paper SCE13WP001.0.

Configuration	Relative Frequency (Weights, %)	Pump Description	Turnovers per Day	Daily Gallons Pumped	Hours of Pumping	Energy Factor (Gal/Watt-hr)	Annual Energy Use (kWh/Yr)
VSD: All Pumping at 28.6 gpm	94.40%	3 hp, Variable Speed	0.98	19,934	11.6	4.37	1,665
VSD: (0.86/0.37 Turnover At Low/High Capacities)	5.60%	3 hp, Variable Speed	0.86	17,493 at 21 gpm	14.1 filtering	4.6 (1,361 RPM)	2,301
			0.37	7,526 at 45 gpm	2.8 pool sweeps	3.0 (2,317 RPM)	

Weighted averages were calculated for the two-speed and variable-speed pump energy usage, as two different operational schemes were assumed for these pumps. The weighted annual energy use for the baseline and retrofit case pool pumps are presented in the following table.

Table 86. Pool-Pump Weighted Annual Energy Use

Pump Type	kWh/Year
Single-speed baseline	3,406
Two-speed baseline	2,206
Variable-speed retrofit	1,701

Annual energy savings, calculated from the difference in weighted annual energy use between the baseline and retrofit pump types, are presented in the following table.

Table 87. Pool-Pump Annual Energy Savings

Baseline Pump Type	kWh/Year
Single-speed	1,705
Two-speed	506

Peak demand savings were determined using calculated electrical demand values and average coincidence factors obtained from the SCE work paper.[83] Electric demand for the single-speed pump was calculated using the SCE work paper regression equation relating electric demand and nameplate horsepower, and the assumed 1.73 horsepower of the single-speed pump. Electric demand for the two-speed pumps was derived from the CEC appliance database, taken for low-speed operation, since this is the default

[83] SCE "Residential Variable Speed Swimming Pool Pump." Work paper SCE13WP001.0. Peak coincident factors are based on DEER peak demand, defined as average demand between 2:00 pm and 5:00 pm during a three-day summer heat wave. The time period is similar to TVA territory peak definition and behavior is assumed to be similar.

operational mode. Electric demand for the variable-speed pump was taken from the SCE program data[84] presented in the work paper. Average pump load for the baseline and retrofit pumps is shown in the following table.

Table 88. Average Pool-Pump Electrical Demand (per Pump)[85]

Pump Type	Electrical Demand (kW)
Single-speed	1.763
Two-speed	0.376
Variable-speed	0.415

The pool pump coincidence factors are presented in the following table.

Table 89. Pool-Pump Coincidence Factors

Pump Type	Coincidence Factor (CF)
Single Speed	0.309
Two speed	0.522
VSD	0.390

Summer peak demand savings, calculated as the difference in the product of electrical demand and coincidence factor for the baseline and retrofit cases, are presented in the following table. No winter peak demand savings are realized from this measure.

Table 90. Pool-Pump Summer Peak Demand Savings

Baseline Pump Type	Peak Demand Savings (kW)
Single-speed	0.383
Two-speed	0.034

Measure Life:

10 years (DEER 2008)

Attachment:

TVA - Variable Speed Pool Pump.xlsx

[84] SCE 2006-2008 Innovative Designs for Energy-Efficiency (InDEE) program.

[85] SCE "Residential Variable Speed Swimming Pool Pump." Work paper SCE13WP001.0.

5.2 Non-Residential, Non-Weather-Sensitive Measures

The following sections document savings for non-residential, non-weather-sensitive measures. Savings are documented for certain measures that are applicable within the industrial sector. However, typically peak demand savings should be calculated on a case-by-case basis for the industrial sector. The measures with an asterisk are also applicable to new construction applications (as a single, stand-alone measure).

Table 91. Non-Residential, Non-Weather-Sensitive Deemed Measures

Measure Name	End Use
Screw-in CFL	Lighting
Hardwired CFL	Lighting
Cold Cathode	Lighting
Linear Fluorescent Lamp Removal	Lighting
High Performance T8	Lighting
Reduced Wattage T8	Lighting
LED Open Sign	Lighting
LED Lighting	Lighting
LED Exit Sign	Lighting
High Bay Lighting	Lighting
Pulse Start or Ceramic MH	Lighting
Integrated Ballast Ceramic MH	Lighting
Parking Garage - HID	Lighting
Parking Garage - High Wattage CFL	Lighting
Bi-Level Fixture	Lighting
LED Traffic Signal	Lighting
Occupancy Sensors	Lighting
Photocells	Lighting
Freezer/Cooler fixtures with LED lighting	Refrigeration
Freezer/Cooler case lighting controls	Refrigeration
ENERGY STAR Freezer/Cooler*	Refrigeration
Freezer/Cooler Case Doors	Refrigeration
High Efficiency Open and Reach-In Display Cases*	Refrigeration
High Efficiency Door Retrofit	Refrigeration
Night Curtains	Refrigeration
Electronic Commutated Motor in Reach-Ins	Refrigeration
Electronic Commutated Motor in Walk-Ins	Refrigeration
Evaporator Fan Controller	Refrigeration

Measure Name	End Use
Freezer/Cooler Auto Door Closers	Refrigeration
Strip Curtains	Refrigeration
Door Gaskets	Refrigeration
Anti-sweat heater controls	Refrigeration
Floating Head Pressure Controls	Refrigeration
Domestic Electric Water Heaters*	Water Heater
Pre-Rinse Sprayer	Water Heater
Vending Machine Controller - cold drinks	Miscellaneous
Vending Machine Controller - snacks	Miscellaneous
Cooking Equipment*	Miscellaneous
Icemakers*	Miscellaneous
Variable Speed Drive on Air Compressor	Miscellaneous
High Efficiency Transformer*	Miscellaneous
Battery Chargers	Miscellaneous
Engine Block Heater Timer	Agricultural
Low Pressure Sprinkler Nozzles	Agricultural
VSD on Dairy Vacuum/Transfer Pump	Agricultural

The calculations for the measures are provided in Nonres NWS Calculators.zip. In the zip file are the individual calculators referenced under the measures.

5.2.1 Non-Residential Lighting

This section discusses energy savings and demand reductions for a variety of typical lighting retrofit measures.

Annual Energy Savings and Demand Reduction Calculation Methodology

Annual measure energy savings and demand reduction were determined using the following formulas:

$$\text{kW demand reduction} = (\text{Fixture wattage}_{baseline} - \text{Fixture wattage}_{retrofit}) / 1000\ \text{W/kW}$$

$$\text{Peak kW demand reduction} = \text{kW demand reduction} * \text{DIF} * \text{CF}$$

OR

$$\text{Annual kWh savings} = (\text{Fixture wattage}_{baseline} * \text{Hours}_{baseline} - \text{Fixture wattage}_{retrofit} * \text{Hours}_{retrofit}) / 1000\ \text{W/kW} * \text{EIF}$$

Where:

Fixture $wattage_{baseline}$	= the existing lamp or fixture kW
Fixture $wattage_{retrofit}$	= the new lamp or fixture kW
Hours	= annual operating hours of the lamp or fixture (existing/new)
EIF	= energy interactive factors
DIF	= demand interactive factors
CF	= coincidence factor (winter and summer)

2008 DEER Data[86]

Most lighting measure data come from the DEER; the 2008 DEER provides detailed lighting operating hours. The hours by building type are also broken up by usage group.[87] DEER catalogs measure attributes and values for a variety of lighting fixtures and lamps. KEMA extracted required data elements from the DEER, as well as other sources, to use in calculating measure energy savings to provide a simple, comprehensive list of lighting retrofit measures. Additionally, the 2008 DEER provides measure life for several lighting measures, which vary by building type (operating hours) and ballast-rated hours.

The following table provides annual operating hours by building end-use and lighting fixture type.[88] It is important to note that 2011 DEER has updated operating hours from more metered data since the 2008 data were published. Since these are not specific to the Valley and there are existing efforts in the TVA service area, the existing values will remain. Valley-specific data are available from the 2014 TVA Commercial and Industrial Program Evaluation for three building types: Retail – Single-story, Large; Retail – Small; and Storage – Unconditioned. For these building types the Non-CFL annual operating hours were updated by averaging the 2008 DEER and program evaluation hours. As more Valley-specific data becomes available, the TRM will be updated accordingly. Additionally, the DEER data left many

[86] DEER 2008, www.deeresources.com. Many states other than California use this resource for deemed lighting operating hours. The DEER non-residential lighting operating hours are based on metered data and other sources.
[87] Usage groups (or space use) are different areas of the building, such as in retail, there is the showroom and storage. DEER's building operating hours is the weighted average across the usage groups.

[88] Operating hours for the original DEER Building Types of Education – College and Education – Secondary School were averaged. For TVA, these are modeled as one building type since the usage and building construction are typically similar. Details on the assumptions are from California research studies. If specific TVA hours are defined (known) or desired, then it is necessary for TVA to do a lighting metering study.

building types to the average/miscellaneous category. Therefore, another source, the "C&I Lighting Load Shape Project FINAL Report" provides the data for additional building types: municipal, other, religious, and service.[89]

Table 92. Annual Operating Hours by Building Type

Building Type	Hours
Assembly	2,443
Education - College/Secondary	2,459
Education - Primary School	2,167
Education – University	2,322
Grocery (Large)	6,734
Grocery (Small)	2,450
Health/Medical	4,881
Lodging - Hotel	1,965
Lodging - Motel	1,608
Manufacturing - Bio/Tech	3,957
Manufacturing - Light Industrial	3,130
Municipal	3,116
Office - Large	2,651
Office - Small	2,594
Other	4,268
Religious	2,648
Restaurant - Fast-Food	4,835
Restaurant - Sit-Down	4,815
Retail - Mall Department Store	3,372
Retail - Single-Story, Large	3,906
Retail - Small	4,433
Service	3,521
Storage – Air Conditioned	3,441
Storage - Unconditioned	3,932
Refrigerated Warehouse	3,441

Building Type Descriptions

[89] "C&I Lighting Load Shape Project FINAL Report," prepared for the Regional Evaluation Measurement and Verification Forum, a project facilitated by Northeast Energy Efficiency Partnerships (NEEP), KEMA, Inc., July 2011. Those building operating hours assume the same for CFL and non-CFL.

The following table provides the descriptions of the building types.

Table 93. Building Type Descriptions

Building Type	Description[90]
Assembly	Buildings that people gather for social or recreational activities. Includes community center, lodge, meeting hall, convention center, senior center, gymnasium, health club, bowling alley, ice rink, field house, museum, theater, cinema, sports arena, casino, night club, library, funeral home, exhibition hall, broadcasting studio and transportation terminal.
Education - College/Secondary	Middle, junior, or high school. Community college, vocational school, or other adult education building used for classroom instruction. Includes building for academic or technical instructions.
Education - Primary School	Elementary, preschool/daycare, or religious school. Includes building for academic or technical instructions.
Education – University	College and university buildings used for classroom instruction.
Grocery	Grocery or food store. Includes convenience stores with or without gas stations. Primarily for wholesale or retail food sales (does not include refrigerated food distribution centers).
Health/Medical	Hospital, inpatient rehabilitation, dialysis centers and veterinary locations (typically >100,000 sf). Includes buildings or medical offices used as diagnostic and treatment facilities. This category does not include medical offices that do not contain diagnostic or medical treatment equipment, which are categorized as office buildings.
Lodging – Hotel	Lodging facilities with common activity areas (typically >100,000 sf). Includes skilled nursing and other residential care buildings, dormitories, convents or monasteries, shelters and orphanages.
Lodging – Motel	Lodging facilities with common activity areas (typically <100,000 sf). Includes skilled nursing and other residential care buildings, dormitories, convents or monasteries, shelters and orphanages.
Manufacturing - Bio/Tech	Research and manufacturing facilities (e.g., clean rooms).
Manufacturing - Light Industrial	Assembly, machine shops, textile manufacturing.
Municipal	Buildings used for the preservation of law and order or public safety. This category includes police station, fire station, department of public works, jail, penitentiary and courthouse or probation office.
Office – Large	Typically >100,000 sf. May include bank, medical offices with no diagnostic equipment, government offices, social services, call centers, city hall, etc.
Office – Small	Typically <100,000 sf. May include bank, medical offices with no diagnostic equipment, government offices, social services, call centers, city hall, etc.

[90] Descriptions are a combination from: SCE Ninth Edition, February 2013 Solutions Directory, p.87 and primary business type categories used in Commercial Buildings Energy Consumption Survey (CBECS) conducted by the U.S. Energy Information Administration (EIA).

Building Type	Description[90]
Other	Includes buildings that are not easily classifiable into any of the other categories listed here, as well as those that are mixed use with no clear dominate activity and infrastructure type buildings such as bridges and tunnels, waste water treatment, phone switches, and data centers.
Religious	Places where people gather for religious activities such as chapels, temples, etc.
Restaurant - Fast-food	Fast-food restaurant. This includes donut shops.
Restaurant – Sit-down	Sit-down restaurant. Includes buildings used for the preparation and sale of food and beverages. This includes bars and cafeterias.
Retail - Mall Department Store	Enclosed mall with department stores.
Retail - Single-Story, Large	Big box retail, dealerships.
Retail – Small	Stores located in a strip mall. May include galleries, studios, liquor store, etc.
Service	Buildings which some type of service is provided other than food service or retail sales. Includes dry cleaners, Laundromat, post office, salon, copy center, gas station vehicle repair, etc.
Storage – Air Conditioned	Large air-conditioned warehouse (typically >1,000 sf).
Storage – Unconditioned	Non-refrigerated or unconditioned warehouse, like a distribution center.
Refrigerated Warehouse	Large Refrigerated warehouse (typically > 100,00sf)

Non-Standard Building Types

Many facilities do not easily map to the building types in the above table of building types or to building space-use types. The following are an example of these non-standard types.

- College or university with dorm rooms, large assembly, labs, workshops, etc.
- 24-hour gyms
- Agricultural facilities, i.e. chicken farms
- Car repair shops/gas stations with long hours
- High operating warehouse/distribution facility

The standard building types described in the above table in some cases encompass a wide range of operating conditions. The deemed operating hours are an average of a sample of buildings in each category; which include a variety of space-use types within a facility. If exceptions for high operating hours are provided, then the hours provided above need to be reassessed and potentially decreased accordingly. The deemed operating hours are intended to cover the average or typical building in that category, which includes the extreme cases. If there is a mix of building usage for a project, the predominant (i.e., greater than 50% of floor space) building type should be selected, otherwise, the miscellaneous building type should be selected.

The manual also includes new building types for Industrial/Warehouse with 1-shift, 2-shift, and 3-shift operations and Other, as described in the above table. Valley-specific data from the 2014 TVA Commercial and Industrial Program Evaluation was also used to update the Non-CFL annual operating hours for these building types by averaging the 2008 DEER and program evaluation hours.

If the number of shifts is known in the industrial/warehouse, this new category can be chosen. If a facility such as a 24-hour gym or agricultural building does not have a proper match, then Other can be selected. The TVA may consider adding additional building types if the proper MFS data are collected to inform the refined building type categories.

Table 94. Annual Operating Hours by Shift for Industrial/Warehouse[91]

Shift	Operating Hours
One-shift	4,230
Two-shift	5,660
Three-shift	7,805

Interactive Effects

Many utilities report interactive savings for lighting efficiency upgrades. Interactive effect factors are not presented in the tables below; however, they are included in the accompanying workbook. Interactive effects include reduced internal heat gain, due to installation of more efficient lighting that results in lower load on an air-conditioning system, as well as heating penalty especially for an electric heat source. Savings with interactive effects are provided in the TVA Ltg 2015.xlsx workbook. Details on including interactive effects are discussed in Appendix Section 2. The tables in this section do **NOT** include interactive effects.

Coincidence Factors

Data for the industrial/warehouse shifts were adopted from a Northeast metering study. Manufacturing buildings are assumed to have operating hours during the peak period similar to a one-shift

[91] Data collection efforts were from a study in the Northeast.

industrial/warehouse. The other building types are from the NEEP C&I Lighting load shape study (Northeast study). These use coincident diversity factors that are not from eQuest models but from facility metering and spreadsheet modeling efforts. The following values are used.

Table 95: Non-Residential Lighting Peak Coincidence Factors

Building Type	Central- Summer	Central – Winter	Eastern - Summer	Eastern - Winter
Assembly	0.500	0.270	0.510	0.290
Education - College/Secondary	0.461	0.551	0.383	0.674
Education - Primary School	0.240	0.160	0.220	0.340
Education – University	0.592	0.548	0.530	0.617
Grocery (Large)	0.906	0.811	0.895	0.894
Health/Medical	0.679	0.652	0.618	0.755
Lodging – Hotel	0.170	0.240	0.260	0.240
Lodging – Motel	0.140	0.200	0.210	0.200
Manufacturing - Bio/Tech	0.758	0.794	0.758	0.794
Manufacturing - Light Industrial	0.758	0.794	0.758	0.794
Municipal	0.547	0.429	0.452	0.602
Office – Large	0.687	0.589	0.586	0.720
Office – Small	0.672	0.576	0.573	0.704
Other	0.700	0.488	0.655	0.607
Refrigerated Warehouse	0.560	0.050	0.460	0.390
Religious	0.349	0.324	0.321	0.488
Restaurant - Fast-Food	0.650	0.580	0.650	0.640
Restaurant - Sit-Down	0.770	0.120	0.770	0.220
Retail - Mall Department Store	0.720	0.300	0.680	0.570
Retail - Single-Story, Large	0.770	0.290	0.770	0.580
Retail – Small	0.990	0.390	0.880	0.810
Service	0.862	0.454	0.759	0.703
Storage – Air Conditioned	0.860	0.150	0.710	0.650
Storage - Unconditioned	1.000	0.330	0.790	0.650
Industrial/Warehouse 1-shift	0.758	0.794	0.758	0.794
Industrial/Warehouse 2-shift	0.831	0.977	0.831	0.977
Industrial/Warehouse 3-shift	0.993	0.999	0.993	0.999

Measure Life

The measure life is presented for each measure. In some cases, for linear fluorescent, CFL, and LED, the measure life could be calculated at rated life (by manufacturer) divided by annual operating hours. In most cases, the maximum claimed life is presented here.

Attachment

TVA - NR Ltg 2013.xlsx

5.2.1.1 Screw-in Compact Fluorescent Lamps (CFL)

Sources:

Illinois TRM, 2013, Illinois Statewide Technical Resource Manual

DEER, 2008. www.deeresources.com/

Measure Description:

This measure consists of installing screw-in CFLs. Incandescent lamps, the most common existing condition, are less efficient than CFLs because incandescent lamps convert approximately 90% of the energy they consume into heat, compared to approximately 30% for a CFL.

This measure is applicable to the installation of ENERGY STAR-qualified CFLs under 40 W.

It is important to note that new federal standards (Energy Independence and Security Act of 2007, EISA) have adjusted the baseline conditions for incandescent lamps. All general purposed lamps between 40 and 100 W must be more efficient. This process is phased. The 100 W lamp baseline changed in 2012, 75 W in 2013, and 60 W and 40 W in 2014. The updated savings below include an adjusted baseline.

Assumptions:

Baseline and retrofit equipment wattage assumptions from the IL TRM are presented in the following table, which indicates an average baseline and retrofit wattages, as well as wattage reduction, by the reported size categories that were used in the savings calculation.

Table 96. Wattage Reduction for Screw-in CFL Measure

Fixture Category (W)	Existing Fixture Wattage	Retrofit Fixture Wattage	Wattage Reduction
1-13 W	29	11	18
14-26 W	56	20	36
27 W – 60 W	150	42	108

The 14 W – 26 W category is an average of the 100 W, 75 W, and 60 W replaced with a general service lamp that meets the ENERGY STAR requirements.

Savings:

Energy savings are separated into three size categories by wattage. The following table shows energy savings by replacing an incandescent lamp with a screw-in CFL by building type.

Table 97. Screw-In CFL Annual kWh Savings (per Lamp)

Building Type	1-13 W	14-26 W	27-40 W
Assembly	41	83	247
Education - College/Secondary	46	93	276
Education - Primary School	43	87	259
Education - University	45	90	268
Grocery	44	89	265
Health/Medical	74	148	441
Lodging – Hotel	30	60	179
Lodging – Motel	26	53	158
Manufacturing - Bio/Tech	63	127	378
Manufacturing - Light Industrial	47	95	283
Industrial/Warehouse 1-shift	91	184	546
Industrial/Warehouse 2-shift	111	224	665
Industrial/Warehouse 3-shift	153	309	919
Municipal	56	113	337
Office – Large	57	114	340
Office – Small	55	112	333
Religious	48	96	286
Restaurant - Fast-Food	87	176	522
Restaurant - Sit-Down	87	175	520
Retail - Mall Department Store	67	135	400
Retail - Single-Story, Large	69	139	412
Retail – Small	67	135	402
Service	63	128	380
Storage - Conditioned	50	101	300
Storage - Unconditioned	50	101	300
Other	77	155	461

Table 98. 1-13 W Screw-In CFL Peak Demand Savings (kW, per Lamp)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0085	0.0046	0.0086	0.0049
Education - College/Secondary	0.0068	0.0058	0.0062	0.0079

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Education - Primary School	0.0047	0.0032	0.0044	0.0069
Education – University	0.0061	0.0058	0.0057	0.0074
Grocery	0.0061	0.0061	0.0061	0.0061
Health/Medical	0.0091	0.0090	0.0091	0.0091
Lodging – Hotel	0.0027	0.0037	0.0039	0.0037
Lodging – Motel	0.0023	0.0032	0.0035	0.0033
Manufacturing - Bio/Tech	0.0136	0.0143	0.0136	0.0143
Manufacturing - Light Industrial	0.0136	0.0143	0.0136	0.0143
Industrial/Warehouse 1-shift	0.0136	0.0143	0.0136	0.0143
Industrial/Warehouse 2-shift	0.0150	0.0176	0.0150	0.0176
Industrial/Warehouse 3-shift	0.0179	0.0180	0.0179	0.0180
Municipal	0.0099	0.0077	0.0081	0.0109
Office – Large	0.0120	0.0098	0.0088	0.0140
Office - Small	0.0117	0.0096	0.0086	0.0136
Religious	0.0063	0.0058	0.0058	0.0088
Restaurant - Fast-Food	0.0117	0.0103	0.0117	0.0115
Restaurant - Sit-Down	0.0137	0.0021	0.0137	0.0040
Retail - Mall Department Store	0.0143	0.0059	0.0135	0.0114
Retail - Single-Story, Large	0.0135	0.0050	0.0134	0.0101
Retail - Small	0.0150	0.0058	0.0133	0.0122
Service	0.0155	0.0082	0.0137	0.0127
Storage - Conditioned	0.0125	0.0022	0.0102	0.0095
Storage - Unconditioned	0.0128	0.0041	0.0100	0.0083
Other	0.0126	0.0088	0.0118	0.0109

Table 99. 14-26 W Screw-In CFL Peak Demand Savings (kW, per Lamp)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0172	0.0093	0.0174	0.0099
Education - College/Secondary	0.0138	0.0117	0.0125	0.0159
Education - Primary School	0.0096	0.0064	0.0089	0.0139
Education - University	0.0122	0.0118	0.0114	0.0149
Grocery	0.0122	0.0122	0.0122	0.0122
Health/Medical	0.0183	0.0182	0.0183	0.0183
Lodging - Hotel	0.0054	0.0074	0.0079	0.0075
Lodging - Motel	0.0047	0.0065	0.0070	0.0066

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Manufacturing - Bio/Tech	0.0275	0.0288	0.0275	0.0288
Manufacturing - Light Industrial	0.0275	0.0288	0.0275	0.0288
Industrial/Warehouse 1-shift	0.0275	0.0288	0.0275	0.0288
Industrial/Warehouse 2-shift	0.0302	0.0355	0.0302	0.0355
Industrial/Warehouse 3-shift	0.0361	0.0363	0.0361	0.0363
Municipal	0.0231	0.0156	0.0191	0.0219
Office - Large	0.0242	0.0199	0.0177	0.0282
Office - Small	0.0237	0.0194	0.0173	0.0275
Religious	0.0127	0.0118	0.0117	0.0177
Restaurant - Fast-Food	0.0237	0.0209	0.0237	0.0233
Restaurant - Sit-Down	0.0277	0.0042	0.0277	0.0081
Retail - Mall Department Store	0.0288	0.0120	0.0272	0.0229
Retail - Single-Story, Large	0.0272	0.0102	0.0271	0.0205
Retail - Small	0.0302	0.0117	0.0269	0.0247
Service	0.0313	0.0165	0.0276	0.0256
Storage - Conditioned	0.0252	0.0044	0.0207	0.0192
Storage - Unconditioned	0.0258	0.0084	0.0202	0.0167
Other	0.0255	0.0177	0.0238	0.0221

Table 100. > 27 W Screw-In CFL Peak Demand Savings (kW, per Lamp)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0510	0.0275	0.0518	0.0295
Education - College/Secondary	0.0410	0.0349	0.0372	0.0473
Education - Primary School	0.0284	0.0190	0.0265	0.0413
Education - University	0.0364	0.0351	0.0339	0.0442
Grocery	0.0363	0.0363	0.0363	0.0363
Health/Medical	0.0545	0.0540	0.0544	0.0544
Lodging - Hotel	0.0159	0.0221	0.0236	0.0223
Lodging - Motel	0.0140	0.0194	0.0207	0.0196
Manufacturing - Bio/Tech	0.0819	0.0858	0.0819	0.0858
Manufacturing - Light Industrial	0.0819	0.0858	0.0819	0.0858
Industrial/Warehouse 1-shift	0.0819	0.0858	0.0819	0.0858
Industrial/Warehouse 2-shift	0.0897	0.1055	0.0897	0.1055
Industrial/Warehouse 3-shift	0.1072	0.1079	0.1072	0.1079
Municipal	0.0592	0.0464	0.0489	0.0651

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Office - Large	0.0719	0.0590	0.0525	0.0837
Office - Small	0.0703	0.0578	0.0514	0.0819
Religious	0.0378	0.0350	0.0347	0.0527
Restaurant - Fast-Food	0.0704	0.0620	0.0704	0.0693
Restaurant - Sit-Down	0.0825	0.0124	0.0825	0.0240
Retail - Mall Department Store	0.0857	0.0355	0.0808	0.0681
Retail - Single-Story Large	0.0809	0.0302	0.0806	0.0608
Retail - Small	0.0897	0.0349	0.0798	0.0733
Service	0.0931	0.0491	0.0820	0.0760
Storage - Conditioned	0.0750	0.0132	0.0614	0.0572
Storage - Unconditioned	0.0768	0.0248	0.0601	0.0496
Other	0.0757	0.0527	0.0707	0.0656

Measure Life:

The average CFL life is 2.8 years (assuming the average lamp has 8,000 hours rated operation).

The life for CFLs depends on their rated operating hours, which are defined by the manufacturer (rated operating hours divided by annual operating hours). Measure life is calculated as an average across building types and use areas, as shown in the following table by CFL operating-hour ratings.

Table 101. Screw-In CFL Life

Operating Hours	Life
12,000	4.2
10,000	3.5
8,000	2.8
6,000	2.1

5.2.1.2 Hardwired, Compact Fluorescent Fixture

Sources:

DEER, 2008. www.deeresources.com/

SCE. "Hardwired Fluorescent Fixture." Work papers WPSCNRLG0047.1 - 49.1, 2007.

Measure Description:

This measure is for replacing an incandescent (or other type) lighting fixture with a hardwired, compact fluorescent fixture (CFF). Hardwired CFFs typically include pin-based lamps with separate ballast. This measure's savings are reported for interior hardwired CFL fixtures; only complete new fixtures or modular hardwired retrofits with hardwired electronic ballasts qualify. The CFL ballast must be programmed start or programmed rapid start with a power factor (PF) ≥ 90 and a total harmonic distortion (THD) ≤ 20%.

Assumptions:

The following table provides the baseline and retrofit wattages for this measure. There are two baseline wattage options (incandescent and mercury vapor); the average across the two baseline options was used for calculating energy savings. Wattage assumptions were taken from the 2006 PG&E work papers, and the baseline incandescent wattages for categories 5 to 13 and 14 to 26 were updated based on the EISA efficiency standard for general service lamps. The wattage reduction is the average of the two possible baseline assumptions.

Table 102. Hardwired CFF Baseline and Retrofit Wattage

Fixture Category (W)	Retrofit Wattage	Baseline Incandescent Wattage	Baseline Mercury Vapor Wattage	Average Wattage Reduction
5 to 13	13	43	NA	30
14 to 26	26	72	NA	46
27 to 65	58	200	125	104
66 to 90	84	300	200	166
> 90	116	500	285	276

Savings:

The following table provides the calculated annual kWh savings for this measure by wattage category.

Table 103. Hardwired CFF kWh Savings (per Fixture)

Building Type	5 to 13 W	14 to 26 W	27 to 65 W	66 to 90 W	≥ 90 W
Assembly	69	105	239	380	633
Education - College/Secondary	77	118	267	424	706
Education - Primary School	72	110	251	398	663
Education - University	75	114	260	413	687
Grocery	74	113	256	407	679
Health/Medical	123	188	427	678	1,129
Lodging - Hotel	50	76	529	840	1,398

Building Type	5 to 13 W	14 to 26 W	27 to 65 W	66 to 90 W	≥ 90 W
Lodging - Motel	44	67	643	1,022	1,702
Manufacturing - Bio/Tech	105	161	889	1,412	2,352
Manufacturing - Light Industrial	79	120	174	276	459
Industrial/Warehouse 1-shift	152	233	153	243	404
Industrial/Warehouse 2-shift	185	283	366	581	968
Industrial/Warehouse 3-shift	255	391	274	435	724
Municipal	93	143	326	517	862
Office - Large	95	145	329	523	871
Office - Small	92	142	322	512	852
Religious	79	122	277	440	732
Restaurant - Fast-Food	145	222	505	803	1,337
Restaurant - Sit-Down	144	221	503	799	1,331
Retail - Mall Department Store	111	170	387	615	1,024
Retail - Single-Story, Large	114	175	398	633	1,054
Retail - Small	112	171	389	618	1,029
Service	106	162	368	584	974
Storage - Conditioned	83	128	291	461	769
Storage - Unconditioned	83	128	291	461	769
Other	128	196	446	708	1180

Table 104. 5-13 W, Hardwired, CFF Peak Demand Savings (per Fixture)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0142	0.0076	0.0144	0.0082
Education - College/Secondary	0.0114	0.0097	0.0103	0.0131
Education - Primary School	0.0079	0.0053	0.0074	0.0115
Education - University	0.0101	0.0097	0.0094	0.0123
Grocery	0.0101	0.0101	0.0101	0.0101
Health/Medical	0.0151	0.0150	0.0151	0.0151
Lodging - Hotel	0.0044	0.0061	0.0065	0.0062
Lodging - Motel	0.0039	0.0054	0.0058	0.0055
Manufacturing - Bio/Tech	0.0227	0.0238	0.0227	0.0238
Manufacturing - Light Industrial	0.0227	0.0238	0.0227	0.0238
Industrial/Warehouse 1-shift	0.0227	0.0238	0.0227	0.0238
Industrial/Warehouse 2-shift	0.0249	0.0293	0.0249	0.0293
Industrial/Warehouse 3-shift	0.0298	0.0300	0.0298	0.0300
Municipal	0.0164	0.0129	0.0136	0.0181

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Office - Large	0.0200	0.0164	0.0146	0.0233
Office - Small	0.0195	0.0160	0.0143	0.0227
Religious	0.0105	0.0097	0.0096	0.0147
Restaurant - Fast-Food	0.0196	0.0172	0.0196	0.0192
Restaurant - Sit-Down	0.0229	0.0034	0.0229	0.0067
Retail - Mall Department Store	0.0238	0.0099	0.0225	0.0189
Retail - Single-Story, Large	0.0225	0.0084	0.0224	0.0169
Retail - Small	0.0249	0.0097	0.0222	0.0204
Service	0.0259	0.0136	0.0228	0.0211
Storage - Conditioned	0.0208	0.0037	0.0171	0.0159
Storage - Unconditioned	0.0213	0.0069	0.0167	0.0138
Other	0.0210	0.0146	0.0197	0.0182

Table 105. 14-26 W, Hardwired, CFF Peak Demand Savings (per Fixture)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0217	0.0117	0.0221	0.0126
Education - College/Secondary	0.0174	0.0149	0.0158	0.0201
Education - Primary School	0.0121	0.0081	0.0113	0.0176
Education - University	0.0155	0.0149	0.0145	0.0188
Grocery	0.0155	0.0155	0.0155	0.0155
Health/Medical	0.0232	0.0230	0.0232	0.0232
Lodging - Hotel	0.0068	0.0094	0.0100	0.0095
Lodging - Motel	0.0060	0.0083	0.0088	0.0084
Manufacturing - Bio/Tech	0.0349	0.0365	0.0349	0.0365
Manufacturing - Light Industrial	0.0349	0.0365	0.0349	0.0365
Industrial/Warehouse 1-shift	0.0349	0.0365	0.0349	0.0365
Industrial/Warehouse 2-shift	0.0382	0.0449	0.0382	0.0449
Industrial/Warehouse 3-shift	0.0457	0.0460	0.0457	0.0460
Municipal	0.0252	0.0197	0.0208	0.0277
Office - Large	0.0306	0.0252	0.0224	0.0357
Office - Small	0.0299	0.0246	0.0219	0.0349
Religious	0.0161	0.0149	0.0148	0.0225
Restaurant - Fast-Food	0.0300	0.0264	0.0300	0.0295
Restaurant - Sit-Down	0.0351	0.0053	0.0351	0.0102
Retail - Mall Department Store	0.0365	0.0151	0.0344	0.0290

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Retail - Single-Story, Large	0.0345	0.0129	0.0343	0.0259
Retail - Small	0.0382	0.0149	0.0340	0.0312
Service	0.0397	0.0209	0.0349	0.0324
Storage - Conditioned	0.0320	0.0056	0.0262	0.0243
Storage - Unconditioned	0.0327	0.0106	0.0256	0.0211
Other	0.0322	0.0225	0.0301	0.0279

Table 106. 27-65 W, Hardwired, CFF Peak Demand Savings (per Fixture)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0527	0.0284	0.0501	0.0286
Education - College/Secondary	0.0381	0.0325	0.0360	0.0458
Education - Primary School	0.0249	0.0166	0.0256	0.0400
Education - University	0.0329	0.0317	0.0328	0.0427
Grocery	0.0351	0.0351	0.0352	0.0352
Health/Medical	0.0630	0.0624	0.0527	0.0526
Lodging - Hotel	0.0182	0.0252	0.0228	0.0216
Lodging - Motel	0.0149	0.0207	0.0201	0.0190
Manufacturing - Bio/Tech	0.0792	0.0830	0.0792	0.0830
Manufacturing - Light Industrial	0.0792	0.0830	0.0792	0.0830
Industrial/Warehouse 1-shift	0.0792	0.0830	0.0792	0.0830
Industrial/Warehouse 2-shift	0.0868	0.1021	0.0868	0.1021
Industrial/Warehouse 3-shift	0.1038	0.1044	0.1038	0.1044
Municipal	0.0572	0.0449	0.0473	0.0630
Office - Large	0.0585	0.0481	0.0508	0.0810
Office - Small	0.0680	0.0559	0.0497	0.0792
Religious	0.0366	0.0339	0.0336	0.0510
Restaurant - Fast-Food	0.0681	0.0600	0.0681	0.0670
Restaurant - Sit-Down	0.0798	0.0120	0.0798	0.0233
Retail - Mall Department Store	0.0755	0.0313	0.0782	0.0659
Retail - Single-Story, Large	0.0704	0.0263	0.0780	0.0588
Retail - Small	0.0759	0.0295	0.0772	0.0709
Service	0.0901	0.0475	0.0794	0.0735
Storage - Conditioned	0.0899	0.0158	0.0594	0.0553
Storage - Unconditioned	0.0919	0.0297	0.0581	0.0480
Other	0.0732	0.0510	0.0684	0.0635

Table 107. 66-90 W, Hardwired, CFF Peak Demand Savings (per Fixture)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0784	0.0423	0.0796	0.0454
Education - College/Secondary	0.0630	0.0537	0.0571	0.0727
Education - Primary School	0.0437	0.0293	0.0407	0.0635
Education - University	0.0559	0.0539	0.0522	0.0679
Grocery	0.0559	0.0558	0.0559	0.0558
Health/Medical	0.0837	0.0829	0.0837	0.0836
Lodging - Hotel	0.0245	0.0339	0.0362	0.0343
Lodging - Motel	0.0215	0.0298	0.0319	0.0302
Manufacturing - Bio/Tech	0.1258	0.1318	0.1258	0.1318
Manufacturing - Light Industrial	0.1258	0.1318	0.1258	0.1318
Industrial/Warehouse 1-shift	0.1258	0.1318	0.1258	0.1318
Industrial/Warehouse 2-shift	0.1379	0.1622	0.1379	0.1622
Industrial/Warehouse 3-shift	0.1648	0.1658	0.1648	0.1658
Municipal	0.0909	0.0713	0.0751	0.1001
Office - Large	0.1105	0.0908	0.0807	0.1287
Office - Small	0.1081	0.0888	0.0789	0.1259
Religious	0.0581	0.0538	0.0533	0.0811
Restaurant - Fast-Food	0.1082	0.0953	0.1082	0.1065
Restaurant - Sit-Down	0.1268	0.0190	0.1268	0.0369
Retail - Mall Department Store	0.1317	0.0546	0.1243	0.1047
Retail - Single-Story, Large	0.1243	0.0464	0.1239	0.0935
Retail - Small	0.1379	0.0537	0.1227	0.1127
Service	0.1431	0.0755	0.1261	0.1167
Storage - Conditioned	0.1153	0.0203	0.0944	0.0879
Storage - Unconditioned	0.1180	0.0382	0.0924	0.0762
Other	0.1163	0.0810	0.1087	0.1008

Table 108. > 90 W, Hardwired, CFF Peak Demand Savings (per Fixture)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.1306	0.0704	0.1326	0.0756
Education - College/Secondary	0.1049	0.0894	0.0951	0.1211
Education - Primary School	0.0728	0.0488	0.0678	0.1058
Education - University	0.0932	0.0898	0.0869	0.1131

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Grocery	0.0931	0.0930	0.0931	0.0930
Health/Medical	0.1395	0.1381	0.1393	0.1393
Lodging - Hotel	0.0407	0.0565	0.0603	0.0571
Lodging - Motel	0.0359	0.0497	0.0531	0.0503
Manufacturing - Bio/Tech	0.2096	0.2195	0.2096	0.2195
Manufacturing - Light Industrial	0.2096	0.2195	0.2096	0.2195
Industrial/Warehouse 1-shift	0.2096	0.2195	0.2096	0.2195
Industrial/Warehouse 2-shift	0.2298	0.2701	0.2298	0.2701
Industrial/Warehouse 3-shift	0.2746	0.2762	0.2746	0.2762
Municipal	0.1515	0.1187	0.1252	0.1667
Office - Large	0.1841	0.1512	0.1344	0.2143
Office - Small	0.1800	0.1479	0.1315	0.2096
Religious	0.0967	0.0896	0.0888	0.1350
Restaurant - Fast-Food	0.1803	0.1587	0.1803	0.1774
Restaurant - Sit-Down	0.2112	0.0317	0.2112	0.0615
Retail - Mall Department Store	0.2194	0.0910	0.2070	0.1744
Retail - Single-Story, Large	0.2071	0.0773	0.2063	0.1557
Retail - Small	0.2297	0.0894	0.2044	0.1877
Service	0.2384	0.1258	0.2100	0.1945
Storage - Conditioned	0.1921	0.0339	0.1572	0.1464
Storage - Unconditioned	0.1965	0.0636	0.1538	0.1269
Other	0.1938	0.1350	0.1811	0.1679

Measure Life:

12 years (DEER 2008)

5.2.1.3 Cold-Cathode CFLs

Sources:

SCE. "Cold Cathode Fluorescent Lamp, 3 to 5 Watts." Work paper WPSCNRLG0063, 2007.

DEER, 2008. www.deeresources.com/

Measure Description:

Cold-cathode CFLs (CCFLs) offer long life, are dimmable, tolerate frequent on/off cycles, and work well in cold environments. They are suited for specialty purposes, such as for chandeliers, marquees, and signage. Under this measure, all CCFLs must replace incandescent lamps that are between 10 W and 40 W. Cold-cathode lamps may be medium (Edison) or candelabra base, and the CCFLs must be rated for at least 18,000 average life hours.

Assumptions:

Retrofit assumptions were taken from SCE work papers[92] and KEMA research of cold-cathode manufacturers. The following table provides baseline (EISA adjusted) and retrofit lamp wattages used for calculating energy savings.

Table 109. Cold-Cathode Baseline and Retrofit Wattages

Measures	Baseline Wattage	Retrofit Wattage	Wattage Reduction
Incandescent (15 W) > Cold Cathode (5 W)	15	5	10
Incandescent (30 W) > Cold Cathode (5 W)	30	5	25
Incandescent (40 W) > Cold Cathode (8 W)	29	8	21
Average			**18.7**

Savings:

The following table provides the calculated measure savings of using cold-cathode CFLs over incandescent lamps.

Table 110. Cold-Cathode Savings (per Lamp)

Building Type	kWh Savings
Assembly	43
Education - College/Secondary	48
Education - Primary School	45
Education - University	46
Grocery	46
Health/Medical	76
Lodging - Hotel	31
Lodging - Motel	27
Manufacturing - Bio/Tech	65

[92] SCE. “Cold Cathode Fluorescent Lamp.” Work paper WPSCNRLG0063, 2007.

Building Type	kWh Savings
Manufacturing - Light Industrial	49
Industrial/Warehouse 1-shift	94
Industrial/Warehouse 2-shift	115
Industrial/Warehouse 3-shift	159
Municipal	58
Office - Large	59
Office - Small	58
Religious	49
Restaurant - Fast-Food	90
Restaurant - Sit-Down	90
Retail - Mall Department Store	69
Retail - Single-Story Large	71
Retail - Small	69
Service	66
Storage - Conditioned	52
Storage - Unconditioned	52
Other	80

Table 111. Cold-Cathode Peak Demand Savings (per Lamp)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0088	0.0048	0.0090	0.0051
Education - College/Secondary	0.0071	0.0060	0.0064	0.0082
Education - Primary School	0.0049	0.0033	0.0046	0.0071
Education - University	0.0063	0.0061	0.0059	0.0076
Grocery	0.0063	0.0063	0.0063	0.0063
Health/Medical	0.0094	0.0093	0.0094	0.0094
Lodging - Hotel	0.0028	0.0038	0.0041	0.0039
Lodging - Motel	0.0024	0.0034	0.0036	0.0034
Manufacturing - Bio/Tech	0.0141	0.0148	0.0141	0.0148
Manufacturing - Light Industrial	0.0141	0.0148	0.0141	0.0148
Industrial/Warehouse 1-shift	0.0141	0.0148	0.0141	0.0148
Industrial/Warehouse 2-shift	0.0155	0.0182	0.0155	0.0182
Industrial/Warehouse 3-shift	0.0185	0.0186	0.0185	0.0186
Municipal	0.0102	0.008	0.0085	0.0113
Office - Large	0.0124	0.0102	0.0091	0.0145
Office - Small	0.0122	0.0100	0.0089	0.0142

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Religious	0.0065	0.0060	0.0060	0.0091
Restaurant - Fast-Food	0.0122	0.0107	0.0122	0.0120
Restaurant - Sit-Down	0.0143	0.0021	0.0143	0.0042
Retail - Mall Department Store	0.0148	0.0061	0.0140	0.0118
Retail - Single-Story, Large	0.0140	0.0052	0.0139	0.0105
Retail - Small	0.0155	0.0060	0.0138	0.0127
Service	0.0161	0.0085	0.0142	0.0131
Storage - Conditioned	0.0130	0.0023	0.0106	0.0099
Storage - Unconditioned	0.0133	0.0043	0.0104	0.0086
Other	0.0131	0.0091	0.0122	0.0113

Measure Life:

5 years (SCE work paper)

5.2.1.4 T12/Standard T8 to 2-foot, 3-foot, and 8-foot T8 Lamps with Electronic Ballasts

Sources:

DEER, 2008 and 2011. www.deeresources.com/

Pennsylvania TRM lighting worksheet

GDS, "Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures," for the New England State Program Working Group, by GDS Associates, Inc., March 2007.

Measure Description:

This measure consists of replacing existing T12 lamps and magnetic ballasts or standard T8 lamps and electronic ballasts with efficient T8 lamps and electronic ballasts. The T8 lamps must have a color-rendering index (CRI) ≥ 80. The electronic ballast must be high frequency (≥ 20 kHz), UL-listed, and warranted against defects for five years. Ballasts must have a power factor (PF) ≥ 0.90. For 2- and 3-foot lamps, ballasts must have THD ≤ 32 % at full light output.

It is important to note that new federal standards have eliminated manufacturing and importing magnetic ballasts and T12 lamps. Hence, it is important to redefine baseline. Subsequently, TVA has adopted a standard T8 baseline for all linear fluorescent fixtures.[93] Retrofitting T12 fixtures to T8 fixtures is a highly recommended measure; however, the adjusted baseline for this measure is T8 lamps and electronic ballasts.

Assumptions:

The assumptions used to calculate measure energy savings are listed in the following table. Baseline and retrofit wattages use standard industry values per lamp linear length. The fixture wattage used is representative of the fixture category and not meant to illustrate an absolute baseline and retrofit fixture. For calculation purposes, the demand savings per lamp is calculated to produce a single demand reduction value for all retrofit opportunities in the measure category. It is recommended that retrofits of 8-foot T12 HO or 8-foot VHO fixtures be covered as a custom measure.

Table 112. Baseline and Retrofit Wattage Assumptions for 2-foot, 3-foot, and 8-foot Lamps

Measure Description	Base Lamp Wattage	Retrofit Lamp Wattage	Demand Savings per lamp (kW)	Baseline Description	Retrofit Description
2-foot T8	33	29	0.0020	Fluorescent, (2) 24", T-8 lamp, Instant Start Ballast, NLO (BF: 0.85-0.95)	Fluorescent, (2) 24", T-8 lamp, Instant Start Ballast, RLO (BF< 0.85)
3-foot T8	46	42	0.0020	Fluorescent, (2) 36", T-8 lamp, Instant Start Ballast, NLO (BF: 0.85-0.95)	Fluorescent, (2) 36", T-8 lamp, Instant Start Ballast, RLO (BF< 0.85)
8-foot T8	109	98	0.0055	Fluorescent, (2) 96", T-8 lamp, Instant Start Ballast, NLO (BF: 0.85-0.95)	Fluorescent, (2) 96", T-8 lamp, Instant Start Ballast, RLO (BF< 0.85)

Savings:

The following table shows average savings by building type and lamp length.

Table 113. Standard T12/T8 to T8 Lamp and Ballast Retrofit kWh Savings (per Lamp)

Building Type	2-foot	3-foot	8-foot
Assembly	4.89	4.89	13.44

[93] The TVA Small Business Direct Install Program will continue to use a T12 baseline where applicable through TVA FY15. Beginning TVA FY16 the T8 baseline will apply to all programs with no exceptions.

Building Type	2-foot	3-foot	8-foot
Education - College/Secondary	4.92	4.92	13.52
Education - Primary School	4.33	4.33	11.92
Education - University	4.64	4.64	12.77
Grocery	4.90	4.90	13.48
Health/Medical	9.76	9.76	26.85
Lodging - Hotel	3.93	3.93	10.81
Lodging - Motel	3.22	3.22	8.84
Manufacturing - Bio/Tech	7.91	7.91	21.76
Manufacturing - Light Industrial	6.26	6.26	17.22
Industrial/Warehouse 1-shift	8.46	8.46	23.27
Industrial/Warehouse 2-shift	11.32	11.32	31.13
Industrial/Warehouse 3-shift	15.61	15.61	42.93
Municipal	6.23	6.23	17.14
Office - Large	5.30	5.30	14.58
Office - Small	5.19	5.19	14.27
Religious	5.30	5.30	14.56
Restaurant - Fast-Food	9.67	9.67	26.59
Restaurant - Sit-Down	9.63	9.63	26.48
Retail - Mall Department Store	6.74	6.74	18.55
Retail - Single-Story Large	7.81	7.81	21.48
Retail - Small	8.87	8.87	24.38
Service	7.04	7.04	19.37
Storage - Conditioned	6.88	6.88	18.93
Storage - Unconditioned	7.86	7.86	21.63
Other	8.54	8.54	23.47

Table 114. 2-foot Standard T12 to T8 Lamp and Ballast Retrofit Peak Demand Savings (per Lamp)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0010	0.0005	0.0010	0.0006
Education - College/Secondary	0.0007	0.0006	0.0007	0.0008
Education - Primary School	0.0005	0.0003	0.0004	0.0007
Education - University	0.0006	0.0006	0.0006	0.0008
Grocery	0.0007	0.0007	0.0007	0.0007
Health/Medical	0.0012	0.0012	0.0012	0.0012
Lodging - Hotel	0.0003	0.0005	0.0005	0.0005
Lodging - Motel	0.0003	0.0004	0.0004	0.0004

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Manufacturing - Bio/Tech	0.0015	0.0016	0.0015	0.0016
Manufacturing - Light Industrial	0.0015	0.0016	0.0015	0.0016
Industrial/Warehouse 1-shift	0.0015	0.0016	0.0015	0.0016
Industrial/Warehouse 2-shift	0.0017	0.0020	0.0017	0.0020
Industrial/Warehouse 3-shift	0.0020	0.0020	0.0020	0.0020
Municipal	0.0000	0.0000	0.0000	0.0000
Office - Large	0.0011	0.0009	0.0008	0.0013
Office - Small	0.0011	0.0009	0.0008	0.0013
Religious	0.0007	0.0006	0.0006	0.0010
Restaurant - Fast-Food	0.0013	0.0011	0.0013	0.0013
Restaurant - Sit-Down	0.0015	0.0002	0.0015	0.0004
Retail - Mall Department Store	0.0014	0.0006	0.0014	0.0011
Retail - Single-Story Large	0.0015	0.0006	0.0015	0.0012
Retail - Small	0.0020	0.0008	0.0018	0.0016
Service	0.0017	0.0009	0.0015	0.0014
Storage - Conditioned	0.0017	0.0003	0.0014	0.0013
Storage - Unconditioned	0.0020	0.0007	0.0016	0.0013
Other	0.0014	0.0010	0.0013	0.0012

Table 115. 3-foot Standard T12 to T8 Lamp and Ballast Retrofit Peak Demand Savings (per Lamp)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0010	0.0005	0.0010	0.0006
Education - College/Secondary	0.0007	0.0006	0.0007	0.0008
Education - Primary School	0.0005	0.0003	0.0004	0.0007
Education - University	0.0006	0.0006	0.0006	0.0008
Grocery	0.0007	0.0007	0.0007	0.0007
Health/Medical	0.0012	0.0012	0.0012	0.0012
Lodging - Hotel	0.0003	0.0005	0.0005	0.0005
Lodging - Motel	0.0003	0.0004	0.0004	0.0004
Manufacturing - Bio/Tech	0.0015	0.0016	0.0015	0.0016
Manufacturing - Light Industrial	0.0015	0.0016	0.0015	0.0016
Industrial/Warehouse 1-shift	0.0015	0.0016	0.0015	0.0016
Industrial/Warehouse 2-shift	0.0017	0.0020	0.0017	0.0020
Industrial/Warehouse 3-shift	0.0020	0.0020	0.0020	0.0020

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Municipal	0.0011	0.0009	0.0009	0.0012
Office - Large	0.0011	0.0009	0.0008	0.0013
Office - Small	0.0011	0.0009	0.0008	0.0013
Religious	0.0007	0.0006	0.0006	0.0010
Restaurant - Fast-Food	0.0013	0.0011	0.0013	0.0013
Restaurant - Sit-Down	0.0015	0.0002	0.0015	0.0004
Retail - Mall Department Store	0.0014	0.0006	0.0014	0.0011
Retail - Single-Story Large	0.0015	0.0006	0.0015	0.0012
Retail - Small	0.0020	0.0008	0.0018	0.0016
Service	0.0017	0.0009	0.0015	0.0014
Storage - Conditioned	0.0017	0.0003	0.0014	0.0013
Storage - Unconditioned	0.0020	0.0007	0.0016	0.0013
Other	0.0014	0.0010	0.0013	0.0012

Table 116. 8-foot Standard T12 to T8 Lamp and Ballast Retrofit Peak Demand Savings (per Lamp)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0028	0.0015	0.0028	0.0016
Education - College/Secondary	0.0020	0.0017	0.0018	0.0023
Education - Primary School	0.0013	0.0009	0.0012	0.0019
Education - University	0.0017	0.0017	0.0016	0.0021
Grocery	0.0018	0.0018	0.0018	0.0018
Health/Medical	0.0033	0.0033	0.0033	0.0033
Lodging - Hotel	0.0010	0.0013	0.0014	0.0013
Lodging - Motel	0.0008	0.0011	0.0012	0.0011
Manufacturing - Bio/Tech	0.0042	0.0044	0.0042	0.0044
Manufacturing - Light Industrial	0.0042	0.0044	0.0042	0.0044
Industrial/Warehouse 1-shift	0.0042	0.0044	0.0042	0.0044
Industrial/Warehouse 2-shift	0.0046	0.0054	0.0046	0.0054
Industrial/Warehouse 3-shift	0.0055	0.0055	0.0055	0.0055
Municipal	0.0000	0.0000	0.0000	0.0000
Office - Large	0.0031	0.0025	0.0022	0.0036
Office - Small	0.0030	0.0025	0.0022	0.0035
Religious	0.0019	0.0018	0.0018	0.0027
Restaurant - Fast-Food	0.0036	0.0032	0.0036	0.0035
Restaurant - Sit-Down	0.0042	0.0006	0.0042	0.0012
Retail - Mall Department Store	0.0040	0.0016	0.0037	0.0032
Retail - Single-Story Large	0.0042	0.0016	0.0042	0.0032

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Retail - Small	0.0054	0.0021	0.0048	0.0044
Service	0.0047	0.0025	0.0042	0.0039
Storage - Conditioned	0.0047	0.0008	0.0039	0.0036
Storage - Unconditioned	0.0055	0.0018	0.0043	0.0036
Other	0.0039	0.0027	0.0036	0.0033

Measure Life:

15 years (GDS)

5.2.1.5 Delamping (Permanent Lamp Removal)

Sources:

DEER, 2008 and 2011. www.deeresources.com/

Pennsylvania TRM lighting worksheet

GDS, "Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures," for the New England State Program Working Group, by GDS Associates, Inc., March 2007.

Measure Description:

This measure consists of permanently removing existing fluorescent lamps, which results in a net reduction in the overall installed number of foot lamps (total number of linear feet). This measure is only applicable for retrofits from T12 lamps to T8 lamps or standard T8 lamps to high-efficiency T8 lamps. This measure requires the removal of all unused lamps, ballasts, and tombstones to ensure it is permanent.

It is important to note that new federal standards have eliminated the manufacturing and importing of magnetic ballasts and T12 lamps. Hence, it is important to redefine baseline. Subsequently, the TVA has adopted a standard T8 baseline for all linear fluorescent fixtures. Retrofitting T12 fixtures to T8 fixtures is a highly recommended measure; however, the adjusted baseline for this measure is T8 lamps and electronic ballasts.

Assumptions:

The fixture wattage used is representative of the fixture category and not meant to illustrate an absolute baseline fixture. For calculation purposes, the demand savings per lamp is calculated to produce a single demand reduction value for all retrofit opportunities in the measure category. Lamp wattage assumptions are presented in the following two tables.

Table 117. Wattages for 2-foot, 3-foot, and 8-foot Lamp Removal

Measure Description	Base Lamp Wattage	Demand Savings per lamp (kW)	Baseline Description
2-foot	33	0.0165	Fluorescent, (2) 24", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)
3-foot	46	0.0230	Fluorescent, (2) 36", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)
8-foot	109	0.0545	Fluorescent, (2) 96", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)

Table 118. Wattages for 4-foot Lamps

Retrofit	Baseline Fixture Wattage	Removed Lamp Wattage	Weight Percentages
Four 4' T12/T8 > Three 4' T8 (32W)	112	28.0	10%
Three 4' T12/T8 > Two 4' T8 (32W)	89	29.7	25%
Two 4' T12/T8 > One 4' T8 (32W)	59	29.5	10%
Four 4' T12/T8 > Two 4' T8 (32W)	112	28.0	49%
Three 4' T12/T8 > One 4' T8 (32W)	89	29.7	5%
Total Weighted Average		**28.7**	

Savings:

The following tables show the average savings by building type and lamp length removed.

Table 119. Delamping kWh Savings (per Lamp Removed)

Building Type	2-foot	3-foot	4-foot	8-foot
Assembly	40.3	56.2	70.0	133.1
Education - College/Secondary	40.6	56.6	70.5	134.0
Education - Primary School	35.8	49.8	62.1	118.1
Education - University	38.3	53.4	66.5	126.5
Grocery	40.4	56.4	70.2	133.5
Health/Medical	80.5	112.3	139.9	266.0
Lodging - Hotel	32.4	45.2	56.3	107.1
Lodging - Motel	26.5	37.0	46.1	87.6

Building Type	2-foot	3-foot	4-foot	8-foot
Manufacturing - Bio/Tech	65.3	91.0	113.4	215.7
Manufacturing - Light Industrial	51.6	72.0	89.7	170.6
Industrial/Warehouse 1-shift	69.8	97.3	121.2	230.5
Industrial/Warehouse 2-shift	93.4	130.2	162.2	308.5
Industrial/Warehouse 3-shift	128.8	179.5	223.6	425.4
Municipal	51.4	71.7	89.3	169.8
Office - Large	43.7	61.0	76.0	144.5
Office - Small	42.8	59.7	74.3	141.4
Religious	43.7	60.9	75.9	144.3
Restaurant - Fast-Food	79.8	111.2	138.5	263.5
Restaurant - Sit-Down	79.4	110.7	138.0	262.4
Retail - Mall Department Store	55.6	77.6	96.6	183.8
Retail - Single-Story, Large	64.4	89.8	111.9	212.9
Retail - Small	73.1	102.0	127.0	241.6
Service	58.1	81.0	100.9	191.9
Storage - Conditioned	56.8	79.1	98.6	187.5
Storage - Unconditioned	64.9	90.4	112.7	214.3
Other	70.4	98.2	122.3	232.6

Table 120. 2-foot Delamping Peak Demand Savings (per Lamp Removed)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0083	0.0045	0.0084	0.0048
Education - College/Secondary	0.0060	0.0051	0.0055	0.0070
Education - Primary School	0.0039	0.0026	0.0037	0.0057
Education - University	0.0052	0.0050	0.0048	0.0063
Grocery	0.0055	0.0055	0.0055	0.0055
Health/Medical	0.0099	0.0099	0.0099	0.0099
Lodging - Hotel	0.0029	0.0040	0.0043	0.0040
Lodging - Motel	0.0024	0.0033	0.0035	0.0033
Manufacturing - Bio/Tech	0.0125	0.0131	0.0125	0.0131
Manufacturing - Light Industrial	0.0125	0.0131	0.0125	0.0131
Industrial/Warehouse 1-shift	0.0125	0.0131	0.0125	0.0131
Industrial/Warehouse 2-shift	0.0137	0.0161	0.0137	0.0161
Industrial/Warehouse 3-shift	0.0164	0.0165	0.0164	0.0165
Municipal	0.0009	0.0071	0.0075	0.0099

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Office - Large	0.0092	0.0076	0.0067	0.0108
Office - Small	0.0090	0.0074	0.0066	0.0105
Religious	0.0058	0.0053	0.0053	0.0081
Restaurant - Fast-Food	0.0108	0.0095	0.0108	0.0106
Restaurant - Sit-Down	0.0126	0.0019	0.0126	0.0037
Retail - Mall Department Store	0.0119	0.0049	0.0112	0.0095
Retail - Single-Story, Large	0.0127	0.0047	0.0126	0.0095
Retail - Small	0.0163	0.0064	0.0145	0.0133
Service	0.0142	0.0075	0.0125	0.0116
Storage - Conditioned	0.0142	0.0025	0.0116	0.0108
Storage - Unconditioned	0.0166	0.0054	0.0130	0.0107
Other	0.0116	0.0081	0.0108	0.0100

Table 121. 3-foot Delamping Peak Demand Savings (per Lamp Removed)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0116	0.0063	0.0118	0.0067
Education - College/Secondary	0.0084	0.0072	0.0076	0.0097
Education - Primary School	0.0055	0.0037	0.0051	0.0079
Education - University	0.0072	0.0070	0.0068	0.0088
Grocery	0.0077	0.0077	0.0077	0.0077
Health/Medical	0.0139	0.0137	0.0139	0.0138
Lodging - Hotel	0.0040	0.0056	0.0059	0.0056
Lodging - Motel	0.0033	0.0045	0.0049	0.0046
Manufacturing - Bio/Tech	0.0174	0.0183	0.0174	0.0183
Manufacturing - Light Industrial	0.0174	0.0183	0.0174	0.0183
Industrial/Warehouse 1-shift	0.0174	0.0183	0.0174	0.0183
Industrial/Warehouse 2-shift	0.0191	0.0225	0.0191	0.0225
Industrial/Warehouse 3-shift	0.0228	0.0230	0.0228	0.0230
Municipal	0.0126	0.0099	0.0104	0.0139
Office - Large	0.0129	0.0106	0.0094	0.0150
Office - Small	0.0126	0.0104	0.0092	0.0147
Religious	0.0080	0.0075	0.0074	0.0112
Restaurant - Fast-Food	0.0150	0.0132	0.0150	0.0148
Restaurant - Sit-Down	0.0176	0.0026	0.0176	0.0051
Retail - Mall Department Store	0.0166	0.0069	0.0157	0.0132

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Retail - Single-Story, Large	0.0176	0.0066	0.0176	0.0133
Retail - Small	0.0228	0.0089	0.0203	0.0186
Service	0.0198	0.0105	0.0175	0.0162
Storage - Conditioned	0.0198	0.0035	0.0162	0.0151
Storage - Unconditioned	0.0231	0.0075	0.0181	0.0149
Other	0.0161	0.0112	0.0151	0.0140

Table 122. 4-foot Delamping Peak Demand Savings (per Lamp Removed)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0144	0.0078	0.0147	0.0084
Education - College/Secondary	0.0105	0.0089	0.0095	0.0121
Education - Primary School	0.0068	0.0046	0.0063	0.0099
Education - University	0.0090	0.0087	0.0084	0.0110
Grocery	0.0096	0.0096	0.0096	0.0096
Health/Medical	0.0173	0.0171	0.0173	0.0172
Lodging - Hotel	0.0050	0.0069	0.0074	0.0070
Lodging - Motel	0.0041	0.0057	0.0061	0.0057
Manufacturing - Bio/Tech	0.0217	0.0228	0.0217	0.0228
Manufacturing - Light Industrial	0.0217	0.0228	0.0217	0.0228
Industrial/Warehouse 1-shift	0.0217	0.0228	0.0217	0.0228
Industrial/Warehouse 2-shift	0.0238	0.0280	0.0238	0.0280
Industrial/Warehouse 3-shift	0.0285	0.0286	0.0285	0.0286
Municipal	0.0157	0.0123	0.0013	0.00173
Office - Large	0.0160	0.0132	0.0117	0.0187
Office - Small	0.0157	0.0129	0.0115	0.0183
Religious	0.0100	0.0093	0.0092	0.0140
Restaurant - Fast-Food	0.0187	0.0164	0.0187	0.0184
Restaurant - Sit-Down	0.0219	0.0033	0.0219	0.0064
Retail - Mall Department Store	0.0207	0.0086	0.0195	0.0165
Retail - Single-Story, Large	0.0220	0.0082	0.0219	0.0165
Retail - Small	0.0284	0.0110	0.0252	0.0232
Service	0.0247	0.0130	0.0218	0.0202
Storage - Conditioned	0.0246	0.0043	0.0202	0.0188
Storage - Unconditioned	0.0288	0.0093	0.0225	0.0186
Other	0.0201	0.0140	0.0188	0.0174

Table 123. 8-foot Delamping Peak Demand Savings (per Lamp Removed)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0275	0.0148	0.0279	0.0159
Education - College/Secondary	0.0199	0.0170	0.0180	0.0230
Education - Primary School	0.0130	0.0087	0.0121	0.0188
Education - University	0.0172	0.0165	0.0160	0.0208
Grocery	0.0183	0.0183	0.0183	0.0183
Health/Medical	0.0329	0.0325	0.0328	0.0328
Lodging - Hotel	0.0095	0.0132	0.0141	0.0133
Lodging - Motel	0.0078	0.0108	0.0115	0.0109
Manufacturing - Bio/Tech	0.0413	0.0433	0.0413	0.0433
Manufacturing - Light Industrial	0.0413	0.0433	0.0413	0.0433
Industrial/Warehouse 1-shift	0.0413	0.0433	0.0413	0.0433
Industrial/Warehouse 2-shift	0.0453	0.0532	0.0453	0.0532
Industrial/Warehouse 3-shift	0.0541	0.0544	0.0541	0.0544
Municipal	0.0299	0.0234	0.0247	0.0329
Office - Large	0.0305	0.0251	0.0223	0.0355
Office - Small	0.0299	0.0245	0.0218	0.0348
Religious	0.0191	0.0177	0.0175	0.0266
Restaurant - Fast-Food	0.0355	0.0313	0.0355	0.0350
Restaurant - Sit-Down	0.0416	0.0062	0.0416	0.0121
Retail - Mall Department Store	0.0394	0.0163	0.0372	0.0313
Retail - Single-Story, Large	0.0418	0.0156	0.0417	0.0314
Retail - Small	0.0539	0.0210	0.0480	0.0441
Service	0.0470	0.0248	0.0414	0.0383
Storage - Conditioned	0.0469	0.0083	0.0384	0.0357
Storage - Unconditioned	0.0548	0.0177	0.0429	0.0354
Other	0.0382	0.0266	0.0357	0.0331

Measure Life:

15 years (GDS)

5.2.1.6 High-Performance, 4-foot T8 Retrofit

Sources:

DEER, 2008 and 2011. www.deeresources.com/

DEER, 2011. www.deeresources.com/

Consortium for Energy Efficiency (CEE), www.cee1.org

GDS, "Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures," for the New England State Program Working Group, by GDS Associates, Inc., March 2007.

Measure Description:

This measure consists of replacing existing lamps and ballasts with high-performance 4-foot T8 lamps and ballasts. This measure is based on CEE's high-performance T8 specifications, which is included in the non-residential lighting workbook and can also be accessed at www.cee1.org. Additionally, a list of qualified lamps and ballasts is available in the workbook and a regularly updated list can be found at www.cee1.org. These fixtures typically have a higher lumen per watt than standard T8 and electronic ballast fixtures.

Assumptions:

The assumptions used to calculate measure energy savings are listed in the following table. Baseline and retrofit wattages use standard industry values. The fixture wattage used is representative of the fixture category. For calculation purposes, the demand reductions per lamp for various configurations are weighted (based on KEMA assumptions), and then are averaged to produce a single demand reduction value.

It is important to note that new federal standards have eliminated the manufacturing and importing of magnetic ballasts and T12 lamps. Hence, it is important to redefine baseline. Subsequently, the TVA has adopted a standard T8 baseline for all linear fluorescent fixtures. Retrofitting T12 fixtures to T8 fixtures is a recommended measure; however, the adjusted baseline for this measure is T8 lamps and electronic ballasts.

Table 124. Baseline and Retrofit Wattages for High-Performance Fixture Retrofits

T8, 4-foot Configuration	Base Fixture Wattage	Retrofit Lamp Wattage	Retrofit Fixture Wattage	Demand Reduction per fixture (kW)	Demand Reduction per lamp (kW)	Weight Percentages
4-lamp	112	32	107	0.0050	0.0012	36%
3-lamp	89	32	87	0.0025	0.0008	16%
2-lamp	59	32	57	0.0016	0.0008	32%
1-lamp	31	3	31	0.0001	0.0001	16%
Weighted Average					0.0008	

Savings:

The following table provides high-performance T8 savings over T12 lamps and magnetic ballasts or standard T8 lamps and electronic ballasts, by building type.

Table 125. High Performance T8 Savings (per Lamp)

Building Type	kWh Savings
Assembly	1.54
Education - College/Secondary	1.55
Education - Primary School	1.37
Education - University	1.46
Grocery	1.55
Health/Medical	3.08
Lodging - Hotel	1.24
Lodging - Motel	1.01
Manufacturing - Bio/Tech	2.50
Manufacturing - Light Industrial	1.97
Industrial/Warehouse 1-shift	2.67
Industrial/Warehouse 2-shift	3.57
Industrial/Warehouse 3-shift	4.92
Municipal	1.97
Office - Large	1.67
Office - Small	1.64
Religious	1.67
Restaurant - Fast-Food	3.05
Restaurant - Sit-Down	3.04
Retail - Mall Department Store	2.13
Retail - Single-Story, Large	2.46

Building Type	kWh Savings
Retail - Small	2.80
Service	2.22
Storage - Conditioned	2.17
Storage - Unconditioned	2.48
Other	2.69

Peak demand savings were determined by using indoor lighting specific end-use load profiles developed with eQUEST software for the TVA region commercial baseline prototypes. Average peak load factors (except for the industrial/warehouse shifts where the coincident diversity factor is used) were extracted from the load profiles using TVA's peak period times and then applied to the annual kWh savings of the corresponding building type and measure. Listed below are the results for the summer and winter peak periods in TVA's districts.

Table 126. High Performance T8 Peak Demand Savings (per Lamp)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0003	0.0002	0.0003	0.0002
Education - College/Secondary	0.0002	0.0002	0.0002	0.0003
Education - Primary School	0.0002	0.0001	0.0001	0.0002
Education - University	0.0002	0.0002	0.0002	0.0002
Grocery	0.0002	0.0002	0.0002	0.0002
Health/Medical	0.0004	0.0004	0.0004	0.0004
Lodging - Hotel	0.0001	0.0002	0.0002	0.0002
Lodging - Motel	0.0001	0.0001	0.0001	0.0001
Manufacturing - Bio/Tech	0.0005	0.0005	0.0005	0.0005
Manufacturing - Light Industrial	0.0005	0.0005	0.0005	0.0005
Industrial/Warehouse 1-shift	0.0005	0.0005	0.0005	0.0005
Industrial/Warehouse 2-shift	0.0005	0.0006	0.0005	0.0006
Industrial/Warehouse 3-shift	0.0006	0.0006	0.0006	0.0006
Municipal	0.0003	0.0003	0.0003	0.0004
Office - Large	0.0004	0.0003	0.0003	0.0004
Office - Small	0.0003	0.0003	0.0003	0.0004
Religious	0.0002	0.0002	0.0002	0.0003
Restaurant - Fast-Food	0.0004	0.0004	0.0004	0.0004
Restaurant - Sit-Down	0.0005	0.0001	0.0005	0.0001

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Retail - Mall Department Store	0.0005	0.0002	0.0004	0.0004
Retail - Single-Story, Large	0.0005	0.0002	0.0005	0.0004
Retail - Small	0.0006	0.0002	0.0006	0.0005
Service	0.0005	0.0003	0.0005	0.0004
Storage - Conditioned	0.0005	0.0001	0.0004	0.0004
Storage - Unconditioned	0.0006	0.0002	0.0005	0.0004
Other	0.0004	0.0003	0.0004	0.0004

Measure Life:

15 years (GDS), assumed to be the same as standard T8 lamps and ballasts.

5.2.1.7 Reduced-Wattage, 4-foot T12 to T8 Retrofit

Sources:

DEER, 2008. www.deeresources.com

Consortium for Energy Efficiency (CEE), www.cee1.org

GDS, "Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures," for the New England State Program Working Group, by GDS Associates, Inc., March 2007.

Measure Description:

This measure consists of replacing existing adjust baseline T12 lamps and magnetic ballasts or standard T8 lamps and electronic ballasts with reduced-wattage (28 W or 25 W) 4-foot T8 lamps with electronic ballasts. This measure is based on the CEE's reduced wattage specification, which is available in the non-residential lighting workbook and can be accessed at www.cee1.org. A list of qualified lamps and ballasts can also be found in the workbook and a regularly updated list can be accessed at www.cee1.org.

Assumptions:

The assumptions used to calculate measure energy savings are listed in the following table. Baseline and retrofit wattages use standard industry values. For calculation purposes, the demand savings per lamp for various configurations are weighted (based on KEMA assumptions), and are then averaged to produce a single demand reduction value.

It is important to note that new federal standards have eliminated the manufacturing and importing of magnetic ballasts and T12 lamps. Hence, it is important to redefine baseline. Subsequently, the TVA has adopted a standard T8 baseline for all linear fluorescent fixtures. Retrofitting T12 fixtures to T8 fixtures is a recommended measure; however, the adjusted baseline for this measure is T8 lamps and electronic ballasts.

Table 127. Baseline and Retrofit Wattages for Reduced-Wattage Fixture Retrofits

T8, 4-foot Configuration	Base Fixture Wattage	Retrofit Lamp Wattage	Retrofit Fixture Wattage	Demand Savings per fixture (kW)	Demand Savings per lamp (kW)	Weight Percentages
4-lamp	112	28	94	0.0181	0.0045	13%
3-lamp	89	28	75	0.0140	0.0047	20%
2-lamp	59	28	50	0.0092	0.0046	13%
1-lamp	31	28	27	0.0037	0.0037	12%
4-lamp	112	25	85	0.0267	0.0067	5%
3-lamp	89	25	67	0.0221	0.0074	11%
2-lamp	59	25	45	0.0143	0.0072	5%
1-lamp	31	25	24	0.0070	0.0070	4%
Weighted Average					**0.0044**	

Savings:

The following table lists average T8 reduced wattage savings over T12 lamps or standard T8 lamps by building type.

Table 128. Reduced-Wattage Fixture Retrofits, 4-foot T8 Savings (per Lamp)

Building Type	kWh Savings
Assembly	10.6
Education - College/Secondary	10.7
Education - Primary School	9.4
Education - University	10.1
Grocery	10.7
Health/Medical	21.2
Lodging - Hotel	8.5
Lodging - Motel	7.0
Manufacturing - Bio/Tech	17.2
Manufacturing - Light Industrial	13.6

Building Type	kWh Savings
Industrial/Warehouse 1-shift	18.4
Industrial/Warehouse 2-shift	24.6
Industrial/Warehouse 3-shift	34.0
Municipal	13.6
Office - Large	11.5
Office - Small	11.3
Religious	11.5
Restaurant - Fast-Food	21.0
Restaurant - Sit-Down	20.9
Retail - Mall Department Store	14.7
Retail - Single-Story, Large	17.0
Retail - Small	19.3
Service	15.3
Storage - Conditioned	15.0
Storage - Unconditioned	17.1
Other	18.6

Table 129. Reduced-Wattage Fixture Retrofits, 4-foot T8 Peak Demand Savings (per Lamp)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0022	0.0012	0.0022	0.0013
Education - College/Secondary	0.0016	0.0014	0.0014	0.0018
Education - Primary School	0.0010	0.0007	0.0010	0.0015
Education - University	0.0014	0.0013	0.0013	0.0017
Grocery	0.0015	0.0015	0.0015	0.0015
Health/Medical	0.0026	0.0026	0.0026	0.0026
Lodging - Hotel	0.0008	0.0011	0.0011	0.0011
Lodging - Motel	0.0006	0.0009	0.0009	0.0009
Manufacturing - Bio/Tech	0.0033	0.0035	0.0033	0.0035
Manufacturing - Light Industrial	0.0033	0.0035	0.0033	0.0035
Industrial/Warehouse 1-shift	0.0033	0.0035	0.0033	0.0035
Industrial/Warehouse 2-shift	0.0036	0.0043	0.0036	0.0043
Industrial/Warehouse 3-shift	0.0043	0.0043	0.0043	0.0043
Municipal	0.0016	0.0013	0.0013	0.0018
Office - Large	0.0024	0.0020	0.0018	0.0028
Office - Small	0.0024	0.0020	0.0017	0.0028
Religious	0.0015	0.0014	0.0014	0.0021

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Restaurant - Fast-Food	0.0028	0.0025	0.0028	0.0028
Restaurant - Sit-Down	0.0033	0.0005	0.0033	0.0010
Retail - Mall Department Store	0.0031	0.0013	0.0030	0.0025
Retail - Single-Story, Large	0.0033	0.0012	0.0033	0.0025
Retail - Small	0.0043	0.0017	0.0038	0.0035
Service	0.0038	0.0020	0.0033	0.0031
Storage - Conditioned	0.0037	0.0007	0.0031	0.0029
Storage - Unconditioned	0.0044	0.0014	0.0034	0.0028
Other	0.0030	0.0021	0.0028	0.0026

Measure Life:

15 years (GDS), assumed to be the same as standard T8 lamps and ballasts.

5.2.1.8 Reduced-Wattage, 4-foot Lamp used with Existing Ballast

Sources:

DEER, 2008. www.deeresources.com

Consortium for Energy Efficiency (CEE), www.cee1.org

Measure Description:

This measure consists of replacing standard 32 W T8 lamps with reduced-wattage T8 lamps (28 W or 25 W) when an electronic ballast is already present. The lamps must be reduced wattage in accordance with the CEE's specification.[94] The measure assumes replacement lamps have a nominal wattage of 28 W (≥ 2,585 lumens) or 25 W (≥ 2,400 lumens). Mean system efficacy must be ≥ 90 MLPW and CRI ≥ 80 with lumen maintenance at 94%.

Assumptions:

The following table provides assumptions used to calculate measure energy savings. Baseline and retrofit wattages use standard industry values. For calculation purposes, the demand savings per lamp for various

[94] Qualified products can be found at www.cee1.org.

configurations are weighted (based on KEMA assumptions), and are then averaged to produce a single demand reduction value.

Table 130. Baseline and Retrofit Wattages for 4-foot T8 Lamp with Existing Ballast

T8, 4-foot Configuration	Base Fixture Wattage	Retrofit Lamp Wattage	Retrofit Fixture Wattage	Demand Savings per fixture (kW)	Demand Savings per lamp (kW)	Weights
4-lamp	112	28	94	0.0181	0.0045	36%
3-lamp	89	28	75	0.0140	0.0047	16%
2-lamp	59	28	50	0.0092	0.0046	32%
1-lamp	31	28	27	0.0037	0.0037	16%
Weighted Average					0.0044	

Savings:

The following table lists average T8 reduced wattage savings over standard T8 lamps by building type.

Table 131. Standard T8 to Reduced Wattage, 4-foot T8 Savings (per Lamp)

Building Type	kWh Savings
Assembly	10.7
Education - College/Secondary	10.8
Education - Primary School	9.5
Education - University	10.2
Grocery	10.7
Health/Medical	21.4
Lodging - Hotel	8.6
Lodging - Motel	7.0
Manufacturing - Bio/Tech	17.3
Manufacturing - Light Industrial	13.7
Industrial/Warehouse 1-shift	18.5
Industrial/Warehouse 2-shift	24.8
Industrial/Warehouse 3-shift	34.2
Municipal	13.6
Office - Large	11.6
Office - Small	11.4
Religious	11.6
Restaurant - Fast-Food	21.2
Restaurant - Sit-Down	21.1
Retail - Mall Department Store	14.8
Retail - Single-Story, Large	17.1

Building Type	kWh Savings
Retail - Small	19.4
Service	15.4
Storage - Conditioned	15.1
Storage - Unconditioned	17.2
Other	18.7

Peak demand savings were determined by using indoor lighting specific end-use load profiles developed with eQUEST software for the TVA region commercial baseline prototypes. Average peak load factors (except for the industrial/warehouse shifts where a coincident diversity factor is used) were extracted from the load profiles using TVA's peak period times and then applied to the annual kWh savings of the corresponding building type and measure. Listed below are the results for the summer and winter peak periods in TVA's districts.

Table 132. Standard T8 to Reduced Wattage, 4-foot, T8 Peak Demand Savings (per Lamp)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0022	0.0012	0.0022	0.0013
Education - College/Secondary	0.0016	0.0014	0.0015	0.0018
Education - Primary School	0.0010	0.0007	0.0010	0.0015
Education - University	0.0014	0.0013	0.0013	0.0017
Grocery	0.0015	0.0015	0.0015	0.0015
Health/Medical	0.0026	0.0026	0.0026	0.0026
Lodging - Hotel	0.0008	0.0011	0.0011	0.0011
Lodging - Motel	0.0006	0.0009	0.0009	0.0009
Manufacturing - Bio/Tech	0.0033	0.0035	0.0033	0.0035
Manufacturing - Light Industrial	0.0033	0.0035	0.0033	0.0035
Industrial/Warehouse 1-shift	0.0033	0.0035	0.0033	0.0035
Industrial/Warehouse 2-shift	0.0036	0.0043	0.0036	0.0043
Industrial/Warehouse 3-shift	0.0043	0.0044	0.0043	0.0044
Municipal	0.0017	0.0013	0.0014	0.0018
Office - Large	0.0025	0.0020	0.0018	0.0029
Office - Small	0.0024	0.0020	0.0018	0.0028
Religious	0.0015	0.0014	0.0014	0.0021
Restaurant - Fast-Food	0.0029	0.0025	0.0029	0.0028
Restaurant - Sit-Down	0.0033	0.0005	0.0033	0.0010
Retail - Mall Department Store	0.0032	0.0013	0.0030	0.0025
Retail - Single-Story, Large	0.0034	0.0013	0.0033	0.0025
Retail - Small	0.0043	0.0017	0.0039	0.0035

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Service	0.0038	0.0020	0.0033	0.0031
Storage - Conditioned	0.0038	0.0007	0.0031	0.0029
Storage - Unconditioned	0.0044	0.0014	0.0034	0.0028
Other	0.0031	0.0021	0.0029	0.0027

Measure Life:

3 years, based on the life of the lamp only[95]

5.2.1.9 LED, 4-foot Linear Replacement Lamps

Sources:

DEER, 2008. www.deeresources.com/

Consortium for Energy Efficiency (CEE), www.cee1.org

Designlights Consortium (DLC), https://www.designlights.org/

Measure Description:

This measure consists of replacing standard 32 W T8 lamps with reduced-wattage linear LED lamps. The measure assumes replacement lamps have a mean efficacy ≥ 100 MLPW and CRI ≥ 80.

Assumptions:

The following table provides assumptions used to calculate measure energy savings. Baseline wattages use standard industry values. For calculation purposes, the baseline lamp wattage is based on weighted (based on KEMA assumptions), and are then averaged to produce a single per lamp wattage.

Table 133. Baseline Wattages, 4-foot Linear Fluorescent T8 Lamp

T8, 4-foot Configuration	Base Fixture Wattage	Per Lamp Wattage	Weights
4-lamp	112	31.0	36%
3-lamp	89	29.5	16%
2-lamp	59	29.7	32%

[95] KEMA assumption

T8, 4-foot Configuration	Base Fixture Wattage	Per Lamp Wattage	Weights
1-lamp	31	28.0	16%
Weighted Average		29.9	

The retrofit lamp wattage is based on the average lamp wattage of 1,057 lamps that meet the measure description assumptions in the November 14, 2014 version of the DLC list of qualified 4-foot linear replacement lamps. The list ranges from 9.1 W to 28.2 W, with an average of 18.5 W.

Table 134. Baseline Wattages, 4-foot Linear Fluorescent T8 Lamp

Measure Description	Base Lamp Wattage	Retrofit Lamp Wattage	Demand Savings per lamp (kW)
T8 to LED	29.9	18.5	0.0113

Savings:

The following table lists LED savings over standard T8 lamps by building type.

Table 135. Standard T8 to LED, 4-foot T8 Savings (per Lamp)

Building Type	kWh Savings
Assembly	28
Education - College/Secondary	28
Education - Primary School	25
Education - University	26
Grocery	28
Health/Medical	55
Lodging - Hotel	48
Lodging - Motel	64
Manufacturing - Bio/Tech	89
Manufacturing - Light Industrial	22
Industrial/Warehouse 1-shift	18
Industrial/Warehouse 2-shift	75
Industrial/Warehouse 3-shift	36
Municipal	35
Office - Large	30
Office - Small	29
Religious	30

Building Type	kWh Savings
Restaurant - Fast-Food	55
Restaurant - Sit-Down	55
Retail - Mall Department Store	38
Retail - Single-Story, Large	44
Retail - Small	50
Service	40
Storage - Conditioned	39
Storage - Unconditioned	45
Other	48

Peak demand savings were determined by using indoor lighting specific end-use load profiles developed with eQUEST software for the TVA region commercial baseline prototypes. Average peak load factors (except for the industrial/warehouse shifts where a coincident diversity factor was used) were extracted from the load profiles using TVA's peak period times and then applied to the annual kWh savings of the corresponding building type and measure. Listed below are the results for the summer and winter peak periods in TVA's districts.

Table 136. Standard T8 to LED, Peak Demand Savings (per Lamp)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0057	0.0031	0.0058	0.0033
Education - College/Secondary	0.0041	0.0035	0.0038	0.0048
Education - Primary School	0.0027	0.0018	0.0025	0.0039
Education - University	0.0036	0.0034	0.0033	0.0043
Grocery	0.0038	0.0038	0.0038	0.0038
Health/Medical	0.0068	0.0068	0.0068	0.0068
Lodging - Hotel	0.0086	0.0090	0.0086	0.0090
Lodging - Motel	0.0094	0.0111	0.0094	0.0111
Manufacturing - Bio/Tech	0.0113	0.0113	0.0113	0.0113
Manufacturing - Light Industrial	0.0020	0.0027	0.0029	0.0028
Industrial/Warehouse 1-shift	0.0016	0.0022	0.0024	0.0023
Industrial/Warehouse 2-shift	0.0086	0.0090	0.0086	0.0090
Industrial/Warehouse 3-shift	0.0086	0.0090	0.0086	0.0090
Municipal	0.0062	0.0049	0.0051	0.0068
Office - Large	0.0064	0.0052	0.0046	0.0074
Office - Small	0.0062	0.0051	0.0045	0.0072

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Religious	0.0040	0.0037	0.0036	0.0055
Restaurant - Fast-Food	0.0074	0.0065	0.0074	0.0073
Restaurant - Sit-Down	0.0087	0.0013	0.0087	0.0025
Retail - Mall Department Store	0.0082	0.0034	0.0077	0.0065
Retail - Single-Story, Large	0.0087	0.0032	0.0087	0.0065
Retail - Small	0.0112	0.0044	0.0100	0.0092
Service	0.0098	0.0052	0.0086	0.0080
Storage - Conditioned	0.0098	0.0017	0.0080	0.0074
Storage - Unconditioned	0.0114	0.0037	0.0089	0.0074
Other	0.0080	0.0055	0.0074	0.0069

Measure Life:

The measure life is 14.3 years, based on the average lamp life (50,650) in the DLC list of qualified 4-foot linear replacement lamps and the average building hours.

5.2.1.10 LED Open Sign

Sources:

DEER, 2008. www.deeresources.com

PG&E work papers, 2006

Measure Description:

This measure consists of replacing a store's neon open sign; the sign displays the word "OPEN." Replacement signs cannot use more than 20% of the actual input power of the sign that was replaced.

Assumptions:

The assumptions are presented in the following table. The wattage reductions are from PG&E work papers on open signs.

Table 137. Demand Reduction for Open Signs (per Sign)

Sign Type	Demand Savings (kW)	Weight Percentages
Replacement of Neon-Large Neon-Like Appearance	0.169	33%
Replacement of Neon-Small Dot Pattern	0.125	33%
Replacement of Neon-Large Oblong Dot Pattern	0.180	33%
Weighted Average	0.158	

Savings:

The following table provides the energy savings by building type. Many of these buildings types may not have open signs. Open signs are assumed to be on during the typical operating hours of these buildings. CFL operating hour factors are used in the savings calculations.

Table 138. LED Open Signs Savings (per Sign)

Building Type	kWh Savings
Assembly	362
Education - College/Secondary	404
Education - Primary School	379
Education - University	393
Grocery	388
Health/Medical	645
Lodging - Hotel	262
Lodging - Motel	231
Manufacturing - Bio/Tech	553
Manufacturing - Light Industrial	414
Industrial/Warehouse 1-shift	799
Industrial/Warehouse 2-shift	972
Industrial/Warehouse 3-shift	1344
Municipal	492
Office - Large	498
Office - Small	487
Religious	418
Restaurant - Fast-Food	764
Restaurant - Sit-Down	761
Retail - Mall Department Store	585
Retail - Single-Story, Large	602
Retail - Small	588
Service	556
Storage - Conditioned	439

Building Type	kWh Savings
Storage - Unconditioned	439
Other	674

Peak demand savings were determined by using indoor lighting specific end-use load profiles developed with eQUEST software for the TVA region commercial baseline prototypes. Average peak load factors (except for the industrial/warehouse shifts where a coincident diversity factor is used) were extracted from the load profiles using TVA's peak period times and then applied to the annual kWh savings of the corresponding building type and measure. Listed below are the results for the summer and winter peak periods in TVA's districts.

Table 139. LED Open Signs Peak Demand Savings (per Sign)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0746	0.0402	0.0758	0.0432
Education - College/Secondary	0.0599	0.0511	0.0544	0.0692
Education - Primary School	0.0416	0.0279	0.0387	0.0604
Education - University	0.0532	0.0513	0.0497	0.0646
Grocery	0.0532	0.0532	0.0532	0.0532
Health/Medical	0.0797	0.0789	0.0796	0.0796
Lodging - Hotel	0.0233	0.0323	0.0345	0.0326
Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Lodging - Motel	0.0205	0.0284	0.0303	0.0287
Manufacturing - Bio/Tech	0.1198	0.1255	0.1198	0.1255
Manufacturing - Light Industrial	0.1198	0.1255	0.1198	0.1255
Industrial/Warehouse 1-shift	0.1198	0.1255	0.1198	0.1255
Industrial/Warehouse 2-shift	0.1313	0.1544	0.1313	0.1544
Industrial/Warehouse 3-shift	0.1569	0.1578	0.1569	0.1578
Municipal	0.0866	0.0678	0.0715	0.0952
Office - Large	0.1052	0.0864	0.0768	0.1225
Office - Small	0.1029	0.0845	0.0751	0.1198
Religious	0.0553	0.0512	0.0508	0.0772
Restaurant - Fast-Food	0.1030	0.0907	0.1030	0.1014
Restaurant - Sit-Down	0.1207	0.0181	0.1207	0.0352
Retail - Mall Department Store	0.1254	0.0520	0.1183	0.0997
Retail - Single-Story, Large	0.1184	0.0442	0.1179	0.0890
Retail - Small	0.1312	0.0511	0.1168	0.1073

Service	0.1362	0.0719	0.1200	0.1111
Storage - Conditioned	0.1098	0.0193	0.0898	0.0836
Storage - Unconditioned	0.1123	0.0363	0.0879	0.0725
Other	0.1107	0.0771	0.1035	0.0960

Measure Life:

16 years (2008 DEER), assumed to be the same as LED exit signs.

5.2.1.11 LED Lighting

Sources:

Illinois Statewide TRM, May 2012

Measure Description:

This measure consists of replacing non-LED lamps with light emitting diode (LED) recessed down or screw-in lamps.

Assumptions:

The assumptions used to calculate measure energy savings are provided in the following table. Baseline and retrofit wattages use standard industry values from the Illinois TRM (select default wattages were used per lamp category).

Table 140. Baseline and Retrofit Wattages for LED Lamps

LED Lamp	Base Lamp Wattage	Retrofit Lamp Wattage	Demand Savings per Lamp (kW)
Screw and Pin-based Bulbs, Omnidirectional, < 10W	29	6.5	0.023
Screw and Pin-based Bulbs, Omnidirectional, >= 10W	53	20	0.033
Screw and Pin-based Bulbs, Decorative	25	3.75	0.021
Screw-Bulbs, Directional, < 15W	40	10	0.030
Screw-based Bulbs, Directional, >= 15W	125	31.25	0.094
Screw-in Trim Kits	54.3	17.6	0.037

Savings:

The following table provides average energy savings for replacing incandescent lamps with LED lamps by building type.

Table 141. LED Lamp Savings (per Lamp)

Building Type	Omnidirectional, < 10 W	Omnidirectional, >= 10 W	Decorative	Directional, < 15 W	Directional, >= 15 W	Trim Kits
Assembly	52	76	49	69	215	84
Education - College/Secondary	56	84	54	77	240	94
Education - Primary School	57	79	51	72	225	88
Education - University	54	82	53	75	233	91
Grocery	55	81	52	74	230	90
Health/Medical	92	135	87	123	383	150
Lodging - Hotel	37	55	35	50	156	61
Lodging - Motel	33	48	31	44	137	54
Manufacturing - Bio/Tech	79	116	74	105	328	128
Manufacturing - Light Industrial	59	86	56	79	246	96
Industrial/Warehouse 1-shift	114	167	107	152	474	186
Industrial/Warehouse 2-shift	138	203	131	185	577	226
Industrial/Warehouse 3-shift	191	281	181	255	797	312
Municipal	70	103	66	93	292	114
Office - Large	71	104	67	95	295	116
Office - Small	69	102	65	92	289	113
Religious	60	87	56	79	248	97
Restaurant - Fast-Food	109	160	103	145	453	177
Restaurant - Sit-Down	108	159	102	144	451	177
Retail - Mall Department Store	83	122	79	111	347	136
Retail - Single-Story, Large	86	126	81	114	357	140
Retail - Small	84	123	79	112	349	137
Service	79	116	75	106	330	129
Storage - Conditioned	63	92	59	83	261	102
Storage - Unconditioned	63	92	59	83	261	102
Other	96	103	91	128	400	157

Peak demand savings were determined by using indoor lighting specific end-use load profiles developed with eQUEST software for the TVA region commercial baseline prototypes. Average peak load factors (except for the industrial/warehouse shifts where a coincident diversity factor is used) were extracted from the load profiles using TVA's peak period times and then applied to the annual kWh savings of the corresponding building type and measure. Listed below are the results for the summer and winter peak periods in TVA's districts.

Table 142. LED, Omnidirectional, < 10 W Lamp, Peak Demand Savings (per Lamp)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0106	0.0057	0.0108	0.0061
Education - College/Secondary	0.0085	0.0073	0.0077	0.0099
Education - Primary School	0.0059	0.0040	0.0055	0.0086
Education - University	0.0076	0.0073	0.0071	0.0092
Grocery	0.0076	0.0076	0.0076	0.0076
Health/Medical	0.0113	0.0112	0.0113	0.0113
Lodging – Hotel	0.0171	0.0179	0.0171	0.0179
Lodging – Motel	0.0187	0.0220	0.0187	0.0220
Manufacturing - Bio/Tech	0.0223	0.0225	0.0223	0.0225
Manufacturing - Light Industrial	0.0033	0.0046	0.0049	0.0046
Industrial/Warehouse 1-shift	0.0029	0.0040	0.0043	0.0041
Industrial/Warehouse 2-shift	0.0171	0.0179	0.0171	0.0179
Industrial/Warehouse 3-shift	0.0171	0.0179	0.0171	0.0179
Municipal	0.0123	0.0097	0.0102	0.0136
Office – Large	0.0150	0.0123	0.0109	0.0174
Office – Small	0.0146	0.0120	0.0107	0.0171
Religious	0.0079	0.0073	0.0072	0.0110
Restaurant - Fast-Food	0.0147	0.0129	0.0147	0.0144
Restaurant - Sit-Down	0.0172	0.0026	0.0172	0.0050
Retail - Mall Department Store	0.0179	0.0074	0.0168	0.0142
Retail - Single-Story, Large	0.0169	0.0063	0.0168	0.0127
Retail - Small	0.0187	0.0073	0.0166	0.0153
Service	0.0194	0.0102	0.0171	0.0158
Storage - Conditioned	0.0156	0.0028	0.0128	0.0119
Storage - Unconditioned	0.0160	0.0052	0.0125	0.0103
Other	0.0158	0.0110	0.0147	0.0137

Table 143. LED, Omnidirectional, ≥ 10 W Lamp, Peak Demand Savings (per Lamp)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0156	0.0084	0.0158	0.0090
Education - College/Secondary	0.0125	0.0107	0.0114	0.0144
Education - Primary School	0.0087	0.0058	0.0081	0.0126

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Education - University	0.0111	0.0107	0.0104	0.0135
Grocery	0.0111	0.0111	0.0111	0.0111
Health/Medical	0.0166	0.0165	0.0166	0.0166
Lodging - Hotel	0.0250	0.0262	0.0250	0.0262
Lodging - Motel	0.0274	0.0322	0.0274	0.0322
Manufacturing - Bio/Tech	0.0328	0.0330	0.0328	0.0330
Manufacturing - Light Industrial	0.0049	0.0067	0.0072	0.0068
Industrial/Warehouse 1-shift	0.0043	0.0059	0.0063	0.0060
Industrial/Warehouse 2-shift	0.0250	0.0262	0.0250	0.0262
Industrial/Warehouse 3-shift	0.0250	0.0262	0.0250	0.0262
Municipal	0.0181	0.0142	0.0149	0.0199
Office - Large	0.0220	0.0180	0.0160	0.0256
Office - Small	0.0215	0.0176	0.0157	0.0250
Religious	0.0231	0.0161	0.0106	0.0161
Restaurant - Fast-Food	0.0115	0.0107	0.0215	0.0212
Restaurant - Sit-Down	0.0215	0.0189	0.0252	0.0073
Retail - Mall Department Store	0.0252	0.0038	0.0247	0.0208
Retail - Single-Story, Large	0.0262	0.0109	0.0246	0.0186
Retail - Small	0.0247	0.0092	0.0244	0.0224
Service	0.0274	0.0107	0.0251	0.0232
Storage - Conditioned	0.0285	0.0150	0.0188	0.0175
Storage - Unconditioned	0.0229	0.0040	0.0184	0.0152
Other	0.0235	0.0076	0.0216	0.0200

Table 144. LED Decorative Lamp, Peak Demand Savings (per Lamp)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0100	0.0054	0.0102	0.0058
Education - College/Secondary	0.0081	0.0069	0.0073	0.0093
Education - Primary School	0.0056	0.0037	0.0052	0.0081
Education - University	0.0072	0.0069	0.0067	0.0087
Grocery	0.0072	0.0071	0.0072	0.0071
Health/Medical	0.0107	0.0106	0.0107	0.0107
Lodging - Hotel	0.0161	0.0169	0.0161	0.0169
Lodging - Motel	0.0177	0.0208	0.0177	0.0208
Manufacturing - Bio/Tech	0.0211	0.0212	0.0211	0.0212

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Manufacturing - Light Industrial	0.0031	0.0043	0.0046	0.0044
Industrial/Warehouse 1-shift	0.0028	0.0038	0.0041	0.0039
Industrial/Warehouse 2-shift	0.0161	0.0169	0.0161	0.0169
Industrial/Warehouse 3-shift	0.0161	0.0169	0.0161	0.0169
Municipal	0.0116	0.0091	0.0096	0.0128
Office - Large	0.0141	0.0116	0.0103	0.0165
Office - Small	0.0138	0.0114	0.0101	0.0161
Religious	0.0074	0.0069	0.0068	0.0104
Restaurant - Fast-Food	0.0139	0.0122	0.0139	0.0136
Restaurant - Sit-Down	0.0162	0.0024	0.0162	0.0047
Retail - Mall Department Store	0.0169	0.0070	0.0159	0.0134
Retail - Single-Story, Large	0.0159	0.0059	0.0159	0.0120
Retail - Small	0.0177	0.0069	0.0157	0.0144
Service	0.0183	0.0097	0.0161	0.0149
Storage - Conditioned	0.0148	0.0026	0.0121	0.0112
Storage - Unconditioned	0.0151	0.0049	0.0118	0.0098
Other	0.0149	0.0104	0.0139	0.0129

Table 145. LED, Directional, < 15 W Lamp, Peak Demand Savings (per Lamp)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0142	0.0076	0.0144	0.0082
Education - College/Secondary	0.0114	0.0097	0.0103	0.0131
Education - Primary School	0.0079	0.0053	0.0074	0.0115
Education - University	0.0101	0.0097	0.0094	0.0123
Grocery	0.0101	0.0101	0.0101	0.0101
Health/Medical	0.0151	0.0150	0.0151	0.0151
Lodging - Hotel	0.0227	0.0238	0.0227	0.0238
Lodging - Motel	0.0249	0.0293	0.0249	0.0293
Manufacturing - Bio/Tech	0.0298	0.0300	0.0298	0.0300
Manufacturing - Light Industrial	0.0044	0.0061	0.0065	0.0062
Industrial/Warehouse 1-shift	0.0039	0.0054	0.0058	0.0055
Industrial/Warehouse 2-shift	0.0227	0.0238	0.0227	0.0238
Industrial/Warehouse 3-shift	0.0227	0.0238	0.0227	0.0238
Municipal	0.0164	0.0129	0.0136	0.0181
Office - Large	0.0200	0.0164	0.0146	0.0233

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Office - Small	0.0195	0.0160	0.0143	0.0227
Religious	0.0105	0.0097	0.0096	0.0147
Restaurant - Fast-Food	0.0196	0.0172	0.0196	0.0192
Restaurant - Sit-Down	0.0229	0.0034	0.0229	0.0067
Retail - Mall Department Store	0.0238	0.0099	0.0225	0.0189
Retail - Single-Story, Large	0.0225	0.0084	0.0224	0.0169
Retail - Small	0.0249	0.0097	0.0222	0.0204
Service	0.0259	0.0136	0.0228	0.0211
Storage - Conditioned	0.0208	0.0037	0.0171	0.0159
Storage - Unconditioned	0.0213	0.0069	0.0167	0.0138
Other	0.0210	0.0146	0.0197	0.0182

Table 146. LED, Directional, ≥ 15 W Lamp, Peak Demand Savings (per Lamp)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0443	0.0239	0.0450	0.0256
Education - College/Secondary	0.0356	0.0303	0.0323	0.0410
Education - Primary School	0.0247	0.0165	0.0230	0.0359
Education - University	0.0316	0.0305	0.0295	0.0383
Grocery	0.0316	0.0315	0.0316	0.0315
Health/Medical	0.0473	0.0468	0.0472	0.0472
Lodging - Hotel	0.0711	0.0744	0.0711	0.0744
Lodging - Motel	0.0779	0.0916	0.0779	0.0916
Manufacturing - Bio/Tech	0.0931	0.0937	0.0931	0.0937
Manufacturing - Light Industrial	0.0138	0.0191	0.0204	0.0194
Industrial/Warehouse 1-shift	0.0122	0.0169	0.0180	0.0170
Industrial/Warehouse 2-shift	0.0711	0.0744	0.0711	0.0744
Industrial/Warehouse 3-shift	0.0711	0.0744	0.0711	0.0744
Municipal	0.0514	0.0402	0.0424	0.0565
Office - Large	0.0624	0.0513	0.0456	0.0727
Office - Small	0.0610	0.0501	0.0446	0.0711
Religious	0.0328	0.0304	0.0301	0.0458
Restaurant - Fast-Food	0.0611	0.0538	0.0611	0.0601
Restaurant - Sit-Down	0.0716	0.0107	0.0716	0.0209
Retail - Mall Department Store	0.0744	0.0308	0.0702	0.0591
Retail - Single-Story, Large	0.0702	0.0262	0.0700	0.0528

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Retail - Small	0.0779	0.0303	0.0693	0.0636
Service	0.0808	0.0426	0.0712	0.0659
Storage - Conditioned	0.0651	0.0115	0.0533	0.0496
Storage - Unconditioned	0.0666	0.0215	0.0522	0.0430
Other	0.0657	0.0458	0.0614	0.0569

Table 147. LED, Trim-Kit Lamp, Peak Demand Savings (per Lamp)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0173	0.0093	0.0176	0.0100
Education - College/Secondary	0.0139	0.0119	0.0126	0.0161
Education - Primary School	0.0097	0.0065	0.0090	0.0140
Education - University	0.0124	0.0119	0.0115	0.0150
Grocery	0.0124	0.0123	0.0124	0.0123
Health/Medical	0.0185	0.0183	0.0185	0.0185
Lodging - Hotel	0.0278	0.0291	0.0278	0.0291
Lodging - Motel	0.0305	0.0359	0.0305	0.0359
Manufacturing - Bio/Tech	0.0364	0.0367	0.0364	0.0367
Manufacturing - Light Industrial	0.0054	0.0075	0.0080	0.0076
Industrial/Warehouse 1-shift	0.0048	0.0066	0.0070	0.0067
Industrial/Warehouse 2-shift	0.0278	0.0291	0.0278	0.0291
Industrial/Warehouse 3-shift	0.0278	0.0291	0.0278	0.0291
Municipal	0.0201	0.0158	0.0166	0.0221
Office - Large	0.0244	0.0201	0.0178	0.0284
Office - Small	0.0239	0.0196	0.0175	0.0278
Religious	0.0128	0.0119	0.0118	0.0179
Restaurant - Fast-Food	0.0239	0.0211	0.0239	0.0235
Restaurant - Sit-Down	0.0280	0.0042	0.0280	0.0082
Retail - Mall Department Store	0.0291	0.0121	0.0275	0.0231
Retail - Single-Story, Large	0.0275	0.0103	0.0274	0.0207
Retail - Small	0.0305	0.0119	0.0271	0.0249
Service	0.0316	0.0167	0.0279	0.0258
Storage - Conditioned	0.0255	0.0045	0.0209	0.0194
Storage - Unconditioned	0.0261	0.0084	0.0204	0.0168
Other	0.0257	0.0179	0.0240	0.0223

Measure Life:

16 years (DEER 2008), assumed to be the same as LED exit signs.

5.2.1.12 LED Exit Signs

Sources:

DEER, 2008. www.deeresources.com/

Measure Description:

This measure consists of retrofitting an incandescent exit sign with an LED unit.[96] This measure applies to a new exit sign or retrofit kit. All new exit signs or retrofit exit signs must be UL924 listed, have a minimum lifetime of 10 years, and have an input wattage ≤ 5 W per sign.

Assumptions:

The following table presents 2008 DEER wattage assumptions for this measure. The average wattage reduction for the two different descriptions is 29.5 W, which is used in the savings calculation.

Table 148. Exit Sign Wattage Assumptions

Existing Description	Existing Fixture Wattage	Retrofit Description	Retrofit Fixture Wattage
(1) 25 W Incandescent	25	(1) 2 W LED	2
(2) 20 W Incandescent	40	(2) 2 W LED	4
Average	32.5		3

Savings:

Retrofitting to LED exit signs results in annual savings of 258 kWh. Due to the nature of the use of exit signs in commercial buildings (powered on all the time, 8,760 hours a year), the peak demand savings for LED exit signs are 0.0295 kW per sign.

Measure Life:

16 years (DEER 2008)

[96] The TRM is only presenting electrified options for retrofit. Photoluminescent signs would have more savings than LED.

5.2.1.13 High-Bay, T5 High-Output Retrofit

Sources:

DEER, 2008. www.deeresources.com/

GDS, "Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures," for the New England State Program Working Group, by GDS Associates, Inc., March 2007.

Measure Description:

This measure consists of retrofitting an existing high-intensity discharge (HID), high-bay fixture with a fixture containing T5 high-output (HO) lamps.

Assumptions:

Baseline and retrofit wattages, in the following table, use standard industry values. For calculation purposes, the wattage reductions for various configurations are weighted across retrofit options, and are then averaged together to produce a single wattage reduction value.

Table 149. T5 HO Measure Wattage Reduction

Existing Fixture Description	Retrofit Fixture Description	Baseline Fixture Wattage	Retrofit Fixture Wattage	Wattage Reduction	Weight Percentages
320 W Metal Halide	4L T5 HO	365	234	131	10%
400 W Metal Halide	4L T5 HO	456	234	222	65%
400 W Metal Halide	6L T5 HO	456	351	105	10%
400 W Mercury Vapor	4L T5 HO	455	234	221	10%
700 W Mercury Vapor	6L T5 HO	780	351	429	5%
Weighted Average				**211**	

Savings:

The following table provides average energy savings gained by retrofitting HID, high-bay fixtures with T5 HO fixtures by building type.

Table 150. T5 HO Savings (per Fixture)

Building Type	kWh Savings
Assembly	517
Education - College/Secondary	520

Building Type	kWh Savings
Education - Primary School	458
Education - University	491
Grocery	518
Health/Medical	1,032
Lodging - Hotel	415
Lodging - Motel	340
Manufacturing - Bio/Tech	837
Manufacturing - Light Industrial	662
Industrial/Warehouse 1-shift	894
Industrial/Warehouse 2-shift	1,197
Industrial/Warehouse 3-shift	1,650
Municipal	659
Office - Large	561
Office - Small	549
Religious	560
Restaurant - Fast-Food	1,022
Restaurant - Sit-Down	1,018
Retail - Mall Department Store	713
Retail - Single-Story, Large	826
Retail - Small	937
Service	745
Storage - Conditioned	728
Storage - Unconditioned	831
Other	902

Peak demand savings were determined by using indoor lighting specific end-use load profiles developed with eQUEST software for the TVA region commercial baseline prototypes. Average peak load factors (except for the industrial/warehouse shifts where a coincident diversity factor is used) were extracted from the load profiles using TVA's peak period times and then applied to the annual kWh savings of the corresponding building type and measure. Listed below are the results for the summer and winter peak periods in TVA's districts.

Table 151. T5 HO Peak Demand Savings (per Fixture)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.1066	0.0575	0.1082	0.0617

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Education - College/Secondary	0.0772	0.0658	0.0700	0.0891
Education - Primary School	0.0503	0.0337	0.0468	0.0731
Education - University	0.0666	0.0642	0.0621	0.0808
Grocery	0.0711	0.0710	0.0710	0.0710
Health/Medical	0.1275	0.1263	0.1274	0.1273
Lodging - Hotel	0.0369	0.0511	0.0546	0.0517
Lodging - Motel	0.0302	0.0418	0.0447	0.0423
Manufacturing - Bio/Tech	0.1603	0.1679	0.1603	0.1679
Manufacturing - Light Industrial	0.1603	0.1679	0.1603	0.1679
Industrial/Warehouse 1-shift	0.1603	0.1679	0.1603	0.1679
Industrial/Warehouse 2-shift	0.1757	0.2066	0.1757	0.2066
Industrial/Warehouse 3-shift	0.2100	0.2112	0.2100	0.2112
Municipal	0.1158	0.0908	0.0957	0.1275
Office - Large	0.1184	0.0973	0.0865	0.1379
Office - Small	0.1159	0.0952	0.0846	0.1349
Religious	0.0740	0.0685	0.0679	0.1033
Restaurant - Fast-Food	0.1379	0.1214	0.1379	0.1357
Restaurant - Sit-Down	0.1615	0.0242	0.1615	0.0470
Retail - Mall Department Store	0.1528	0.0633	0.1441	0.1214
Retail - Single-Story, Large	0.1623	0.0606	0.1616	0.1220
Retail - Small	0.2093	0.0814	0.1862	0.1710
Service	0.1823	0.0962	0.1606	0.1487
Storage - Conditioned	0.1819	0.0321	0.1488	0.1385
Storage - Unconditioned	0.2126	0.0687	0.1664	0.1373
Other	0.1482	0.1032	0.1385	0.1284

Measure Life:

15 years (GDS), assumed to be the same as standard T8 lamps and ballasts.

5.2.1.14 Metal-Halide (Ceramic or Pulse-Start) Fixture

Sources:

PG&E. "Ceramic Metal Halide Directional Fixture." Work paper PGECOLTG104.1, 2009.

SCE. "Interior PSMH Fixtures." Work paper WPSCNRLG0046.2, 2007.

DEER. *2005 Database for Energy Efficiency Resources Update Study Final Report - Residential and Commercial Non-Weather Sensitive Measures*, 2005.

DEER, 2008. www.deeresources.com

Measure Description:

This measure consists of retrofitting HID fixtures with either pulse-start, metal-halide (MH) or ceramic metal-halide fixtures.

Assumptions:

The assumptions used to calculate measure energy savings are provided in the following table. Baseline and retrofit wattages use standard industry values. For calculation purposes, the wattage reductions for various base cases are weighted (based on KEMA assumptions), and then averaged to produce a single wattage reduction value.

Table 152. Metal-Halide Baseline and Retrofit Wattages[97]

Measures	Baseline Wattage	Retrofit Wattage	Wattage Reduction
100 W or Less			
50 W lamp > Ceramic MH (20 W lamp)	57	22	35
75 W lamp > Ceramic MH (39 W lamp)	83	46	37
100 W lamp > Ceramic MH (25 W lamp)	100	27	73
Average			**48**
101 W-200 W			
250 W lamp > MH (175 W lamp)	295	208	87
175 W lamp > MH (150 W lamp)	208	185	23
Metal-Halide (250 W) > Pulse Start, MH (175 W)	295	210	85
Average			**65**
201 W-350 W			
400 W lamp > MH (320 W lamp)	458	365	93
400 W > Pulse Start, MH (250 W)	458	299	159
Average			**126**

Savings:

97 PG&E. "Ceramic Metal Halide Directional Fixture." Work paper PGECOLTG104.1, 2009.
SCE. "Interior PSMH Fixtures." Work paper WPSCNRLG0046.2; DEER. *2005 Database for Energy Efficiency Resources Update Study Final Report - Residential and Commercial Non-Weather Sensitive Measures.*

The following table shows average energy savings for replacing HID fixtures with MH fixtures by building type and fixture wattage.

Table 153. Pulse-Start, Metal-Halide Energy Savings (per Fixture)

Building Type	100 W or Less	101 - 200 W	201 - 350 W
Assembly	118.1	158.8	307.8
Education - College/Secondary	118.9	159.8	309.8
Education - Primary School	104.7	140.9	273.0
Education – University	112.2	150.9	292.6
Grocery	118.4	159.3	308.7
Health/Medical	235.9	317.3	615.0
Lodging – Hotel	95.0	127.7	247.6
Lodging – Motel	77.7	104.5	202.6
Manufacturing - Bio/Tech	191.3	257.2	498.6
Manufacturing - Light Industrial	151.3	203.5	394.4
Industrial/Warehouse 1-shift	204.5	275.0	533.0
Industrial/Warehouse 2-shift	273.6	367.9	713.2
Industrial/Warehouse 3-shift	377.2	507.3	983.4
Municipal	150.6	202.5	392.6
Office – Large	128.1	172.3	334.0
Office – Small	125.4	168.6	326.8
Religious	128.0	172.1	333.6
Restaurant - Fast-Food	233.7	314.3	609.2
Restaurant - Sit-Down	232.7	313.0	606.7
Retail - Mall Department Store	163.0	219.2	424.9
Retail - Single-Story, Large	188.8	253.9	492.2
Retail – Small	214.3	288.1	558.6
Service	170.2	228.9	443.6
Storage – Conditioned	166.3	223.7	433.6
Storage – Unconditioned	190.0	255.6	495.4
Other	206.3	277.4	537.8

Peak demand savings were determined by using indoor lighting specific end-use load profiles developed with eQUEST software for the TVA region commercial baseline prototypes. Average peak load factors (except for the industrial/warehouse shifts where a coincident diversity factor is used) were extracted from the load profiles using TVA's peak period times and then applied to the annual kWh savings of the corresponding building type and measure. Listed below are the results for the summer and winter peak periods in TVA's districts.

Table 154. 100 W or Less, Pulse-Start, Metal-Halide, Peak Demand Savings (per Fixture)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0244	0.0131	0.0247	0.0141
Education - College/Secondary	0.0176	0.0150	0.0160	0.0204
Education - Primary School	0.0115	0.0077	0.0107	0.0167
Education – University	0.0152	0.0147	0.0142	0.0185
Grocery	0.0162	0.0162	0.0162	0.0162
Health/Medical	0.0291	0.0289	0.0291	0.0291
Lodging - Hotel	0.0366	0.0384	0.0366	0.0384
Lodging - Motel	0.0402	0.0472	0.0402	0.0472
Manufacturing - Bio/Tech	0.0480	0.0483	0.0480	0.0483
Manufacturing - Light Industrial	0.0084	0.0117	0.0125	0.0118
Industrial/Warehouse 1-shift	0.0069	0.0096	0.0102	0.0097
Industrial/Warehouse 2-shift	0.0366	0.0384	0.0366	0.0384
Industrial/Warehouse 3-shift	0.0366	0.0384	0.0366	0.0384
Municipal	0.0265	0.0207	0.0219	0.0291
Office - Large	0.0271	0.0222	0.0198	0.0315
Office - Small	0.0265	0.0218	0.0193	0.0308
Religious	0.0169	0.0157	0.0155	0.0236
Restaurant - Fast-Food	0.0315	0.0277	0.0315	0.0310
Restaurant - Sit-Down	0.0369	0.0055	0.0369	0.0108
Retail - Mall Department Store	0.0349	0.0145	0.0329	0.0278
Retail - Single-Story, Large	0.0371	0.0138	0.0369	0.0279
Retail - Small	0.0478	0.0186	0.0426	0.0391
Service	0.0417	0.0220	0.0367	0.0340
Storage - Conditioned	0.0416	0.0073	0.0340	0.0317
Storage - Unconditioned	0.0486	0.0157	0.0380	0.0314
Other	0.0339	0.0236	0.0317	0.0294

Table 155. 101 W - 200 W, Pulse-Start, Metal-Halide, Peak Demand Savings (per Fixture)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0328	0.0177	0.0333	0.0190
Education - College/Secondary	0.0237	0.0202	0.0215	0.0274
Education - Primary School	0.0155	0.0104	0.0144	0.0225
Education - University	0.0205	0.0197	0.0191	0.0248

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Grocery	0.0218	0.0218	0.0218	0.0218
Health/Medical	0.0392	0.0388	0.0391	0.0391
Lodging - Hotel	0.0493	0.0516	0.0493	0.0516
Lodging - Motel	0.0540	0.0635	0.0540	0.0635
Manufacturing - Bio/Tech	0.0645	0.0649	0.0645	0.0649
Manufacturing - Light Industrial	0.0113	0.0157	0.0168	0.0159
Industrial/Warehouse 1-shift	0.0093	0.0129	0.0137	0.0130
Industrial/Warehouse 2-shift	0.0493	0.0516	0.0493	0.0516
Industrial/Warehouse 3-shift	0.0493	0.0516	0.0493	0.0516
Municipal	0.0356	0.0279	0.0294	0.0392
Office - Large	0.0364	0.0299	0.0266	0.0424
Office - Small	0.0356	0.0293	0.0260	0.0415
Religious	0.0227	0.0211	0.0209	0.0317
Restaurant - Fast-Food	0.0424	0.0373	0.0424	0.0417
Restaurant - Sit-Down	0.0496	0.0075	0.0496	0.0145
Retail - Mall Department Store	0.0470	0.0195	0.0443	0.0373
Retail - Single-Story Large	0.0499	0.0186	0.0497	0.0375
Retail - Small	0.0643	0.0250	0.0572	0.0526
Service	0.0560	0.0296	0.0494	0.0457
Storage - Conditioned	0.0559	0.0099	0.0457	0.0426
Storage - Unconditioned	0.0653	0.0211	0.0511	0.0422
Other	0.0456	0.0317	0.0426	0.0395

Table 156. 201 W - 350 W, Pulse-Start, Metal-Halide, Peak Demand Savings (per Fixture)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0635	0.0342	0.0645	0.0367
Education - College/Secondary	0.0460	0.0392	0.0417	0.0531
Education - Primary School	0.0300	0.0201	0.0279	0.0435
Education - University	0.0397	0.0382	0.0370	0.0482
Grocery	0.0423	0.0423	0.0423	0.0423
Health/Medical	0.0760	0.0752	0.0759	0.0758
Lodging – Hotel	0.0955	0.1000	0.0955	0.1000
Lodging – Motel	0.1047	0.1231	0.1047	0.1231
Manufacturing - Bio/Tech	0.1251	0.1259	0.1251	0.1259
Manufacturing - Light Industrial	0.0220	0.0304	0.0325	0.0308

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Industrial/Warehouse 1-shift	0.0180	0.0249	0.0266	0.0252
Industrial/Warehouse 2-shift	0.0955	0.1000	0.0955	0.1000
Industrial/Warehouse 3-shift	0.0955	0.1000	0.0955	0.1000
Municipal	0.0690	0.0541	0.0570	0.0760
Office – Large	0.0706	0.0580	0.0515	0.0822
Office – Small	0.0690	0.0567	0.0504	0.0804
Religious	0.0441	0.0408	0.0405	0.0615
Restaurant - Fast-Food	0.0821	0.0723	0.0821	0.0808
Restaurant - Sit-Down	0.0962	0.0144	0.0962	0.0280
Retail - Mall Department Store	0.0910	0.0377	0.0859	0.0724
Retail - Single-Story Large	0.0967	0.0361	0.0963	0.0727
Retail - Small	0.1247	0.0485	0.1110	0.1019
Service	0.1086	0.0573	0.0957	0.0886
Storage - Conditioned	0.1084	0.0191	0.0887	0.0826
Storage - Unconditioned	0.1267	0.0410	0.0992	0.0818
Other	0.0883	0.0615	0.0825	0.0765

Measure Life:

16 years (DEER 2005)

5.2.1.15 Integrated-Ballast, Ceramic-Metal-Halide Fixture

Sources:

PG&E. “CMH Directional Lamp Replacement.” Work paper PGECOLTG102.1, 2009.

Illinois Statewide TRM, May 2012

Measure Description:

This measure consists of replacing a non-MH lamp with an integrated, electronic, self-ballasted, ceramic-MH fixture. These lamps include a ballast, ceramic-metal light source, and reflector in the same package. These lamps operate via line-voltage, medium-screw base sockets. Lamps are typically 25 W or less and have an integrated ballast, ceramic-MH PAR (parabolic aluminized reflector) lamp with a rated life of 10,500 hours or greater.

Assumptions:

Baseline and retrofit equipment assumptions are presented in the following table. For calculation purposes, the wattage reductions for various base cases are weighted (based on KEMA assumptions) and averaged to produce a single wattage reduction value. Savings calculations assume that a PAR 38 halogen (45 W - 90 W) lamp[98] is replaced by an integrated, electronic, self-ballasted, 25 W, ceramic-metal-halide lamp. All baseline wattages have been adjusted due to EISA general service lamp standards.

Table 157. Integrated-Ballast, Ceramic-Metal-Halide Baseline and Retrofit Wattages

Base Lamp Wattage	Retrofit Lamp Wattage	Demand Savings per fixture	Weights
33	27	0.006	15%
43	27	0.016	30%
53	27	0.026	10%
64	27	0.037	25%
72	27	0.045	20%
Weighted Average		0.026	

Savings:

The following table shows average energy savings for replacing incandescent fixtures with self-ballasted, ceramic-MH fixtures by building type and fixture wattage.

Table 158. Integrated, Electronic, Self-Ballasted, Ceramic, MH Savings (per Lamp)

Building Type	kWh Savings
Assembly	65
Education - College/Secondary	65
Education - Primary School	57
Education - University	61
Grocery	65
Health/Medical	129
Lodging - Hotel	112
Lodging - Motel	149
Manufacturing - Bio/Tech	206
Manufacturing - Light Industrial	52
Industrial/Warehouse 1-shift	42
Industrial/Warehouse 2-shift	92
Industrial/Warehouse 3-shift	83

98 Assumed value is used to define the default savings estimate for typical retrofits of integrated ballast ceramic metal halide.

Building Type	kWh Savings
Municipal	82
Office - Large	70
Office - Small	81
Religious	70
Restaurant - Fast-Food	128
Restaurant - Sit-Down	127
Retail - Mall Department Store	89
Retail - Single-Story, Large	103
Retail - Small	117
Service	93
Storage - Conditioned	91
Storage - Unconditioned	101
Other	11.

Peak demand savings were determined by using indoor lighting specific end-use load profiles developed with eQUEST software for the TVA region commercial baseline prototypes. Average peak load factors (except for the industrial/warehouse shifts where a coincident diversity factor is used) were extracted from the load profiles using TVA's peak period times and then applied to the annual kWh savings of the corresponding building type and measure. Listed below are the results for the summer and winter peak periods in TVA's districts.

Table 159. Integrated, Electronic, Self-Ballasted Ceramic-MH, Peak Demand Savings (per Lamp)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.0125	0.0067	0.0127	0.0072
Education - College/Secondary	0.0100	0.0085	0.0091	0.0116
Education - Primary School	0.0069	0.0047	0.0065	0.0101
Education - University	0.0089	0.0086	0.0083	0.0108
Grocery	0.0089	0.0089	0.0089	0.0089
Health/Medical	0.0133	0.0132	0.0133	0.0133
Lodging - Hotel	0.0200	0.0210	0.0200	0.0210
Lodging - Motel	0.0219	0.0258	0.0219	0.0258
Manufacturing - Bio/Tech	0.0262	0.0264	0.0262	0.0264
Manufacturing - Light Industrial	0.0039	0.0054	0.0058	0.0055
Industrial/Warehouse 1-shift	0.0034	0.0047	0.0051	0.0048
Industrial/Warehouse 2-shift	0.0200	0.0210	0.0200	0.0210
Industrial/Warehouse 3-shift	0.0200	0.0210	0.0200	0.0210

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Municipal	0.0145	0.0113	0.0119	0.0159
Office - Large	0.0148	0.0121	0.0128	0.0205
Office - Small	0.0145	0.0119	0.0126	0.0200
Religious	0.0092	0.0086	0.0085	0.0129
Restaurant - Fast-Food	0.0172	0.0152	0.0172	0.0169
Restaurant - Sit-Down	0.0202	0.0030	0.0202	0.0059
Retail - Mall Department Store	0.0209	0.0087	0.0198	0.0166
Retail - Single-Story, Large	0.0203	0.0076	0.0197	0.0149
Retail - Small	0.0261	0.0102	0.0195	0.0179
Service	0.0228	0.0120	0.0200	0.0186
Storage - Conditioned	0.0227	0.0040	0.0150	0.0140
Storage - Unconditioned	0.0265	0.0086	0.0147	0.0121
Other	0.0185	0.0129	0.0173	0.0160

Measure Life:

10,500 hours (PG&E. "CMH Directional Lamp Replacement." Work paper PGECOLTG102.1, 2009)

5.2.1.16 Pulse-Start, Metal-Halide Fixtures (Parking Garage)

Sources:

SCE. "Interior PSMH Fixtures." Work paper WPSCNRLG0046.2, 2007.

DEER. *2005 Database for Energy Efficiency Resources Update Study Final Report - Residential and Commercial Non-Weather Sensitive Measures*.

DEER, 2008. www.deeresources.com/

Measure Description:

This measure consists of retrofitting HID fixtures with pulse-start MH fixtures. This section only applies to interior and exterior parking garages and is presented separately from other building types due to operating hour differences. An interior parking structure is enclosed, so it is reasonable to assume that all lighting is on during the day. This includes underground parking structures and stand-alone parking structures that may be semi-enclosed. Exterior parking structures are outdoor parking lots where light fixtures do not operate during the day.

Assumptions:

The assumptions used to calculate measure energy are provided in the following tables. Baseline and retrofit wattages use standard industry values. For calculation purposes, the wattage reductions for various base cases are weighted (based on KEMA assumptions) and averaged together to produce a single wattage reduction value.

Table 160. Metal-Halide Baseline and Retrofit Wattages[99]

Measures	Base Wattage (W)	Retrofit Wattage (W)	Wattage Reduction (W)
101-200 W			
250 W lamp > MH (175 W lamp)	295	208	87
175 W lamp > MH (150 W lamp)	208	185	23
Metal Halide (250 W) > Pulse-Start, MH (175 W)	295	210	85
Average			**65**
201-350 W			
400 W lamp > MH (320 W lamp)	458	365	93
Mercury Vapor (400 W) > Pulse-Start, MH (250 W)	458	299	159
Average			**126**

Table 161. Parking Garage Operating Hours

Building Type	Annual Operating Hours
Interior	8,760
Exterior	4,380

Savings:

The following table shows average energy savings for replacing HID fixtures with metal-halide fixtures by building type and fixture wattage.

Table 162. Pulse-Start, MH Fixture Annual Energy Savings (per Fixture)

Building Type	101 W - 200 W	201 W - 350 W
Interior Parking Garage	569	1104
Exterior Parking Garage	284	551

[99] PG&E. "Ceramic Metal Halide Directional Fixture." Work paper PGECOLTG104.1, 2009; SCE. "Interior PSMH Fixtures. "Work paper WPSCNRLG0046.2, 2007; DEER. *2005 Database for Energy Efficiency Resources Update Study Final Report - Residential and Commercial Non-Weather Sensitive Measures.*

The peak demand savings for measures located in interior parking garages are equivalent to the demand reduction of the particular base case and measure replacement because interior garage lights are assumed to be always on. Since we assume exterior parking garages have their lights on for only 12 hours a day, which may or may not coincide with TVA's winter peak times; we assume zero peak demand savings.

Table 163. Pulse-Start, MH Fixture Peak Demand Savings (per Fixture)

Building Type	101 W - 200 W	201 W - 350 W
Interior Parking Garage	0.065	0.126
Exterior Parking Garage	0	0

Measure Life:

16 years (DEER 2005)

5.2.1.17 High-Wattage, Screw-in CFLs (Parking Garage)

Sources:

DEER, 2008. www.deeresources.com/

PG&E. "Compact Fluorescent Fixtures" Work paper PGECOLTG131.1, 2009

Measure Description:

This measure consists of replacing of HID or incandescent lamps with screw-in CFLs. Incandescent lamps are less efficient than CFLs because incandescent lamps convert approximately 90% of the energy they consume into heat, compared to approximately 30% for a CFL. The lamp/ballast combination must have an efficacy of ≥40 lumens per Watt (LPW).

This section only applies to interior and exterior parking garages and is presented separately from other building types due to operating hour differences. An interior parking structure is enclosed, so it is reasonable to assume that all lighting is on during the day. This includes underground parking structures and stand-alone parking structures that may be semi-enclosed exterior parking structures are outdoor parking lots where light fixtures do not operate during the day.

Assumptions:

Baseline and retrofit equipment assumptions are presented in the tables below. Most lighting retrofits assume an early replacement of existing technologies in which the baseline represents the equipment removed. The table shows the wattages used for the savings calculations. Since incandescent lamps produce lower lumens per watt compared to HIDs, they tend to have higher wattage for a given application. Savings are therefore greater in the incandescent case.

Table 164. High-Wattage, CFL Baseline and Retrofit Wattages

Baseline	Base Wattage (W)	Retrofit Wattage (W)	kW Reduction (kW)
75 MH	85	42	0.043
150 MH	165	68	0.097
175 MH	188	68	0.12
175 MH	203	100	0.103
250 MH	295	150	0.145
HID Baseline			**0.102**
200 Incandescent	200	55	0.145
250 Incandescent	250	68	0.182
400 Incandescent	400	85	0.315
Incandescent Baseline			**0.214**
Average			**0.158**

Table 165. Parking Garage Operating Hours

Building Type	Annual Operating Hours
Interior	8,760
Exterior	4,380

Savings:

The following tables provide the calculated annual kWh savings for this measure by baseline fixture type.

Table 166. Garage, High-Wattage CFL Savings

Building Type	HID Baseline	Incandescent Baseline
Interior	890	1,875
Exterior	445	937

The peak demand savings for measures located in interior parking garages are equivalent to the demand reduction of the particular base case and measure replacement because interior garage lights are assumed to be always on. Since we assume exterior parking garages have their lights on for only 12 hours a day, which may or may not coincide with TVA's winter peak times; we assume zero peak demand savings.

Table 167. Garage, High-Wattage CFL Peak Demand Savings (per Lamp)

Building Type	HID Baseline	Incandescent Baseline
Interior	0.102	0.214
Exterior	0	0

Measure Life:

2.5 years (DEER 2008)

5.2.1.18 Bi-Level Light Fixture

Sources:

PG&E. "Bi-Level Light Fixture." Work paper PGECOLTG101.1, 2009.

Measure Description:

Bi-level fixtures are typically found in hallways, stairwells, and garages. These fixtures are intended for use where high lighting levels are required when occupied, but are actually unoccupied for the majority of the time. These fixtures employ a motion sensor lighting switch to provide lower levels of light while unoccupied and full illumination while occupied.

Assumptions:

This measure assumes that an existing 2-lamp, T8 fixture (60 W) is replaced by a 2-lamp, T8, bi-level fixture. At full output, the bi-level fixture consumes 62 W, while at low-light level the fixture consumes 18 W. Bi-level fixtures are in low-output mode 69% of the time.

Savings:

The demand savings are calculated as follows:

$$\text{Demand Reduction} = \text{Pre-Retrofit Wattage} - \text{Bi-Level Fixture Wattage}$$

Bi-Level Fixture Wattage is calculated by a time-weighted average as follows:

$$(0.69*18W) + (0.31*62W) = 31.64W$$

The demand reduction is therefore 28.36 W or 0.028 kW, and annual energy savings is 248 kWh per year.

Peak demand savings are assumed to be equivalent to the demand reduction. The bi-level fixture is assumed to be on all the time, 8,760 hours a year. Metering would be required to determine a more accurate value for how often the bi-level fixtures are in low/high-output mode during TVA's peak times. Peak demand savings are 0.028 kW per fixture.

Measure Life:

8 years (DEER 2008). These fixtures have the same lifetime as occupancy sensors.

5.2.1.19 LED Traffic- and Pedestrian-Signal Lamps

Sources:

SCE. "VC Project 3 Oxnard Yellow Traffic Lamp." Work paper WPSCNRMI0045, 2007.

Lamp." Work paper WPSCNRMI0047, 2007.

Pennsylvania Technical Reference Manual, 2013

Measure Description:

This measure consists of replacing incandescent traffic lamps with LED lamps, including red, yellow, and green traffic signals, orange hand pedestrian crossing signals, and white walking man crossing signals. Red, yellow, and green traffic signals are standard 8-inch or 12-inch round traffic signals that consist of a light source and a lens.

Assumptions:

The percent time on multiplied by 8,760 hours was calculated to determine each individual lamp's yearly operating hours. The following table presents each signal's percent time on and corresponding annual operating hours.

Table 168. Traffic-Lamp Operating Hours

Signal Type	% Time On	Operating Hours
Red Lamp	55%	4818
Yellow Lamp	2%	175
Green Lamp	43%	3767
Turn Arrow/Pedestrian	8%	701
Hand/Man Interval	100%	8760

The assumed base case and retrofit wattages are presented in the following table.

Table 169. Traffic- and Pedestrian-Signal Baseline and Retrofit Wattage Assumptions

Signal Type	Baseline Wattage	Retrofit Wattage	kW Reduction
Red Lamp 8”	69	7	0.062
Red Lamp 12”	150	6	0.144
Yellow Lamp 8”	69	10	0.059
Yellow Lamp 12”	150	13	0.137
Green Lamp 8”	69	9	0.06
Green Lamp 12"	150	12	0.138
Yellow Lamp Turn Arrow 8”	116	7	0.109
Yellow Lamp Turn Arrow 12”	116	9	0.107
Green Lamp Turn Arrow 8”	116	7	0.109
Green Lamp Turn Arrow 12”	116	7	0.109
Hand/Man Interval	116	8	0.108

Savings:

The following table provides the calculated annual kWh savings (by replacing incandescent with LED lamps) for these measures by signal type.

Table 170. LED Traffic- and Pedestrian-Signal Savings (per Lamp)

Signal Type	kWh Savings
Red Lamp 8”	229
Red Lamp 12”	694
Yellow Lamp 8”	10
Yellow Lamp 12”	24
Green Lamp 8”	226
Green Lamp 12”	520
Yellow Lamp Turn Arrow 8”	76
Yellow Lamp Turn Arrow 12”	75
Green Lamp Turn Arrow 8”	76
Green Lamp Turn Arrow 12”	76
Hand/Man Interval	946

Peak demand savings will not be calculated using load profile peak factors because models are unavailable for traffic signal activity. Instead, coincident factors (CF) will be assumed for each signal type (See Table 171), and peak demand savings will be calculated using the following formula:

$$\text{Peak Demand(kW)} = \text{Demand Reduction(kW)} \times \text{CF}$$

Table 171. Traffic- and Pedestrian-Signal Coincidence Factors

Signal Type	Coincidence Factor (CF)
Red Lamp	0.55
Yellow Lamp	0.02
Green Lamp	0.43
Turn Arrow	0.08
Walking Man	1.00

Using the calculated demand reductions from Table 169 and the coincidence factors from the Table 171 peak demand savings were calculated for each signal type and are listed in the following table.

Table 172. Traffic- and Pedestrian-Signal Peak Demand Savings (per Lamp)

Signal Type	Peak kW Savings
Red Lamp 8”	0.0341
Red Lamp 12”	0.0792
Yellow Lamp 8”	0.0012
Yellow Lamp 12”	0.0027
Green Lamp 8”	0.0258
Green Lamp 12”	0.0593
Yellow Lamp Turn Arrow 8”	0.0087
Yellow Lamp Turn Arrow 12”	0.0086
Green Lamp Turn Arrow 8”	0.0087
Green Lamp Turn Arrow 12”	0.0087
Hand/Man Interval	0.1080

Measure Life:

The EUL of LED traffic-signal equipment is 35,000 to 50,000 hours.[100] SCE work papers estimate measure life at a midrange of these hours, at 42,500 hours. Actual measure life depends on the on-time percentage of each individual lamp. However, EUL is typically limited to 10 years, based on industry average lifetimes for LED lighting fixtures.[101]

[100] SCE work papers

[101] SCE. “VC Project 3 Oxnard Yellow Traffic Lamp.” Work paper WPSCNRMI0045, 2007.

5.2.1.20 Occupancy Sensors

Sources:

DEER, 2008. www.deeresources.com

SCE. "Occupancy Sensors: Wall or Ceiling Mounted." Work paper WPSCNRLG0025.1.

Measure Description:

Infrared or ultrasonic motion-detection devices turn lights on or off when a person enters or leaves a room. Only hardwired, passive infrared and/or ultrasonic detectors are relevant to this measure quantification. Wall- or ceiling-mounted sensors should control no more than 1,000 W.

Assumptions:

The energy savings calculation assumes that the occupancy sensor controls three T8 fixtures for a total of 174 W controlled. Assumed operating hours were taken from the 2008 DEER. Occupancy sensor savings assume a 20% time-off value for all controlled spaces.[102] Savings are calculated using the following equation:

$$\text{Energy Savings (kWh)} = \frac{(\text{controlled wattage}) \times (\text{annual operating hours}) \times (20\%)}{1{,}000}$$

Savings:

The following table provides the savings per sensor. However, the measure savings can be considered on a per controlled wattage basis to more accurately reflect site-specific savings. Common retrofits may include fixture-mounted controls, for example, on high-bay T5 high-output fixtures. The savings below would underestimate these applications. Additionally, there is an evaluation near completion in the Northeast that may provide better estimates for percent time off values, as well as coincidence factors for occupancy sensors (and other lighting controls). We recommend considering this new data when it becomes available.

[102] SCE. "Occupancy Sensors: Wall or Ceiling Mounted." Work paper WPSCNRLG0025.1.

Table 173. Occupancy-Sensor Savings, per Sensor

Building Type	kWh Savings
Assembly	85
Education - College/Secondary	86
Education - Primary School	75
Education - University	81
Grocery	85
Health/Medical	170
Lodging - Hotel	68
Lodging - Motel	56
Manufacturing - Bio/Tech	138
Manufacturing - Light Industrial	109
Industrial/Warehouse 1-shift	176
Industrial/Warehouse 2-shift	214
Industrial/Warehouse 3-shift	296
Office - Large	92
Office - Small	90
Restaurant - Fast-Food	168
Restaurant - Sit-Down	168
Retail - Mall Department Store	117
Retail - Single-Story, Large	119
Retail - Small	113
Storage - Conditioned	120
Storage - Unconditioned	120
Average	108

Due to the nature of occupancy sensors, peak demand savings cannot be sufficiently determined without case-by-case metering. This manual will not claim peak demand savings for occupancy sensors until TVA-specific metering is performed to provide a peak demand percentage. More details are provided in Section 8.3.1 for estimating peak demand savings for lighting controls.

Measure Life:

8 years (DEER 2008)

5.2.1.21 Photocells

Sources:

PG&E. "Photocell." Work paper PGECOLTG129.1, 2009.

DEER. *2005 Database for Energy Efficiency Resources Update Study Final Report - Residential and Commercial Non-Weather Sensitive Measures.*

Measure Description:

Photocells can be used to control both outdoor and indoor lamps; however, this measure only applies to photocells that are used to control outdoor lighting. When there is enough daylight, lights are automatically turned off.

Assumptions:

The measure assumes that existing exterior lighting is controlled by a time clock, which is retrofitted with a new photocell. With a photocell, exterior lights operate approximately 4,100 hours per year. Without the photocell, the lights would operate an additional 280 hours per year (approximately 3 months at 3 hours per day). For this measure, the photocell controls four 70 W, high-pressure, sodium exterior lamps with an effective 95 W per fixture including the ballast for a total of 380 W (4 fixtures x 95 W/fixture).

Savings:

Demand reduction assumes that savings result from turning off the connected load, which is 0.38 kW. Photocells save 106 kWh annually. There are no summer peak demand savings because it is assumed there is enough daylight during the peak time range that the photocell-controlled lighting will be off. This manual will not claim winter peak demand savings for photocell measures because of the uncertainty of actual "on" times for the photocell-controlled lighting. Photocells are slightly programmable in that they can be tuned to be more or less light sensitive. This restricts the possibility of using sunrise/sunset times to determine when the photocell-controlled lighting is on.

Measure Life:

8 years (DEER 2008), the same as a time clock or daylighting controls.

5.2.2 Refrigeration - Walk-In Coolers and Freezers

KEMA developed a refrigeration savings calculator. The spreadsheet, TVA Refrigeration.xls, uses a cooling load calculation for the refrigeration load of a typical refrigerated case or walk-in cooler or freezer found in convenience stores, grocery stores, or restaurants. This calculator is not applicable for stand-alone display cases without a walk-in main door. Savings calculated in the spreadsheet are attributed to decreased cooling load and compressor usage.

Cooling load calculations are based on ASHRAE methodology[103] for the calculation of typical refrigeration loads. Details of the analysis are provided in Appendix Section 8. The total cooling load of a refrigerated space requires calculation of the following:

1. Transmission or conduction load
2. Anti-sweat heater (ASH) load
3. Internal load (load due to evaporator fan motors, lighting, and people)
4. Product load (product shelving and product pull-down load)
5. Infiltration load

Additional assumptions must be made regarding the air properties of the refrigerated and adjacent spaces, number of doors, door type, and door size. Current values are based on KEMA field observations in California, SCE work paper assumptions,[104] and ADM evaluation results of gasket and strip curtain installations.[105] All assumptions and their source are documented in the spreadsheet.

Savings estimates for different measures can be calculated by adjusting these parameters and comparing the pre-retrofit and post-retrofit annual energy consumptions. The spreadsheet calculator contains the details. The calculator is set up for cooler walk-in, freezer walk-in, cooler reach-in, and freezer reach-in. The difference between the two in this document is that the reach-in is a walk-in with glass doors. Stand-alone refrigerated cases are not applicable to the calculator. The analysis adjustments per measure are discussed below. Based on the results using this calculator, refrigeration measures may not be as cost-effective as previously assumed in other utility territories.

[103] ASHRAE 2002. Refrigeration Handbook. Atlanta, Georgia. pp. 12.1

[104] Southern California Edison Company. WPSCNRRN002.1 – Infiltration Barriers – Strip Curtains, October 2007.

[105] "Commercial Facilities Contract Group Direct Impact Evaluation Draft Final Report: HIM Appendices". ADM Associates, Inc., prepared for the California Public Utilities Commission, December 8, 2009.

Calculator Shortcomings

The calculator methodology is based on assumptions that require further research to validate. However, based on the available information, they are currently deemed sufficient for calculating deemed savings. The calculator is based largely on the methodology and assumptions found in the SCE refrigeration work papers.[106] The SCE methodology assumes that the system is comprised of a single reciprocating compressor and an air-cooled condenser. Refrigeration system configurations vary widely depending on capacity and use. For example, systems found at many large commercial grocery stores consist of multiplex systems with water-cooled condensers.

In addition, the methodology for determining the EER for both medium and low temperature applications uses SCE's internal review of reciprocating compressor manufacturer performance curves to calculate EER. Their data and analysis are not available for review. Questions have arisen about whether these data are applicable to different areas of the country, since these performance curves are dependent on saturated condensing temperature, cooling load, and the cooling capacity of the compressor. Further research is recommended to account for different types and how they would affect overall system efficiency and energy usage. Weather normalization can be improved by using TMY3 8,760 hourly weather data. However, only a simplified normalization is currently used.

5.2.2.1 LED Refrigeration-Case Lighting

Sources:

2013 DesignLights Consortium— Qualified Products List: http://www.designlights.org/QPL

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.

Measure Description:

This measure applies to lighting for reach-in glass doors for cooler (above 32°F) and freezers (below 32°F). This includes reach-in display cases as well as reach-in glass doors on walk-in cases.

Refrigeration cases are found in most grocery stores and in some specialty stores. They are used to display perishable products. Lighting in refrigerated cases is usually provided by fluorescent lamps. The

[106] Southern California Edison Company. WPSCNRRN002.1 – Infiltration Barriers – Strip Curtains, October 2007.

brightness, long life, and high efficacy of LEDs make them a great energy efficient replacement for fluorescent lighting in refrigeration cases. In real world refrigeration case applications, LEDs were found to perform better than fluorescent lights. LEDs save energy, perform well in the cold environment, and provide consistent lighting. The LED lighting equipment also emits less heat, thus resulting in reduced refrigeration work.

Assumptions:

Refrigerated case lighting operates an estimated 365 days per year for 17 hours each day. The total annual operating hours are 6,205 hours.[107] The base case lighting consists of 5-foot, F51SS and F51ILL fluorescent fixtures and 6-foot, F61SHS fluorescent fixtures. The retrofit lighting wattage is the average measured wattage of all tested refrigerated case lighting products within the DesignLights Consortium (DLC) Qualified Products List as of February 19, 2013. The savings calculation assumes two lighting fixtures per door and 2.5 linear feet of case per door. The base case and retrofit fixture values are presented in the following table.

Table 174. Fixture Wattage Assumptions, per Door

Fixture Type	Fixture Code	Fixture Wattage	Watts per Door[108]	Watts per Linear Foot of Case[109]	Weight
1-5' T12	F51SS	63	126	50.4	35%
1-5' T8	F51ILL	36	72	28.8	35%
1-6' T12 HO	F61SHS	120	240	96	30%
Base case weighted average			**141.3**	**56.5**	
Average of DLC Qualified Refrigeration Case Lamps	N/A	21.6	43.3	17.3	100%

In addition to the direct electric load savings, savings are also attributed to decreased refrigeration load, since LED case lighting emits less heat than standard fluorescent case lighting.

[107] Pacific Gas and Electric's Application Assessment Report #0608, LED Supermarket Case Lighting Grocery Store, Northern California.

[108] Assumes two fixtures per door.

[109] Assumes 2.5 feet per door.

Savings:

Energy savings are based on the calculation of direct lighting wattage reduction and decreased refrigeration load using the equation below:

$$\text{kWh saving} = \frac{\frac{\text{Watts}}{\text{ft}}_{\text{Basecase}} - \frac{\text{Watts}}{\text{ft}}_{\text{LED}}}{\frac{1000\text{ W}}{1\text{ kW}}} \times (1 + \text{IF}_{\text{CZ}}) \times \text{Annual operating hours}$$

The savings from the reduction in refrigeration load are accounted for by the inclusion of the interactive factor (IF) term in the savings equation (see Appendix Section 8 for description of IF calculation). The IF is the ratio of compressor energy reduction to direct caseload reduction, using the calculated EER values for medium temperature and low temperature cases for the TVA climate zones.

Summer demand savings are calculated using the energy savings equation without inclusion of the operating-hours term, as shown the equation below:

$$\text{kW saving} = \frac{\frac{\text{Watts}}{\text{ft}}_{\text{Baseline}} - \frac{\text{Watts}}{\text{ft}}_{\text{LED}}}{\frac{1000\text{ W}}{1\text{ kW}}} \times \text{IF}_{\text{CZ}}$$

Winter demand savings assume no interactive HVAC or refrigeration effects, and so the IF term is removed from the summer demand savings equation.

The energy and demand savings per linear foot of display case are presented in the following table for open display cases, medium-temperature (MT) refrigerated cases, and low-temperature (LT) freezer display cases.

Table 175. Savings for LED Case Lighting (per Linear Foot of Case)

	Open Display Case			Cooler (MT) Display Case			Freezer (LT) Display Case		
Climate Zone	kWh/yr	Summer Peak kW	Winter Peak kW	kWh/yr	Summer Peak kW	Winter Peak kW	kWh/yr	Summer Peak kW	Winter Peak kW
Knoxville	231	0.0531	0.0392	391	0.0630	0.0392	429	0.0692	0.0392
Nashville	238	0.0534	0.0392	393	0.0634	0.0392	434	0.0699	0.0392
Chattanooga	234	0.0549	0.0392	393	0.0633	0.0392	433	0.0698	0.0392
Memphis	242	0.0532	0.0392	396	0.0639	0.0392	438	0.0706	0.0392
Huntsville	234	0.0530	0.0392	394	0.0635	0.0392	434	0.0700	0.0392

Measure Life:

8 years (2009 Pacific Gas and Electric Work paper)

Attachment:

TVA - Refrigeration Case Measure Calculations.xlsx

5.2.2.2 Refrigeration-Case Lighting Controller

Sources:

2013 DesignLights Consortium— Qualified Products List: http://www.designlights.org/QPL

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.

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Measure Description:

This measure applies to the installation of a refrigeration case lighting controller on an existing refrigeration case without lighting controls.

Assumptions:

The case lighting fixture technology is assumed be either fluorescent or LED. The fluorescent lighting consists of 5-foot, T12 and T8 fluorescent fixtures, and 6-foot, T12 high output fluorescent fixtures. The LED lighting wattage is the average measured wattage of all tested refrigerated case lighting products within the DesignLights Consortium (DLC) Qualified Products List as of February 19, 2013. These lighting fixtures and averaged wattages are presented in the following table:

Table 176. Lighting Fixture Assumptions

Fixture Type	Fixture Code	Fixture Wattage	Watts per Door[110]	Watts per Linear Foot of Case[111]	Weight
Fluorescent Lamp Type					
1-5' T12	F51SS	63	126	50.4	35%
1-5' T8	F51ILL	36	72	28.8	35%
1-6' T12 HO	F61SHS	120	240	96	30%
Fluorescent Lamp Weighted Average			141.3	56.5	100%
LED Lamp Type					
Average of DLC Qualified Refrigeration Case Lamps	N/A	21.6	43.3	17.3	100%

For either lamp type, the base case lighting is estimated to run 365 days per year for 17 hours each day, for a total of 6,205 annual operating hours.[112] The lighting controller is assumed to reduce the operating hours by 30%. Each lighting controller is assumed to operate three case doors that are 2.5 feet wide each.

Savings:

Energy savings are based on the calculation of decreased lighting operating hours and decreased refrigeration load using the equation below:

$$\text{kWh Savings} = \frac{\frac{\text{Watts}}{\text{ft}} \times (1 + \text{IF}_{\text{CZ}}) \times \text{Operating hours} \times \text{Savings factor} \times 2.5\,\frac{\text{ft}}{\text{door}} \times 3\,\frac{\text{doors}}{\text{controller}}}{\frac{1000\ \text{Wh}}{1\ \text{kWh}}}$$

The savings from the reduction in refrigeration load is accounted for by the inclusion of the Interactive Factor (IF) term in the savings equation. The IF is the ratio of compressor energy reduction to direct-case load reduction, using the calculated EER values for medium temperature and low temperature cases for the TVA climate zones.

[110] Assumes two fixtures per door
[111] Assumes 2.5 feet per door
[112] PG&E's Application Assessment Report #0608, LED Supermarket Case Lighting Grocery Store, Northern California.

For the open display cases, KEMA employed the lighting energy and demand interactive factors developed for TVA to account for the reduced HVAC system compressor load that results from reducing the building's internal heat load. Unlike the IF terms described above, the lighting interactive factors account for the direct and indirect load reduction, and so the open case kWh savings equation excludes the "1+" term in the above equation.

Summer demand savings are calculated using the energy savings equation, but without the inclusion of the operating hours term, as shown the equation below:[113]

$$\text{kW Savings} = \frac{\frac{\text{Watts}}{\text{ft}} \times (1 + \text{IF}_{\text{CZ}}) \times \text{Savings factor} \times 2.5\frac{\text{ft}}{\text{door}} \times 3\frac{\text{doors}}{\text{controller}}}{\frac{1000\text{ W}}{1\text{ kW}}}$$

The energy and demand savings, per controller, are presented in the following table.

Table 177. Savings for Refrigeration-Case Lighting Controller (per Controller)

Climate Zone	Open-Case Energy Savings (kWh/yr)	Open-Case Demand Savings (kW)	MT-Case Energy Savings (kWh/yr)	MT-Case Demand Savings (kW)	LT-Case Energy Savings (kWh)	LT-Case Demand Savings (kW)
Controlling Fluorescent Lamps						
Knoxville	750	0.1724	1,268	0.2043	1,392	0.2244
Nashville	771	0.1731	1,276	0.2056	1,406	0.2267
Chattanooga	759	0.1749	1,274	0.2054	1,405	0.2264
Memphis	786	0.1724	1,285	0.2071	1,421	0.2291
Huntsville	760	0.1717	1,279	0.2061	1,408	0.2270
Controlling LED Lamps						
Knoxville	230	0.0528	388	0.0626	426	0.0687
Nashville	236	0.0530	391	0.0630	431	0.0694
Chattanooga	232	0.0536	390	0.0629	430	0.0694
Memphis	241	0.0528	394	0.0634	435	0.0702
Huntsville	233	0.0526	392	0.0631	431	0.0695

[113] The equation for open-case demand savings excludes the "1+" term, as is the case with the open case energy savings equations.

Measure Life:

8 years (DEER 2008)

Attachment:

TVA - Refrigeration Case Measure Calculations.xlsx

5.2.2.3 Electronically Commutated Motor (ECM) Walk-ins

Sources:

Southern California Edison work paper WPSCNRRN0011 Revision 0, "Efficient Evaporator Fan Motors (Shaded Pole to ECM)" October 2007.

California Database for Energy Efficiency Resources, www.deeresources.com/(DEER 2008)

GE ECM Evaporator Fan Motor Energy Monitoring, FSTC Report # 5011.04.13. Fisher-Nickel, Inc. July 2006.

Measure Description:

This measure consists of replacing an evaporator fan shaded-pole motor with a higher efficiency electronically commutated motor.

Assumptions:

Energy savings are based on the methodology found in SCE's work paper and depend on display-case type, either cooler or freezer. The baseline condition assumes a motor with a connected wattage of 135.5W per the FSTC report, with a fan motor efficiency of 70%. The post retrofit condition assumes a power reduction of 67% (44 W) and a new efficiency of 85%. These motors are assumed to be in continuous operation, i.e., no evaporator fan controller installed.

Savings:

Total savings for replacing an existing electronically commuted motor with a new, more efficient unit are presented in the following table. The savings values from the spreadsheet TVA-Refrigeration.xls are added to the wattage reduction from the shaded-pole unit to the electronically commutated motor.

Table 178. EC Motor kWh Savings for Walk-Ins (per Motor)

City	Cooler		Freezer	
	kWh	kW	kWh	kW
Knoxville	1267	0.1447	1392	0.1589
Nashville	1276	0.1456	1406	0.1605
Chattanooga	1274	0.1454	1405	0.1604
Memphis	1285	0.1467	1421	0.1622
Huntsville	1279	0.1460	1408	0.1607

Life:

15 years (DEER 2008)

Attachment:

TVA - ECM.xlsx

5.2.2.4 Evaporator Fan Controller

2009 Pacific Gas and Electric Work paper - PGECOREF106.1 - Evaporator Fan Controller for Walk-In Coolers and Freezers

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

GE ECM Evaporator Fan Motor Energy Monitoring, FSTC Report # 5011.04.13. Fisher-Nickel, Inc. July 2006.

Measure Description:

This measure applies to the installation of an evaporator-fan controller to evaporator fans (shaded-pole or EC-motor) located in refrigerated walk-in coolers and freezers. These controllers reduce airflow when no refrigerant is flowing through the evaporator coil. This typically occurs when the compressor is in an on-off cycle or when the compressor is turned off due to adequate space temperature. A typical unit in a walk-in cooler contains one or more fans with fractional horsepower motors that are running continuously.

Energy savings are achieved by reducing the speed of the evaporator fan motors by at least 75% during the compressor off-cycle. Savings are also achieved by reducing the actual refrigeration load, since the fans won’t be running at full speed continuously which will result in less motor waste heat input into the cooled space.

Assumptions:

The base case for the existing equipment is a walk-in cooler or freezer with either shaded-pole evaporator or electronically commutated motors that are continuously running at full speed. Shaded pole and electronically commutated motor wattages are taken from the FSTC Evaporator Fan Motor Energy Monitoring Study.[114] One shaded pole evaporator fan motor has an average connected wattage of 135.5 W. One electronically commutated motor has an average connected wattage of 44 W. Walk-in cases are assumed to contain two evaporator fan motors each. Walk-in cases with reach-in glass doors are assumed to contain six evaporator fan motors.

Evaporator fan controller savings are dependent on compressor duty cycle. Assumed compressor duty cycle is 40% for winter and 50% for non-winter seasons. Weather data for the five representative TVA cities are used to find the distribution of annual below freezing (winter) and above freezing (non-winter) hours. These hours are multiplied by their respective duty cycle assumptions to arrive at an estimate for compressor annual operating hours. The fan controller ensures that fans are turned off when the compressor is off. Fan power savings are calculated by multiplying the connected evaporator fan motor wattage by the total hours the compressor is turned off. Interactive effects are calculated by multiplying the evaporator fan heat load by the percent on-time of the compressor.

Savings:

Savings are provided in the tables below.

Table 179. Shaded-Pole Motor, Evaporator-Fan Controller Savings (per Controller)

City	Cooler (MT) Walk-in Door		Freezer (LT) Walk-in Door		Cooler (MT) Walk-in Door w/Reach-in Glass		Freezer (LT) Walk-in Door w/Reach-in Glass	
	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Knoxville	1878	0.2143	2053	0.2343	5853	0.6681	6296	0.7187
Nashville	1884	0.2151	2067	0.2360	5876	0.6707	6342	0.7240
Chattanooga	1870	0.2135	2052	0.2343	5831	0.6657	6297	0.7189
Memphis	1887	0.2154	2076	0.2370	5885	0.6718	6371	0.7273
Huntsville	1884	0.2151	2065	0.2357	5875	0.6707	6336	0.7233

[114] GE ECM Evaporator Fan Motor Energy Monitoring, FSTC Report # 5011.04.13. Fisher-Nickel, Inc. July 2006.

Table 180. ECM Evaporator-Fan Controller Savings (per Controller)

City	Cooler (MT) Walk-in Door		Freezer (LT) Walk-in Door		Cooler (MT) Walk-in Door w/Reach-in Glass		Freezer (LT) Walk-in Door w/Reach-in Glass	
	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Knoxville	1540	0.1759	1838	0.2098	4841	0.5526	5652	0.6452
Nashville	1559	0.1780	1871	0.2135	4900	0.5593	5753	0.6567
Chattanooga	1551	0.1771	1863	0.2127	4874	0.5564	5730	0.6541
Memphis	1578	0.1801	1902	0.2172	4960	0.5662	5851	0.6679
Huntsville	1564	0.1786	1874	0.2139	4917	0.5612	5762	0.6578

Measure Life:

16 years (DEER 2008)

Attachment:

TVA - Evap Fan Controller (SHP).xlsx

TVA - Evap Fan Controller (ECM).xlsx

5.2.2.5 Electronically Commutated Motors for Open and Reach-In Display Cases

Sources:

2012 Pacific Gas & Electric Work paper - PGE3PREF124-R1 - Display Case ECM Motor Retrofit

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Measure Description:

This measure applies to the installation of new electronically commutated (EC) evaporator fan motors on refrigerated display cases with existing shaded-pole (SP) evaporator fan motors. This measure cannot be used in conjunction with any motor controls measure.

Assumptions:

The base case shaded-pole motor load is 0.33 amps per linear foot of display case, while the retrofit electronically commutated motor load is 0.13 amps per linear foot of display case.[115] Annual operating hours for both evaporator fan motors are assumed to be 8,760. The base case and retrofit evaporator fan motor values are presented in the following table.

Table 181. Case Evaporator-Fan Motor Assumptions (per Linear Foot of Case)

Variable	Evaporator Fan
Base case, SP Motor	
Amps/ft	0.33
Annual Run hours	8760
Voltage	115
Annual kWh	329
Retrofit, EC Motor	
Amps/ft	0.13
Annual Run hours	8760
Voltage	115
Annual kWh	131
ΔkWh direct	**197**
ΔkW direct	**0.023**

Savings:

Energy savings are based on the direct load reduction of the evaporator fan motor and the associated decreased refrigeration compressor load using the following series of equations:

$$\text{Annual kWh} = \frac{\text{amps}}{\text{ft}} \times \text{voltage} \times \text{annual hours}$$

$$\Delta\text{ kWh direct} = \text{Annual kWh}_{\text{Baseline}} - \text{Annual kWh}_{\text{Retrofit}}$$

$$\text{kWh Savings} = \Delta\text{ kWh direct} \times (1 + \text{IF}_{\text{CZ}})$$

[115] Evaporator fan motor load values sourced from PG&E work paper (PGE3PREF124) Display Case ECM Motor Retrofits.

The savings from the reduction in refrigeration load is accounted for by the inclusion of the IF term in the savings equation. The IF is the ratio of compressor energy reduction to direct caseload reduction, using the calculated EER values for medium temperature and low temperature cases for the TVA climate zones.

For the open display cases, KEMA employed the lighting energy and demand interactive factors developed for TVA to account for the reduced HVAC system compressor load that results from reducing the building's internal heat load. Unlike the IF terms described above, the lighting interactive factors account for the direct and indirect load reduction, and so the open case kWh savings equation is modified to multiply the direct reduction in kWh by the lighting interactive factor, as shown in the equation below:

$$\text{kWh Savings} = \Delta \text{ kWh direct} \times (\text{IF}_{\text{CZ}})$$

Summer demand savings are calculated by dividing the product of direct load reduction and IF term by 8,760 annual operating hours to approximate the average load reduction, as shown in the following equation:[116]

$$\text{kW Savings} = \frac{\Delta \text{ kWh direct } \times (1 + \text{IF}_{\text{CZ}})}{8760 \text{ hrs}}$$

The energy and demand savings, per linear foot of display case, are presented in the following table.

Table 182. Case Evaporator Fan Motor Savings (per Linear Foot of Case)

Climate Zone	Open Case kWh/yr	Open Case Summer Peak kW	MT Case kWh/yr	MT Case Summer Peak kW	LT Case kWh/yr	LT Case Summer Peak kW
Knoxville	187	0.0305	317	0.0361	348	0.0397
Nashville	192	0.0306	319	0.0364	351	0.0401
Chattanooga	190	0.0309	318	0.0363	351	0.0401
Memphis	196	0.0305	321	0.0366	355	0.0405
Huntsville	190	0.0304	319	0.0365	352	0.0402

Measure Life:

15 years (DEER 2008)

[116] The equation for open case demand savings excludes the "1+" term, as is the case with the open case energy savings equations.

Attachment:

TVA - Refrigeration Case Measure Calculations.xlsx

5.2.2.6 Strip Curtains

Sources:

California Database for Energy Efficiency Resources, www.deeresources.com/ (DEER 2008)

2009 Southern California Edison Company- WPSCNRRN0002.1 - Infiltration Barriers - Strip Curtains

Measure Description:

This measure provides the installation of strip curtains where none previously existed. Strip curtains on doorways to walk-in boxes and refrigerated warehouses can decrease the amount of outside air allowed into the refrigerated space and result in energy savings.

Assumptions:

Energy savings data came from the SCE work paper that discussed infiltration barriers (i.e., strip curtains). Savings are calculated by adjusting the coefficient of the effectiveness of the strip curtains. Baseline condition assumes the absence of an existing strip curtain (coefficient of effectiveness of 0). Post-retrofit strip curtain effectiveness uses a value of 0.92.[117]

Savings:

Savings are provided in the following table.

[117] 2009 Southern California Edison Company– WPSCNRRN0002.1 – Infiltration Barriers – Strip Curtains

Table 183. Strip Curtain Savings (per Square Foot)

City	Cooler (MT)		Freezer (LT)	
	kWh	kW	kWh	kW
Knoxville	58	0.0066	226	0.0258
Nashville	59	0.0068	231	0.0263
Chattanooga	59	0.0067	231	0.0263
Memphis	60	0.0070	238	0.0272
Huntsville	59	0.0068	233	0.0266

Measure Life:

4 years (DEER 2008)

Attachment:

TVA - Strip Curtains.xlsx

5.2.2.7 Door Gaskets

Sources:

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

2009 Southern California Edison Company- WPSCNRRN0004.1 - Door Gaskets for Glass Doors of Walk-In Coolers.

2009 Southern California Edison Company- WPSCNRRN0001.1 - Door Gaskets for Main Door of Walk-in Coolers and Freezers

Measure Description:

This measure replaces weak, worn-out gaskets with new, better-fitting gaskets on refrigerator or freezer doors to reduce heat loss through air infiltration. These values are taken from the SCE Gasket work papers and vary significantly depending whether the cooler/freezer is considered airtight or poorly sealed.

Assumptions:

The closed-door infiltration rate of the refrigerated case uses different inputs for the pre- and post-retrofit cases. The infiltration rate of a poorly sealed cooler/freezer uses the following equation from the SCE work paper:[118]

$$\dot{V}_{closed} = 29.65(\Delta p)^{0.534} \times K$$

The post retrofit case uses the following equation to calculate the infiltration rate of an airtight room:

$$\dot{V}_{closed} = 4.65(\Delta p)^{0.733} \times K$$

Where,

Δp = pressure differential between inside and outside of walk-in, 0.10197 mmWC (millimeters water column)

K = conversion factor, 35.315 ft^3/m^3

Savings:

The following table summarizes the savings. The savings are not cost-effective based on the assumptions used.

Table 184. Annual Energy Savings for Door Gaskets (per Linear Foot)

City	Cooler Walk-in Door		Freezer Walk-in Door		Cooler (MT) Reach-in Glass Door		Freezer (LT) Reach-in Glass Door	
	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Knoxville	8.9	0.0010	28.1	0.0032	3.3	0.0004	21.1	0.0024
Nashville	9.0	0.0010	28.7	0.0033	3.4	0.0004	21.6	0.0025
Chattanooga	9.0	0.0010	28.7	0.0033	3.3	0.0004	21.6	0.0025
Memphis	9.2	0.0011	29.4	0.0034	3.4	0.0004	22.2	0.0025
Huntsville	9.1	0.0010	28.8	0.0033	3.4	0.0004	21.7	0.0025

[118] This methodology is not finalized within the California evaluation framework as of May 2010, however, this portion per the ADM study of the cooling load is small and gaskets are not deemed a cost-effective measure per the results of the study.

Measure Life:

4 years (DEER 2008)

Attachment:

TVA - Gaskets.xlsx

5.2.2.8 Night Covers on Open Refrigeration Display Cases

Sources:

2009 Pacific Gas and Electric Work paper - PGECOREF104-R1 - New Refrigeration Display Cases with Doors

1997 SCE study: Effects of the low Emissivity Shields on Performance and Power use of a Refrigerated Display Case

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Measure Description:

This measure applies to the installation and use of low emissivity night curtains on existing open refrigeration display cases without night covers. This measure is not applicable to retailers that are open for business more than 18 hours per day.

Assumptions:

The refrigeration case cooling capacities used for these calculations are the averages of multiple display case model specifications.[119] The annual operating hours for the refrigeration cases are assumed to be 8,760. The compressor savings factor is 9% assuming that the night covers are deployed a minimum of 6 hours per 24-hour period (e.g., 12 a.m. to 6 a.m.).[120] The aforementioned calculation variables and their values are presented in the following table.

[119] Case cooling capacities are from PG&E work paper – PGECOREF104-1—New Display Cases with Doors.

[120] Compressor savings factor sourced from SCE study: Effects of the low Emissivity Shields on Performance and Power use of a Refrigerated Display Case, 1997

Table 185. Night Cover Calculation Assumptions

Variable	Value
Medium Temperature Case Cooling Capacity (BTU/ hr·linear ft)	1,397
Low Temperature Case Cooling Capacity (BTU/ hr·linear ft)	1,798
BTU/ Ton of Cooling	12,000
Hours per Year (hr)	8,760
Compressor Savings (%)	9%

The compressor duty cycle and kW/ton compressor efficiency values were calculated by KEMA for the TVA climate zones and are shown in the following table (see Appendix Section 8 for details).

Table 186. Compressor Duty Cycle and Efficiency Values

Climate Zone	MT Duty Cycle	MT kW/ton	LT Duty Cycle	LT kW/ton
Chattanooga	0.725	1.89	0.706	2.45
Huntsville	0.715	1.95	0.700	2.53
Knoxville	0.712	1.95	0.698	2.53
Memphis	0.705	2.02	0.693	2.61
Nashville	0.719	1.95	0.702	2.53

Savings:

Energy savings are based upon the reduced compressor load that results from the decreased mixing of refrigerated display case air and the air outside of the case. The following equation was used to calculate the compressor energy savings:

$$\text{kWh Savings} = \left(\frac{\text{Cooling Capacity}}{\text{BTU per Ton}}\right) \times \frac{\text{kW}}{\text{Ton}} \times \text{Duty Cycle} \times \text{Compressor Savings (\%)} \times \text{Hours per year}$$

Demand savings are not recognized for this measure as the reduced load only occurs during off-peak hours

Energy savings per linear foot of night curtain installed are presented in the following table.

Table 187. Savings for Night Covers (per Linear Foot of Curtain)

Climate Zone	MT Case (kWh/yr ft)	LT Case (kWh/yr ft)
Knoxville	126	159
Nashville	128	163
Chattanooga	128	162
Memphis	131	166
Huntsville	129	163

Measure Life:

5 years (DEER 2008)

Attachment:

TVA - Refrigeration Case Measure Calculations.xlsx

5.2.2.9 Anti-Sweat Heater (ASH) Controls

Sources:

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Southern California Edison work paper WPSCNRRN0009 Revision 0, "Anti-Sweat Heat (ASH) Controls."

Measure Description:

Anti-sweat heaters remove moisture from doors and frames by heating the door rails, case frame, and glass doors of walk-ins. In standard installations, these heaters operate at full power 100% of the time. Energy savings result by reducing run-time of anti-sweat heaters and modulating the heater power supplied according to the measured ambient dew point, which is dependent on relative humidity and temperature.

Assumptions:

The ASH controller determines the amount of power necessary by sensing the ambient dew point within the installation's location. Methodology is taken from the SCE work paper, which derives ASH runtime based on ambient space conditions and controller set points. It's assumed that these controllers are set to turn off at 42.89°F dew point (35% relative humidity) as the "All OFF Set Point" and all on at 52.87°F dew point (50% relative humidity) as the "All ON Set Point." Between these values, the ASH duty cycle changes proportionally:

$$\text{ASH ON\%} = \frac{DP_{meas} - \text{All OFF Set Point}}{\text{All ON Set Point - All OFF Set Point}}$$

Where,

DP_{meas} = measured dew point temperature inside the sales area

Energy savings are dependent on climate zone. Direct power savings are calculated using TMY3 weather data for the five typical Tennessee cities, using the methodology outlined above for each representative hour. The percent ASH on-time is then multiplied by the instantaneous ASH power, which is assumed to be 0.04255 kW/linear foot per the SCE work paper. The total ASH direct energy consumption is calculated by taking the sum of all 1-hour kW consumption values for the entire representative TMY3 year. Interactive savings are calculated for the retrofit case by multiplying the baseline ASH heat load by the percent ASH runtime for each representative city.

Savings:

Savings are presented in the following table.

Table 188. Savings for Anti-Sweat Heater Controls (per Linear Foot)

City	Freezer (LT) Walk-in Door		Cooler (MT) Walk-in w/Reach-in Glass		Freezer (LT) Walk-in w/Reach-in Glass	
	kWh	kW	kWh	kW	kWh	kW
Knoxville	232	0.0265	150	0.0171	182	0.0208
Nashville	238	0.0272	157	0.0180	189	0.0216
Chattanooga	242	0.0276	163	0.0186	194	0.0222
Memphis	246	0.0281	165	0.0189	197	0.0225
Huntsville	241	0.0275	160	0.0183	192	0.0219

Life:

12 years (DEER 2008).

Attachment:

TVA - ASH Controls.xlsx

5.2.2.10 Door Auto Closers: Walk-Ins

Sources:

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Measure Description:

An auto closer is an automatic, hydraulic-type door closer used on main doors to walk-in coolers or freezers. This measure consists of installing an auto closer where none existed before. Energy savings are gained when an auto closer installation reduces the infiltration of warmer outside air into a cooler or freezer environment.

Assumptions:

Savings assume that an auto closer reduces warm air infiltration on average by 40%[121] and the doors have effective strip curtains. To simulate the reduction, the main door open time is reduced by 40%. Savings are calculated with the assumption that strip curtains that are 100% effective are installed on the doorway.

Savings:

Savings are presented in the table. These savings indicate that the measure is not cost-effective.

Table 189. Savings for Auto-Closers in Walk-In Enclosures (per Closer)

City	Cooler (MT)		Freezer (LT)	
	kWh	kW	kWh	kW
Knoxville	42	0.0048	164	0.0188
Nashville	43	0.0049	168	0.0192
Chattanooga	42	0.0048	168	0.0192
Memphis	43	0.0050	172	0.0197
Huntsville	43	0.0049	169	0.0193

Measure Life:

8 years (DEER 2008).

[121] DEER 2005, D03-208, D03-209

Attachment:

TVA - Main Door Autoclosers.xlsx

5.2.2.11 Door Auto Closers: Glass Reach-In Cooler or Freezer Doors

Sources:

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Measure Description:

This measure consists of installing an automatic, hydraulic-type door closer on glass reach-in doors to walk-in coolers or freezers. Energy savings are gained when an auto-closer installation reduces the infiltration of warmer outside air into a cooler or freezer environment.

Assumptions:

Savings assume that an auto closer reduces warm air infiltration on average by 40%.[122] To simulate the reduction, the reach-in door open time is reduced by 40%.

Savings:

Savings are presented in the following table.

Table 190. Savings for Auto-Closers for Reach-In Doors (per Closer)

City	Cooler (MT)		Freezer (LT)	
	kWh	kW	kWh	kW
Knoxville	97	0.0111	418	0.0477
Nashville	99	0.0113	428	0.0489
Chattanooga	99	0.0113	427	0.0488
Memphis	101	0.0115	438	0.0500
Huntsville	100	0.0114	429	0.0490

Measure Life:

The average life of an auto closer (assumed to be the same as those for walk-ins) is 8 years, per DEER 2008.

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[122] DEER 2005, D03-208, D03-209

Attachment:

TVA - Reach-In Door Autoclosers.xlsx

5.2.2.12 High-Efficiency Open and Reach-In Display Cases/Open Case to Reach-In Door Retrofit

Sources:

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

2012 Pacific Gas and Electric Work paper - PGE3PREF124-R1 - Display Case ECM Motor Retrofit

2009 Pacific Gas and Electric Work paper - PGECOREF104-R1 - New Refrigeration Display Cases with Doors

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Measure Description:

This measure applies to the installation of high-efficiency open and reach-in refrigeration display cases to replace existing standard efficiency refrigeration display cases or to the addition of case doors onto an existing open refrigeration display case.

Assumptions:

The base case display case has T-12 lamps, shaded-pole, evaporator-fan motors, and standard glass doors with anti-sweat heaters. The high efficiency display case is assumed to have energy efficient LED case lighting, electronically commutated evaporator fan motors, and high efficiency low/no anti-sweat heat display case doors (applicable to reach-in cases).

The measure assumes the following operating hours for both standard and high efficiency display cases:

- Evaporator fan and anti-sweat heaters operate 365 days per year for 24 hours each day for a total of 8,760 annual operating hours
- Lighting operates 365 days per year for 17 hours each day for a total of 6,205 annual operating hours[123]

[123] Pacific Gas and Electric's Application Assessment Report #0608, LED Supermarket Case Lighting Grocery Store, Northern California.

- Defrost cycles for the open and medium temperature cases are 730 annual hours, while the low temperature case defrost cycle hours are 274

The base case and high efficiency display case component load values are presented in the three tables below.

Table 191. Open Display-Case Assumptions (per Linear Foot of Case)

Variable	Evaporator Fan[124]	ASH[125]	Lighting[126]	Defrost[127]	Component Total (Annual kWh/linear foot)
Base case					
Amps/ft	0.33	0	0.49	0	
Annual Run hours	8,760	8,760	6,205	730	
Voltage	115	115	115		
Annual kWh	329	0	351	0	**679**
High Efficiency					
Amps/ft	0.13	0	0.15	0	
Annual Run hours	8,760	8,760	6,205	730	
Voltage	115	115	115		
Annual kWh	131	0	107	0	**239**
				ΔkWh direct	**440**
				ΔkW direct	**0.050**

[124] Evaporator fan motor load values sourced from PG&E work paper – PGE3PREF124 – Display Case ECM Motor Retrofits.

[125] Anti-sweat heater (ASH) load values sourced from PG&E work paper – PGECOREF104-R1 – New Refrigeration Display Cases with Doors for open cases or from the TVA TRM door retrofit measure data for reach-in cases.

[126] Lighting load values sourced from TVA TRM display case lighting retrofit measure data.

[127] Defrost load values sourced from PG&E work paper – PGECOREF104-R1 – New Refrigeration Display Cases with Doors.

Table 192. Medium-Temperature Display-Case Assumptions (per Linear Foot of Case)

Variable	Evaporator Fan	ASH	Lighting	Defrost	Component Total (Annual kWh/linear foot)
Base case					
Amps/ft	0.33	0.70	0.49	0	
Annual Run hours	8,760	8,760	6,205	730	
Voltage	115	115	115		
Annual kWh	329	704	351	0	**1,383**
High Efficiency					
Amps/ft	0.13	0.20	0.15	0	
Annual Run hours	8,760	8,760	6,205	730	
Voltage	115	115	115		
Annual kWh	131	197	107	0	**436**
				ΔkWh direct	**947**
				ΔkW direct	**0.108**

Table 193. Low-Temperature Display-Case Assumptions (per Linear Foot of Case)

Variable	Evap Fan	ASH	Lighting	Defrost	Component Total (Annual kWh/linear foot)
Base case					
Amps/ft	0.33	1.26	0.49	1.35	
Annual Run Hours	8,760	8,760	6,205	274	
Voltage	115	115	115	208	
Annual kWh	329	1,266	351	77	**2,022**
High Efficiency					
Amps/ft	0.13	0.42	0.151	1.35	
Annual Run Hours	8,760	8,760	6,205	274	
Voltage	115	115	115	208	
Annual kWh	131	425	107	77	**740**
				ΔkWh direct	**1,282**
				ΔkW direct	**0.146**

Savings:

Energy savings are based on the summation of direct load reduction of the evaporator fan, anti-sweat heat, and lighting components, as well as the associated decreased refrigeration compressor load using the following series of equations:

$$\text{Annual kWh}_{\text{ component}} = \frac{\text{amps}}{\text{ft}} \times \text{voltage} \times \text{annual hours}$$

$$\text{Component total annual kWh} = \sum \text{Annual kWh}_{\text{ component}}$$

$$\Delta \text{ kWh direct} = \text{Component total annual kWh}_{\text{Baseline}} - \text{Component total annual kWh}_{\text{High Efficiency}}$$

$$\text{kWh Savings} = \Delta \text{ kWh direct} \times (1 + \text{IF}_{\text{CZ}})$$

The savings from the reduction in refrigeration load are accounted for by the inclusion of the IF term in the savings equation. The IF is the ratio of compressor energy reduction to direct caseload reduction, using the calculated EER values for medium temperature and low temperature cases for the TVA climate zones.

For the open display cases, KEMA employed the lighting energy and demand interactive factors developed for TVA to account for the reduced HVAC system compressor load that results from reducing the building's internal heat load. Unlike the IF terms described above, the lighting interactive factors account for the direct and indirect load reduction, and so the open case kWh savings equation is modified to multiply the direct reduction in kWh by the lighting interactive factor, as shown in the equation below:

$$\text{kWh Savings} = \Delta \text{ kWh direct} \times (\text{IF}_{\text{CZ}})$$

Summer demand savings are calculated by dividing the product of direct load reduction and IF term by 8,760 annual operating hours to approximate the average load reduction, as shown in the equation below:[128]

$$\text{kW Savings} = \frac{\Delta \text{ kWh direct} \times (1 + \text{IF}_{\text{CZ}})}{8760 \text{ hrs}}$$

The energy and demand savings per linear foot of display case are presented in the following table.

Table 194. Savings for High-Efficiency Display Cases (per Linear Foot of Case)

Climate Zone	Open Case kWh/yr	Open Case Summer Peak kW	MT Case kWh/yr	MT Case Summer Peak kW	LT Case kWh/yr	LT Case Summer Peak kW
Knoxville	418	0.0681	1522	0.1737	2261	0.2581
Nashville	430	0.0684	1532	0.1749	2284	0.2608
Chattanooga	423	0.0691	1530	0.1746	2282	0.2605

[128] The equation for open case demand savings excludes the "1+" term, as is the case with the open case energy savings equations.

Climate Zone	Open Case kWh/yr	Open Case Summer Peak kW	MT Case kWh/yr	MT Case Summer Peak kW	LT Case kWh/yr	LT Case Summer Peak kW
Memphis	439	0.0682	1543	0.1762	2308	0.2635
Huntsville	424	0.0679	1535	0.1753	2287	0.2611

For the addition of doors to an open refrigeration display case measure, refer to the applicable medium temperature or low temperature case energy and demand savings from the above savings table.

Measure Life:

12 years (DEER 2008)

Attachment:

TVA - Refrigeration Case Measure Calculations.xlsx

5.2.2.13 Reach-In Refrigeration Case-Door Retrofit

Sources:

Zero Zone, Inc, www.zero-zone.com/spec-sheets.php, accessed January 2015

Hussmann Corporation, http://www.hussmann.com/en/Products/Glass-Doors-Lids/pages/default.aspx, accessed March 2013

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Measure Description:

This measure applies to the installation of low-heat and no-heat reach-in refrigeration case doors on existing units with continuously operating heated doors. Low-heat doors only qualify on low temperature refrigeration case applications. This measure cannot be used in conjunction with any anti-sweat heater controls or refrigerator door heater controls measures.

Assumptions:

The annual operating hours are assumed to be 8,760 for the base case and retrofit door models. For both the medium-temperature (MT) and low-temperature (LT) case doors, KEMA collected data on the current loads of multiple standard-heat, low-heat, and no-heat door models to calculate an average current draw for each door type.[129] The following table lists these calculated average current load values.

Table 195. Amperage Assumptions from Sample of Manufacturers

Variable	Amps
Current of Base case Doors on MT Case	1.748
Current of No-heat Doors on MT Case	0.392
Current of Base case Doors on LT Case	3.142
Current of Low-heat Doors on LT Case	1.360
Current of No-heat Doors on LT Case	0.747

Savings:

Energy savings are based on the summation of direct load reduction of the anti-sweat heat, as well as the associated decreased refrigeration compressor load using the following equation:

$$\mathbf{kWh\ Savings} = \frac{(\mathbf{Amps_{basecase}} - \mathbf{Amps_{retrofit}}) \times \mathbf{115V} \times (\mathbf{1} + \mathbf{IF_{CZ}}) \times \mathbf{Hours\ per\ year}}{\frac{\mathbf{1000\ Wh}}{\mathbf{1\ kWh}}}$$

The savings from the reduction in refrigeration load is accounted for by the inclusion of the IF term in the savings equation. The IF is the ratio of compressor energy reduction to direct caseload reduction, using the calculated EER values for medium temperature and low temperature cases for the TVA climate zones.

Demand savings are calculated using the kWh savings equation, but with the exclusion of the "hours per year" term, as shown in the equation below:

$$\mathbf{kW\ Savings} = \frac{(\mathbf{Amps_{basecase}} - \mathbf{Amps_{retrofit}}) \times \mathbf{115V} \times (\mathbf{1} + \mathbf{IF_{CZ}})}{\frac{\mathbf{1000\ W}}{\mathbf{1\ kW}}}$$

The energy and demand savings per display case door are presented in the following table.

[129] Case door current loads sourced from Zero Zone, Inc, (www.zero-zone.com/spec-sheets.php) and Hussmann Corporation (www.hussmann.com/ServiceAndParts/Pages/Reach-inDisplayMerchandisers.aspx) product specification sheets.

Table 196. Savings for Low-or No-Heat Door Retrofit (per Door)

Climate Zone	No-Heat Doors on MT Case		Low-Heat Doors on Low Temp Case		No-Heat Doors on Low Temp Case	
	Energy Savings	Demand Savings	Energy Savings	Demand Savings	Energy Savings	Demand Savings
Knoxville	2,193	0.2504	3,165	0.3613	4,255	0.4857
Nashville	2,208	0.2520	3,198	0.3651	4,299	0.4907
Chattanooga	2,205	0.2517	3,195	0.3647	4,295	0.4903
Memphis	2,224	0.2539	3,232	0.3689	4,344	0.4959
Huntsville	2,213	0.2526	3,202	0.3656	4,305	0.4914

Measure Life:

12 years (DEER 2008)

Attachment:

TVA - Refrigeration Case Measure Calculations.xlsx

5.2.2.14 Floating-Head Pressure Controls for Refrigeration Systems

Sources:

2010 Efficiency Vermont Technical Resource Manual (TRM)

National Renewable Energy Laboratory, Renewable Resource Data Center, National Solar Resource Data Base, http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Measure Description:

This measure requires installing automatic controls to lower the condensing pressure at lower ambient temperature (i.e. floating head pressure controls) in multiplex refrigeration systems. The following are measure requirements where the savings presented are applicable:

- Controls installed must vary head pressure to adjust condensing temperature in relation to the outdoor air temperature.

- The proposed control scheme must have a minimum SCT (Saturated Condensing Temperature) programmed for the floating head pressure control of greater than, or equal to 70°F.

- Head pressure control valves (flood-back control valve) must be installed to lower minimum condensing head pressure from a fixed position (180 psig for R-22) to a saturated pressure equivalent to 70°F or less.

- Installation must include balanced-port expansion valves[130] (to replace existing constant pressure or manually controlled systems) that are sized to meet the load requirement at a 70°F condensing temperature and vary head pressure based on outdoor air temperature. Alternatively, a device may be installed to supplement refrigeration feed to each evaporator attached to a condenser that is reducing head pressure.

Assumptions:

Annual energy savings and the demand savings were calculated by taking a weighted average savings from the 2010 Efficiency Vermont TRM, per the tables below and adjusting the savings using a bin analysis comparing the TMY3 hourly dry bulb temperatures of Montpelier Vermont and the five TVA climate zone cities: Chattanooga, Huntsville, Knoxville, Memphis, and Nashville.

Table 197. Floating-Head, Pressure-Control, kWh/hp Savings from Efficiency Vermont TRM[131]

Compressor Type	Temperature Range			Weighting	Weighted Average kWh Savings/hp
	Low Temperature (-35° F to -5° F SST)	Medium Temperature (0° F to 30° F SST)	High Temperature (35° F to 55° F SST)		
Standard Reciprocating	695	727	657	0.33	635
Discus	607	598	694	0.33	
Scroll	669	599	509	0.33	
Weighted Average	0.25	0.25	0.5		

Table 198. Floating-Head, Pressure-Control, kW/hp Savings from Efficiency Vermont TRM

Compressor Type	Temperature Range	Weighting	Weighted

[130] Please note that the expansion valve is a device used to meter the flow of liquid refrigerant entering the evaporator at a rate that matches the amount of refrigerant being boiled off in the evaporator.

[131] 2010 Efficiency Vermont Technical Resource Manual (TRM).

	Low Temperature (-35° F to -5° F SST)	Medium Temperature (0° F to 30° F SST)	High Temperature (35° F to 55° F SST)		
Standard Reciprocating	0.08382	0.08767	0.07923	0.33	0.0765
Discus	0.07320	0.07212	0.08370	0.33	
Scroll	0.08068	0.07224	0.06138	0.33	
Weighted Average	0.25	0.25	0.5		

It was assumed that low temperature, medium temperature, and high temperature had weightings of 25%, 25%, and 50%. A straight average weighting was assumed for the different compressor types.

Savings:

A linear interpolation was used to account for the greater savings that would occur at lower temperatures. The two points used for the linear interpolation are as follows: The weighted average kW/hp for VT was determined by dividing the average kWh/hp value (determined using the weight factors and values described above) by the total number of hours from the TMY3[132] data in Montpelier when savings were expected to occur; i.e., all of the hours when the temperature is below 75°F. It was assumed that this average kW/hp value would correspond to the average temperature that savings were expected to occur, which turned out to be 43.13 °F. This was the first point for the interpolation. The second point for the interpolation was 75 °F, the point at which 0 savings are expected to occur. The equation resulting from this linear interpolation is:

$$\mathrm{kW}/_{\mathrm{hp}}\ \text{Reduction} = \frac{-0.0024\ \mathrm{kW}/_{\mathrm{hp}}}{\text{Degree (F)}} \times \text{Dry Bulb Temp (F)} + 0.1801\ \mathrm{kW}/_{\mathrm{hp}}$$

This linear equation was applied to each dry bulb temperature bin below 75°F, and the equation output was then multiplied by the corresponding number of hours for that temperature bin to produce kWh/hp values for each bin. The total kWh/hp savings are the sum of all the kWh/hp values. This process was executed for each TVA climate zone. The equation below illustrates the calculation of total kWh/hp savings.

$$\mathrm{kWh}/_{\mathrm{hp}}\ \text{Savings} = \sum \left[\mathrm{kW}/_{\mathrm{hp}}\ \text{Reduction}_{\text{Temp Bin}} \times \text{Hours}_{\text{Temp Bin}}\right]$$

[132] National Solar Resource Data Base, http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/ Accessed May 22, 2013.

For each TVA climate zone, the winter peak kW/hp demand savings were determined by averaging the kW per hp saving for the top 10 coldest hours during the winter peak period. No summer peak savings are achieved through this measure, because for all TVA climate zones the ambient dry bulb temperatures during top ten hottest hours of the summer peak period are above the temperature at which savings are achieved.

The annual kWh/hp and winter peak kW/hp savings are presented in the following table.

Table 199. Savings for Floating-Head Pressure Controls (per Compressor hp)

Climate Zone	Annual Savings (kWh/hp)	Winter Peak Demand Savings kW/hp
Chattanooga	338	0.1321
Huntsville	347	0.1467
Knoxville	384	0.1520
Memphis	307	0.1349
Nashville	358	0.1517
Average	**347**	**0.1435**

Measure Life:

15 years (DEER 2008)[133]

Attachment:

Floating Head Pressure Controls.xlsx

5.2.2.15 ENERGY STAR Commercial Refrigerator and Freezer

Sources:

ENERGY STAR Program, www.energystar.gov (accessed May 2013)

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Office, http://www1.eere.energy.gov/buildings/appliance_standards/ (accessed May 2013)

[133] EUL from DEER 2008 Refrigeration Upgrades measure.

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Measure Description:

This measure applies to the installation of a new ENERGY STAR commercial reach-in refrigerator or freezer with solid or glass doors replacing an existing standard efficiency reach-in refrigeration case. The installed case must meet ENERGY STAR Version 2.1 specifications.

Assumptions:

Savings are broken out by internal volume classes. The base case unit is a standard reach-in case that operates at the Federal maximum daily energy consumption (MDEC) requirement[134] for its volume class, while the ENERGY STAR unit is assumed to operate at the ENERGY STAR MDEC requirement[135] for its volume class. The base case and ENERGY STAR MDEC requirements are presented in the following table.

Table 200. Commercial Refrigerator and Freezer Requirements

Volume Class (ft^3)	Base case Refrigerator	ENERGY STAR Refrigerator	Base case Freezer	ENERGY STAR Freezer
Solid Door Cabinets				
0 < V < 15	≤ 0.10 V + 2.04	≤ 0.089 V + 1.411	≤ 0.40 V + 1.38	≤ 0.250 V + 1.250
15 ≤ V < 30		≤ 0.037 V + 2.200		≤ 0.400 V - 1.000
30 ≤ V < 50		≤ 0.056 V + 1.635		≤ 0.163 V + 6.125
50 ≤ V		≤ 0.060 V + 1.416		≤ 0.158 V + 6.333
Glass Door Cabinets				
0 < V < 15	≤ 0.12 V + 3.34	≤ 0.118 V + 1.382	≤ 0.75 V + 4.10	≤ 0.607 V + 0.893
15 ≤ V < 30		≤ 0.140 V + 1.050		≤ 0.733 V - 1.000
30 ≤ V < 50		≤ 0.088 V + 2.625		≤ 0.250 V + 13.500
50 ≤ V		≤ 0.110 V + 1.500		≤ 0.450 V + 3.500

Savings:

134 Baseline kWh/ day calculated using Federal Maximum Daily Energy Consumption Formulas (Standards effective 1/10/2010): http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/52

135 ENERGY STAR® kWh/day calculated using the ENERGY STAR Maximum Daily Energy Consumption (MDEC) Requirements: http://www.energystar.gov/index.cfm?c=commer_refrig.pr_crit_commercial_refrigerators

Daily energy consumption is calculated for each case type and volume class. For the purpose of calculating the base case and ENERGY STAR MDEC, KEMA calculated the average volume[136] of the ENERGY STAR qualified products which fall within each volume class. The calculated average volume per class and the daily energy consumption for the base case and ENERGY STAR refrigeration cases are presented in the following two tables.

Table 201. Base case and ENERGY STAR Refrigerator Case Assumptions

Refrigerator Volume Class (ft^3)	Average ENERGY STAR Volume (ft^3)	Base case kWh/day	ENERGY STAR kWh/day
Solid Door Cabinets			
0 < V < 15	9.07	2.95	2.22
15 ≤ V < 30	20.48	4.09	2.96
30 ≤ V < 50	43.21	6.36	4.05
50 ≤ V	67.82	8.82	5.49
Glass Door Cabinets			
0 < V < 15	7.39	4.23	2.25
15 ≤ V < 30	21.81	5.96	4.10
30 ≤ V < 50	42.70	8.46	6.38
50 ≤ V	66.87	11.36	8.86

Table 202. Base case and ENERGY STAR Freezer Case Assumptions

Freezer Volume Class (ft^3)	Average ENERGY STAR Volume (ft^3)	Base case kWh/day	ENERGY STAR kWh/day
Solid Door cabinets			
0 < V < 15	7.24	4.28	3.06
15 ≤ V < 30	20.77	9.69	7.31
30 ≤ V < 50	43.00	18.58	13.13
50 ≤ V	62.83	26.51	16.26
Glass Door Cabinets			
0 < V < 15	8.39	10.40	5.99
15 ≤ V < 30	22.81	21.21	15.72
30 ≤ V < 50	44.12	37.19	24.53
50 ≤ V	68.07	55.15	34.13

[136] Average ENERGY STAR Volume calculated from lists of Qualified Refrigerators and Freezers: http://www.energystar.gov/index.cfm?fuseaction=products_for_partners.showRefrigComm

The energy savings for each case type and volume class are calculated using the following equation:

$$\text{kWh Savings} = \left(\text{Daily kWh}_{\text{Basecase}} - \text{Daily kWh}_{\text{ENERGY STAR®}}\right) \times 365\ \text{days/year}$$

Demand reduction is calculated by dividing the annual kWh savings by 8,760 annual operating hours, as shown in the equation below:

$$\text{kW Savings} = \frac{\text{kWh Savings}}{8{,}760\ \text{hours}}$$

The energy and demand savings for each refrigeration unit type and volume class are presented in the following table.

Table 203. Refrigeration Case Savings (per Unit)

Volume Class (ft^3)	Refrigerator Energy Savings (kWh/Year)	Refrigerator Demand Savings (kW)	Freezer Energy Savings (kWh/Year)	Freezer Demand Savings (kW)
Solid Door Cabinets				
0 < V < 15	266	0.0304	444	0.0507
15 ≤ V < 30	413	0.0471	869	0.0992
30 ≤ V < 50	842	0.0962	1,989	0.2271
50 ≤ V	1,219	0.1391	3,745	0.4275
Glass Door Cabinets				
0 < V < 15	721	0.0823	1,610	0.1838
15 ≤ V < 30	677	0.0773	2,004	0.2288
30 ≤ V < 50	760	0.0868	4,624	0.5278
50 ≤ V	916	0.1046	7,677	0.8764

Table 204. Refrigeration Case Summer Peak Demand Savings (per Unit)

Refrigerator Volume Class (ft^3)	Chattanooga	Huntsville	Knoxville	Memphis	Nashville
Solid Door Cabinets					
0 < V < 15	0.0391	0.0409	0.0387	0.0414	0.0412
15 ≤ V < 30	0.0606	0.0634	0.0600	0.0643	0.0639
30 ≤ V < 50	0.1237	0.1293	0.1224	0.1311	0.1304
50 ≤ V	0.1790	0.1871	0.1771	0.1897	0.1887
Glass Door Cabinets					
0 < V < 15	0.1058	0.1106	0.1047	0.1122	0.1115

15 ≤ V < 30	0.0994	0.1039	0.0984	0.1054	0.1048
30 ≤ V < 50	0.1116	0.1167	0.1104	0.1183	0.1177
50 ≤ V	0.1345	0.1407	0.1331	0.1426	0.1418
Freezer Volume Class (ft³)	**Chattanooga**	**Huntsville**	**Knoxville**	**Memphis**	**Nashville**
Solid Door cabinets					
0 < V < 15	0.0652	0.0682	0.0645	0.0692	0.0688
15 ≤ V < 30	0.1276	0.1335	0.1263	0.1353	0.1346
30 ≤ V < 50	0.2921	0.3054	0.2890	0.3096	0.3080
50 ≤ V	0.5498	0.5749	0.5440	0.5828	0.5797
Freezer Volume Class (ft³)	**Chattanooga**	**Huntsville**	**Knoxville**	**Memphis**	
Glass Door Cabinets					
0 < V < 15	0.2364	0.2471	0.2339	0.2506	0.2492
15 ≤ V < 30	0.2943	0.3077	0.2912	0.3120	0.3103
30 ≤ V < 50	0.6790	0.7098	0.6718	0.7197	0.7158
50 ≤ V	1.1273	1.1786	1.1154	1.1950	1.1885

Table 205. Refrigeration Case Winter Peak Demand Savings (per Unit)

Refrigerator Volume Class (ft³)	Chattanooga	Huntsville	Knoxville	Memphis	Nashville
Solid Door Cabinets					
0 < V < 15	0.0259	0.0248	0.0258	0.0243	0.0246
15 ≤ V < 30	0.0402	0.0385	0.0400	0.0377	0.0382
30 ≤ V < 50	0.0821	0.0786	0.0815	0.0769	0.0779
50 ≤ V	0.1188	0.1138	0.1180	0.1113	0.1127
Glass Door Cabinets					
0 < V < 15	0.0702	0.0673	0.0697	0.0658	0.0666
15 ≤ V < 30	0.0660	0.0632	0.0655	0.0618	0.0626
30 ≤ V < 50	0.0741	0.0710	0.0736	0.0694	0.0703
50 ≤ V	0.0893	0.0855	0.0887	0.0836	0.0847
Freezer Volume Class (ft³)	**Chattanooga**	**Huntsville**	**Knoxville**	**Memphis**	**Nashville**
Solid Door Cabinets					
0 < V < 15	0.0433	0.0415	0.0430	0.0406	0.0411
15 ≤ V < 30	0.0847	0.0811	0.0841	0.0794	0.0804
30 ≤ V < 50	0.1939	0.1857	0.1926	0.1816	0.1840
50 ≤ V	0.3649	0.3495	0.3624	0.3418	0.3463
Glass Door Cabinets					
0 < V < 15	0.1569	0.1503	0.1558	0.1469	0.1489

15 ≤ V < 30	0.1953	0.1871	0.1940	0.1830	0.1854
30 ≤ V < 50	0.4506	0.4316	0.4475	0.4221	0.4276
50 ≤ V	0.7482	0.7166	0.7431	0.7008	0.7100

Measure Life:

12 years (2008 DEER)

Attachment:

TVA - EStar Reach-In.xlsx

Sources:

5.2.3 Miscellaneous Measures

5.2.3.1 Low-Flow, Pre-Rinse Sprayers

Sources:

SBW Consulting, Inc. *Impact and Process Evaluation Final Report. 2004-05 Pre-Rinse Spray Valve Installation Program (Phase 2).*Prepared for the California Urban Water Conservation Council. Submitted to the CPUC. February 2007.

Labs, Kenneth. "Underground Building Climate." Solar Age. October. p. 44. 1979.

Energy Right Program Model Assumptions.

Illinois Statewide TRM, May 2012

Food Service Technology Center Pre-Rinse Spray Valve testing http://www.fishnick.com/equipment/sprayvalves/, accessed January 2015

Measure Description:

High-efficiency, pre-rinse spray heads reduce water usage and save energy by decreasing the amount of electricity required to heat water. By installing a low-flow pre-rinse spray head, the amount of hot water (and the amount of energy to heat that water) consumed per year is passively lower, because of the physical flow restrictions that reduce water flow rate.

This measure applies to the replacement of standard pre-rinse spray heads with low-flow pre-rinse spray heads with 1.6 GPM or less flow rate and a cleanability factor of 26 seconds or less. This is only applicable for systems with electric storage water heaters.

Assumptions:

Flow rates for base and measure cases follow flow rates documented in the Illinois Statewide TRM published in May of 2012 and a study of low-flow rinse sprayers published by the Food Service Technology Center (FSTC).

The following table provides IL TRM and FSTC report assumptions as well as others used to estimate energy savings.

Table 206. Pre-Rinse Sprayer Variable Assumptions

Variable Name	Value	Source
Base Case Flow Rate	1.9 gallons per minute	IL TRM, 2012
Measure Case Flow Rate	1.06 gallons per minute	FSTC testing results average, 2013
Base Case Hours of Operation	0.44 hours per day	Average of grocery/non-grocery category; CUWCC report, 2007
Measure Case Hours of Operation	0.60 hours per day	Average of grocery/non-grocery category; CUWCC report, 2007
Cold-water Temperature	60 degrees F	Labs, Kenneth. 1979.
Mixed-water Temperature	105 degrees F	Average of grocery/non-grocery category; CUWCC report, 2007
Water-Heater Efficiency	0.89 EF	Energy Right Program Model Assumptions
Water Temp Difference	105 - 60 = 45 degrees F	Calculated
Flow-Rate Difference	2.23 - 1.12 = 1.11 gallons per minute	Calculated
Water Density	8.33 lb/gal	
Specific Heat Water	1 Btu/lb-degF	
Unit Conversion	3413 Btu/kWh	

Savings:

The following formula was used to estimate water savings and saved energy.

$$\text{Gallons of Water Saved per year} = [(\text{BaseFlowRate}) \times (\text{BaseHoursofOperation}) - (\text{MeasureFlowRate}) \times (\text{MeasureHoursofOperation})] \times (60\text{minutes/hour}) \times (365\text{days/year})$$

$$\text{kWh Saved per year} = (\text{GallonsofWaterSavedperYear}) \times (\text{WaterTempDifference}) \times (\text{WaterDensity}) \times (\text{SpecificHeatWater}) / (\text{WaterHeaterEF}) / (\text{UnitConversion})$$

Annual savings total 4,380 gallons of water and 541 kWh, using the assumptions and formulas above. Peak demand savings are assumed to be conservative since specific data are not available for this measure. It is assumed to be an average across the year, at 8,760 hours. The peak demand savings are 0.0618 kW.

Table 207. Pre-Rinse Sprayer Peak kW Savings per Unit

Peak kW Savings	kW/unit
Summer (central)	0.0411
Winter (central)	0.0412
Summer (eastern)	0.0480
Summer (eastern)	0.0506

Measure Life:

5 years (CPUC 2003)[137]

Attachment:

TVA - Pre-Rinse Sprayer.xls

5.2.3.2 Vending Machine Control - Beverages and Snacks

Sources:

Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008 and 2005)

Measure Description:

Vending-machine controls use a custom passive infrared sensor to completely power down a vending machine when the area surrounding it is unoccupied for 15 minutes. Once powered down, the vending-machine control will measure the ambient room temperature of the vending machine's location. Using this information, the vending-machine control automatically powers up the vending machine in one to three intervals, independent of occupancy, to ensure that the vended products stay cold for the beverage machine. When there is no activity in the area, the vending machine can go into "sleep" mode for a maximum of 4 hours.

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137 From the *CPUC Energy Efficiency Policy Manual, Version 2, Table 4.1,* prepared by the Energy Division, August 2003.

Assumptions and Savings:

There have been many studies conducted on the savings of vending-machine controls. Savings for beverage- and snack-machine controls provided here are taken from the 2005 DEER.[138] The energy savings baseline is a machine with no controls installed. It is assumed that the controls are only effective during off-peak hours and, thus, have no summer peak-kW savings. For winter peak demand savings, the kWh divided by 8,760 hours per year is assumed.

Table 208. Vending-Machine Controls Savings

Vending Machine Type	kWh Savings	Winter Peak kW Savings
Beverages	1,612	0.184
Snack	287	0.033

Measure Life:

5 years (DEER 2008)

Attachment:

None

5.2.3.3 ENERGY STAR Convection Oven

Sources:

ENERGY STAR website and calculator, www.energystar.gov (ESTAR, March 2013)

PG&E. "Commercial Kitchen Appliance Technology Assessment." Developed by the Food Service Technology Center.

PG&E Work Paper PGECOFST101 Commercial Convection Oven Revision #4, June 2012

Measure Description:

[138] The data is from the Pacific Northwest Regional Technical Forum database.

Commercial electric convection ovens are the most widely used appliances in the food service industry. Convection ovens consist of a motorized fan (or blower) that forces heated air to move throughout the oven's cavity to more evenly distribute heat around the food. Forced convection can reduce cook time significantly on long-cooking items, such as potatoes, and can allow more food to be cooked in a given period of time.[139]

Oven performance is determined by the American Society for Testing and Materials (ASTM) Standard Test Method, defined in standard F1496 for the Performance of Convection Ovens, which is considered the industry standard for quantifying convection-oven efficiency and performance.

The following table shows key ENERGY STAR standards for electric convection ovens. This standard, version 1.0 became effective on May 16, 2009.

Table 209. Energy Efficiency Requirements for Commercial Convection Ovens

Size	Cooking Energy Efficiency	Idle Energy Rate (kW)
Half Size	≥70%	≤1.0
Full Size (≤ 5 pans)	≥70%	≤1.6
Full Size (> 5 pans)	≥73%	≤1.9

Assumptions:

Measure data for savings calculations are based on average equipment characteristics, as established by ENERGY STAR. Annual energy use was calculated using preheat, idle, and cooking energy-efficiency and production-capacity test results derived from standard ASTM F1496.

The following formula calculates daily energy consumption, per PG&E work papers. Savings assume a full-size oven that operates 365 days per year with one preheat daily.

$$\text{EDay} = \text{LBFood} * \frac{\text{EFood}}{\text{Efficiency}} + \text{IdleRate} * (\text{OpHrs} - \frac{\text{LBFood}}{\text{PC}} - \frac{\text{TpreHT}}{60}) + \text{EpreHT}$$

$$\text{Average Demand} = \frac{\text{EDay}}{\text{OpHrs}}$$

[139] "Commercial Kitchen Appliance Technology Assessment." PG&E Food Service Technology Center. Section 7, Ovens.

The following table shows the values assumed for the baseline and efficient oven daily energy consumption calculations.

Table 210. Convection Oven Variable Assumptions[140]

Variable	Variable Description (Units)	Value Assumed (Baseline)	Value Assumed (Energy Efficient)
EDay	Daily Energy Consumption (kWh/day)	28.2	21.6
LBFood	Pounds of Food Cooked per Day (lb/day)	100	100
Efood	ASTM Energy to Food (kWh/lb) = kWh/pound of energy absorbed by food product during cooking	0.0732	0.0732
Efficiency	Heavy-Load Cooking Energy Efficiency %	65%	73%
IdleRate	Idle Energy Rate (kW)	1.5	1.0
OpHrs	Operating Hours/Day (hr/day)	12	12
PC	Production Capacity (lbs/hr)	70	82
TPreHt	Preheat Time (min/day)	15	15
EPreHt	Preheat Energy (kWh/day)	1.5	1.0

Savings:

The savings calculated for an ENERGY STAR convection oven are 2,440 kWh per year and average demand savings of 0.557 kW, based on the full size > 5-pan model.

Peak demand savings for cooking appliances utilize California commercial load shapes developed and released by PG&E. Average peak load factors were extracted from these load shapes using TVA's peak times and applied to the annual energy (kWh) savings of the measure. Below are the peak demand savings listed by building type and TVA district.

[140] PG&E Work Paper Commercial Convection Oven Revision #4

Table 211. Convection Oven Peak Demand Savings (kW)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.310	0.318	0.294	0.364
High School/College	0.445	0.443	0.439	0.482
Primary School	0.138	1.122	0.080	1.209
University	0.445	0.443	0.439	0.482
Grocery	0.308	0.310	0.298	0.320
Hospital	0.329	0.400	0.322	0.404
Hotel	0.485	0.382	0.439	0.424
Motel	0.485	0.382	0.439	0.424
Bio/Tech Manufacturing	n/a	n/a	n/a	n/a
Light Industrial Manufacturing	n/a	n/a	n/a	n/a
Large Office	0.408	0.217	0.374	0.296
Small Office	0.408	0.217	0.374	0.296
Fast-food Restaurant	0.352	0.307	0.344	0.328
Full Service Restaurant	0.352	0.307	0.344	0.328
Mall Department Store	0.445	0.217	0.436	0.333
Large Retail	0.445	0.217	0.436	0.333
Small Retail	0.445	0.217	0.436	0.333
Refrigerated Warehouse	0.000	0.000	0.000	0.000
Unrefrigerated Warehouse	0.000	0.000	0.000	0.000

Measure Life:

12 years (PG&E Work Paper Commercial Convection Oven Revision #4)

Attachments:

TVA - Cooking Appliances.xlsx

5.2.3.4 ENERGY STAR Griddle

Sources:

ENERGY STAR website and calculator, www.energystar.gov (ESTAR)

PG&E. "Commercial Kitchen Appliance Technology Assessment." Developed by the Food Service Technology Center.

PG&E Work Paper PGECOFST103 Commercial Griddle Revision #4, May 2012

Measure Description:

Griddles consist of a large flat heated metal plate used to cook food, with splashguards attached to the sides and rear and a shallow trough to guide grease and scraps into a holding tray. The griddle plate is heated from underneath by electric elements, and controls are generally located on the front of the appliance. Griddle temperatures range from 200°F to 450°F, depending on the food being cooked.[141]

Griddle performance is determined by applying the ASTM Standard Test Method for the Performance of Griddles defined in standards F1275 and 1605,[142] considered industry standards for quantifying griddle efficiency and performance.

The following table shows the ENERGY STAR standard for electric griddles. The standard is current, as of May 2009.

Table 212. ENERGY STAR Griddles Key Product Criteria

Tier	Cooking Energy Efficiency	Idle Energy Rate (W/ft^2)
1	≥ 70%	≤ 355
2	≥ 70%	≤ 320

Assumptions:

Measure data for savings calculations are based on average equipment characteristics established by PG&E Food Service and Technology Center. Annual energy use was calculated based on preheat, idle, and cooking energy-efficiency and production-capacity test results derived from standard ASTM F1275.

The following formula calculates daily energy consumption, per the PG&E work papers.

$$EDay = LBFood * \frac{EFood}{Efficiency} + IdleRate * (OpHrs - \frac{LBFood}{PC} - \frac{TpreHT}{60}) + EpreHT$$

$$Average\ Demand = \frac{EDay}{OpHrs}$$

[141] "Commercial Kitchen Appliance Technology Assessment." PG&E Food Service Technology Center.

[142] American Society for Testing and Materials. "Standard Test Method for the Performance of Griddles." ASTM Designation F1275 99, in *Annual Book of ASTM Standards*, West Conshohocken, PA.

The following table shows the values assumed for the baseline and efficient griddle daily energy consumption calculations.

Table 213. Griddles Variable Assumptions[143]

Variable	Variable Description (Units)	Value Assumed (Baseline)	Value Assumed (Energy Efficient)
EDay	Daily Energy Consumption (kWh/day)	48.5	41.2
LBFood	Pounds of Food Cooked per Day (lb/day)	100	100
Efood	ASTM Energy to Food (kWh/lb) = kWh/pound of energy absorbed by food product during cooking	0.139	0.139
Efficiency	Heavy-Load Cooking Energy Efficiency %	60%	75%
IdleRate	Idle Energy Rate (kW)	2.4	2.1
OpHrs	Operating Hours/Day (hr/day)	12	12
PC	Production Capacity (lbs/hr)	35	49
TPreHt	Preheat Time (min/day)	15	15
EPreHt	Preheat Energy (kWh/day)	4.0	2.0

Savings:

The savings calculated for an ENERGY STAR griddle are 2,663 kWh per year and average demand savings of 0.608 kW. Peak demand savings for cooking appliances utilize California commercial load shapes developed and released by PG&E. Average peak load factors were extracted from these load shapes using TVA's peak times and applied to the annual energy (kWh) savings of the measure. Below are the peak demand savings, listed by building type and TVA district.

Table 214. Griddles Peak Demand Savings (kW)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.339	0.347	0.321	0.397
High School/College	0.485	0.483	0.479	0.526
Primary School	0.151	1.225	0.087	1.319
University	0.485	0.483	0.479	0.526
Grocery	0.336	0.338	0.325	0.349
Hospital	0.359	0.437	0.352	0.441
Hotel	0.529	0.417	0.479	0.463

[143] PG&E Work Paper PGECOFST103 Commercial Griddle Revision #4, May 2012

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Motel	0.529	0.417	0.479	0.463
Bio/Tech Manufacturing	n/a	n/a	n/a	n/a
Light Industrial Manufacturing	n/a	n/a	n/a	n/a
Large Office	0.445	0.237	0.408	0.323
Small Office	0.445	0.237	0.408	0.323
Fast-food Restaurant	0.384	0.335	0.375	0.358
Full Service Restaurant	0.384	0.335	0.375	0.358
Mall Department Store	0.486	0.236	0.476	0.363
Large Retail	0.486	0.236	0.476	0.363
Small Retail	0.486	0.236	0.476	0.363
Refrigerated Warehouse	0.000	0.000	0.000	0.000
Unrefrigerated Warehouse	0.000	0.000	0.000	0.000

Measure Life:

12 years (PG&E Work Paper PGECOFST103 Commercial Griddle Revision #4, May 2012)

Attachments:

TVA - Cooking Appliances.xlsx

5.2.3.5 ENERGY STAR Fryer and Large Vat Fryers

Sources:

ENERGY STAR website and calculator, www.energystar.gov (ESTAR)

PG&E Work Paper PGECOFST102 Commercial Fryer Revision #4, June 2012

PG&E Work Paper PGECOFST114 Commercial Steam Cooker, Revision #1, June 2009

Measure Description:

Fried foods continue to be popular at restaurants, and as a result, fryers have become available in a range of configurations. All fryers share a common basic design: the kettle, or "frypot," contains enough hot oil to suspend cooking food so that it does not sink to the bottom of the kettle. Electric fryers use heating elements immersed in the oil. The most common size of large vat fryers has an 18-inch wide frypot, although frypots are available as large as 34 inches wide.

Fryer performance is determined by applying the ASTM *Standard Test Method for the Performance of Open Deep Fat Fryers* (F1361-05),[144] considered the industry standard test method for quantifying the efficiency and performance of fryers. Large vat fryer performance is determined by applying the ASTM *Standard Test Method for the Performance of Large Vat Fryers* (F2144-05), considered the industry standard test method for quantifying the efficiency and performance of large vat fryers.

The following table shows the ENERGY STAR standard for electric fryers. The standard is current, as of April 2011.

Table 215. Energy Efficiency Requirements for Commercial Fryers

Fryer	Cooking Energy Efficiency	Idle Energy Rate (W)
Standard, < 18 in	≥ 80%	≤ 1,000
Large Vat, ≥ 18 in	≥ 80%	≤ 1,100

Assumptions:

Measure data for savings calculations are based on average equipment characteristics established by PG&E Food Service and Technology Center (www.fishnick.com). Annual energy use was calculated using on preheat, idle, and potato cooking energy-efficiency and production-capacity test results from standard ASTM F1361-05 for standard fryers and ASTM 2144-05 for large vat fryers.

The following formula calculates daily energy consumption, per the PG&E work papers.

$$EDay = LBFood * \frac{EFood}{Efficiency} + IdleRate * (OpHrs - \frac{LBFood}{PC} - \frac{TpreHT}{60}) + EpreHT$$

$$Average\ Demand = \frac{EDay}{OpHrs}$$

The following table shows the values assumed for the baseline and efficient fryer daily energy consumption calculations. Savings assume fryers operate 365 days per year for 12 hours per day with one preheat daily.

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[144] American Society for Testing and Materials. *Standard Test Method for the Performance of Open Deep Fat Fryers.* ASTM Designation F1361-05, in *Annual Book of ASTM Standards,* West Conshohocken, PA.

Table 216. Commercial Electric Fryer Variable Assumptions[145]

Variable	Variable Description (Units)	Value Assumed (Baseline)	Value Assumed (Energy Efficient)
EDay	Daily Energy Consumption (kWh/day) or (BTU/day)	49.8	41.4
LBFood	Pounds of Food Cooked per Day (lb/day)	150	150
Efood	ASTM Energy to Food (kWh/lb) = kWh/pound of energy absorbed by food product during cooking or (BTU/lb)	0.167	0.167
Efficiency	Heavy-Load Cooking Energy Efficiency %	75%	80%
IdleRate	Idle Energy Rate (kW)	1.20	1.0
OpHrs	Operating Hours/Day (hr/day)	14	14
PC	Production Capacity (lbs/hr)	71	71
TPreHt	Preheat Time (min/day)	15	15
EPreHt	Preheat Energy (kWh/day) or (BTU/day)	2.4	1.9

Table 217. Large Vat Fryer Variable Assumptions[146]

Variable	Variable Description (Units)	Value Assumed (Baseline)	Value Assumed (Energy Efficient)
EDay	Daily Energy Consumption (kWh/day)	49.7	34.9
LBFood	Pounds of Food Cooked per Day (lb/day)	150	100
Efood	ASTM Energy to Food (kWh/lb) = kWh/pound of energy absorbed by food product during cooking or (BTU/lb)	0.167	0.167
Efficiency	Heavy Load Cooking Energy Efficiency %	75%	80%
IdleRate	Idle Energy Rate (kW)	1.35	1.1
OpHrs	Operating Hours/Day (hr/day)	12	12
PC	Production Capacity (lbs/hr)	100	110
TPreHt	Preheat Time (min/day)	15	15
EPreHt	Preheat Energy (kWh/day) or (BTU/day)	2,500	2,100

Savings:

The savings calculated for a 15-inch commercial deep-fat fryer are 1,794 kWh per year and an average demand savings of 0.351 kW. The savings calculated for a commercial large vat fryer are 5,416 kWh per year and a peak demand savings of 1.237 kW. Peak demand savings for cooking appliances utilize California commercial load shapes developed and released by PG&E. Average peak load factors were extracted from these load shapes using TVA's peak times and applied to the annual energy (kWh) savings of the measure. Below are the peak demand savings, listed by building type and TVA district.

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[145] PG&E Work Paper PGECOFST102 Commercial Fryer Revision #4, June 2012.

[146] PG&E Food Service Equipment work papers, June 2006.

Table 218. Fryer Peak Demand Savings (kW)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.228	0.234	0.216	0.268
High School/College	0.327	0.326	0.323	0.355
Primary School	0.102	0.825	0.059	0.889
University	0.327	0.326	0.323	0.355
Grocery	0.226	0.228	0.219	0.235
Hospital	0.242	0.294	0.237	0.297
Hotel	0.357	0.281	0.323	0.312
Motel	0.357	0.281	0.323	0.312
Large Office	0.300	0.160	0.275	0.218
Small Office	0.300	0.160	0.275	0.218
Fast-food Restaurant	0.259	0.226	0.253	0.241
Full Service Restaurant	0.259	0.226	0.253	0.241
Mall Department Store	0.327	0.159	0.321	0.245
Large Retail	0.327	0.159	0.321	0.245
Small Retail	0.327	0.159	0.321	0.245
Refrigerated Warehouse	0.000	0.000	0.000	0.000
Unrefrigerated Warehouse	0.000	0.000	0.000	0.000

Table 219. Large Vat Fryer Peak Demand Savings (kW)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.688	0.706	0.653	0.808
High School/College	0.987	0.983	0.975	1.070
Primary School	0.307	2.491	0.178	2.683
University	0.987	0.983	0.975	1.070
Grocery	0.683	0.687	0.660	0.710
Hospital	0.730	0.889	0.715	0.897
Hotel	1.077	0.847	0.974	0.942
Motel	1.077	0.847	0.974	0.942
Bio/Tech Manufacturing	n/a	n/a	n/a	n/a
Light Industrial Manufacturing	n/a	n/a	n/a	n/a
Large Office	0.905	0.482	0.829	0.657
Small Office	0.905	0.482	0.829	0.657
Fast-food Restaurant	0.782	0.682	0.763	0.729
Full Service Restaurant	0.782	0.682	0.763	0.729
Mall Department Store	0.989	0.481	0.968	0.739

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Large Retail	0.989	0.481	0.968	0.739
Small Retail	0.989	0.481	0.968	0.739
Refrigerated Warehouse	0.000	0.000	0.000	0.000
Unrefrigerated Warehouse	0.000	0.000	0.000	0.000

Measure Life:

12 years (PG&E Work Paper PGECOFST102 Commercial Fryer Revision #4, June 2012)

Attachments:

TVA - Cooking Appliances.xlsx

5.2.3.6 ENERGY STAR Hot Food Holding Cabinets

Sources:

ENERGY STAR website and calculator, www.energystar.gov (ESTAR)

PG&E Work Paper PGECOFST105 Insulated Holding Cabinet - Electric, Revision #3, June 2012

Measure Description:

Hot-food holding cabinets can safely maintain all types of heated foods and are available in a multitude of sizes and configurations. Models that qualify for the ENERGY STAR label incorporate better insulation, which reduces heat loss, and they may offer additional energy-saving devices, such as magnetic door gaskets, auto-door closures, or Dutch doors. An insulated cabinet also provides better temperature uniformity within the cabinet from top to bottom and reduces heat gain to the kitchen in comparison to a non-insulated cabinet.

Hot-food holding cabinets that meet current ENERGY STAR specifications (as of October 2011) must meet a maximum idle energy rate, as shown in the following table.

Table 220. ENERGY STAR Hot Food Holding Cabinet Criteria

Internal Volume (ft^3)	Idle Energy Rate (Watts)
$0 < V < 13$	$\leq 21.5\ V$
$13 \leq V < 28$	$\leq 2.0\ V + 254.0$
$28 \leq V$	$\leq 3.8\ V + 203.5$

Assumptions:

All operating energy-rates savings assumptions are used in accordance with ASTM Standard F2140. Energy-usage calculations are based on 15 hours per day, 365 days per year operation (5,475 hours) at a typical temperature setting of 150°F (based on ENERGY STAR assumptions).

To estimate energy savings, hot-food holding cabinets are categorized into three size categories, as shown in the following table.

Table 221. Cabinet Size Assumptions[147]

Size	Internal Volume (ft^3)	Average Volume for Calculations
Full-size	$13 \leq V < 28$	20 ft^3
Three-quarter size	$0 < V < 13$	12 ft^3
Half-size	$0 < V < 13$	8 ft^3

The following formula calculates daily energy consumption per the ENERGY STAR hot-food holding cabinet calculator.

$$EDay = \frac{InternalVolume * (IdleRate) * (OpHrs)}{1000}$$

$$Average\ Demand = \frac{EDay}{OpHrs}$$

The following two tables show the values assumed for the base and ENERGY STAR hot-food holding cabinet daily energy consumption calculations.

[147] ENERGY STAR commercial hot food holding cabinet calculator, based on PG&E FSTC research.

Table 222. Base Model Hot-Food Holding Cabinet Variable Assumptions[148]

Variable	Variable Description (Units)	Full-size	Three-quarter size	Half-size
EDay	Daily Energy Consumption (kWh/day)	9.6	5.8	3.8
InternalVolume	Holding cabinet Size (ft^3)	20	12	8
IdleRate	Idle Energy Rate (W/ft^3)	40	40	40
OpHrs	Operating Hours/Day (hr/day)	12	12	12

Table 223. ENERGY STAR Model Hot-Food Holding Cabinet Variable Assumptions[149]

Variable	Variable Description (Units)	Full-size	Three-quarter size	Half-size
EDay	Daily Energy Consumption (kWh/day)	3.5	3.1	2.1
InternalVolume	Holding cabinet Size (ft^3)	20	12	8
IdleRate	Idle Energy Rate (W/ft^3)	15	22	22
OpHrs	Operating Hours/Day (hr/day)	12	12	12

Savings:

The savings, based on ENERGY STAR savings methodology, are summarized in the following table.

Table 224. Hot-Food Holding Cabinet Savings by Size

	Full-size	Three-quarter size	Half-Size
Energy Savings (kWh/Year)	2216	972	648
Demand Savings (kW)	0.506	0.222	0.148

Peak demand savings for cooking appliances utilize California commercial load shapes developed and released by the Pacific Gas and Electric Company (PG&E). Average peak load factors were extracted from these load shapes using TVA's peak times and applied to the annual energy (kWh) savings of the measure. Below are the peak demand savings, listed by building type and TVA district.

148 ENERGY STAR commercial hot food holding cabinet calculator, based on PG&E FSTC research.

149 ENERGY STAR commercial hot food holding cabinet calculator, based on PG&E FSTC research.

Table 225. Full-Size Holding Cabinet Peak Demand Savings (kW)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.282	0.289	0.267	0.331
High School/College	0.404	0.402	0.399	0.438
Primary School	0.126	1.019	0.073	1.098
University	0.404	0.402	0.399	0.438
Grocery	0.279	0.281	0.270	0.291
Hospital	0.299	0.364	0.293	0.367
Hotel	0.441	0.347	0.398	0.385
Motel	0.441	0.347	0.398	0.385
Bio/Tech Manufacturing	n/a	n/a	n/a	n/a
Light Industrial Manufacturing	n/a	n/a	n/a	n/a
Large Office	0.370	0.197	0.339	0.269
Small Office	0.370	0.197	0.339	0.269
Fast-food Restaurant	0.320	0.279	0.312	0.298
Full Service Restaurant	0.320	0.279	0.312	0.298
Mall Department Store	0.405	0.197	0.396	0.302
Large Retail	0.405	0.197	0.396	0.302
Small Retail	0.405	0.197	0.396	0.302
Refrigerated Warehouse	0.000	0.000	0.000	0.000
Unrefrigerated Warehouse	0.000	0.000	0.000	0.000

Table 226. Three-Quarter Size Holding Cabinet Peak Demand Savings (kW)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.124	0.127	0.117	0.145
High School/College	0.177	0.177	0.175	0.192
Primary School	0.055	0.447	0.032	0.482
University	0.177	0.177	0.175	0.192
Grocery	0.123	0.123	0.119	0.128
Hospital	0.131	0.160	0.128	0.161
Hotel	0.193	0.152	0.175	0.169
Motel	0.193	0.152	0.175	0.169
Bio/Tech Manufacturing	n/a	n/a	n/a	n/a
Light Industrial Manufacturing	n/a	n/a	n/a	n/a
Large Office	0.162	0.087	0.149	0.118
Small Office	0.162	0.087	0.149	0.118
Fast-food Restaurant	0.140	0.122	0.137	0.131
Full Service Restaurant	0.140	0.122	0.137	0.131
Mall Department Store	0.177	0.086	0.174	0.133
Large Retail	0.177	0.086	0.174	0.133
Small Retail	0.177	0.086	0.174	0.133

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Refrigerated Warehouse	0.000	0.000	0.000	0.000
Unrefrigerated Warehouse	0.000	0.000	0.000	0.000

Table 227. Half-Size Holding Cabinet Peak Demand Savings (kW)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.082	0.084	0.078	0.097
HS/College	0.118	0.118	0.117	0.128
Primary School	0.037	0.298	0.021	0.321
University	0.118	0.118	0.117	0.128
Grocery	0.082	0.082	0.079	0.085
Hospital	0.087	0.106	0.086	0.107
Hotel	0.129	0.101	0.117	0.113
Motel	0.129	0.101	0.117	0.113
Bio/Tech Manufacturing	n/a	n/a	n/a	n/a
Light Industrial Manufacturing	n/a	n/a	n/a	n/a
Large Office	0.108	0.058	0.099	0.079
Small Office	0.108	0.058	0.099	0.079
Fast-food Restaurant	0.094	0.082	0.091	0.087
Full Service Restaurant	0.094	0.082	0.091	0.087
Mall Department Store	0.118	0.058	0.116	0.088
Large Retail	0.118	0.058	0.116	0.088
Small Retail	0.118	0.058	0.116	0.088
Refrigerated Warehouse	0.000	0.000	0.000	0.000
Unrefrigerated Warehouse	0.000	0.000	0.000	0.000

Measure Life:

12 years (PG&E Work Paper PGECOFST105 Insulated Holding Cabinet - Electric, Revision #3, June 2012)

Attachments:

TVA - Cooking Appliances.xlsx

5.2.3.7 ENERGY STAR Steam Cookers

Sources:

ENERGY STAR website and calculator, www.energystar.gov (ESTAR)

PG&E Work Paper PGECOFST104 Commercial Steam Cooker, Revision #3, May 2012

Measure Description:

Steam cookers, also known as compartment steamers, provide a fast cooking option for preparing large quantities of food, while preserving nutrients, color, and texture. Steamers are available in a variety of configurations, including countertop models, wall-mounted models, and floor models mounted on a stand, pedestal, or cabinet-style base. A steamer may consist of one to six stacked cavities, though two compartment steamers are the most prevalent in the industry. The cavity is usually designed to accommodate a standard 12" x 20" x 2 ½" pan.

Steamer performance is determined by applying the ASTM *Standard Test Method for the Performance of Steam Cookers* (F1484), which is the industry standard for quantifying the efficiency and performance of steamers.

The following table shows ENERGY STAR standards for electric steam cookers. The standard is current (version 1.1), as of August 2003 (consistent with the cee1.org criteria set in 2010).

Table 228. ENERGY STAR Steam Cooker Standards

Pan Capacity	Cooking Energy Efficiency[150]	Idle Rate (W)
3-pan	50%	400
4-pan	50%	530
5-pan	50%	670
6-pan and larger	50%	800

Assumptions:

Measure data for savings calculations are based on average equipment characteristics. Annual energy use was calculated based on preheat, idle, and potato cooking energy-efficiency and production-capacity test results from standard ASTM F1484.

The following formula calculates daily energy consumption, per the PG&E work papers.

[150] Cooking Energy Efficiency is based on heavy-load (potato) cooking capacity.

$$EDay = LBFood * \frac{EFood}{Efficiency} + IdleRate * (OpHrs - \frac{LBFood}{PC} - \frac{TpreHT}{60}) + EpreHT$$

$$Average\ Demand = \frac{EDay}{OpHrs}$$

The following table shows the values assumed for base and efficient steam cooker daily energy consumption calculations.

Table 229. Steam Cooker Variable Assumptions[151]

Variable	Variable Description (Units)	Value Assumed (Baseline)	Value Assumed (Energy Efficient)
EDay	Daily Energy Consumption (kWh/day)	23.7	16.2
LBFood	Pounds of Food Cooked per Day (lb/day)	100	100
Efood	ASTM Energy to Food (kWh/lb) = kWh/pound of energy absorbed by food product during cooking	0.0308	0.0308
Efficiency	Heavy-Load Cooking Energy Efficiency %	26%	50%
IdleRate	Idle Energy Rate (kW)	1.0	0.8
OpHrs	Operating Hours/Day (hr/day)	12	12
PC	Production Capacity (lbs/hr)	70	88
TPreHt	Preheat Time (min/day)	15	15
EPreHt	Preheat Energy (kWh/day)	1.5	1.5

Savings assume a 6-pan steam cooker operating 12 hours per day; 365 days per year with one preheat daily (PG&E work paper).

Savings:

Savings for an ENERGY STAR-rated steam cooker over a standard cooker are 2,744 kWh per year with average demand savings of 0.626 kW. Peak demand savings for cooking appliances utilize California commercial load shapes developed and released by the PG&E. Average peak load factors were extracted from these load shapes using TVA's peak times and applied to the annual energy (kWh) savings of the measure. Below are the peak demand savings, listed by building type and TVA district.

[151] ENERGY STAR commercial steam-cooker calculator.

Table 230. ENERGY STAR Steam Cooker Peak Demand Savings (kW)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	0.349	0.357	0.331	0.410
HS/College	0.500	0.498	0.494	0.542
Primary School	0.155	1.262	0.090	1.359
University	0.500	0.498	0.494	0.542
Grocery	0.346	0.348	0.335	0.360
Hospital	0.370	0.450	0.362	0.454
Hotel	0.545	0.429	0.493	0.477
Motel	0.545	0.429	0.493	0.477
Bio/Tech Manufacturing	n/a	n/a	n/a	n/a
Light Industrial Manufacturing	n/a	n/a	n/a	n/a
Large Office	0.458	0.244	0.420	0.333
Small Office	0.458	0.244	0.420	0.333
Fast-food Restaurant	0.396	0.346	0.387	0.369
Full Service Restaurant	0.396	0.346	0.387	0.369
Mall Department Store	0.501	0.244	0.490	0.374
Large Retail	0.501	0.244	0.490	0.374
Small Retail	0.501	0.244	0.490	0.374
Refrigerated Warehouse	0.000	0.000	0.000	0.000
Unrefrigerated Warehouse	0.000	0.000	0.000	0.000

Measure Life:

12 years (PG&E Work Paper PGECOFST104 Commercial Steam Cooker, Revision #3, May 2012)

Attachments:

TVA - Cooking Appliances.xlsx

5.2.3.8 Combination Oven

Sources:

ENERGY STAR website and calculator, www.energystar.gov (ESTAR)

PG&E. "Commercial Kitchen Appliance Technology Assessment." PG&E Food Service Technology Center.

PG&E Work Paper PGECOFST100 Commercial Combination Oven, Revision #4, May 2012

Measure Description:

A combination oven is a convection oven that includes the added capability to inject steam into the oven cavity and typically offers at least three distinct cooking modes. In the combination mode, it provides a way to roast or bake with moist heat (hot air and steam); in the convection mode, it operates purely as a convection oven providing dry heat; or it can serve as a straight pressureless steamer.[152]

Oven performance is determined by the ASTM Standard Test Method for the Performance of Combination Ovens defined in standard F1639-05,[153] considered to be the industry standard for quantifying combination oven efficiency and performance.[154]

Savings calculations for combination ovens assume they meet or exceed heavy-load cooking energy efficiencies of ≥50% for steam-mode cooking and convection mode cooking energy efficiency of ≥70% utilizing the ASTM standard F2861.

Assumptions:

Measure data for savings calculations are based on average equipment characteristics established by ENERGY STAR. Annual energy use was calculated based on preheat, idle, and cooking energy-efficiency and production-capacity test results from standard ASTM F2861.

The following formula calculates daily energy consumption for combination ovens, per the PG&E work papers.

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[152] PG&E. "Commercial Kitchen Appliance Technology Assessment." PG&E Food Service Technology Center. Section 7 Ovens.

[153] American Society for Testing and Materials. "Standard Test Method for the Performance of Convection Ovens." ASTM Designation F1639-05. in *Annual Book of ASTM Standards*, West Conshohocken, PA.

[154] PG&E Food Service.

$$EDay = LBFood * \frac{EFood}{Efficiency} + IdleRate * (OpHrs - \frac{LBFood}{PC} - \frac{TpreHT}{60}) + EpreHT$$

$$Average \ Demand = \frac{EDay}{OpHrs}$$

The following table shows the values assumed for base and efficient large vat fryer daily energy consumption calculations.

Table 231. Combination Oven Variable Assumptions[155]

Variable	Variable Description (Units)	Value Assumed (Baseline)	Value Assumed (Energy Efficient)
EDay	Daily Energy Consumption (kWh/day)	91	60
LBFood	Pounds of Food Cooked per Day (lb/day)	200	200
Efood	ASTM Energy to Food (kWh/lb) = kWh/pound of energy absorbed by food product during cooking	0.0732	0.0732
Efficiency	Steam Cooking Energy Efficiency	40%	50%
Efficiency	Convection Cooking Energy Efficiency	65%	70%
Efficiency	Percentage Time in Steam Mode	50%	50%
IdleRate	Steam Idle Energy Rate (kW)	10.0	5.0
IdleRate	Convection Idle Energy Rate (kW)	3.0	2.0
OpHrs	Operating Hours/Day (hr/day)	12	12
PC	Steam Production Capacity (lbs/hr)	100	120
PC	Convection Production Capacity (lbs/hr)	80	100
TPreHt	Preheat Time (min/day)	15	15
EPreHt	Preheat Energy (kWh/day)	3.0	1.5

Annual energy savings are based on a standard 15-pan oven operating for 12 hours per day, 365 days per year with one preheat daily.

Savings:

The savings calculated for an energy-efficient combination oven are 11,310 kWh per year and average demand savings of 2.582 kW. Peak demand savings for cooking appliances utilize California commercial load shapes developed and released by PG&E. Average peak load factors were extracted from these load shapes using TVA's peak times and applied to the annual energy (kWh) savings of the measure. Below are the peak demand savings, listed by building type and TVA district.

[155] PG&E Food Service Equipment work papers, May 2012.

Table 232. Combination Oven Peak Demand Savings (kW)

Building Type	Central Time Districts		Eastern Time Districts	
	Summer	Winter	Summer	Winter
Assembly	1.438	1.473	1.365	1.688
High School/College	2.061	2.053	2.035	2.235
Primary School	0.641	5.202	0.371	5.603
University	2.061	2.053	2.035	2.235
Grocery	1.426	1.435	1.379	1.484
Hospital	1.525	1.855	1.494	1.873
Hotel	2.248	1.769	2.033	1.966
Motel	2.248	1.769	2.033	1.966
Bio/Tech Manufacturing	n/a	n/a	n/a	n/a
Light Industrial Manufacturing	n/a	n/a	n/a	n/a
Large Office	1.890	1.007	1.731	1.371
Small Office	1.890	1.007	1.731	1.371
Fast-food Restaurant	1.632	1.424	1.594	1.522
Full Service Restaurant	1.632	1.424	1.594	1.522
Mall Department Store	2.064	1.004	2.022	1.542
Large Retail	2.064	1.004	2.022	1.542
Small Retail	2.064	1.004	2.022	1.542
Refrigerated Warehouse	0.000	0.000	0.000	0.000
Unrefrigerated Warehouse	0.000	0.000	0.000	0.000

Measure Life:

12 years (PG&E Work Paper PGECOFST100 Commercial Combination Oven, Revision #4, May 2012)

Attachments:

TVA - Cooking Appliances.xlsx

5.2.3.9 High-Efficiency Icemakers

Sources:

U.S. Department of Energy, Energy Efficiency & Renewable Energy, Building Technologies Office, http://www1.eere.energy.gov/buildings/appliance_standards/index.html

Consortium for Energy Efficiency, www.cee1.org

ENERGY STAR Program, www.energystar.gov/

California Database for Energy Efficiency Resources, http://www.deeresources.com (DEER 2008)

Measure Description:

This measure covers ice machines that generate 60 grams (2 oz.) or lighter ice cubes, crushed, or fragmented ice. Only air-cooled machines qualify (self-contained, ice-making heads, or remote condensing). The machine must have a minimum capacity of 101 lb of ice per 24-hour period. The manufacturer's specification sheet must show the rating in accordance to ARI standard 810.

Assumptions:

The baseline icemaker efficiencies are assumed to be equivalent to the federal minimum standard.[156] The minimum efficiency required is per CEE Tier 1[157] or ENERGY STAR[158] of the same type of ice maker (ice-making-head, remote condensing, self-contained), and the above minimum efficiency Tier 2[159] is presented for comparison in savings. The icemakers are also assumed to be connected to power 8,760 hours a year, with a duty cycle of 57.[160]

The following table lists the baseline icemaker energy consumption (kWh/100 lb of ice) for each equipment type and ice harvest rate (IHR) class, which is determined by an equation. The table also shows the IHR used to calculate energy use for the baseline and qualifying equipment. These IHR values represent the average IHR of ENERGY STAR[161] qualified products, as of May 2013, within each equipment type and IHR class.

Table 233. Baseline Icemaker Energy Use (kWh/100 lb. Ice)

Equipment Type	IHR Class (lb per 24 hours)	IHR	Baseline (kWh/100 lb ice)
Ice-Making Head	$100 < IHR < 450$	321	7.5
	$IHR \geq 450$	783	6.0
Remote Condensing	$100 < IHR < 1000$	758	6.0

[156] Accessed May 20th, 2013.
[157] Accessed May 17, 2013.
[158] Accessed May 22, 2013. The average of batch and continuous ice machines.
[159] www.cee1.org, Accessed May 17, 2013.
[160] 2013 Illinois Statewide Technical Reference Manual for Energy Efficiency.
[161] ENERGY STAR, Accessed May 22, 2103.

Equipment Type	IHR Class (lb per 24 hours)	IHR	Baseline (kWh/100 lb ice)
	IHR ≥ 1000	1646	5.1
Remote Condensing (with Remote Compressor)	100 < IHR< 934	727	6.1
	IHR ≥ 934	1589	5.3
Self- Contained Units	100 < IHR < 175	127	12.0
	IHR ≥ 175	261	9.8

The following table lists the CEE Tier 1, ENERGY STAR, and Tier 2 retrofit icemaker energy consumption values.

Table 234. Retrofit Icemaker Energy Use (kWh/100 lb. Ice)

Equipment Type	IHR Class (lb per 24 hours)	CEE Tier 1 (kWh/100 lb ice)	ENERGY STAR (kWh/100 lb ice)	CEE Tier 2 (kWh/100 lb ice)
Ice-Making Head	100 < IHR < 450	6.8	6.7	6.5
	IHR ≥ 450	5.4	5.7	4.6
Remote Condensing	100 < IHR < 1000	5.4	5.3	4.7
	IHR ≥ 1000	4.6	4.9	4.2
Remote Condensing (with remote compressor)	100 < IHR< 934	5.5	5.4	4.7
	IHR ≥ 934	4.8	4.9	4.2
Self- Contained Units	100 < IHR < 175	11.2	10.6	9.6
	IHR ≥ 175	9.1	8.3	7.0

Savings:

The savings methodology for this measure is based on the method presented in the 2013 Illinois Statewide TRM.[162] The savings are based on the difference in the ice harvest rate (IHR) which is expressed as kWh per 100 lb. Icemaker sizes are expressed by the rate of their production in pounds per 24-hour period. The following are the equations used to calculate the annual kWh savings and peak kW savings.

$$kWh\ \text{Savings} = \frac{\left[\frac{\text{kWh}}{100\ \text{lb}}_{\text{Baseline}} - \frac{\text{kWh}}{100\ \text{lb.}}_{\text{Efficient}}\right]}{100\ \text{lb.}} \times \text{IHR}\left(\frac{\text{lbs}}{\text{day}}\right) \times \text{Duty Cycle} \times \frac{365\ \text{days}}{\text{year}}$$

[162] 2013 Illinois Statewide Technical Reference Manual for Energy Efficiency.

$$Peak\ kW\ Savings = \frac{kWh\ Savings}{(Operating\ Hours\ \times Duty\ Cycle)} \times Peak\ CF^{163}$$

The following table lists the annual energy savings in kWh and peak demand savings in kW.

Table 235. Icemaker Measure Savings (per Icemaker Unit)

Equipment Type	IHR Class	CEE Tier 1		ENERGY STAR		CEE Tier 2	
		Annual kWh Savings	Peak kW Savings	Annual kWh Savings	Peak kW Savings	Annual kWh Savings	Peak kW Savings
Ice-Making Head	100 < IHR < 450	495	0.093	547	0.103	698	0.131
	IHR ≥ 450	996	0.187	488	0.092	2,251	0.422
Remote Condensing	100 < IHR < 1000	903	0.169	979	0.184	2,022	0.380
	IHR ≥ 1000	1,575	0.296	811	0.152	3,182	0.597
Remote Condensing (with remote compressor)	100 < IHR< 934	880	0.165	1,073	0.201	2,043	0.383
	IHR ≥ 934	1,587	0.298	1,416	0.266	3,695	0.693
Self-Contained Units	100 < IHR < 175	233	0.044	388	0.073	648	0.122
	IHR ≥ 175	375	0.070	810	0.152	1,498	0.281

Measure Life:

10 years (DEER 2008)

Attachment:

TVA - High Efficiency Icemakers.xls

5.2.3.10 Hotel Guest Room Energy Management (GREM) System

Sources:

Michigan Energy Measures Database 2010. http://www.michigan.gov/mpsc/0,4639,7-159-52495_55129---,00.html

Cornell University, Northeast Regional Climate Center. http://www.nrcc.cornell.edu/ccd/nrmhdd.html

[163] The peak coincidence factor for this equipment is assumed to be 0.937, as cited in the 2013 Illinois Statewide TRM.

Cornell University, Northeast Regional Climate Center. http://www.nrcc.cornell.edu/ccd/nrmcdd.html

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Measure Description:

This measure applies to hotel guest room energy management systems that control HVAC units for individual hotel rooms based upon occupancy sensors or key cards that indicate room occupancy. Sensors controlled by a front desk system are not eligible.

Either the guest room temperature set point or the on/off cycle of the HVAC unit must be controlled by an automatic occupancy sensor or key-card system that indicates the occupancy status of the room. During unoccupied periods the default setting for controlled units must differ from the operating set point by at least five degrees (or shut the unit fan and heating or cooling off completely). The control system may also be tied into other electric loads, such as lighting and plug loads, to shut them off when occupancy is not sensed. The incentive is per guestroom controlled, rather than per sensor, for multi-room suites. Replacement or upgrades of existing occupancy-based controls are not eligible for an incentive.

The savings are based on GREM's ability to automatically adjust the guest room's set temperatures or reduce the cycle time of the HVAC unit for various occupancy modes.

Assumptions:

This measure assumes the base case is a manual heating/cooling temperature set point and fan on/off/auto thermostat controlling the guest room HVAC system. The measure savings are adapted from the GREM measure found in the Michigan Database. The values shown in the following table are from the Michigan savings database.

Table 236. GREM Savings from Michigan Database[164]

Cooling Type	Cooling kWh		Heating (kWh & therms)		Total kWh		Average Across Unit Sizes		
	3/4 ton	1 ton	3/4 ton	1 ton	3/4 ton	1 ton	Cooling	Heating	Total
Package Terminal Air Conditioner (PTAC)	208	287	1,234 kWh	1,645 kWh	1,441	1,932	248	1440	1687
Package Terminal Heat Pump (PTHP)	181	263	721 kWh	988 kWh	902	1,251	222	855	1077
Fan coil Unit with Gas Heat/Electric Cool	407	542	53 therms	70 therms	407	542	475	61.5 therms	475

Savings:

To adapt the Michigan values to the TVA climate zones, the Michigan savings, averaged across unit sizes, were multiplied by the ratio of TVA climate zone to Michigan climate zone cooling degree-days (CDD) or heating degree-days (HDD). The savings for the five TVA climates were then averaged to produce a single savings value for each cooling type. The process was completed for each cooling type. This calculation method is illustrated with the following sequence of equations:

$$\text{kWh Savings}_{\text{TVA CZ}} = \text{kWh Savings}_{\text{Michigan CZ}} \times \frac{\text{CDD or HDD}_{\text{TVA CZ}}}{\text{CDD or HDD}_{\text{Michigan CZ}}}$$

$$\text{kWh Savings}_{\text{TVA}} = \text{Average of kWh Savings}_{\text{TVA CZ}}$$

The following table shows the CDD and HDD values used for Michigan and the five TVA climate zones.

[164] Michigan Energy Measures Database. http://www.michigan.gov/mpsc/0,4639,7-159-52495_55129---,00.html

Table 237. CDD and HDD Values for Michigan and TVA

Climate Zone	CDD[165]	HDD[166]
Detroit	727	6,449
Chattanooga	1,608	3,427
Huntsville	1,671	3,262
Knoxville	1,450	3,685
Memphis	2190	3033
Nashville	1656	3658

The annual kWh savings, per HVAC unit controlled, are summarized in the following table.[167]

Table 238. Annual kWh Energy Savings (per HVAC Unit Controlled)

Cooling Type	Cooling	Heating	Total
PTAC	584	762	1,346
PTHP	524	452	976
FCU with Gas Heat/Elec Cool	1,119	-	1,119

The coincident kW impacts for this measure have not been sufficiently studied or modeled to provide a confident estimate. In the meantime, the following kW impacts are estimated for systems that control cooling operation.

kW Savings per ton = (12/HVAC energy-efficiency ratio or EER) x average on peak uncontrolled load factor of 50% (estimated from anecdotal observations by KEMA) x estimated cycling reduction of 30% (estimated by KEMA from empirical observations and logging from manufacturers for NV Energy).

$$kW = (12/8.344) \times 0.5 \times 0.3 = 0.215 \text{ kW per one-ton unit}$$

[165] This CDD data is from the National Oceanic and Atmospheric Administration, National Climatic Data Center, but it is no longer available in tabular form directly from NOAA. As of January 14, 2015, this data is available via the Cornell University, Northeast Regional Climate Center website. http://www.nrcc.cornell.edu/ccd/nrmcdd.html .

[166] This HDD data is from the National Oceanic and Atmospheric Administration, National Climatic Data Center, but it is no longer available in tabular form directly from NOAA. As of January 14, 2015, this data is available via the Cornell University, Northeast Regional Climate Center website. http://www.nrcc.cornell.edu/ccd/nrmhdd.html.

[167] It is important to note that this savings is not validated via empirical data, however, it is being used in many different places.

Where,

HVAC EER = is based on a 1 ton unit at code baseline efficiency of PTAC, defined as EER = 10.9 - (0.213 x 12000 btu/hr/1000) = 8.344

It is estimated as 0.74 as the coincident factor to be consistent with the other HVAC measures.

Coincident kW Savings = 0.215 x 0.74 = 0.159 kW per one-ton unit.

Measure Life:

15 years (DEER 2008)

Attachment:

TVA - GREM.xlsx

5.2.3.11 Variable Speed Drive (VSD) Air Compressor

Sources:

http://www.sullaircompressors.com/ Accessed Jan.13, 2015. http://sullairinfo.com/Library/
http://www.quincycompressor.com/. Accessed Jan.13, 2015.
http://www.quincycompressor.com/resources/cagi-data-sheets/

http://us.kaeser.com/ . Accessed January 13, 2015.
http://us.kaeser.com/Advisor/CAGI_data_sheets/default.asp

Measure Description:

This measure applies to VSDs on new air compressors whose rated horsepower (hp) is less than or equal to 200 hp.[168] The new VSD air compressor must replace an existing constant speed compressor having an equal or higher hp rating and annual operating hours of at least 1,200 hours per year. Back-up and redundant air compressors are not eligible for this incentive. Air compressors on multiple-compressor systems are not eligible.

[168] This threshold is provided to limit application of deeming impact to smaller air compressors.

System and demand conditions that require the air compressor to be constantly operated at a load greater than eighty percent (80%) or lower than thirty percent (30%) do not qualify for the default savings provided here. These operating conditions will not realize savings from a VSD-controlled compressor.

This measure focuses on the control mechanism applied to control the capacity of air produced by the compressor. Since rotary screw machines are the dominant type, the analysis here is based on this type. They have four major control mechanisms: inlet modulation (IM), variable displacement (VD), load/no-load (LNL), and VSD controls. These controls are presented in increasing order based on their ability to maintain high system efficiency at partial loads, with IM being the least efficient and VSD controls being the most efficient at part load operation.

It is expected that projects include the following information to be able to calculate more accurate savings estimates or adjust the default value, appropriately.

1. Rated power (hp) of the air compressors
2. Rated volume flow rate (scfm) of the air compressors
3. Existing (if any) storage capacity per rated volume flow rate (gallons per scfm) of the air compressors
4. Annual operating hours

Assumptions:

Savings will be estimated by establishing average compressor power draw for both base case and measure case capacities. Applying this difference in compressor power load between base and measure case to the estimated full load compressor energy usage over the year will result in energy savings due to the variable speed drive.

Savings:

Annual energy (kWh) and maximum non-coincident demand (kW) saved are calculated using the following formulas. The base case assumes a single compressor with LNL controls, while the measure case assumes the same sized air compressor with VSD control. The savings is calculated based on the horsepower (hp) rating of the new air compressor.

$$\text{kWh}_{\text{Saved}} = \left\{\left(\frac{\text{HP}_x \times \text{SF}}{\eta_x} \times \text{PPD}_x\right) - \left(\frac{\text{HP}_p \times \text{SF}}{\eta_p} \times \text{PPD}_p\right)\right\} \times C_1 \times \text{NEI} \times \text{hours}$$

$$\text{kW}_{\text{Saved}} = \left\{\left(\frac{\text{HP}_x \times \text{SF}}{\eta_x} \times \text{PPD}_x\right) - \left(\frac{\text{HP}_p \times \text{SF}}{\eta_p} \times \text{PPD}_p\right)\right\} \times C_1 \times \text{NEI} \times \text{CF}_{\text{comp air}}$$

The following table shows the values assumed for the energy and demand savings calculations.

Table 239. Variables for VSD Air Compressor Savings

Component	Definition	Value	Source
HP_x	Rated horsepower	HP_p	Project specific input
SF	Service factor	118%	Review of three manufacturer specification sheet data[(a)]
H	Motor efficiency	Existing, 90% Proposed, 95%	Assumption
PPD	Percentage of air compressor's full load power draw	Existing, 72.05% Proposed, 50.00%	Review of 12 air compressor projects, average[(b)]
C_1	Conversion constant	0.746 kW/hp	
NEI	Increase in nameplate efficiency	1.15	Review of three manufacturer specification sheet data[(c)]
Hours	Project operating hours	Hours range through 8,760 hours. Default: 6,240 hours[169]	Application, KEMA[(d)]
$CF_{comp\ air}$	compressed air coincidence factor	0.865	New Jersey's Clean Energy Program[170]

Please refer to the following notes:

a) The service factor was fixed at one hundred and eighteen percent (118%) after averaging the values provided on the specification sheets of three major manufactures of VSD compressors in the U.S. (Sullair, Kaeser, and Quincy compressors). Forty different compressors were surveyed with ratings from 50-hp to 300-hp. Tables below are available for reference.

b) Twelve compressed air projects were surveyed, where older, traditional controlled air compressors were replaced with similar sized VSD air compressors. The total power consumption was metered over a seven-day period both before construction and after construction. The average power draw (kW) for each project was analyzed. Using these data, the percent volume flow rate (CFM) loading of all of the VSD compressors was found using the manufacturers' specification sheet. It showed that on average, these compressors were loaded to 47% of their full load CFM. The after-construction files (with VSD installed) were analyzed because the profile with these compressors give the most accurate prediction of the facility's actual air demand, with the assumption that the facility's air demand did not change from before

[169] 16 hours per day, 5 days per week, minus 9 holidays and 3 scheduled downtime days.

[170] KEMA, New Jersey's Clean Energy Program Energy Impact Evaluation and Protocol Review, July 10 2009.

to after construction conditions. For a VSD compressor loaded at 47% it draws 50.00% of its full load rated kW, hence PPD = 50.00%. An IM and LNL, at this loading will draw 84.10% and 60.00% respectively, and by averaging these two values, the PPD is calculated as 72.05%. The PPD for IM and LNL compressors were averaged because of the ability to run a LNL compressor in IM mode and vice versa. The PPD was determined from standardized CAGI estimated performance comparison curves.

c) From the before mentioned 40 air compressors surveyed, the average nameplate efficiency was 4.69 CFM/hp. The old compressor efficiency was assumed to be 4.00 CFM/hp as a result of age and other factors. This represents a 15% increase in efficiency, hence the 1.15 factor included in the equation as the NEI (nameplate efficiency increase referenced in the variables table above). Refer to the following three tables.

Based on the compressed air system being continuously operated (8,760-hrs/yr), or never being shut off, the usage factor (UF) is shown as eighty-one percent (81%). On average, the compressed air systems in these industrial projects operate approximately 7,100-hours per year. We believe that this compressed air measure will be installed in similar industrial facilities operating in similar circumstances. For this analysis, we have determined that a typical industrial facility using compressed air operates three shifts per week or approximately 6,240-hrs/yr.

These following three tables summarize the nameplate efficiency and Service Factor calculated directly from data on three compressor manufacturer's CAGI data sheet.

Table 240. Manufacturer CAGI Data Sheet, Sullair[171]

Model #	hp	Fan hp	kW at Full Load	hp at Full Load	Full Load CFM	Nameplate Efficiency (CFM/hp)	Service Factor
1107eV	15.0	1.0	14.6	19.6	62.9	4.19	18.2%
1507eV	20.0	1.0	19.3	25.9	90.6	4.53	18.8%
1807eV	25.0	1.0	24.0	32.1	107.8	4.31	19.2%
1807V	25.0	1.0	23.8	31.9	116.0	4.64	18.5%
2207V	30.0	1.0	28.3	38.0	138.0	4.60	18.3%
3007V	40.0	1.5	38.2	51.2	182.0	4.55	19.0%
4509V	60.0	2.0	54.9	73.6	260.0	4.33	15.8%
4507PV	60.0	3.0	56.9	76.3	305.0	5.08	17.4%
5507V	75.0	3.0	70.5	94.5	377.0	5.03	17.5%

[171] http://sullairinfo.com/Library/

Model #	hp	Fan hp	kW at Full Load	hp at Full Load	Full Load CFM	Nameplate Efficiency (CFM/hp)	Service Factor
7507V	100.0	3.0	93.7	125.6	493.0	4.93	18.0%
7507PV	100.0	3.0	92.8	124.4	500.0	5.00	17.2%
V200S-125LAC	125.0	3.0	114.4	153.4	633.0	5.06	16.5%
V200S-150LAC	150.0	3.0	139.0	186.3	757.0	5.05	17.9%
V200S-200LAC	200.0	7.5	181.6	243.4	967.0	4.84	14.8%
V320TS-250LAC	250.0	5.0	225.6	302.4	1,300.0	5.20	15.7%
V320TS-300HAC	300.0	10.0	320.0	429.0	1,400.0	4.67	27.7%
V320TS-300LAC	300.0	10.0	269.4	361.1	1,550.0	5.17	16.9%
Hp limit for this Manufacturer							
Average Name-plate Efficiency				Average Service Factor			
4.78				18.1%			

Table 241. Manufacturer CAGI Data Sheet, Quincy[172]

Model #	hp	Fan hp	kW at Full Load	hp at Full Load	Full Load CFM	Nameplate Efficiency (CFM/hp)	Service Factor
QGV-20	20	1	18.3	24.5	83.50	4.18	14.4%
QGV-25	25	1	21.4	28.7	116.4	4.66	9.4%
QGV-30	30	1	26.8	35.9	135.7	4.52	13.7%
QGV-40	40	1	36.8	49.3	185.3	4.63	16.9%
QGV-50	50	1.5	41.8	56.0	226.1	4.52	8.1%
QGV-60	60	3	58.5	78.4	291.3	4.86	19.7%
QGV-75	75	3	72.4	97.1	371.5	4.95	19.6%
QGV-100	100	3	89.1	119.4	470.9	4.71	13.8%
QGV-125	125	7.5	119.2	159.8	583.1	4.66	17.1%
QGV-150	150	5	142.2	190.6	738.1	4.92	18.7%
QGV-200	200	10	179	240.0	960.2	4.80	12.5%
Hp limit for this Manufacturer							
Average Name-plate Efficiency				Average Service Factor			
4.67				14.9%			

[172] http://www.quincycompressor.com/resources/cagi-data-sheets

Table 242. Manufacturer CAGI Data Sheet, Kaeser[173]

Model #	hp	Fan hp	kW at Full Load	hp at Full Load	Full load CFM	Nameplate Efficiency (CFM/hp)	Service Factor
SFC18	25	0.75	26.7	35.8	124.0	4.96	28.1%
SFC22	30	0.75	31.1	41.7	137.4	4.58	28.0%
SFC30S	40	0.75	38.4	51.5	190.7	4.77	22.3%
SFC37	50	1.2	45.9	61.5	220.0	4.40	18.7%
SFC45	60	1.5	58.8	78.8	291.3	4.86	23.9%
SFC55	75	1.5	76.2	102.1	367.3	4.90	26.6%
SFC90	100	3	98	131.4	475.7	4.76	23.9%
SFC110	125	3	123.4	165.4	613.1	4.90	24.4%
SFC 132S	175	3	146	195.7	706.3	4.04	10.6%
SFC 132S	200	3	164.2	220.1	867.0	4.34	9.1%
SFC 200	270	3.5	231.7	310.6	1,236.0	4.58	13.1%
Hp limit for this Manufacturer							
Average Name-plate Efficiency				Average Service Factor			
4.64				20.8%			
Overall average System Efficiency				**4.70**			
Overall average Service Factor				**18%**			

The anticipated annual energy savings (kWh/year per hp) for this analysis can be realized by the following equation:

$$\text{kWh Savings} = \left\{\left(\frac{\text{HP} \times 1.18}{0.90} \times 0.72\right) - \left(\frac{\text{HP} \times 1.18}{0.95} \times 0.500\right)\right\} \times \frac{0.746\text{kW}}{\text{hp}} \times 1.15 \times 6{,}240 \text{ hrs/yr}$$

$$\text{kWh Savings} = 1{,}729 \frac{\text{kWh}}{\text{year} \cdot \text{HP}}$$

The anticipated maximum non-coincident demand savings (kW/hp) for this analysis can be realized by the following equation:

[173] http://us.kaeser.com/Advisor/CAGI_data_sheets/default.asp

$$\text{kW Savings} = \left\{\left(\frac{\text{HP} \times 1.18}{0.90} \times 0.72\right) - \left(\frac{\text{HP} \times 1.18}{0.95} \times 0.500\right)\right\} \times \frac{0.746\text{kW}}{\text{hp}} \times 1.15 \times 86.5\%$$

$$\text{kW Savings} = 0.240\ \frac{\text{kW}}{\text{HP}}$$

Measure Life:

The anticipated life of this measure has been estimated at 15 years, the same as energy efficient motors and variable speed drives.

5.2.3.12 Battery Chargers

Sources:

"Emerging Technologies Program Application Assessment Report #0808 - Industrial Battery Charger Energy Savings Opportunities", PG&E 2009

Measure Description:

This measure covers large battery chargers that are used with such products as forklifts, airport transport equipment, neighborhood electric vehicles and golf carts. Large battery chargers can be found in residential, commercial, and industrial applications using both single-phase and three-phase power. Industrial battery-powered motive equipment has been utilized in warehouses, ports, airport baggage systems, and manufacturing facilities for decades.

Assumptions:

Ferro resonant battery chargers were weighted 63% and SCR battery chargers were given a weight factor of 38%. Tests were performed for 8-, 16-, and 24-hour shifts.

Table 243. Savings for HF Chargers, Weighted Average Baselines - Replacement

Shift	kWh Savings	Coin-kW Savings
8-hour Shift	1,460	0.2888
16-hour Shift	2,688	0.2888
24-hour Shift	3,638	0.9630

For the new construction savings table, the following weighting factors were applied: ferroresonant 53%, SCR 32%, hybrid 5%, and high frequency 11%.

Table 244. Savings for HF Chargers, Weighted Average Baselines - New Construction

Shift	kWh Savings	Coin-kW Savings
8- hour Shift	1,238	0.2436
16-hour Shift	2,287	0.2439
24-hour Shift	3,094	0.8130

For the final savings table, a mix of retrofit and new construction was examined, assuming 0.75 retrofit and 0.25 new construction. The applied weighting factors are the same as those applied for the new construction savings table.

Table 245. kW Savings for HF Chargers, Weighted Average Baselines - Replacement & New Construction Mix

Shift	kWh Savings	Coin-kW Savings
8-hour Shift	1,405	0.2775
16-hour Shift	2,588	0.2775
24-hour Shift	3,502	0.9251

Measure Life:

12 years (PG&E)

Attachment:

TVA - High Frequency Battery Chargers.xlsx

5.2.3.13 NEMA Premium Low Voltage Dry-Type Distribution Transformers

Sources:

U.S. Department of Energy, Energy Efficiency & Renewable Energy, Building Technologies Office. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/66

National Electrical Manufacturers Association, NEMA Premium Efficiency Transformers Program. http://www.nema.org/Policy/Energy/Efficiency/Documents/NEMA_Premium_Efficiency_Transformer_Product_Specifications.pdf

U.S. Department of Energy, Energy Efficiency & Renewable Energy, Building Technologies Office. http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/dt_nopr_tsd_complete.pdf

2010 Efficiency Vermont, Technical Reference User Manual

Measure Description:

This measure applies to single or three-phase low voltage dry-type distribution transformers meeting or exceeding the NEMA Premium efficiency requirements at 35% load. 'Low voltage dry-type distribution transformer' means a distribution transformer that (A) has an input voltage of 600 volts or less, (B) is air-cooled, and (C) does not use oil as a coolant.

Utility-owned transformers and non-distribution transformers are not eligible. Non-distribution transformers are defined as transformers with multiple voltage taps where the highest is at least 20% more than the lowest; and transformers designed to be used in special purpose applications, such as drive transformers, rectifier transformers, auto-transformers, impedance transformers, regulating transformers, sealed and non-ventilating transformers, machine tool transformers, welding transformers, grounding transformers, and testing transformers.

Assumptions:

This measure assumes the base case transformer meets the federal minimum required efficiency levels, which are listed below.

Table 246. Federal Minimum Efficiencies[174]

Single Phase		Three Phase	
kVA	Efficiency @ 35%	kVA	Efficiency @ 35%
15	97.70%	15	97.00%
25	98.00%	30	97.50%
37.5	98.20%	45	97.70%
50	98.30%	75	98.00%
75	98.50%	112.5	98.20%
100	98.60%	150	98.30%
167	98.70%	225	98.50%
250	98.80%	300	98.60%
333	98.90%	500	98.70%
-	-	750	98.80%
-	-	1,000	98.90%

174 http://energy.gov/eere/buildings/standards-and-test-procedures. Accessed January 13, 2015

Transformers must have a rated efficiency greater than or equal to the NEMA Premium efficiency at 35% load provided in Table below. Additional incremental savings are also provided here for transformers exceeding the NEMA Premium efficiency values.

Table 247. NEMA Premium Efficiencies[175]

Single Phase		Three Phase	
kVA	Efficiency @ 35%	kVA	Efficiency @ 35%
15	98.39%	15	97.90%
25	98.60%	30	98.25%
37.5	98.74%	45	98.39%
50	98.81%	75	98.60%
75	98.95%	112.5	98.74%
100	99.02%	150	98.81%
167	99.09%	225	98.95%
250	99.16%	300	99.02%
333	99.23%	500	99.09%
-	-	750	99.16%
-	-	1,000	99.23%

On February 10, 2012, the DOE made public their 'Notice of Proposed Rulemaking' (NOPR), which gave industry and vested stakeholders one last opportunity to make comments on the proposed new efficiency levels, which was taken into consideration, and was made official on April 18, 2013, and should take effect on January 1, 2016.[176] With the NOPR, the DOE provided extensive documentation on savings and cost values for various types and sizes of transformers so stakeholders could understand how the DOE determines the proposed values. The engineering analysis spreadsheets for low voltage dry-type transformers provide over 9,000 transformer design configurations. For each design point, which is based on coil sizing, material selection, and other variables, a unique transformer efficiency value is given. In these extensive tables compiled by the DOE, core losses, also known as constant or no-load losses, are presented for each design and efficiency value. Also presented are coil losses, which are dependent on the square of the load factor, and are presented by the DOE at both 35% and 100% load. According to sources in the 2010 Efficiency Vermont TRM, the average load on low voltage dry-type transformers is 15.9%, so an adjustment was made to the coil losses presented by the DOE at 100% load according to the

[175] http://www.nema.org/Policy/Energy/Efficiency/Documents/NEMA_Premium_Efficiency_Transformer_Product_Specifications.pdf. Accessed January 13, 2015.

[176] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/66. Accessed May 15, 2013.

following equation which relates the coil losses at a desired load to the coil losses at full load by the desired load squared:

$$\text{Coil Losses}_{15.9\%} = \text{Coil Losses}_{100\%} \times (15.9\%)^2$$

In order to keep the engineering analysis for the NOPR simple, the DOE looked at three reference sizes within each design line (DL) and provided a scaling algorithm derived from the physical laws affecting transformers (further information can be found in the DOE documents). The representative units for each design line are shown below.

Figure 1. Representative Units for Transformer Design Lines

Single Phase kVA	Design Line
15	DL 6
25	DL 6 (Rep Unit)
37.5	DL 6
50	DL 6
75	DL 6
100	DL 6
167	DL 6
250	DL 6
333	DL 6

Three Phase kVA	Design Line
15	DL 7
30	DL 7
45	DL 7 (Rep Unit)
75	DL 7
112.5	DL 7
150	DL 7
225	DL 8 (Rep Unit)
300	DL 8
500	DL 8
750	DL 8
1,000	DL 8

The scaling factors can be applied to the total losses (TL) according to the following equation:

$$TL_1 = TL_0 \times (kVA_1/kVA_0)^E$$

Where TL_0 are the total losses of the reference size transformer, and TL_1 are the total losses for a unit of a different size where all other design aspects besides size are kept constant. The variable kVA_0 is the size of the reference transformer, and kVA_1 is the size of the transformer being scaled. The exponent E is the scaling factor, and for single-phase transformers has a derived value of 0.75, while for three phase transformers, has a value of 0.67.[177]

[177] http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/dt_nopr_tsd_complete.pdf page 507 Accessed January 13, 2015.

Based on the many data points from the DOE technical analysis, linear regression equations were derived for the three representative units to show the relationship between transformer efficiency and total losses. With this relationship set for the reference sizes, total losses for the remaining units are calculated using the scaling rule. Total losses are calculated at 15.9% load to determine annual energy savings impact and at 85% load to determine the peak demand savings. The 85% load factor is based on documentation in the DOE NOPR.[178] The total losses for NEMA Premium and Federal Minimum transformers at these different loads are shown below.

Table 248. Total Losses in Watts for Single-Phase, Dry-Type Transformers at 15.9% and 85% Load, and at NEMA Premium, and Federal Minimum Transformers

kVA	Total Losses for Federal Minimum Transformers (@ 15.9% Load)	Total Losses for NEMA Premium Transformers (@ 15.9% Load)	Total Losses in for Federal Minimum Transformers (@ 85% Load)	Total Losses for NEMA Premium Transformers (@ 85% Load)
15	99.24	64.70	448.77	334.60
25	126.59	82.52	572.42	426.79
37.5	154.42	100.67	698.27	520.63
50	180.96	117.97	818.29	610.11
75	216.42	141.08	978.63	729.66
100	250.63	163.38	1,133.33	845.01
167	341.89	222.88	1,546.00	1,152.69
250	427.11	278.43	1,931.37	1,440.02
333	485.44	316.45	2,195.11	1,636.66

Table 249. Total Losses in Watts for Three-Phase, Dry-Type Transformers at 15.9% and 85% Load, and at NEMA Premium, and Federal Minimum Transformers

kVA	Total Losses for Federal Minimum Transformers (@ 15.9% Load)	Total Losses for NEMA Premium Transformers (@ 15.9% Load)	Total Losses for Federal Minimum Transformers (@ 85% Load)	Total Losses for NEMA Premium Transformers (@ 85% Load)
15	221.21	148.11	717.46	560.24
30	293.30	196.38	951.28	742.82
45	354.07	237.07	1,148.35	896.71

[178] http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/dt_nopr_tsd_complete.pdf page 202. Accessed January 13, 2015.

kVA	Total Losses for Federal Minimum Transformers (@ 15.9% Load)	Total Losses for NEMA Premium Transformers (@ 15.9% Load)	Total Losses for Federal Minimum Transformers (@ 85% Load)	Total Losses for NEMA Premium Transformers (@ 85% Load)
75	433.54	290.28	1,406.10	1,097.97
112.5	511.98	342.80	1,660.50	1,296.62
150	845.77	523.13	2,677.45	2,284.50
225	979.21	605.66	3,099.88	2,644.93
300	1,108.21	685.45	3,508.25	2,993.37
500	1,449.03	896.25	4,587.16	3,913.94
750	1,755.08	1,085.54	5,556.01	4,740.60
1000	1,950.82	1,206.61	6,175.66	5,269.31

Savings:

The kWh savings are based on the difference in the total losses in Watts for NEMA premium (NP) and federal minimum (FM) transformers at 15.9% load, operating 8,760 hours per year, and the peak demand savings are based on the difference in total losses in kilowatts at 85% load. The equations below illustrate the annual energy and peak demand savings calculations.

$$\text{kWh Savings} = (TL_{FM\text{-}15.9\%} - TL_{NP\text{-}15.9\%}) \times 8{,}760 / 1{,}000$$

$$\text{Peak Demand Savings} = (TL_{FM\text{-}85\%} - TL_{NP\text{-}85\%}) / 1{,}000$$

Incremental savings (both energy and demand) presented for efficiency improvements above NEMA Premium levels are simply linearly extrapolated from the incremental savings resulting from the Federal Minimum to NEMA premium efficiency gain.

$$\text{Incremental Savings per 0.01\% Efficiency Gain} = (\text{Savings from FM to NP}) \times (\text{NP Efficiency - FM efficiency}) / 10{,}000$$

The following tables show the energy and demand savings for each transformer size category.

Table 250. Base Energy Savings, Meeting NEMA Premium Efficiency Levels (kWh/Unit)

Single-Phase		Three-Phase	
kVA	kWh Savings	kVA	kWh Savings
15	302.64	15	640.35
25	386.02	30	849.03
37.5	470.89	45	1,024.93
50	551.83	75	1,254.98
75	659.95	112.5	1,482.04
100	764.28	150	2,826.39
167	1,042.58	225	3,272.32
250	1,302.46	300	3,703.41
333	1,480.31	500	4,842.34
-	-	750	5,865.09
-	-	1,000	6,519.21

Table 251. Base Demand Savings, Meeting NEMA Premium Efficiency Levels (kW/Unit)

Single-Phase		Three-Phase	
kVA	Peak kW Savings	kVA	Peak kW Savings
15	0.1142	15	0.1572
25	0.1456	30	0.2085
37.5	0.1974	45	0.2516
50	0.2449	75	0.3081
75	0.3320	112.5	0.3639
100	0.4119	150	0.3929
167	0.6051	225	0.4549
250	0.8189	300	0.5149
333	1.0154	500	0.6732
-	-	750	0.8154
-	-	1,000	0.9063

Table 252. Incremental Energy Savings, for Units Exceeding NEMA Premium Efficiency Levels by 0.01% (kWh/Unit)

Single-Phase		Three- Phase	
kVA	kWh Savings	kVA	kWh Savings
15	4.39	15	7.11
25	6.43	30	11.32
37.5	8.72	45	14.85
50	10.82	75	20.92
75	14.67	112.5	27.45
100	18.20	150	55.42
167	26.73	225	72.72
250	36.18	300	88.18
333	44.86	500	124.16
-	-	750	162.92
-	-	1,000	197.55

Table 253. Incremental Demand Savings, for Units Exceeding NEMA Premium Efficiency Levels by 0.01% (kW/Unit)

Single-Phase		Three-Phase	
kVA	Peak kW Savings	kVA	Peak kW Savings
15	0.00165	15	0.00175
25	0.00243	30	0.00278
37.5	0.00366	45	0.00365
50	0.00480	75	0.00514
75	0.00738	112.5	0.00674
100	0.00981	150	0.00770
167	0.01552	225	0.01011
250	0.02275	300	0.01226
333	0.03077	500	0.01726
-	-	750	0.02265
-	-	1,000	0.02747

Measure Life:

30 years (Efficiency Vermont TRM 2010)

Attachment:

TVA - Transformer.xlsx

5.2.4 Agricultural Measures

5.2.4.1 Engine Block Heater Timer

Sources:

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Measure Description:

This measure applies to the installation of an engine block heater timer controller onto an existing engine block heater that is turned on and off manually. Engine block heater timers save energy by reducing the amount of time that the heaters operate. Typical heater operation involves the heater being plugged in during the night and staying on until the engine is used in the morning. With a timer-controlled heater, the heater can turn on at a pre-set time during the night and only supply power to the engine block heater when it's needed. In addition to the timer function, the timers included under this measure require a thermostat function that restricts power from being delivered to the engine block heater if ambient temperature is above a certain threshold, typically 39°F.

Assumptions:

It is assumed that a typical engine block heater without a timer would be turned on during the night before the operator retires for the day and turned off when the operator resumes work in the morning. This amount of time can vary significantly depending on the operator; however, it is assumed that a typical time range would be 10-12 hours. The timer would turn the heater on only long enough to sufficiently heat the engine, which typically can range from 2-4 hours.

Table 254. Assumptions for Engine Block Timer Measure[179]

Component	Type	Value
Power	Variable	Default: 1 kW. Depending on engine size, heaters typically range from 0.4 kW to 2 kW
Hours	Variable	Default: 8 hours.
Days	Variable	Default: 90 days (Heater used during coldest months only)
Manual Use	Variable	Default: 0.20 (Assumes timer is not used/used incorrectly 20% of the time)

Savings:

The annual kWh savings are calculated using the following equation:

$$\text{Annual kWh Savings per timer} = \text{Power} \times \text{Hours x Days} \times (1 - \text{ManualUse})$$

Where,

$\text{Power} = \text{Load of engine block heater in kW}$

Hours
$= \text{Number of Hours per night that engine block heater timer offsets compared to manual operation}$
$* \text{Includes time that thermostat overrides timer.}$

$\text{Days} = \text{Number of days per year that engine block heater is used}$

$\text{ManualUse} = \text{Fraction of time that engine block heater is used manually}$

The annual kWh savings per engine block timer are 576 kWh per year per timer. There are no peak demand or non-coincident demand savings because it is assumed that the timer (and heater) operates only during off-peak hours and there is no reduction in heater load because of the timer.

Measure Life:

11 years (DEER 2008)[180]

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[179] KEMA assumptions (stated in "Focus on Energy Evaluation *Business Programs: Deemed Savings Manual V1.0"* March 2010). In reviewing Nashville TMY3 data, there are more 700 nighttime hours below 39°F, whereas 720 hours are assumed for the calculation.

[180] The measure life for engine block heater timers is assumed to be 11 years, with reference to DEER 2008 that reports the EUL of "Time Clocks (heating/cooling)." While the actual application for these time clocks may not

5.2.4.2 Low-Pressure Irrigation Nozzles

Sources:

2002 Canessa, Peter. Review of Low Pressure Sprinkler Nozzles - An Express Efficiency Measure, Fresno, CA.

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008, 2005)

Measure Description:

This measure applies to low-pressure sprinkler nozzles that replace (by retrofit) high-pressure sprinkler nozzles with an operating pressure of greater than 50 psi at the sprinkler head. Permanent or solid set (nozzle placement fixed in the area being irrigated) and portable, hand-move nozzles are eligible. The pumping plant for the farmland must rely on electric pumping and must have an overall pumping efficiency of 45% or above.

This low-pressure sprinkler nozzle is for irrigation field applications only. High-pressure nozzles generally break water droplets in to various sizes over its coverage; low-pressure nozzles have different orifice shapes to accomplish the same water coverage while operating under a lower pressure, thus requiring less pumping energy and less water.

Assumptions:

The low-pressure nozzle measure documented in the 2005 DEER has savings estimates for central valley and coastal/coastal valley California regions. It is assumed that these regions' energy savings differences are based primarily on net water applied per acre of irrigated land, which is assumed to be highly correlated to average annual temperatures and relative humidity. The measure savings applied for TVA will be a weighted mix of central valley and coastal/coastal valley California regional DEER savings - 75% central valley and 25% coastal/coastal valley.

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apply to engine block heater timers, other DEER time clock applications ranged between 8 and 11 years. The relatively low usage of the engine block heater timer gives reasonable conclusion to use the upper bound of 11 years.

Savings:

The coincident kW and the annual kWh savings per low-pressure nozzle are documented below. The savings are based on the measures and assumptions covered in the 2005 DEER, which heavily references the California Express Efficiency nozzle measure.[181,182]

Table 255. Measure Savings for Low-Pressure Sprinkler Nozzles (per Nozzle)

Measure	kWh	kW
Portable	31.3	0.029
Solid Set	9.3	0.004

Measure Life:

3 years for portable-set nozzles, 5 years for solid-set nozzles (DEER 2008).

5.2.4.3 VSD on Dairy Milking Pumps

Sources:

2010 Pacific Gas and Electric Work paper - WPenNRPR0006 Rev7 - Milk Vacuum Pump VSD

2010 Pacific Gas and Electric Work paper - WPenNRPR0004 Rev11 - Milk Transfer Pump VSD

2007 kW Engineering - EM&V for the 2004-2005 California Multi-Measure Farm Program

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Measure Description:

This measure applies to VSD for milking transfer pumps and VSD for milk vacuum pumps. VSD controls on milk transfer pumps allow the motor to match its speed with the amount (load) of milk in the receiver tank and allow a more uniform flow over the pre-cooler plate, which increases the plate's effectiveness and reduces the amount of energy needed to mechanically cool the milk. Note that a pre-cooler plate must be present for this measure savings to be applicable. VSD controls on milk vacuum

[181] DEER Measure IDs D03-970 and D03-971.

[182] Canessa, Peter. 2002. Review of Low Pressure Sprinkler Nozzles – An Express Efficiency Measure, Fresno, CA.

pumps modulate the speed of the pump when the milking units are taken on and off the cows' udders. Less vacuum is needed when the units are attached to udders; thus, appreciable savings are realized (due to lower motor speeds) during the actual milking process. Less vacuum also reduces possible udder irritation/inflammation due to high-pressure suction.

Assumptions:

Saving for this measure assumes no existing VSD control. Existing transfer pumps or vacuum pumps must operate at a constant speed. Eligible transfer pump VSD applications must be used in conjunction with a well water-to-milk pre-cooler. The two tables below show the value assumptions employed in the savings calculations. Ideally, savings would be calculated using the following inputs instead of the default values:

- Milking vacuum pump
- Nominal hp of pump
- Number of milking units controlled by pump/VSD
- Estimated hours per day milking pump operates
- Estimated days per year that milking pump runs
- Milk transfer pump
- Nominal hp of pump
- Estimated days per year that pump runs

Table 256. Assumptions for Milking Vacuum-Pump VSD Measure

Component	Type	Value	Source
Milk Units	Variable	Default: 10 units	KEMA
Milk Hours	Variable	Default: 15 hours (3x per day, 5 hours each milking, assumed conservative)	KEMA
Milk Days	Variable	Default: 365 days	KEMA
HP	Variable	Default: 5 hp	KEMA
CF	Constant	1.0	KEMA
0.25 HP	Constant	0.25 hp per milking unit that VSD consumes	PG&E Milk Vacuum Pump VSD work paper (WPenNRPR0006.7)
0.88 kW/hp	Constant	Conversion from hp to kW (0.746 kW/hp) and assumed 85% motor efficiency	PG&E Milk Vacuum Pump VSD work paper (WPenNRPR0006.7)

Table 257. Assumptions for Milking Transfer-Pump VSD Measure

Component	Type	Value	Source
0.39	Constant	0.39 kWh/day/100gal	kW Engineering. March 15, 2007. EM&V for the 2004-2005 California Multi-Measure Farm Program
Milk Days	Variable	Default: 365	PG&E Milk Transfer Pump VSD work paper (WPenNRPR0004.11)
CF	Constant	0.5	PG&E Milk Transfer Pump VSD work paper (WPenNRPR0004.11)
Annual Operating Hours	Variable	Default: 5,475 hours (15 hours per day, 365 days per year)	2006-2008 California Dairy Energy Efficiency Program, as discussed in the PG&E Milk Transfer Pump VSD work paper (WPenNRPR0004.11)

Savings:

The coincident kW and the annual kWh savings per pump hp controlled by VSD are documented below. The savings are heavily informed by the measures and assumptions covered in the California PG&E work papers.[183,184]

The following equations are used to estimate the milking vacuum pump VSD savings:

$$\text{Annual kWh Savings per HP} = \frac{[(\text{HP} - (0.25 \times \text{MilkUnits})) \times 0.88 \times \text{MilkHours} \times \text{MilkDays}]}{\text{HP}}$$

[183] PG&E Measure Codes WPenNRPR0006 Rev7 (Milk Vacuum Pump VSD. EnSave, Inc. (March 10, 2010) and WPenNRPR0004 Rev11 (Milk Transfer Pump VSD. EnSave, Inc. (March 5, 2010).

[184] The PG&E VSD Vacuum pump work paper value was derived using an equation for the California 2006-2008 Dairy Energy Efficiency Program and averaged results across all installations.

$$\text{Peak kW Savings per HP} = \frac{\text{Annual kWh Savings per HP}}{\text{MilkHours} \times \text{MilkDays}} \times \text{CF}$$

Where,

$\text{HP} = \text{Pump power in horsepower}$

$0.25 = \text{HP required per milking unit that VSD uses}$

$\text{MilkUnits} = \text{Numbers of milking units with VSD}$

$0.88 = {}^{\text{kW}}/_{\text{HP}}$ conversion and efficiency (Assumed 85%) constant. $\frac{0.746\ {}^{\text{kW}}/_{\text{HP}}}{0.85} = 0.88$

$$\text{MilkHours} = \text{Hours per day milking pump runs}$$

$$\text{MilkDays} = \text{Days per year that milking pump runs}$$

$$\text{CF} = \text{On peak coincidence factor}$$

The following equation is used to estimate the milking transfer pump VSD savings:

$$\frac{\text{Annual kWh Savings}}{\text{100 gallons per day of milk production per dairy site}} = 0.39 \times \text{MilkDays} = \text{AnnualkWh}$$

$$\frac{\text{Peak kW Savings}}{\text{100 gallons per day of milk production per dairy site}} = \frac{\text{AnnualkWh}}{\text{AnnualOperatingHours}} \times \text{CF}$$

Where,

$0.39 = \text{Daily savings in kWh per 100 gallons milk production}$

$365 = \text{Number of days per year dairy farm produces milk}$

$\text{CF} = \text{On peak coincidence factor}$

$\text{AnnualOperatingHours} = \text{Number of hours milking transfer pump is in operation per year}$

Table 258. Measure Savings for Milking Pump VSDs (per Unit)

Measure	Unit Definition	kWh	Peak kW
Milking Vacuum-Pump VSD	Vacuum-pump motor Hp	2,409	0.440
Milking Transfer-Pump VSD	100 gallons of milk production per day	142	0.013

Measure Life:

15 years (2008 DEER) for variable speed drives.

6. Deemed Weather-Sensitive Measures

This section discusses weather-sensitive measures. When the performance of a measure is directly affected by the climate, it is considered to be weather-sensitive. In the case of this manual, the measures discussed here are HVAC related for space conditioning.

After the DOE-2 models for load shape analysis had been created and calibrated, the models were applied to generate hourly deemed savings for commercial and residential end-use measures. The analytical approach for each measure required TVA-specific definitions of the "baseline" and "retrofit" parameters. Each of the models, as applicable, will first be redefined with the baseline parameters for each measure and exercised to generate 8,760 hourly whole building and end-use kW (per square foot and per measure unit, such as per ton of cooling); however, for some measures, the prototype is the baseline. Then, the same model will be redefined again with the retrofit parameters for the same measure and exercised to generate 8,760 whole building kW. Finally, the 8,760 hourly savings for each measure and model is calculated by simple subtraction.

Both energy and demand savings are extracted from the 8,760 hourly kW savings for any or all periods of time (such as seasonal kWh savings) or demand windows (such as summer and winter coincident peak demand windows) of interest to TVA. These savings are provided by building type by climate zone.

The weather sensitive peak load shape factors are used. These are based on the top ten hottest and coldest hours during the respective peak period (see Section 3.0). In some cases, for certain building types and weather zones, these top ten hours catch the "extremes" in the models. DOE-2.2 models HVAC usage by modeling the building load variations to reach the set point. In order to reach the set point, the HVAC is made to overcompensate (overheat or overcool). Therefore, in some of the outputs, it is believed that the top ten hours catch these extreme values, which then show up in the savings.

All the assumptions for modeling a measure using eQUEST are discussed for each individual measure. If a measure uses IHEE evaluation results, then the information is provided in the IHEE report (for single-family measures only). The user should also have the necessary tools to revise the measure (and baseline) to revise the savings calculation accordingly.

6.1 Residential Weather-Sensitive Measures

This section provides the methodology for calculating savings for residential weather-sensitive measures. The following is the list of measures provided in this section.

Table 259. Residential Deemed Weather Sensitive Measures

Measure Name	Category
Air Conditioning	HVAC
Heat Pump	HVAC
ENERGY STAR Room AC	HVAC
Ductless Heat Pump	HVAC
Ground Source Heat Pump	HVAC
Duct Insulation	HVAC
Window Replacement	Envelope
Insulation (Attic, Floor, Wall)	Envelope
Weatherization	Envelope
Duct Leakage Reduction	HVAC
Refrigerant Charge Correction	HVAC
Whole House Fans	HVAC

The measure savings sources are from two different KEMA studies. One was from the 2010 TRM effort and the second from the IHEE FY10 Program Impact and Process Evaluation.

The summary of the savings is provided in the Res Measure Summary.xlsx.

6.1.1 Residential (Single-Family) Measures (IHEE Program Results)

Some single-family measures are from the "In-Home Energy Evaluation FY10 Program Impact and Process Evaluation Final Report."[185] The evaluation looked at the following set of measures. These measures were all modeled in DOE-2. The starred items are presented in the water heating section of the report.

- HVAC Replacement (AC and heat pump)
- Duct Sealing
- HVAC Tune-Up (refrigerant charge)
- Primary Windows

[185] Tennessee Valley Authority, KEMA, Inc., July 2012. (IHEE)

- Storm Windows
- Attic insulation/ventilation (must be non-powered)
- Floor or perimeter insulation and vapor barrier (ground cover)
- Air Sealing
- Duct Repair/replacement (existing HVAC)
- Electric water heater tank wrap*
- Water Pipe Insulation*

Assumptions:

The IHEE evaluation objectives were to:

- Derive new adjusted energy and demand savings value estimates for each measure offered in the IHEE program
- Develop and document the baseline and measure-level installation rate inputs that populated DOE-2.1E prototype models to develop measure-level savings
- The results assess:
  - Electric energy savings by primary heating participant group (heat pump, electric strip heat, and gas customers)
  - Electric energy savings by measures type (HVAC, water heating, lighting, insulation, infiltration, ductwork, windows, and rehabilitation)
  - Electric demand savings for summer and winter peak periods for Nashville (assumed to be the average for the valley.

Appendix K of the IHEE report provides the modeling assumptions of the prototypical home per heating fuel type (heat pump, gas heat, or electric strip heat).

6.1.1.1 Single-Family AC Unit (Central or Split System)

Sources:

Database for Energy Efficiency Resources (DEER) 2008

Consortium for Energy Efficiency (www.cee1.org)

"In-Home Energy Evaluation FY10 Program Impact and Process Evaluation Final Report," Tennessee Valley Authority, KEMA, Inc., July 2012.

Measure Description:

Under this measure, older air-conditioning units are replaced with new units that have rated efficiencies greater than required by building code or appliance standards. It applies to central or split-system AC units.

Installing a high efficiency unit is only one component of AC energy savings. Proper sizing and installation have a significant impact on system operation. Energy savings claims may be different due to this consideration.[186]

Assumptions:

Code and existing baseline efficiencies are listed in the following table. These values are based on federal standards.

Energy efficient air conditioning efficiencies are based on the Consortium for Energy Efficiency (CEE) high-efficiency air conditioning and heat pump specifications, they apply to single-phase equipment ≤ 65,000 Btu/hr.[187] CEE specifications are commonly used in equipment eligibility requirements for utility efficiency programs. For 2015 programs, ENERGY STAR qualifying central air conditioners must be at least 14.5 SEER/12 EER for split systems, and at least 14 SEER/11 EER for single package equipment.[188] The table below illustrates the efficiency values for the baseline and retrofit equipment.

[186] Programs may consider requiring quality installation and proper sizing through Manual J.
[187] www.cee1.org
[188] ENERGY STAR website. http://www.energystar.gov/index.cfm?c=airsrc_heat.pr_crit_as_heat_pumps

Table 260. Fiscal Year 2016 Baseline and Energy-Efficient Central AC Assumptions[189]

Central Air Conditioners		
	SEER	**EER**
Baseline Packaged/Split AC	14	12
Split		
CEE Tier 1/ENERGY STAR	15	12.5
CEE Tier 2	16	13
CEE Tier 3	18	13
Packaged		
CEE Tier 1/ENERGY STAR	15	12
CEE Tier 2	16	12

Seasonal energy-efficiency ratio (SEER) is a measure of equipment energy efficiency over the cooling season. It represents the total cooling of a central air conditioner or heat pump (in Btu) during the normal cooling season as compared to the total electric energy input (in watt-hours) consumed during the same period. SEER is based on tests performed in accordance with AHRI 210/240 (formerly ARI Standard 210/240).

Energy-efficiency ratio (EER) is a measure of the instantaneous energy efficiency of cooling equipment. EER is the steady-state rate of heat energy removal (e.g., cooling capacity) by the equipment in Btuh divided by the steady-state rate of energy input to the equipment in watts. This ratio is expressed in Btuh per watt (Btuh/watt). EER is based on tests performed in accordance with AHRI 210/240 (formerly ARI Standard 210/240).

Savings values are determined for ENERGY STAR, Tier 1, Tier 2 and Tier 3 of the CEE residential AC systems. The savings calculations were performed by utilizing DOE-2 models generated for the IHEE evaluation for the baseline and CEE Tier 1/ENERGY STAR retrofit case. The measure case efficiency assumption is 14.3 SEER. The other tier (for split system) uses a ratio calculation to determine the savings.

Savings:

These savings can be found in TVA TRM Savings from IHEE.xlsx and are listed per ton of cooling, by heating type for Nashville weather.

[189] By EER unless otherwise noted.

The ratio adjustment for Tier 2 and Tier 3 savings was calculated using the following.

$$\text{Higher Tier Savings} = \frac{\frac{1}{SEER_{existing}} - \frac{1}{SEER_{new}}}{\frac{1}{SEER_{existing}} - \frac{1}{SEER_{Tier\ 1}}}$$

Maximum demand reduction is also calculated using the following equation. For residential central air conditioning, we use EER to estimate demand reduction:

$$\text{Demand reduction; } kW/ton_{EER} = \frac{12}{EER_{existing}} - \frac{12}{EER_{new}}$$

Table 261. Residential AC Demand Reduction (per Ton)

Type	Efficiency Level	Demand Reduction
Split	CEE Tier 1/ENERGY STAR	0.13*
Split	CEE Tier 2	0.17*
Split	CEE Tier 3	0.17*
Package	CEE Tier 1/ENERGY STAR	0.00[190]*
Package	CEE Tier 2	0.00*

Measure Life:

15 years (2008 DEER)

6.1.1.2 Single-Family Heat Pump Unit

Sources:

Database for Energy Efficiency Resources (DEER 2008)

Consortium for Energy Efficiency (www.cee1.org)

"In-Home Energy Evaluation FY10 Program Impact and Process Evaluation Final Report," Tennessee Valley Authority, KEMA, Inc., July 2012. (IHEE)

[190] Baseline and retrofit EER are the same.

Measure Description:

Under this measure, older heat pump units are replaced with new units that have rated efficiencies greater than required by building code or appliance standards. It applies to central or split-system air-source heat pump units.

Installing a high efficiency unit is only part of the solution for energy savings. Proper sizing and installation may have a significant impact on unit operation. Energy savings claims may be different due to this consideration.[191]

Assumptions:

Code and existing baseline efficiencies are listed in the following table. These values are based on federal standards.

Energy efficient heat pump efficiencies are based on CEE high-efficiency air conditioning and heat pump specifications. CEE specifications are commonly used in equipment eligibility requirements for utility efficiency programs. For 2015 programs, ENERGY STAR qualifying heat pumps must be at least 14.5 SEER/12 EER/8.2 heating seasonal performance factor (HSPF) for split systems, and at least 14 SEER/11 EER/8.0 HSPF for single package equipment.[192] The table below illustrates the efficiency values for the baseline and retrofit equipment.

For Fiscal Year 2016 and beyond, the baseline SEER value will increase to the updated federal minimum level of 14. Around the time this occurs, it is expected that the ENERGY STAR qualification will be increased to the current CEE Tier 1 level. A higher class of equipment with efficiencies greater than CEE Tier 1/ ENERGY STAR will be added to maintain the two efficiency level offerings. These baseline and measure efficiency values are presented in the table below.

Table 262: Fiscal Year 2016 Baseline and Energy-Efficient Heat Pump Model Assumptions

Air Source Heat Pumps			
	SEER	**EER**	**HSPF**
Baseline	14	12	8.2
Split			

[191] Programs may consider requiring quality installation and proper sizing through Manual J.

[192] ENERGY STAR website. http://www.energystar.gov/index.cfm?c=airsrc_heat.pr_crit_as_heat_pumps

Air Source Heat Pumps			
CEE Tier 1/ ENERGY STAR	≥15	≥12.5	≥8.5
Advanced Level	17	13	≥8.5
Packaged			
CEE Tier 1/ENERGY STAR	≥15	≥12	≥8.2
Advanced Level	17	13	≥8.2

SEER is a measure of equipment energy efficiency over the cooling season. It represents the total cooling of a central air conditioner or heat pump (in Btu) during the normal cooling season as compared to the total electric energy input (in watt-hours) consumed during the same period. SEER is based on tests performed in accordance with AHRI 210/240 (formerly ARI Standard 210/240).

EER is a measure of the instantaneous energy efficiency of cooling equipment. EER is the steady-state rate of heat energy removal (e.g., cooling capacity) by the equipment in Btuh divided by the steady-state rate of energy input to the equipment in watts. This ratio is expressed in Btuh per watt (Btuh/watt). EER is based on tests performed in accordance with AHRI 210/240 (formerly ARI Standard 210/240).

Heating Seasonal Performance Factor (HSPF) is a measure of a heat pump's energy efficiency over one heating season. It represents the total heating output of a heat pump (including supplementary electric heat) during the normal heating season (in Btu) as compared to the total electricity consumed (in watt-hours) during the same period. HSPF is based on tests performed in accordance with AHRI 210/240 (formerly ARI Standard 210/240).

Savings values are determined for ENERGY STAR, Tier 1, and Tier 2 of the CEE residential heat pump systems. The savings calculations were performed by utilizing DOE-2 models generated for the IHEE evaluation for the baseline and CEE Tier 1/ENERGY STAR retrofit case. The measure case efficiency assumption is 14.3 SEER. The other tier (for split system) uses a ratio calculation to determine the savings.

Savings:

These savings can be found in TVA TRM Savings from IHEE.xlsx and are listed per ton of cooling, by heating type for Nashville weather.

The ratio adjustment for Tier 2 savings was calculated using the following.

$$\text{Higher Tier Savings} = \frac{\frac{1}{SEER_{existing}} - \frac{1}{SEER_{Tier\ 2}}}{\frac{1}{SEER_{existing}} - \frac{1}{SEER_{Tier\ 1}}}$$

$$\text{Demand reduction; kW/ton}_{EER} = \frac{12}{EER_{existing}} - \frac{12}{EER_{new}}$$

Table 263. Heat Pump (Cooling Season) Demand Reduction

Type	Efficiency Level	Demand Reduction (kW/ton)
Split	ENERGY STAR	0.040*
Split	CEE Tier 1	0.040*
Split	CEE Tier 2	0.076*

For residential heat pumps during heating seasons, we use HSPF to estimate demand reduction. However, the HSPF needs to be converted to coefficient of performance (COP), and, hence, kW/ton. The conversion is:[193]

$$COP = (HSPF + 2.4) / 3.2$$

$$\text{Demand reduction; kW/ton} = \left[\frac{12}{COP_{existing}} - \frac{12}{COP_{new}}\right] \times \left(\frac{1}{3.412}\right)$$

Table 264. Heat Pump (Heating Season) Demand Reduction

Type	Efficiency Level	Demand Reduction (kW/ton)
Split	ENERGY STAR	0.168*
Split	CEE Tier 1	0.177*
Split	CEE Tier 2	0.185*

Measure Life:

[193] The conversion is from the residential California Title 24 Alternate Calculation Manual (ACM), equation R4-33 (2005 and 2008).

15 years (2008 DEER)

6.1.1.3 Single-Family Duct Sealing

Sources:

Database for Energy Efficiency Resources (DEER) 2008

"In-Home Energy Evaluation FY10 Program Impact and Process Evaluation Final Report," Tennessee Valley Authority, KEMA, Inc., July 2012.

Measure Description:

This measure seeks to minimize air leakage in heating and air-conditioning supply and return air system ducts located in unconditioned spaces. When ducts are not sealed properly, conditioned air escapes to unconditioned spaces, forcing the HVAC system to work harder and longer.

Assumptions:

The baseline and retrofit values used in the modeling (as well as heating/cooling unit size) are summarized in the following table.

Table 265. Duct Sealing Modeling Baseline and Retrofit Assumptions

Heat Type	Baseline	Retrofit	Qty (tons)
Heat Pump	13%	10.80%	6.73
Gas Heat	15.30%	12.70%	8.59
Strip Heat	10.70%	8.90%	4.24

Savings:

The evaluation results are provided per household. Therefore, the results here are unitized per ton using the assumption presented above for the modeled tonnage.

Table 266. Duct Sealing Savings (per Ton)

Heat Type	kWh Savings	Summer Peak kW	Winter Peak kW
Heat Pump	37.30	0.01	0.03
Gas Heat	18.63	0.01	0.00
Strip Heat	22.64	0.01	0.02

Measure Life:

18 years (2008 DEER)

6.1.1.4 Single-Family Refrigerant Charge

Sources:

Database for Energy Efficiency Resources (DEER) 2008

"In-Home Energy Evaluation FY10 Program Impact and Process Evaluation Final Report," Tennessee Valley Authority, KEMA, Inc., July 2012.

Measure Description:

This measure consists of ensuring AC systems are charged correctly. A refrigerant charge and airflow (RCA) test are typically conducted. If the charge level is too low or high or if the supply airflow is outside the original equipment manufacturer (OEM) specified range (usually 350 to 450 cfm/ton), the technician performs the necessary corrections.

An air conditioner will not operate at optimum conditions with too much or too little refrigerant in the lines. Both the unit EER and cooling capacity suffer if the refrigerant charge is too low or too high. When the refrigerant charge is too low, evaporator capacity is reduced and the average evaporator temperature differential increases, which causes the compressor to work harder to satisfy the same cooling load. If there is too much refrigerant in the system, the excess may be in liquid rather than vapor state and result in a reduced EER value compared with the rated EER of the system.

Assumptions:

The baseline and retrofit values used in the modeling (as well as heating/cooling unit size) are summarized in the following table. It is assumed that efficiency improves by one percent for refrigerant charge and airflow correction.

Table 267. HVAC Tune-Up Modeling Baseline and Retrofit Assumptions

Heat Type	Baseline	Retrofit	Qty (Tons)
Heat Pump	12.17 SEER	12.29 SEER	6.73
Gas Heat	12.17 SEER	12.29 SEER	8.59
Strip Heat	12.17 SEER	12.29 SEER	4.24

Savings:

The evaluation results are provided per household. Therefore, the results here are unitized per ton using the assumption presented above for the modeled tonnage.

Table 268. Single-Family HVAC Tune-Up Savings (per Ton)

Heat Type	kWh Savings	Summer Peak kW	Winter Peak kW
Heat Pump	9.51	0.0015	0.0000
Gas Heat	2.44	0.0012	0.0000
Strip Heat	8.02	0.0047	0.0000

Measure Life:

10 years (2008 DEER)

6.1.1.5 Single-Family Window Replacement

Sources:

Database for Energy Efficiency Resources, www.deeresources.com , (DEER) 2005

"In-Home Energy Evaluation FY10 Program Impact and Process Evaluation Final Report," Tennessee Valley Authority, KEMA, Inc., July 2012. (IHEE)

Measure Description:

Window replacement and retrofit involves replacing existing windows with better performing windows of the same dimensions. The performance of a window is typically measured by its solar heat-gain coefficient (SHGC) and U-value. The SHGC is a measure of the rate of radiant heat transfer through the window. As a result, a lower SHGC is desired for hotter summer seasons, but not necessarily beneficial during the winter season. The U-value measures the conductance of heat (thermal conductivity) through a window. The window frame and assembly are important factors that contribute heavily to the overall window U-value; a frame that utilizes a material with low thermal conduction (vinyl, wood, fiberglass) will typically offer lower U-values than a metal frame. A 'low-e' coating can be applied to the window to help reduce the U-value of the assembly. A low-e coating is a microscopically thin, metal-oxide layer that reduces the amount of infrared radiation traveling from the warm pane to the cool pane of the glass assembly. This results in a lower U-value as the thermal conductivity is reduced through the window. Windows with lower U-values are desired for regions with cold winter and hot summer seasons due to there being less heat transfer through the assembly.

Newer, more energy efficient windows have lower SHGC and lower U-values, but can be expensive. Storm window retrofits are a much cheaper method because they do not require professional labor. Storm windows can be installed within the framing of the current window on the interior or exterior side. They create a tight air pocket between the storm window pane and the existing windowpane, adding to the insulation potential of the window assembly; however, the largest benefit of storm windows is that they reduce air movement through the window assembly.[194] This can greatly reduce the amount of heating and cooling necessary to keep the interior temperature comfortable.

Assumptions:

The following table shows the baseline window characteristics and the measure cases recommended.

Table 269. Window Baseline and Retrofit Characteristics

Model Assumptions	U-value	SHGC
Baseline Window Characteristics [Single-Pane, Clear]	1.09	0.81
Low-E Storm Window Retrofit	0.35	0.40
Double-Pane Retrofit	0.46	0.76

Savings:

The evaluation results are provided per household. Therefore, the results here are unitized per 100 square feet using the assumption presented below for the modeled window area square footage.

Table 270. Modeled Window Square Footage

Heat Type	Square Feet
Heat Pump	226.7
Gas Heat	300.4
Strip Heat	156.5

[194] U.S. DOE Energy Savers

Table 271. Single-Family Window Replacement Savings (per 100 Square Feet)

	Primary			Storm		
Heat Type	kWh Savings	Summer Peak kW	Winter Peak kW	kWh Savings	Summer Peak kW	Winter Peak kW
Heat Pump	1,042	0.2558	0.7058	694	0.0838	0.5955
Gas Heat	445	0.1997	0.0333	109	0.0732	0.0266
Strip Heat	1,250	0.2684	0.6581	1,030	0.0958	0.5495

Measure Life:

20 years (DEER 2008)

6.1.1.6 Single-Family Attic Insulation

Sources:

Database for Energy Efficiency Resources (DEER) 2008

"In-Home Energy Evaluation FY10 Program Impact and Process Evaluation Final Report," Tennessee Valley Authority, KEMA, Inc., July 2012. (IHEE)

Measure Description:

Residential insulation is a cost-effective way to drastically reduce heat loss through the building shell.

Attic/ceiling insulation is particularly important because during heating seasons, warmer air will rise into the attic and, without insulation, can quickly transfer its heat into the roofing material and escape the interior through natural attic ventilation. Attic/ceiling insulation significantly reduces the rate at which heat is lost through the attic/roof, thus reducing the amount of energy consumption required to keep the home at a comfortable temperature. Attic/ceiling insulation will also reduce a building's cooling load during the summer because heat transfer rates between cooler indoor air and warmer ambient and attic air will be inhibited by the insulation.

Assumptions:

Baseline and retrofit insulation levels are based off the IHEE evaluation findings. Those assumptions were implemented in to the DOE-2 building prototypes found from IHEE participants. The baseline and retrofit values used in the modeling are summarized in the following table.

Table 272. Baseline and Retrofit Insulation Levels

	Attic/Ceiling
Baseline	R-10.5
Retrofit	R-35.5

Savings:

These savings can be found in TVA TRM Savings from IHEE.xlsx and are listed per square foot, by heating type for Nashville weather. The total building savings are divided by a normalizing factor to express in a per unit basis of 1,000 square feet of attic insulation.

Table 273. Insulation Square Footage

Heating Type	Attic/Ceiling
Heat Pump	1,442
Gas Heat	1,368
Strip Heat	1,479

The following table is the savings for insulation per 1,000 square feet.

Table 274. Attic Insulation Savings (per 1,000 Square Feet)

Heating Type	kWh Savings	Summer peak kW	Winter peak kW
Heat Pump	1,162	0.25	0.93
Gas Heat	296	0.12	0.04
Strip Heat	1,525	0.26	0.82

Measure Life:

20 years (DEER 2008)

6.1.1.7 Single-Family Weatherization

Sources:

Database for Energy Efficiency Resources (DEER) 2008

"In-Home Energy Evaluation FY10 Program Impact and Process Evaluation Final Report," Tennessee Valley Authority, KEMA, Inc., July 2012. (IHEE)

Measure Description:

The residential weatherization measure includes a number of weatherization applications listed below, all of which are assumed to make up this measure:

- Attic access weather-stripping
- Caulking
- Door weather-stripping
- Installation of outlet gaskets

These weatherization applications are relatively cheap for their material and installation, and ultimately provide a decrease in a building's natural infiltration rate. Depending on the building's location in regards to climate and weather, the decreased infiltration rate of the building can reduce energy consumption for heating.

Assumptions:

The following table lists the assumptions for the baseline and retrofit infiltration rates for the weatherization measure based on the air sealing measure as a part of the IHEE evaluation.

Table 275. Weatherization Baseline and Retrofit Characteristics

Heating Type	Baseline	Retrofit
Heat Pump	0.578 ACH	0.463 ACH
Gas Heat	0.585 ACH	0.469 ACH
Strip Heat	0.460 ACH	0.369 ACH

Savings:

These savings can be found in TVA TRM Savings from IHEE.xlsx, by heating type for Nashville weather. The total building savings are divided by a normalizing factor to express in a per unit basis of 1,000 square feet of conditioned footprint area. The following table provides the savings.

Table 276. Weatherization Savings (per 1,000 Square Feet)

Heating Type	kWh Savings	Summer peak kW	Winter peak kW
Heat Pump	459	0.06	0.55

Heating Type	kWh Savings	Summer peak kW	Winter peak kW
Gas Heat	63	0.05	0.03
Strip Heat	611	0.06	0.43

Measure Life:

11 years (DEER 2008)

6.1.1.8 Single-Family Duct Repair/Replacement

Sources:

California Database for Energy Efficiency Resources (DEER) 2008

"In-Home Energy Evaluation FY10 Program Impact and Process Evaluation Final Report," Tennessee Valley Authority, KEMA, Inc., July 2012. (IHEE)

Measure Description:

Duct insulation provides an additional layer of reducing heating and cooling losses, particularly if ducts are located in unconditioned spaces. Ducts must be insulated with at least 1.2" of insulation.

Assumptions:

Baseline and retrofit insulation levels are based off the IHEE evaluation findings. Those assumptions were implemented in the DOE-2 building prototypes found from IHEE participants. The baseline (0.7" of insulation) and retrofit (1.43" of insulation) values are used in the modeling.

Savings:

These savings can be found in TVA TRM Savings from IHEE.xlsx, by heating type for Nashville weather. The total building savings are divided by a normalizing factor to express in a per unit basis of tons of cooling. The following table shows the savings for insulation per ton of cooling.

Table 277. Duct Insulation Savings (per Ton)

Heating Type	kWh Savings	Summer peak kW	Winter peak kW
Heat Pump	88	0.02	0.07
Gas Heat	38	0.02	0.00
Strip Heat	120	0.02	0.11

Measure Life:

10 years (DEER 2008) for non-residential duct insulation

6.1.2 Ground-Source Heat Pump (GSHP)

KEMA applied ad hoc DOE-2 models to determine preliminary savings estimates for the ground-source heat pumps for TVA's residential customers. These single-family home models, while based on a study in another area of the country, were exercised with Nashville TMY3 weather to better represent the TVA service area.

The average size of the existing home model was 2,665 square feet of conditioned space. The new home model was 3,998 square feet. The average new house shell was found to be more energy efficient than the average existing house.

Measure Description:

The type of geothermal heat pump (GSHP) modeled is a closed loop water-to-air system with vertical deep wells for ground coupling. The ENERGY STAR standard has three tiers for three different types of GSHPs. The models utilized herein represent the Tier 1 (effective December 2009) efficiencies of 14.1 EER for cooling and 3.3 coefficient of performance (COP) for heating.

Assumptions:

The specific model assumptions are summarized in the following table.

Table 278. GSHP Baseline and Retrofit Efficiency Assumptions

	Existing		New Construction	
	Size	Efficiency	Size	Efficiency
GSHP	4 ton	14.0 EER, 3.5 COP	5 ton	14.0 EER, 3.2 COP
Air-Source Heat Pump (ASHP) with Auxiliary Strip Heat	5 ton	13.0 EER, 3.2 COP	6 ton	11.9 EER, 2.8 COP
AC with Strip Heat	4 ton	13.0 EER, 1.0 COP	5 ton	11.9 EER, 1.0 COP

Savings:

The following table shows the results of the models for Nashville weather.

Table 279. GSHP Baseline and Retrofit Efficiency Assumptions (per Unit)

	Existing		New Construction	
	ASHP with Back-Up Strip Heat	AC with Strip Heat	ASHP with Back-Up Strip Heat	AC with Strip Heat
kWh/Year	4,648	9,477	2,931	7,244
Summer peak kW	0.85	0.85	1.67	1.72
Winter peak kW	8.2	8.0	8.7	8.7

The cooling season kWh is somewhat greater for all three baseline systems due to the fact that the increase in pumping power more than offsets the increases in cooling efficiency over the cooling season. On the other hand, summer electric demand savings are positive compared to the two baseline options as the savings from the increased cooling efficiencies during these peak cooling conditions more than offset the required extra pumping power.

Life:

15 years. It is assumed to be the same as an air source heat pump.

Attachment:

TVA GSHP Existing and New Homes.xlsx

6.1.3 Ductless Heat Pump (DHP)

KEMA created and applied ad hoc DOE-2 models to determine preliminary savings estimates for the DHP for TVA's residential customers. These single-family home models were based on the shell of a typical 2,665 square foot single-family house and used Nashville TMY3 weather to represent the TVA service area.

DHPs were simulated in the models using four split systems, each serving a different zone of the house. The four indoor (fan-coil) units were located, respectively, in the living room, kitchen, conditioned basement, and upstairs areas, where they discharge cold and hot air directly into those spaces without any ductwork. Each unit is controlled by its own thermostat.

Measure Description:

Ductless heat pumps (also known as mini-splits and variable refrigerant flow) are characterized by unique operating features that allow them to attain higher system efficiencies during both full and partial load conditions. Ductless systems with the same EER as standard split system air conditioners and heat pumps not only eliminate the system losses due to duct heat gains and air leakage, but also employ variable speed compressors and fans to minimize energy usage during part load conditions. The measure definition here is for ductless heat pumps with at least 11 EER.

In most applications even more energy is saved by providing individual controls (thermostats) in different spaces. This allows the systems to run only as needed to satisfy the cooling and heating loads in the individual spaces they serve, and it is easy to set back or disable the units in spaces that are not used regularly.

Assumptions:

The specific model assumptions are summarized in the following table:

Table 280. DHP Baseline and Retrofit Efficiency Assumptions

	Existing		New Construction	
HVAC System Type	Size	Efficiency	Size	Efficiency
DHP	4.5 ton	10.5 EER	4.5 ton	10.5 EER
ASHP with Auxiliary Strip Heat	4.5 ton	10.5 EER	4.5 ton	14.1 EER
AC with Strip Heat	4.5 ton	10.5 EER	4.5 ton	14.1 EER

The retrofit is the Ductless HP system, while the two options describe two potential baseline systems to be replaced. The primary difference between the existing and new construction homes is the baseline system efficiency, where the 10.5 EER systems are typical of existing efficiency and the 14.1 EER is the current CEE Tier 1 minimum efficiency.

Savings:

The following two tables show the results of the models for Nashville weather:

Table 281. Electric Savings (per Home)

	Existing		New Construction	
	ASHP with Back-Up Strip Heat	AC with Strip Heat	ASHP with Back-Up Strip Heat	AC with Strip Heat
kWh/Year	3,269	7,955	1,768	6,529
Summer Peak kW	1.08	1.08	0.14	0.14
Winter Peak kW	1.71	4.02	2.32	4.02

Life:

15 years. It is assumed to be the same as an air source heat pump.

Attachment:

TVA DHP Existing and New Homes.xlsx

6.1.4 Residential HVAC Measures (including Single-Family,[195] Manufactured Home, and Multifamily Savings)

This section presents measures that were not evaluated as part of the IHEE program, as well as weather-sensitive measures for the manufactured home and multifamily dwelling types. The 2010 TRM manual used residential models by dwelling type built using the Detailed Mode within eQUEST. Therefore, the retrofit efficiencies were modeled as Parametric Measures. Similar to the Energy Efficiency Measure Wizard in the wizard mode of eQUEST, parametric measures will run an identical baseline building but will vary the model according to the parameter adjustment specified. The measure savings values are the difference between baseline and retrofit energy use estimates and normalized to a per ton, per square foot, or other unit (depending on the measure).

When normalizing the savings, it is important to define the savings unit in a manner that is consistent with the program. For example, in most cases, equipment change-out under a prescriptive approach is paid an incentive to the end user on a per-rated ton or per-unit basis. Therefore, the manual normalizes equipment change-out measures to per rated ton. To determine this value, the building load (in kBtuh) contributing to the HVAC measure(s) under evaluation is extracted from the eQUEST model SIM file.

[195] Any measure not addressed by the IHEE study is provided here in this section for the single-family dwelling type.

The SIM file contains all simulation run reports and also generates an 8,760-hour output file. Building loads were extracted using the eQuest report called SS-D (Building HVAC Load Summary).

For cooling loads, the oversize factor is 1.15; for heating loads, the factor is 1.25.[196] These are standard modeling protocol values. Based on the calculation results from the various model outputs, the following table summarizes system size (in tons) for package air conditioning units.[197] These sizes are based on the modeled load requirements predicted in the eQUEST model for the prototypical building by dwelling type. The post-processing analysis of eQUEST output for the residential weather-sensitive measures is in Res WS Runs Data.xls.

From the DOE-2 eQUEST models, coincident diversity factors (CDF) and equivalent full load hours (EFLH) are calculated in Res WS Runs Data.xls. Details of this analysis are provided in Appendix Section 3. The appendix provides the algorithms for using these sets of parameters to calculate simplified estimates for cooling or heating energy savings.

Table 282. Unit Size Assumptions (tons)

Weather Zone	Building Type	Air Conditioner	Heat Pump
Chattanooga	Multifamily	40	40
	Manufactured Home	2	2
	Single-Family	3	3
Huntsville	Multifamily	40	48
	Manufactured Home	2	2.5
	Single-Family	3	3.5
Knoxville	Multifamily	40	48
	Manufactured Home	2	2
	Single-Family	3	3.5
Memphis	Multifamily	40	44
	Manufactured Home	2	2.5
	Single-Family	3	3.5
Nashville	Multifamily	40	52
	Manufactured Home	2	2
	Single-Family	3	3.5

[196] The oversize factors are from ASHRAE 90.1 2004 Standard Appendix G.

[197] Multifamily total tonnage is for 16 units. For air conditioning that results in 2.5 tons per unit. See TVAModelingAssumptions.xls for multifamily model assumptions.

6.1.5 Residential Manufactured Home and Multifamily AC Unit (Central or Split)

Sources:

Database for Energy Efficiency Resources (DEER) 2008

Consortium for Energy Efficiency (www.cee1.org)

Measure Description:

Under this measure, older air-conditioning units are replaced with new units that have rated efficiencies greater than required by building code or appliance standards. It applies to central or split-system AC units.

Installing a high efficiency unit is only one component of AC energy savings. Proper sizing and installation may have a significant impact on system operation. Energy savings claims may be different due to this consideration.[198]

Assumptions:

Code and existing baseline efficiencies are listed in the following table. These values are based on federal standards.

Energy efficient air conditioning efficiencies are based on the Consortium for Energy Efficiency (CEE) high-efficiency air conditioning and heat pump specifications.[199] CEE specifications are commonly used in equipment eligibility requirements for utility efficiency programs. ENERGY STAR qualifying central air conditioners must be at least 14.5 SEER/12 EER for split systems, and at least 14 SEER/11 EER for single package equipment.[200]

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[198] Programs may consider requiring quality installation and proper sizing through Manual J.

[199] www.cee1.org

[200] ENERGY STAR website. http://www.energystar.gov/index.cfm?c=airsrc_heat.pr_crit_as_heat_pumps

Table 283. Baseline and Energy Efficient Central AC Model Assumptions[201]

Central Air Conditioners		
	SEER	**EER**
Single Package /AC Baseline	14	12
Split		
CEE Tier 0/ENERGY STAR	14.5	12
CEE Tier 1	15	12.5
CEE Tier 2	16	13
Packaged		
ENERGY STAR	14	11
CEE Tier 1	15	12
CEE Tier 2	16	12

Savings values are determined for ENERGY STAR, Tier 1, Tier 2, and Tier 3 of the CEE residential AC systems. The savings calculations were performed by utilizing DOE-2 models generated with eQUEST software.

Two models (Gas Heating System 1) for each residential building were simulated in eQUEST in order to represent the SEER and EER levels for the baseline and retrofit efficiency assumptions listed (eQUEST does not allow a user to input both values in one model). However, analysis and savings are based on the EER results only. The HVAC systems modeled for residential prototypes were split system only; therefore, the packaged system retrofit was not investigated for this measure.

Savings:

These savings can be found in Res Measure Summary.xlsx and are listed per ton of cooling, by building type and TVA weather district.

The savings are calculated using the following steps (see Res WS Runs Data 2013.xlsx):

1. Run baseline and retrofit models.
2. Extract annual cooling end-use category total in kWh for all baseline and retrofit runs.
3. From SS-D report, pull the maximum cooling load in kBtuh.

[201] By EER unless otherwise noted.

4. Assume a rated capacity of the installed packaged single zone (PSZ) units based on the maximum cooling load from the SS-D report (see Table 282. Unit Size Assumptions).
5. Extract the summer peak factor (average of top 10 hottest summer hours).
6. Divide the difference of the calculated peak kW savings (peak kW is annual kWh x peak factor) by the rated cooling capacity in tons.

Maximum demand reduction is also calculated using the following equation. For residential central air conditioning, we use EER to estimate demand reduction:

$$\text{Demand reduction; kW/ton}_{\text{EER}} = \frac{12}{\text{EER}_{\text{existing}}} - \frac{12}{\text{EER}_{\text{new}}}$$

Table 284. Residential AC Demand Reduction (per Ton)

Type	Efficiency Level	Demand Reduction
Split	CEE Tier 0/ENERGY STAR	0.13*
Split	CEE Tier 1	0.17*
Split	CEE Tier 2	0.17*
Package	ENERGY STAR	0.00[202]*
Package	CEE Tier 1	0.00*
Package	CEE Tier 2	0.00*

Measure Life:

15 years (2008 DEER)

6.1.6 Residential (Manufactured Home and Multifamily) Heat Pump Unit

Sources:

Database for Energy Efficiency Resources (DEER 2008)

Consortium for Energy Efficiency (www.cee1.org)

Measure Description:

[202] Baseline and retrofit EER are the same.

Under this measure, older heat pump units are replaced with new units that have rated efficiencies greater than required by building code or appliance standards. It applies to central or split-system air-source heat pump units.[203]

Installing a high efficiency unit is only part of the solution for savings energy. Proper sizing and installation may have a significant impact on unit operation. Energy savings claims may be different due to this consideration.[204] **Assumptions:**

Code and existing baseline efficiencies are listed in the following table. These values are based on federal standards.

Energy efficient heat pump efficiencies are based on the CEE high-efficiency air conditioning and heat pump specifications. CEE specifications are commonly used in equipment eligibility requirements for utility efficiency programs. ENERGY STAR qualifying heat pumps must be at least 14.5 SEER/12 EER/8.2 HSPF for split systems, and at least 14 SEER/11 EER/8.0 HSPF for single package equipment.[205]

Table 285. Baseline and Energy-Efficient Heat Pump Model Assumptions

Air-Source Heat Pumps			
	SEER	**EER**	**HSPF**
Baseline	14	12	8.2
Split			
ENERGY STAR	14.5	12	8.2
CEE Tier 0	14.5	12	8.5
CEE Tier 1	15	12.5	8.5
CEE Tier 2	16	13	9.0
Packaged			
ENERGY STAR	14	11	8.0
CEE Tier 1	15	12	8.2
CEE Tier 2	16	12	8.2

[203] This measure is for installing a new high-efficiency heat pump in place of an older heat pump, specifically in the case of a manufactured home. Installing a new heat pump in place of strip heating is a different measure.
[204] Programs may consider requiring quality installation and proper sizing through Manual J.
[205] ENERGY STAR Web site. http://www.energystar.gov/index.cfm?c=airsrc_heat.pr_crit_as_heat_pumps.

Savings values are determined for both ENERGY STAR Tier 1 and Tier 2 of the CEE residential heat pump systems. The savings calculations were performed by utilizing DOE-2 models generated with eQUEST software.

Similar to the AC measure, the baseline equipment efficiency for the split system zone unit in each of the residential building's HVAC system was altered to reflect the baseline SEER/EER and HSPF values listed above.[206] In addition, the user must input cooling EIR (electric-input-ratio) and heating EIR values instead of EER, SEER, COP, and HSPF values.

Two models (Electric Heating System 1) for each residential building were simulated in eQUEST in order to represent the SEER and EER levels for the baseline and retrofit efficiency assumptions listed (eQUEST does not allow a user to input both values in one model). However, analysis and savings are based on the EER results only. The HVAC systems modeled for residential prototypes were split system only; therefore, the packaged system retrofit was not investigated for this measure.

Savings:

These savings can be found in Res Measure Summary.xlsx and are listed per ton of cooling, by building type and TVA weather district.

The savings are calculated using the following steps (see Res WS Runs Data 2013.xlsx):

1. Run baseline and retrofit models.
2. Extract annual cooling and heating end-use category totals in kWh for all baseline and retrofit runs.
3. From SS-D report, pull the maximum cooling and heating load in kBtuh.
4. Assume a rated capacity of the installed PSZ units based on the maximum cooling and heating load from the SS-D report (see Table 282. Unit Size Assumptions above). The maximum load (tonnage) of cooling or heating is used to size the equipment.
5. Extract the summer and winter peak factor (average of top 10 hottest summer and coldest winter hours).
6. Divide the difference of the calculated peak kW savings (peak kW is annual kWh x peak factor) by the rated cooling capacity in tons.

Maximum demand reduction is also calculated using the following equation. For residential heat pumps during cooling seasons, we use EER to estimate demand reduction:

[206] Prototype efficiencies tend to be lower than standard baseline efficiency.

$$\text{Demand reduction; kW/ton}_{EER} = \frac{12}{EER_{existing}} - \frac{12}{EER_{new}}$$

Table 286. Heat Pump (Cooling Season) Demand Reduction

Type	Efficiency Level	Demand Reduction (kW/ton)
Split	ENERGY STAR	0.040*
Split	CEE Tier 0	0.040*
Split	CEE Tier 1	0.054*
Split	CEE Tier 2	0.073*

For residential heat pumps during heating seasons, we use HSPF to estimate demand reduction. However, the HSPF needs to be converted to COP (and hence kW/ton). The conversion is:[207]

$$COP = (HSPF + 2.4) / 3.2$$

$$\text{Demand reduction; kW/ton} = \left[\frac{12}{COP_{existing}} - \frac{12}{COP_{new}}\right] \times \left(\frac{1}{3.412}\right)$$

Table 287. Heat Pump (Heating Season) Demand Reduction

Type	Efficiency Level	Demand Reduction (kW/ton)
Split	ENERGY STAR	0.168*
Split	CEE Tier 0	0.177*
Split	CEE Tier 1	0.185*
Split	CEE Tier 2	0.197*

Measure Life:

15 years (2008 DEER)

[207] The conversion is from the residential California Title 24 Alternate Calculation Manual (ACM), equation R4-33 (2005 and 2008).

6.1.7 ENERGY STAR Room Air Conditioner

Sources:

ENERGY STAR Program, www.energystar.gov

U.S. Department of Energy, Energy Efficiency & Renewable Energy, Building Technologies Office, http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41

California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008)

Measure Description:

This measure applies to the installation of an ENERGY STAR version 3.0-qualified residential room air conditioner in place of a federally minimum-compliant room air conditioner.

Assumptions:

The savings calculation methodology was derived from the current ENERGY STAR room air conditioner savings calculator.[208] The savings calculation assumptions are based on an air conditioning unit of 10,000 Btu/hr capacity (or 0.83 tons), without reverse cycle, and with louvered sides. The baseline efficiency is the Federal minimum, which as of June 1, 2014 requires a combined energy efficiency ratio[209] (CEER) of 10.9.[210] The ENERGY STAR Room Air Conditioner efficiency is taken from program version 3.0, effective October 1, 2013, which requires an EER of 11.3. The following table shows the assumed parameter values.

Table 288. Calculation Assumptions

Parameter	Value	Units
Unit Capacity	10,000	Btu/hour
Unit Type	Louvered sides, without reverse cycle	

[208] https://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorRoomAC.xls.
[209] CEER = (Capacity × Active_Mode_Hours) / (Active_Power × Active_Mode_Hours + Standby_Mode_Hours × Standby_Power, where Active_Mode_Hours = 750 Hours, Standby_Mode_Hours = 5115 Hours. http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/room_ac_efficiency_level_standby_table.pdf.
[210] 11.0 EER equivalent.

Parameter	Value	Units
Baseline EER	11.0	Btu/Watt hour
ENERGY STAR EER	11.3	Btu/Watt hour

Room air-conditioner operating hours vary by TVA weather district and are shown in the following table.

Table 289. Room Air Conditioner Annual Full-Load Operating Hours

Weather District	ENERGY STAR Annual Full Load Hours
Chattanooga	1,353
Huntsville	1,464
Knoxville	1,288
Memphis	1,654
Nashville	1,375

Savings:

Savings were calculated as the difference in annual kWh consumption for the assumed measure unit size, type, and TVA weather district operating hours. The equations below illustrate the calculation of annual kWh consumption and savings for the room air conditioner.

$$\text{Annual kWh} = \left[\frac{\text{kBtu}/\text{hr}}{\text{EER}_{\text{Baseline or ENERY STAR}}}\right] \times \text{Annual Full Load Hours}$$

$$\text{Annual kWh Savings} = \text{Annual kWh}_{\text{Baseline}} - \text{Annual kWh}_{\text{ENERGY STAR}}$$

The annual kWh consumption and savings values, by weather district, are presented in the following table.

Table 290. Annual Energy Consumption and Savings, kWh/Year

Weather District	Baseline Annual kWh	ENERGY STAR Annual kWh	Annual kWh Savings
Chattanooga	1,230	1,197	33
Huntsville	1,331	1,296	35
Knoxville	1,171	1,140	31
Memphis	1,504	1,464	40
Nashville	1,250	1,217	33

The peak demand savings were determined by calculating the difference in kW per ton efficiency and then multiplying by the unit tonnage and a coincident diversity factor (CDF) for a room air conditioner. The equation below illustrates the calculation of peak demand savings.

$$\text{kW Savings} = \left[\frac{12}{\text{EER}_{\text{Baseline}}} - \frac{12}{\text{EER}_{\text{E STAR}}}\right] \times \frac{10\ \frac{\text{kBtu}}{\text{hr}}}{12\ \frac{\text{kBtu/hr}}{\text{ton}}} \times \text{CDF}$$

The following table lists the average CDF and peak demand savings for summer, by building type and TVA's weather district.

Table 291. Peak Demand Savings, kW

Building Type	Weather District	CDF	Summer Peak kW Savings
Multifamily	Chattanooga	0.654	0.016
	Huntsville	0.618	0.015
	Knoxville	0.619	0.015
	Memphis	0.711	0.017
	Nashville	0.627	0.015
Manufactured Home	Chattanooga	0.613	0.015
	Huntsville	0.568	0.014
	Knoxville	0.551	0.013
	Memphis	0.634	0.015
	Nashville	0.569	0.014
Single-Family	Chattanooga	0.705	0.017
	Huntsville	0.669	0.016
	Knoxville	0.648	0.016
	Memphis	0.762	0.018
	Nashville	0.646	0.016

Life:

9 years (DEER 2008)

Attachment:

TVA - ES Room AC.xlsx

6.1.8 Multifamily Duct Sealing

Sources:

Database for Energy Efficiency Resources (DEER) 2008

"A Campaign to Reduce Light Commercial Peak Load in the Southern California Edison Service Territory through Duct Sealing and A/C Tune-ups," October 2002, Modera, Proctor.

2005 California Building Energy Efficiency Standards (Title 24). http://www.energy.ca.gov/title24/2005standards/index.html

Measure Description:

This measure seeks to minimize air leakage in air-conditioning supply and return air system ducts located in unconditioned spaces. When ducts are not sealed properly, conditioned air escapes to unconditioned spaces, forcing the HVAC system to work harder and longer. The measure described in this work paper assumes the duct is sealed to allow no more than a 15% leakage rate.

Assumptions:

The study conducted by Modera and Proctor (2002) found an average leakage before sealing to be 92 cfm/ton with an average fan flow of 325 cfm/ton. This corresponds to an average 28% leakage rate as the baseline condition.

Beginning on October 1, 2005, new duct sealing requirements were released by the California Energy Commission Title 24 building standards for residential homes getting a new central air conditioning or furnace. The California Title 24 requires that ducts leaking 15% or more must be repaired to reduce leaks. Therefore, we assume the retrofit condition of 15% leakage.

Savings:

The analysis in eQUEST is modeled by revising the 'Air-side HVAC System' parameters to have 'Duct Air Loss' ratio of 0.15. This means that 0.15 fraction of the supply air is lost from the ductwork, thereby reducing the design supply air to the zones. Subsequently, the air lost from the ductwork will change the temperature of the zone specified. In eQUEST software, this zone must be a plenum or unconditioned space.

Additionally, in the same Air-side HVAC system parameters window of eQUEST, the "Air Loss Type" parameter is adjusted to being proportional. This means that the duct air loss will vary in proportion to the air flow through the system. These revisions are made for each of the HVAC systems modeled in each building. Due to the limitations in eQUEST in modeling duct sealing, this measure can only be applied to homes that have a ducted HVAC system installed (split system heat pump and split system DX furnace systems).[211]

Measure savings are the difference in HVAC energy usage (heating, cooling, and ventilation end uses) between baseline and measure/retrofit conditions listed above. Savings are expressed per ton of cooling. The cooling/heating load is extracted from the SS-D report in the eQUEST model's SIM file.

Measure Life:

18 years (2008 DEER)

6.1.9 Residential (Manufactured Home and Multifamily) Refrigerant Charge

Sources:

"Field Measurements of Air Conditioners with and without TXVs", Mowris, Blankenship, Jones, 2004 ACEEE Summer Study Proceedings

Wulfinghoff, Donald. "Energy Efficiency Manual." 1999.

Measure Description:

This measure consists of ensuring AC systems are charged correctly. A refrigerant charge and air-flow (RCA) test are typically conducted. If the charge level is too low or high, or if the supply airflow is outside the original equipment manufacturer (OEM) specified range (usually 350 to 450 cfm/ton), the technician performs the necessary corrections.

An air conditioner will not operate at optimum conditions with too much or too little refrigerant in the lines. Both the unit EER and cooling capacity suffer if the refrigerant charge is too low or too high. When the refrigerant charge is too low, evaporator capacity is reduced and the average evaporator temperature differential increases, which causes the compressor to work harder to satisfy the same cooling load. If there is too much refrigerant in the system, the excess may be in liquid rather than vapor state and result in a reduced EER value compared with the rated EER of the system.

[211] The building prototypes with central AC are only modeled with split system, but this measure would apply to packaged systems, too. However, this measure does not apply to ductless systems (such as PTAC or room AC).

Assumptions:

The Mowris, Blankenship, and Jones study found that the average energy savings for correcting RCA are 12.6 percent of the baseline compressor annual energy use. The 12.6 percent energy savings corresponded to a baseline condition of approximately 20 percent out of charge (both over charge and under charge).[212] Also peak kW savings were determined to be 0.32 kW for units with an average capacity of approximately 4 tons.[213] However, we will assume that the prototype weather-sensitive load shape factor for cooling is a proxy for the correctly charged air conditioning unit load shape.

Savings:

The savings for this measure are calculated using the following formulas:

$$\text{AnnualEnergySaved(kWh/ton)} = \frac{12.6\% \times \text{AnnualCompressorEnergy(kWh)}}{\text{CoolingCapacity(tons)}}$$

$$\text{Demand Savings (kW)} = \text{AnnualEnergySavings(kWh/ton)} \times \text{Peak Load Shape Factor for Cooling End Use}$$

Each building's annual compressor energy use (kWh) value is equivalent to the building model's annual cooling end-use energy (that is attributed to the AC unit(s) under analysis) and varies by building type and weather district. This measure uses the prototype buildings for calculating annual energy and peak demand savings; the annual compressor energy (kWh) and peak load shape factors for cooling end use can be found in Res WS Runs Data.xls.

Measure Life:

10 years (2008 DEER)

6.1.10 Residential (Manufactured Home and Multifamily) Window Replacement

Sources:

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212 The 12.6% assumption may be high in light of recent work, however, the evaluation research has not yet been finalized or allocated to multifamily or manufactured home dwelling types. This value should be updated as results are published from evaluations.

213 Study completed field measurements of refrigerant charge and airflow over a three-year period across 4,168 split, packaged and heat pump air conditioners.

Database for Energy Efficiency Resources, www.deeresources.com, (DEER) 2005

2005 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, Publication #P400-03-001, California Energy Commission (CEC), September 2004, Effective Date October 1, 2005 (Title 24).

US DOE Energy Savers,
http://www.energysavers.gov/your_home/windows_doors_skylights/index.cfm/mytopic=13490

"Field Evaluation of Low-E Storm Windows," S. Craig Drumheller (ASHRAE), Christian Kohler (ASHRAE), and Stefanie Minen. (ASHRAE), 2007.

Efficient Windows Collaborative, http://www.efficientwindows.org/ ASHRAE Standard 90.1-2007, "Energy Standard for Buildings Except Low-Rise Residential Buildings," Table A8.2.

2003 International Energy Conservation Code (IECC), "Chapter Six: Simplified Prescriptive Requirements for Detached One- and Two-Family Dwellings and Group R-2, R-4 or Townhouse Residential Buildings."

Measure Description:

Window replacement and retrofit involves replacing existing windows with better performing windows of the same dimensions. The performance of a window is typically measured by its SHGC and U-value. The SHGC is a measure of the rate of radiant heat transfer through the window. As a result, a lower SHGC is desired for hotter summer seasons, but is not necessarily beneficial during the winter season. The U-value measures the conductance of heat (thermal conductivity) through a window. The window frame and assembly are important factors that contribute heavily to the overall window U-value; a frame that utilizes a material with low thermal conduction (vinyl, wood, fiberglass) will typically offer lower U-values than a metal frame. A 'low-e' coating can be applied to the window to help reduce the U-value of the assembly. A low-e coating is a microscopically thin, metal-oxide layer that reduces the amount of infrared radiation traveling from the warm pane to the cool pane of the glass assembly. This results in a lower U-value as the thermal conductivity is reduced through the window. Windows with lower U-values are desired for regions with cold winter and hot summer seasons due to there being less heat transfer through the assembly.

Newer, more energy efficient windows have lower SHGC and lower U-values, but can be expensive. Storm window retrofits are a much cheaper method because they do not require professional labor. Storm windows can be installed within the framing of the current window on the interior or exterior side. They create a tight air pocket between the storm window pane and the existing window pane, adding to the insulation potential of the window assembly; however, the largest benefit of storm windows is that it reduces air movement through the window assembly.[214] This can greatly reduce the amount of heating and cooling necessary to keep the interior temperature comfortable.

Assumptions:

Baseline window type is established from the TVA EnergyRight® Program baseline window characteristics described in the following table. The TVA building prototypes (manufactured homes, single, and multifamily detached) assume a mix of single and double pane windows. This measure description assumes a baseline of single-pane windows. This assumption is based off professional judgment that TVA customers would, in general, only upgrade single-pane windows with either a storm window retrofit or replace them with a double-pane window assembly; there would only be a small number of applications where double-pane windows would be replaced with better performing double-pane window assemblies. Retrofit window assemblies were selectively chosen from the Efficient Windows Collaborative[215] to provide options that will realize their greatest savings based on TVA district climate, as well as meeting the 2003 International Energy Conservation Code (IECC) in Tennessee for windows used in existing or new single-family buildings.[216] The storm window retrofit measure modeled here will be limited to interior type. Table 292 shows the baseline window characteristics for single-family, multifamily, and manufactured homes, and the measure cases recommended.

[214] U.S. DOE Energy Savers.

[215] http://www.efficientwindows.org – The site was developed jointly by the Center for Sustainable Building Research, Alliance to Save Energy, and Lawrence Berkeley National Laboratory.

[216] Table 602.1 in Chapter 6, 2003 IECC Report.

Table 292. Window Baseline and Retrofit Characteristics[217]

Model Assumptions	U-value	SHGC/Shading Coefficient (SC)	Source
Baseline Window Characteristics [Single-Pane, Clear]	1.25	0.82/0.94	ASHRAE 90.1-2007; Table A8.2
Low-E Storm Window Retrofit	0.37	0.63/0.72	"Field Evaluation of Low-E Storm Windows", ASHRAE
Double-Pane Retrofit #1 [e.g., Clear glass, Vinyl Frame (0.50" Air Gap)]	0.49	0.56/0.64	Efficient Windows Collaborative
Double-Pane Retrofit #2 [e.g., Moderate-Solar-Gain Low-E tint, Argon/Krypton Gas Fill, Vinyl Frame (0.50" Air Gap)]	0.35	0.44/0.51	

It was mentioned in the measure description that savings can also be realized from reduced window infiltration (due to tighter framing and window assemblies); however, only savings from assembly U-value and SHGC changes will be modeled and reported.

Savings:

Baseline characteristics (U=1.25, SHGC=0.82) were used in the DOE-2 residential building models developed in eQUEST using TVA weather data. eQUEST baseline models were then revised with the retrofit window characteristics (SHGC, U-value) to estimate savings. Window replacement savings will be based on a per 100 square feet of window assembly (includes glass pane and frame). In eQUEST this involves comparing the difference in HVAC energy consumption (cooling, heating, and ventilation end-uses) between baseline and retrofit window cases and dividing it by a normalizing factor to obtain savings per unit basis of 100 square feet of window assembly (glazing area). The normalizing factor is equal to the buildings total window area divided by 100 square feet. Energy and peak demand savings for this measure can be found in the residential summary workbook.

[217] The U-value and SHGC of the replacement window retrofits are for the entire window assembly, including panes and framing. The U and SHGC of the storm window retrofit (of the single pane baseline window assembly + the low-E storm window assembly) was determined in Window 5.2 (program for calculating total thermal performance of window assemblies) and then imported into eQUEST. Windows 5.2 is publicly available software that provides a versatile heat transfer analysis method consistent with the updated rating procedure developed by the National Fenestration Rating Council (NFRC) that is consistent with the ISO 15099 standard. (Reference: http://windows.lbl.gov/software/window/window.html).

The storm window measure needed additional modeling in Window 5.2,[218] in order to input the complete assembly U-value and SHGC. The following procedure was followed to model the baseline window type with a storm window retrofit:

1. The baseline window assembly modeled in Window 5.2, consisted of the generic single pane glass type (CLEAR_3.DAT), aluminum without thermal break framing; alterations to the solar and infrared transmittance of the glass type produced a U-value and SHGC identical to the baseline values.
2. The storm window retrofit was modeled by adding another pane of glass separated by a 2-inch air gap from the baseline glass pane. A specific glass type (Pilkington Energy Advantage Low-E [Low-E_3.LOF]) was used as the storm window pane, and the U-value of this pane was modified to reflect the value referenced from the ASHRAE Storm Window Field Evaluation paper.
3. Due to the limitation of the modeling software, framing of the assembly was changed from aluminum without thermal break framing to vinyl framing. This change was made to attempt to model the storm window's vinyl framing, which is intended to fit very tightly within the original aluminum framing, effectively reducing the "net" frame U-value.

Measure Life:

20 years (DEER 2008)

6.1.11 Residential (Multifamily and Manufactured Home) Insulation (Attic, Floor, and Wall) and Single-Family Wall Insulation

Sources:

Database for Energy Efficiency Resources (DEER) 2008

Measure Description:

Residential insulation is a cost-effective way to drastically reduce heat loss through the building shell.

Attic/ceiling insulation is particularly important because during heating seasons, warmer air will rise in to the attic and, without insulation, can quickly transfer its heat in to the roofing material and escape the interior through natural attic ventilation. Attic/ceiling insulation significantly reduces the rate at which

[218] Window 5.2 is a windows modeling program developed by Lawrence Berkeley National Labs (LBNL).

heat is lost through the attic/roof, thus reducing the amount of energy consumption required to keep the home at a comfortable temperature. Attic/ceiling insulation will also reduce a building's cooling load during the summer because heat transfer rates between cooler indoor air and warmer ambient and attic air will be inhibited by the insulation.

Floor and wall insulation provide the same heat transfer inhibiting characteristics as their attic/ceiling counterparts; however, floor insulation usually reduces heat transfer between the assembly of the building and the earth beneath it (mainly conductive/convective heat transfer), and wall insulation reduces heat transfer to the interior space. There are several types of insulation material used in residential applications, and each material has physical characteristics that make it more suitable than others in certain situations. These characteristics will be presented in more detail in the assumptions section, when insulation materials are chosen for retrofit measure options.

Assumptions:

Baseline insulation levels are based off the TVA Energy Right Program baseline assumptions for residential auditing. Those baseline assumptions were used in the DOE-2 building prototypes. Vintage (the prototype R-value) and no insulation (R-0) cases are simulated by changing the associated insulation levels. Some types of insulation are only applicable to certain residential building types due to physical construction constraints. The savings provided here disregard any potential degradation of existing insulation effectiveness.

For the purposes of this manual the types of measures available are dependent upon the extent of labor and renovation required. The measures presented here are those that require minimal demolition and construction. This will limit wall insulation to loose-fill and spray foam (open-cell and closed-cell spray polyurethane foam, SPF), materials that require drilling holes the size of a large garden hose in between each stud, filling the cavity with insulation, and then patching the holes in the dry-wall. Floors will be limited to batt and blanket insulation; this is the common type of insulation used for floor retrofits since the insulation comes in pre-sized rolls with widths selected to fit securely between wood-framing members, such as joists and studs. Floor insulation will only be applicable to manufactured homes and single-family homes with a raised floor with crawl space or basements with insulation, which represent 60 percent of the total single-family floor area.[219]

Ceiling/roof and attic insulation will have relatively inexpensive measures available including batt and loose-fill (such as fiber-glass, rock-wool, and cellulose). The following table describes the baseline

[219] Single-family savings are in the IHEE section of the manual.

insulation level cases for residential buildings. For single-family and manufactured home models, there will be two baseline prototypes, one with no insulation and one with pre-existing insulation. There will be only one multifamily baseline prototype. The second following table lists the measure retrofit options available by insulation application (floor, walls, ceiling/roof/attic) and residential building type. Each baseline prototype will have one parametric run for each insulation type change; the parametric runs and associated insulation levels are shown in Table 293. Parametric measures will run an identical baseline building but will vary the model according to the parameter adjustment specified, which in this case is the insulation R-value.

Table 293. Baseline Insulation Level Model Options

Dwelling Type	Attic/Ceiling	Floor	Above-Grade Wall
Single-Family #1	NA	NA	R-0
Single-Family #2	NA	NA	R-11
Multifamily	R-19	R-0	R-11
Manufactured Home #1	R-0	R-0	R-0
Manufactured Home #2	R-14	R-11	R-11

Table 294. Retrofit Insulation Level Assumptions

Dwelling Type	Attic/Ceiling	Floor	Above-Grade Wall
Single-Family	NA	NA	R-24
Multifamily	R-38	N/A	R-24
Manufactured Home	R-38	R-30	R-24

Table 295. Parametric Runs for Insulation Measures[220]

Parametric Run	Dwelling Type	Baseline			Retrofit		
		Attic or Ceiling	Floor	Above-grade Wall	Attic or Ceiling	Floor	Above-grade Wall
3	Single-Family #1	R-0	R-0	R-0	R-0	R-0	***R-24***
6	Single-Family #2	R-19	R-11	R-11	R-19	R-11	***R-24***
7	Multifamily	R-19	R-0	R-11	***R-38***	R-0	R-11
8	Multifamily	R-19	R-0	R-11	R-19	R-0	***R-24***
9	Manufactured Home #1	R-0	R-0	R-0	***R-38***	R-0	R-0
10	Manufactured Home #1	R-0	R-0	R-0	R-0	***R-30***	R-0
11	Manufactured Home #1	R-0	R-0	R-0	R-0	R-0	***R-24***
12	Manufactured Home #2	R-14	R-11	R-11	***R-38***	R-11	R-11
13	Manufactured Home #2	R-14	R-11	R-11	R-14	***R-30***	R-11
14	Manufactured Home #2	R-14	R-11	R-11	R-14	R-11	***R-24***

Savings:

Savings are determined by comparing the difference in HVAC energy consumption (heating, cooling, and ventilation end-uses) modeled in the eQUEST building simulations between baseline and retrofit insulation cases. The savings listed in Res Measure Summary.xlsx provide retrofit savings (new insulation where none existed before) and vintage savings (adding more insulation) by insulation type and R-value for the five different weather-zones in TVA. The total building savings are divided by a normalizing factor to express in a per unit basis of 1,000 square feet of respective insulation (attic, floor, and wall), see Res WS Runs Data 2013.xlsx. Following modeling assumptions, the conditioned top-floor footprint is the attic/ceiling insulation area, the bottom-floor footprint is the floor insulation area, and the perimeter of the exterior of the building multiplied by the wall height subtracted by the total window assembly area is the wall insulation area. These areas are calculated in eQUEST and generated in the LV-

220 The insulation measures listed in the table were modeled as alternative runs in the Parametric Run window of eQUEST as the residential models are built in Detailed Mode. The resistivity of the insulation in each of the attic/ceiling, floor and above grade wall constructions was altered to match the respective baseline and retrofit R-value listed in the table. The models contained the initial baseline insulation values. The associated retrofit improvements listed in the table were run as parametric runs against this baseline. The second set of baseline insulation values was also set up as a parametric run. Numbering of single-family runs is not sequential due to the use of IHEE evaluation results for attic/ceiling and floor insulation savings.

D section of the SIM file reports. The following table summarizes the square footage values per building type.

Table 296. Insulation Square Footage

	Attic/Ceiling	Floor	Wall
Single-Family	NA	NA	1,952
Multifamily	12,519	n/a	8,749
Manufactured Home	1,440	1,440	1,114

Measure Life:

20 years (DEER 2008)

6.1.12 Residential (Multifamily and Manufactured Home) Weatherization

Sources:

Database for Energy Efficiency Resources (DEER) 2008

Measure Description:

The residential weatherization measure includes a number of weatherization applications listed below, all of which are assumed to make up this measure:

- Attic access weather-stripping
- Caulking
- Door weather-stripping
- Installation of outlet gaskets

These weatherization applications are relatively cheap for their material and installation, and ultimately provide a decrease in a building's natural infiltration rate. Depending on the building's location in regards to climate and weather, the decreased infiltration rate of the building can reduce energy consumption for heating.

Assumptions:

Weatherization savings will be estimated by modeling the change (reduction) in the number of air changes per hour (ACH) a building experiences due to the installation of the weatherization measures. A baseline infiltration value of 0.70 ACH will be used for multifamily and manufactured homes. This value is higher than the infiltration ACH values in TVA audit data and the 2008 DEER weatherization baseline assumptions.[221] KEMA chose to raise the baseline ACH value to 0.7 to more realistically represent the TVA homes that would participate in weatherization. A "low" infiltration rate for new/young vintage residential construction (in CA) is 0.25 to 0.35 ACH (per DEER 2008). The 2008 DEER weatherization measure is based on California residential building code and is offered as a low-income measure. However, for this measure in TVA service area, it is estimated that the ACH will be reduced to 0.40, as a conservative estimate for potential weatherization savings.[222] DEER 2005 assumes that retrofitting a building that needed weatherization can reduce the infiltration rate to the (DEER) standard of 0.35 ACH. KEMA will choose a retrofit infiltration rate of 0.40 to remain conservative on the potential savings of weatherization.[223] The following lists the assumptions for the baseline and retrofit infiltration rates for the weatherization measure.

Table 297. Weatherization Baseline and Retrofit Characteristics

Model Assumptions	Infiltration Rate
Baseline	0.70 ACH
Retrofit	0.40 ACH

Savings:

eQUEST prototype (baseline) residential building models were revised with the retrofit weatherization characteristics (change to infiltration rate, ACH) to estimate weatherization retrofit savings. Differences between HVAC energy consumption (cooling, heating, and ventilation end-uses) in the baseline and measure simulation outputs are used to calculate measure savings. The total building savings are divided by a normalizing factor and expressed in a per unit basis of 1,000 square feet of conditioned footprint area (see Res WS Runs Data 2013.xls). The savings are presented in Res Measure Summary.xlsx, based on building type and TVA weather district.

Measure Life:

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[221] TVA audit data has baseline infiltration ACH = 0.50. 2008 DEER low-income weatherization measure has baseline infiltration ACH = 0.45 or 0.47.

[222] Like extremely drafty door and windows. The "need" for weatherization will be obvious, and those types of baseline building conditions will have infiltration rates much higher than 0.5ACH.

[223] Many factors go in to the success of weatherization, including quality of installation, the number and surface area of the doors and windows being weather-stripped, number of outlets lining exterior adjacent walls, and overall condition of the building shell and building insulation.

11 years (DEER 2008)

6.1.13 Whole House Fan

Sources:

Database for Energy Efficiency Resources (DEER) 2005 and 2008, www.deeresources.com

Measure Description:

Whole house fans can be used as an alternative to air conditioning[224] to cool the home during times when outside air is cooler than air inside the home and attic. The fan pulls air in from open windows and other natural house ventilation and releases it through the attic and roof, ultimately displacing warmer, indoor air with cooler, outdoor air. Whole house fan run-time schedules are designed to run only during hot season mornings and evenings after sundown when outdoor air has cooled below indoor air temperatures.

Assumptions:

The savings will be calculated using DOE-2 simulations through eQUEST software for whole house fans. A fan would operate as an alternative to the AC system during moderate outdoor conditions (shoulder periods of the summer season) to accelerate the air movement and therefore provide thermal comfort in the space. In order for the software to model an exhaust fan (to extract air), there needs to be air flow (natural ventilation) entering the house also. Therefore, an operable window schedule was applied during the summer periods. Further, the mechanical cooling schedule was set to not operate when the windows were opened (whole house fan is on) and the interior temperature of the home was less than 78° F.[225] The following table provides the assumptions of the whole house fan and natural ventilation operation.

Table 298. Whole House Fan and HVAC Summer Schedule

Hours	Temperature Range
1-6 a.m.	78°F max (provided by mechanical cooling)
6-8 a.m.	78°F max (provided by mechanical cooling) 68°F min (provided by occupant operating windows)
8 a.m.-5 p.m.	79°F max (provided by mechanical cooling)
5-10 p.m.	78°F max (provided by mechanical cooling) 68°F min (provided by occupant operating windows)

[224] This measure is applicable if there is existing mechanical cooling.

[225] The temperature cut-off is assumed and may need to be revised if field data is available.

Hours	Temperature Range
10 p.m.-12 a.m.	78°F max (provided by mechanical cooling)

The natural ventilation algorithm was specifically used to model the whole house fan as a measure that accelerates the natural ventilation of the house (much like opening windows or doors). The baseline condition will have a central AC system (packaged DX furnace unit) and no whole house fan installed. The retrofit measure will have the same central AC system (packaged DX furnace unit) in conjunction with a whole house fan in the attic space. Retrofit assumptions are based on a whole house fan characteristic of having 0.5 inch water gauge static pressure and provide 3.0 ACH.[226]

Savings:

eQUEST models were revised from baseline conditions (prototype single-family GH1) to measure (retrofit) conditions by assuming the whole house fan is effectively an exhaust fan.

Unit measure savings are on a per household basis. The fan will be specified in eQUEST to meet the load for that particular house size, which will result in having one fan per home for this measure.

Measure Life:

20 years (DEER 2008)

6.2 Non-Residential Weather Sensitive Measures

The measures in this section include common energy efficiency retrofit options for commercial buildings. There are additional opportunities for deemed measures that are not included in this document. These include chiller replacement, room air conditioner replacement, and others. However, these measures are considered custom. Additionally, TVA may use the building prototype models to determine deemed savings for additional measures if interest arises in making these measures deemed in a prescriptive incentive program.

The measures include:

- Package air conditioning
- Package heat pump

[226] 2005 DEER

- Package terminal AC/HP
- Variable speed drives on HVAC motors
- Refrigerant charge correction
- Duct sealing
- Economizer repair/retrofit
- Envelope improvements
  - Cool roof
  - Window film
  - High efficiency windows

The summary of the savings is provided in the nonresidential measures workbook. The post-processing analysis of eQUEST output for the non-residential weather sensitive measures are in NonRes WS Runs Data.xls or specific measure workbooks.

When normalizing the savings, it is important to define the savings unit in a manner that is consistent with the program. For example, in most cases, equipment change-out is paid per rated ton or per unit. Therefore, the manual normalizes equipment change-out measures to per rated ton of cooling capacity. To determine this value, the building load (in kBtuh) contributing to the HVAC measure(s) under evaluation is extracted from the eQUEST model SIM file. The SIM file contains all simulation run reports and also generates an 8,760 hour output file. Building models with mixed/combined HVAC systems required disaggregation of the total building load to determine the rated capacity of the individual HVAC measure. Building loads were extracted using the following procedure:[227]

1. High School/College, Hotel, Grocery, Hospital, and Refrigerated Warehouse models all had mixed/combined HVAC systems; the SS-A report (Component-level System loads Summary Report) was used to extract and sum up individual HVAC system loads. So for example, the

[227] Throughout this section, there are references to the SS-D and SS-A report. Note that ‘SS-D’ might sometimes be used synonymously with ‘SS-A’; when these reports are referenced, it is important to refer to the list of numbers/bullets to understand where the cooling or heating load is coming from.

Hospital model uses both packaged DX systems combined with chilled water coils for cooling; only the max loads of the individual DX systems were extracted to evaluate the per ton savings for the Packaged/Split-System AC measure. This was done for Packaged/Split-System AC and HP measures. All other building types had unitary HVAC systems so the total building load in the SS-D report was used.

2. Similarly to (1), building models with PTAC/PTHP units had their cooling and heating building loads extracted from the SS-A report so that the PTAC/PTHP loads could be summed separately from the other building loads that the PTAC/PTHP units do not service.
3. For the Duct Sealing measure, the method of extracting individual HVAC component building load from the SS-A report used in (1) and (2) is also used. This time, only HVAC systems that are ducted were summed to evaluate the buildings savings/ton. The following systems were ducted in each of the listed models:
   - Hospital (All) - Sys2 (packaged single zone (PSZ), 3 zones)
   - Hotel (Gas Heating #1) - Sys2 (VAV, 3 zones)
   - Hotel (Gas Heating #2 and #3) - Sys2 (VAV, 3 zones) and Sys3 (PSZ, 3 zones)
   - High School/College (Gas Heating #1) - Sys4 (PSZ, 2 zones)
   - High School/College (Gas Heating #2) - Sys1 (VAV, 6 zones) and Sys4 (PSZ, 2 zones)
   - High School/College (Electric Heating) - Sys1 (PSZ) and Sys4 (PSZ)
   - University - Sys1 (VAV, 12 zones)
   - Primary School (Electric Heating) - Sys1 (Only EL1 and EL3)
   - Primary School (Gas Heating) - Sys1 (Only EL1 and EL3)
   - All other building types used the total building maximum load from their SS-D reports.

From the DOE-2 eQUEST models, coincident diversity factors and equivalent full load hours are calculated in NonRes WS Runs Data.xls. Details of this analysis are provided in Appendix Section 3. The appendix provides the algorithms for using these set of parameters to calculate simplified estimates for cooling or heating energy savings.

6.2.1 Single Package and Split-System AC Unit

Sources:

ASHRAE Standard 90.1-2007, Energy Standard for Buildings except Low-Rise Residential Buildings

Database for Energy Efficiency Resources (DEER 2008)

Consortium for Energy Efficiency (CEE) (www.cee1.org)

Measure Description:

Under this measure, older air conditioning units are replaced with new units that have rated efficiencies greater than required by building code or appliance standards. It applies to single-package or split-system units that are cooling only, cooling with electric heating, or cooling/gas heating.

The new unitary air conditioning units must meet or exceed the CEE-Tier 1 efficiency for either (S)EER or IEER. They may be either split systems or packaged units. All packaged cooling equipment must meet Air Conditioning and Refrigeration Institute (ARI) standards (210/240, 320 or 340/360), be UL listed, and use a minimum ozone-depleting refrigerant (e.g., HCFC or HFC).

Assumptions:

Code and existing baseline efficiencies are listed in the following table. These values are based on federal standards.[228] Where no federal standard exists (e.g., for units larger than 20 tons), ASHRAE Standard 90.1-2007 (and effective January 1, 2010) is used.[229] Energy efficient air conditioning efficiencies are based on the CEE high-efficiency commercial air conditioning and heat pump specifications. CEE specifications are commonly used in equipment eligibility requirements for utility efficiency programs. As of January 2012, CEE standards have been updated that changed the tiers from before and include IEER requirements.

Table 299. Baseline and Energy-Efficient Model Assumptions[230]

Size (tons[231])	Size (kBtuh)	Base (S)EER	CEE - Tier 1[232]	CEE - Tier 2	SEER or EER
5.4 or Less	65 or less	14	14	15	SEER
5.4 to 11.25	65 to 135	11.5	**	12	EER
11.25 to 20	135 to 240	11.5	**	12	EER
20 to 63.3[233]	240 to 760	10.3	**	10.6	EER
≥63.3	≥760	9.7	**	10.2	EER

[228] It is assumed that in most cases, air conditioning units are not replaced if there is remaining useful life. Therefore, this measure does not consider existing efficiency for early replacement situations.

[229] Federal minimum for 5.4-20 ton sized units changed January 1, 2010. CEE anticipates changing their efficiency levels (as well as changing from using IPLV to IEER for part load efficiency values) sometime in 2010.

[230] By EER unless otherwise noted. The EER is 0.2 higher for units with electrical resistance heating.

[231] Tons = 12,000 Btuh = 12 kBtuh.

[232] **CEE Tier 1 not applicable for units >65kBtuh for this work paper.

[233] Savings for this category is based on using eQUEST models with the retrofit case at 10.8 EER versus the 10.6 EER. A ratio of the delta efficiencies is used to calculate the adjusted savings.

Table 300. Baseline and Energy-Efficient Model IEER Assumptions[234]

Size (tons)	Size (kBtuh)	Base IEER	CEE - Tier 2
5.4 to 11.25	65 to 135	11.6	13.8
11.25 to 20	135 to 240	11.6	13.0
20 to 63.3	240 to 760	10.4	12.1
≥ 63.3	≥ 760	9.8	11.4

The savings calculations were performed by utilizing DOE-2 models generated with eQUEST software. For units less than 5.4 tons, savings were averaged across AC unit phase type (single- or three-phase systems). Savings are independent of unit type, whether split- or single-package systems.

Five models for each building type were simulated in eQUEST in order to represent the five different categories with the baseline and retrofit efficiency assumptions listed in the above table. The baseline equipment efficiency for the PSZ unit in each HVAC system was changed to reflect each of the baselines' SEER or EER values.[235] The respective retrofit efficiencies were then modeled as energy efficiency measures (EEM) using the EEM Wizard in eQUEST. The wizard will effectively run an identical baseline building but will vary the model according to the parameter adjustment specified the case of this measure, a higher equipment efficiency. Consequently, the measure savings values are the difference between baseline and retrofit energy use estimates and are normalized to a per-ton basis.

The grocery and refrigerated warehouse units were modeled in the detailed interface, because this is the only mode that is allowed in the eQUEST software refrigeration version. As a result, the user is unable to enter SEER, EER, COP, or HSPF values and instead inputs a cooling EIR (electric input ratio) and heating EIR. eQUEST defines the electric input ratio (EIR), or 1/COP, as the ratio of the electric energy input to the rated capacity, when both the energy input and rated capacity are expressed in the same units. The equivalent EIR values are generated by setting the applicable efficiency value for the equipment to each of the SEER and EER values in Wizard Mode and then converting the model to Detailed Mode to view the new calculated EIR. As the grocery and refrigerated warehouse do not have a Wizard Mode, another building type (as a sample) was used to generate EIR for each of the size ranges.
Since single packaged units are specified for only some building types and are utilized only in specific areas (and not the whole building), only a subset of building types were modeled in eQUEST with the PSZ retrofit. The savings could be applied to similar building types, as shown in the following table.

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[234] IEER is not used for the savings calculations.

[235] Prototype efficiencies tend to be lower than standard baseline efficiency.

Table 301: Building Types Modeled with AC Measure

Building Types Modeled	Similar Applicable Building Types
Small Office Building	Large Office Building
Small Retail	Mall/Department Store, Grocery
Large Big-Box Retail	
Hotel	Motel
Grocery	
Assembly	
Primary School	
High School/College	University
Hospital	
Full Service Restaurant	
Fast-Food Restaurant	
Refrigerated Warehouse	Unrefrigerated Warehouse

Savings:

These savings can be found in the non-residential measures workbook and are listed per ton of cooling, by building type, and TVA weather district.

To calculate savings on a per-ton of cooling basis (see NonRes WS Runs Data.xls):

1. Run baseline and retrofit models.
2. Extract annual cooling end-use category total in kWh for all baseline and retrofit runs.
3. From SS-D/SS-A report, pull the maximum cooling load in kBtuh.
4. Assume a 15% oversize factor for the rated capacity of the installed PSZ units (i.e., multiply the maximum cooling load by 1.15).[236]
5. Convert the oversized cooling load to tons.
6. Extract the summer peak factor (average of top 10 hottest summer hours).
7. Divide the difference of the calculated peak kW savings (peak kW is annual kWh x peak factor) by the rated cooling capacity in tons.

Maximum demand reduction is calculated using the following equation.[237]

[236] Based on ASHRAE Appendix G.

[237] We use SEER for units 5.4 tons or less, and EER for all other sizes.

$$EER = (SEER + 1.4) \times 0.778$$

$$kW/ton_{EER}, demand\ reduction = \frac{12}{EER_{existing}} - \frac{12}{EER_{new}}$$

Table 302. Air Conditioning Demand Reduction

Size (Tons)	CEE - Tier 1	CEE - Tier 2
5.4 or less	**	0.13*
5.4 to 11.25	**	0.04*
11.25 to 20	**	0.04*
20 to 63.3	**	0.03*
≥ 63.3	**	0.06*

Measure Life:

15 years (2008 DEER)

6.2.2 Single Package and Split-System Heat Pump

Sources:

ASHRAE Standard 90.1-2007

Database for Energy Efficiency Resources (DEER 2008)

Consortium for Energy Efficiency

Measure Description:

Under this measure, older heat pump units are replaced with new heat pump units that have rated efficiencies greater than required by building code or appliance standards. It applies to single-package or split-system units.

The new unitary heat pumps must meet or exceed the CEE-Tier 1 efficiency. They may be either split systems or packaged units. All packaged and split-system cooling equipment must meet AHRI standards

(210/240, 320, or 340/360), be UL listed, and use a minimum ozone-depleting refrigerant (e.g., HCFC or HFC).

Assumptions:

Code and existing baseline efficiencies are listed in the following table. These values are based on federal standards. Savings are assumed to be for replacement of failed air conditioning units.[238] Where no federal standard exists (e.g., for units larger than 20 tons), ASHRAE Standard 90.1-2007 (effective January 1, 2010) is used.[239] Energy-efficient heat pump efficiencies are based on CEE high-efficiency commercial air conditioning and heat pump specifications.[240] CEE specifications are commonly used in equipment eligibility requirements for utility efficiency programs. As of January 2012, CEE standards have been updated that changed the tiers from before and include IEER requirements. The standards provided below are for illustrative purposes; only the savings for units 5.4 tons or less is provided in this manual.

Table 303. Baseline and Energy Efficient Model Assumptions[241]

Size (Tons)[242]	Size (kBtuh)	Base Cooling (S)EER & Heating HSPF or COP	CEE - Tier 1 (Cooling SEER & Heating HSPF/COP)	CEE - Tier 2 (Cooling (S)EER & Heating HSPF)	SEER or EER/HSPF or COP
5.4 or Less	65 or less	14 & 7.7	14 & 8.5	15 & 9.0	SEER/HSPF
5.4 to 11.25	65 to 135	11.1 & 3.3	11.1 & 3.4		EER/COP
11.25 to 20	135 to 240	10.7 & 3.2	10.7 & 3.2		EER/COP
20 to 63.3	240 to 760	10.1 & 3.1	10.1 & 3.2		EER/COP

Savings values are determined for both tier 1 and tier 2 efficiency levels. The savings calculations were performed by utilizing DOE-2 models generated with eQUEST software. For units less than 5.4 tons, savings were averaged across AC-unit phase type (single- or three-phase systems). Savings are also independent of unit type, split- or single-package systems.

The baseline equipment efficiency for the PSZ unit in each HVAC system was changed to reflect each of the baseline (S)EER and HSPF values.[243] The respective retrofit efficiencies were then modeled as

[238] It is assumed that in most cases, air conditioning units are not replaced if there is remaining useful life. Therefore, this measure does not consider existing efficiency for early replacement situations.

[239] Federal minimum for 5.4-20 ton sized units changed January 1, 2010. CEE anticipates changing their efficiency levels (as well as changing from using IPLV to IEER for part load efficiency values) sometime in 2010.

[240] www.cee1.org.

[241] CEE does not have tier 2 COP values for heat pumps. Tier 1 COP values are near or at baseline levels. Split system HSPF values are used for the retrofit case.

[242] Tons = 12,000 Btuh = 12 kBtuh.

energy-efficiency measures using the EEM Wizard in eQUEST. This wizard will effectively run an identical baseline building but will vary the model according to the parameter adjustment specified in the case of this measure, higher equipment efficiency. Consequently, the measure savings values are the difference between baseline and retrofit energy-use estimates and are normalized to a per-ton basis.

The grocery and refrigerated warehouses were modeled in the *detailed interface* portion of eQUEST's software refrigeration version because this is the only mode that is allowed. As a result, the user is unable to enter SEER, EER, COP or HSPF values but instead may insert a cooling EIR (electric input ratio) and heating EIR. eQUEST defines the EIR, or 1/COP, as the ratio of the electric energy input to the rated capacity, when both the energy input and rated capacity are expressed in the same units.

The equivalent EIR values are generated by setting the applicable efficiency value for the equipment to each of the SEER, EER and HSPF values in Wizard Mode and then converting the model to Detailed Mode to view the new calculated EIR (cooling and heating). As the grocery and refrigerated warehouses do not have a Wizard Mode, another building type (as a sample) was used to generate EIR for each of the size ranges.

Since single packaged units are only specified for some building types and only utilized in specific areas (and not the whole building), only a subset of building types were modeled in eQUEST with the PSZ retrofit, and the savings were applied to similar building types as shown in the following table.

[243] Prototype efficiencies tend to be lower than standard baseline efficiency.

Table 304. Building Types Modeled with HP Measure

Building Types Modeled	Similar Applicable Building Types
Small Office Building	Large Office Building
Small Retail	Mall/Department Store, Grocery
Large Big-Box Retail	
Hotel	Motel
Grocery	
Assembly	
Primary School	
High School/College	University
Hospital	
Full Service Restaurant	
Fast-food Restaurant	
Refrigerated Warehouse	Unrefrigerated Warehouse

Savings:

These savings can be found in the non-residential summary workbook and are listed per ton of cooling, by building type, and TVA weather district.

To calculate savings on a per-ton of cooling basis (see NonRes WS Runs Data.xls):

1. Run baseline and retrofit models.
2. Extract annual cooling and heating end-use category totals in kWh for all baseline and retrofit runs.
3. From SS-D/SS-A report, pull the maximum cooling load and maximum heating load in kBtuh.
4. Assume an oversize factor for the rated capacity of the installed PSZ units (i.e., multiply the maximum cooling load by 1.15 and maximum heating load by 1.25). [244]
5. Convert the oversized cooling and heating load to tons.
6. Extract the peak factor from each measure run (average of top 10 hottest summer and coldest winter hours).
7. Divide the difference of the calculated peak kW savings of cooling and heating (peak kW is annual kWh x peak factor) by the rated cooling capacity and heating capacity, respectively, in tons.

[244] Oversize factors are from ASHRAE Appendix G.

Maximum demand reduction is also calculated using the following equation:[245]

$$EER = (SEER + 1.4) \times 0.778$$

$$kW/ton_{EER}, \text{demand reduction} = \frac{12}{EER_{existing}} - \frac{12}{EER_{new}}$$

$$COP = (HSPF + 2.4) / 3.2$$

$$\text{Demand reduction; kW/ton} = \left[\frac{12}{COP_{existing}} - \frac{12}{COP_{new}}\right] \times \left(\frac{1}{3.412}\right)$$

Table 305. Heat Pump Demand Reduction

Type	CEE - Tier 1	CEE - Tier 2
Cooling	0.00*	0.13*
Heating	0.04*	0.07*

Measure Life:

15 years (2008 DEER)

6.2.3 Package Terminal Air Conditioners and Heat Pumps

Sources:

ASHRAE Standard 90.1-2007, Energy Standard for Buildings except Low-Rise Residential Buildings

Database for Energy Efficiency Resources, www.deeresources.com (DEER 2005 and 2008)

International Energy Conservation Code (IECC 2006 and 2009)

245 We use SEER for units 5.4 tons or less, and EER for all other sizes. The SEER to EER conversion is from the DOE 2 calculation of cooling electrical input ratio and has been empirically derived to match the ARI-created SEER ratings.

Measure Description:

PTACs and PTHPs are through-the-wall self-contained units that are 2 tons (24,000 Btuh) or less. Under this measure, older PTACs/HPs are replaced with new units that have rated efficiencies 20% greater than industry-standard units (IECC 2006 and 2009).

Assumptions:

The new higher efficiency PTAC/HP units are assumed to be 20% more efficient than the industry-standard units, which are defined as meeting IECC 2006 and 2009 guidelines.[246] All EER values must be rated at 95°F outdoor dry-bulb temperature.[247]

The IECC 2006 guidelines require the unit efficiency to be calculated according to the following equation:[248]

$$\text{EER (IECC baseline)} > 10.9 - \left(\frac{0.213 \times \text{Capacity in Btuh}}{1000}\right)$$

$$\text{ForPTHPonly}$$

$$\text{COP (IECCbaseline)} > 2.9 - \left(\frac{0.026 \times \text{Capacity in Btuh}}{1000}\right)$$

For this work paper, we assumed that efficient PTAC and PTHP units are 20% more efficient than the IECC 2006 baseline, which corresponds to the following equation:

$$\text{EER (efficient retrofit)} > 13.08 - \left(\frac{0.2556 \times \text{Capacity in Btuh}}{1000}\right)$$

$$\text{ForPTHPonly}$$

$$\text{COP(efficientretrofit)} > 3.48 - \left(\frac{0.0312 \times \text{Capacity in Btuh}}{1000}\right)$$

Both qualifying efficiency levels and baseline efficiencies are based on the capacity of the unit output. The following table provides the efficiencies for a range of PTAC/HP sizes.

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[246] The IECC 2009 standards did not change from 2006.

[247] For new construction, minimum efficiency is higher per IECC.

[248] PTHP have a slightly lower baseline of 10.8 – (0.213xCap/1000).

Table 306. PTAC/HP Efficiencies

Capacity (Btuh)	Baseline EER	Retrofit EER	Baseline COP	Retrofit COP
6,000	9.6	11.5	2.7	3.3
7,000	9.4	11.3	2.7	3.3
8,000	9.2	11.0	2.7	3.2
9,000	9.0	10.8	2.7	3.2
10,000	8.8	10.5	2.6	3.2
11,000	8.6	10.3	2.6	3.1
12,000	8.3	10.0	2.6	3.1
13,000	8.1	9.8	2.6	3.1
14,000	7.9	9.5	2.5	3.0
15,000	7.7	9.2	2.5	3.0
16,000	7.5	9.0	2.5	3.0
17,000	7.3	8.7	2.5	2.9
18,000	7.1	8.5	2.4	2.9

For the purposes of calculating savings, we assumed a baseline cooling efficiency of 8.24 EER and baseline heating efficiency of 2.58 COP. For the retrofit case, a cooling efficiency of 9.89 EER and a heating efficiency of 3.09 COP were assumed. On average, the efficiencies are for a 12,488 Btuh (~1-ton) unit. The savings calculations were performed by utilizing DOE-2 models utilizing eQUEST software, with the above assumptions and variable values utilized for the baseline and efficient conditions. The measure savings values are the difference between baseline and retrofit energy use (heating and/or cooling end-uses; PTAC/PTHP energy use is not associated with ventilation end-usage) estimates and are normalized to a per-ton basis.

For building types that do not include PTACs/HPs in the prototypical model, certain zones were modeled to be cooled utilizing a PTAC/HP of baseline efficiency compared with PTAC/HP of retrofit EER efficiency. Since PTAC/HPs are utilized in specific areas (and not the whole building), only a subset of building types were modeled in eQUEST with the PTAC/HP retrofit, and the savings were applied to similar building types as shown in the following table. Alternatively, savings for building types not modeled can be calculated using equivalent full-load hours and the coincident diversity factor for HVAC, as shown in Appendix Section 3.

Table 307. Building Types Modeled with PTAC/HP Measure

Building Types Modeled	Similar Applicable Building Types
Small Office Building	Large Office Building
Motel	Hotel
Small Retail	Single-Story, Large, Mall/Department Store, Grocery
Assembly	
Hospital/Medical	
Fast-food Restaurant	Full Service Restaurant
Unrefrigerated warehouse	Refrigerated Warehouse
High School/College	University
Primary School	

Savings:

These savings can be found in the non-residential measures workbook and are listed per ton of cooling, by building type, and TVA weather district.

Maximum demand reduction is also calculated using the following equation:[249]

$$\text{Summer kW/ton, demand reduction} = \frac{12}{EER_{existing}} - \frac{12}{EER_{new}} = 0.23\text{kW/ton}$$

$$\text{Winter kW/ton, demand reduction} = \frac{12}{COP_{existing} \times 3.412} - \frac{12}{COP_{new} \times 3.412} = 0.24\text{ kW/ton}$$

Measure Life:

15 years (2005 DEER)

[249] We use SEER for units 5.4 tons or less, and EER for all other sizes.

6.2.4 Variable Speed Drives (VSDs) on HVAC Motors

Sources:

Database for Energy Efficiency Resources (DEER 2008)

Measure Description:

This applies to VSDs installed on existing HVAC motors up to 200 Hp. The installation of a VSD must accompany the permanent removal or disabling of any flow control devices, such as inlet vanes, bypass dampers, and throttling valves. This measure applies only to VSDs installed with an automatic control technology. This measure does not apply to the following existing equipment or conditions:

- Chillers
- Redundant or backup/standby motors that are expected to operate less than 1,200 operating hours per year
- Variable pitch fans and forward curve with inlet guide vanes unless applicant supplies proof of kWh savings from logged or measured data
- Replacement of a multi-speed motor

Assumptions:

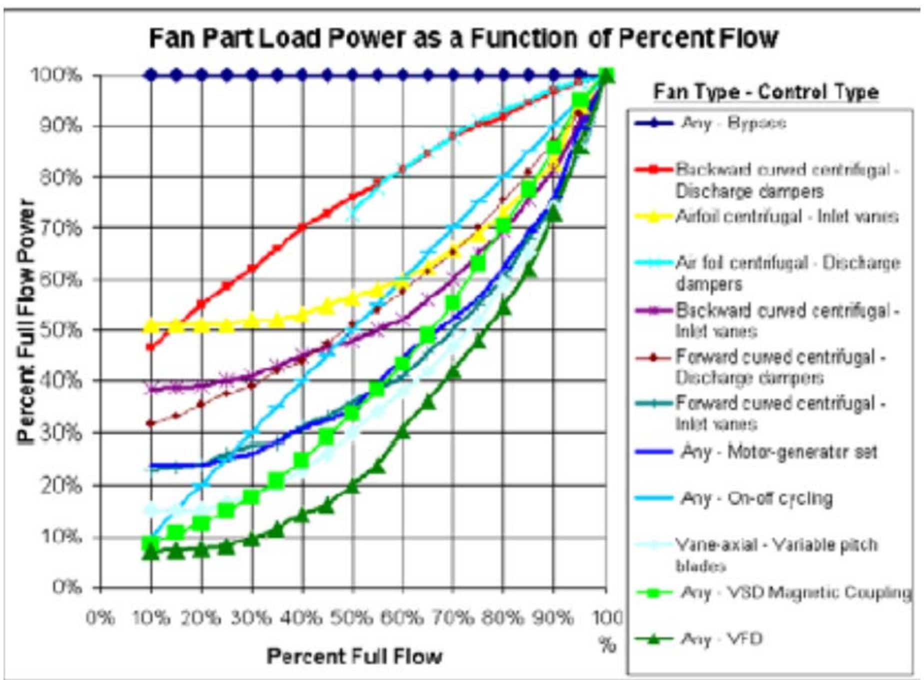
The HVAC motor savings applications are based on the large office building type (eQUEST model prototype) utilizing a 300 ton centrifugal chiller because of the historical predominance of this building in applications for this measure. To calculate the savings by building type, the large office building savings value is multiplied by a ratio of operating hours of the other building type and large office for the specific fan and pump application. Cooling tower fan and chilled (condenser) water pump run hours are assumed to be the same as chiller run hours. In order to directly compare HVAC equipment run hours, eQUEST model prototype buildings with 300 ton centrifugal chiller baseline models were used in place of the TVA prototypical models, which have varying HVAC system types. The following table shows the pre-retrofit conditions for the five VSD applications.

Table 308. Pre-Retrofit Conditions for VSD Applications

Motor Type	Pre-Retrofit
Supply/Return Fan	VAV with inlet guide vanes/airfoil (backward inclined)
Chilled Water Pump	Throttle, no secondary loop
Hot Water Pump	Throttle, no secondary loop
Condenser Water Pump	Constant speed
Cooling Tower Fan	Single speed

KEMA recognizes that there are multiple HVAC fan and control type combinations to consider when assessing savings for the application of VSDs on HVAC fans. The figure below illustrates the percent of power input against percent flow for 12 HVAC fan and control types. KEMA chose to model the VAV with inlet guide vanes/airfoil (backward inclined) supply/return fan system type (purple line) as the curve of percent flow versus percent power for this fan and control type is in the middle of the range for the various air-side HVAC system fan options and thus saving for this fan and control type will be near the middle of the range for these HVAC systems.

Figure 2. Fan Part Load Power as a Function of Percent Flow[250]



Other specifics of the fan modeling include:

- A 1.30 sizing ratio applied to the fan supply volume and the coil size
- Fan power - 0.0006 kW/cfm based off a standard 25,000 CFM size fan (source is Greenheck manufacturer)

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250 How to avoid overestimating Variable Speed Drive Savings, by J.B. Maxwell, Proceedings of the Twenty-seventh Industrial Energy Technology Conference, May 2005, ESL-IE-05-05.

- AF-Fan-w/Vanes default eQUEST fan performance curve
- Fan-Pwr-fPLR-w/VFD generalized fan curve modeled

Savings:

The average annual kWh savings can be found in the non-residential summary workbook and are listed per horsepower, by building type, and by TVA weather district. The summer and winter peak kW savings per horsepower can be found in VSD for HVAC Motors.xlsx, listed by motor type and TVA weather district.

KEMA savings calculations were modeled using eQUEST 3.64. The process for calculating the kWh/HP savings from the installation of variable speed control for each pre-retrofit case is outlined in the list below.

To calculate savings on a per horsepower basis (see the VSD runs data workbook):

1. Run baseline and retrofit models (KEMA modeled the large office building type).
2. Extract total end-use energy in kWh for all baseline and retrofit runs.
3. Subtract the total end-use energy of the retrofit runs from the baseline runs to calculate the difference in total end-use energy.
4. From SV-A or PS-C reports, pull the peak electric use in kW the total annual run hours for the HVAC fan or pump motors.
5. Convert the peak electric use into rated horsepower for each fan or pump motor using the equation below. The LF (load factor) is assumed to be 0.75.

$$\text{Rated motor HP} = \frac{\text{kW}_{\text{eQuest}} \times \text{motor efficiency}}{\frac{0.746\ \text{kW}}{\text{HP}} \times \text{LF}}$$

6. Divide the difference in total end-use energy by the rated motor horsepower to calculate the kWh savings per horsepower.
7. Extract the peak factor from each measure run (average of top 10 hottest summer and coldest winter hours).
8. Calculate the summer and winter peak demand savings by taking the difference of the product of total end-use energy and whole building peak factors for the baseline and retrofit runs. Refer to the equation below:

Peak kW savings = [total end-use energy x whole building peak factor]$_{baseline}$ -[total end-use energy x whole building peak factor]$_{retrofit}$

9. Calculate kW savings per horsepower by dividing the total peak demand savings by the previously calculated rated motor horsepower.

To apportion energy savings to other building types follow steps 10 and 11.

10. Run the 300 ton centrifugal chiller baseline model for the desired building type and pull the total annual run hours for the HVAC fan or pump motors from the SV-A or PS-C reports in the .SIM file.
11. Multiply the previously calculated kWh savings per HP of each motor by the ratio of total annual run hours of each motor for the desired building type to the building type modeled with the VSD retrofits (KEMA modeled the large office building type). Refer to the equation below:

$$\text{Annual kWh savings}_{\text{building type}} = \text{Annual kWh savings}_{\text{large office}} \times \left[\frac{\text{RunHours}_{\text{building type}}}{\text{RunHours}_{\text{large office}}}\right]$$

Measure Life:

15 years (2008 DEER)

Attachment:

TVA - VSD for HVAC Motors.xlsx

6.2.5 Non-Residential Refrigerant Charge

Sources:

Mowris, Blankenship, Jones. "Field Measurements of Air Conditioners with and without TXVs.". ACEEE Summer Study Proceedings, 2004.

Wulfinghoff, Donald. "Energy Efficiency Manual." 1999.

Measure Description:

This measure consists of ensuring AC systems are charged correctly. A refrigerant charge and airflow (RCA) test is typically conducted. If the charge level is too low or high, or if the supply airflow is outside the OEM specified range (usually 350 to 450 cfm/ton), a technician performs the necessary corrections.

An air conditioner will not operate at optimum efficiency with too much or too little refrigerant in the lines. Both the unit EER and cooling capacity suffer if the refrigerant charge is too low or too high. When the refrigerant charge is too low, evaporator capacity is reduced and the average evaporator temperature differential increases, which causes the compressor to work harder to satisfy the same cooling load. If there is too much refrigerant in the system, the excess may be in a liquid rather than vapor state and result in a reduced EER value compared with the rated EER of the system.

Assumptions:

The Mowris, Blankenship, and Jones study found that the average energy savings for correcting RCA is 12.6% of the baseline compressor annual energy use. The 12.6% energy savings corresponded to a baseline condition of approximately 20% out of charge (both overcharge and undercharge).

Also, peak kW savings were determined to be 0.32 kW for units with an average capacity of approximately 4 tons.[251]

Savings:

The savings for this measure are calculated using the following formulas:

$$\text{Annual Energy Saved (kWh/ton)} = \frac{12.6\% \times \text{Annual Compressor Energy (kWh)}}{\text{Cooling Capacity (tons)}}$$

$$\text{Demand Savings (kW)} = \text{Annual Energy Savings (kWh/ton)} \text{ x Peak Load Shape Factor for Cooling End Use}$$

The annual compressor energy use (kWh) value can be obtained from the eQUEST models and varies by building type and weather district. For building types that have only direct-expansion coil (DX type) HVAC units, the 8,760 hours output cooling end-use total is the sum of the annual compressor energy usages. Individual annual compressor energy uses had to be summed from the SS-P report (cooling performance summary by component) for the following buildings that had non-DX type HVAC units: Grocery, High School/College (Gas Heating #1 and #2), Hospital (Gas Heating #1 and #2), Hotel (Gas Heating #2 and #3), and Refrigerated Warehouse (Electric and Gas Heating). Cooling loads (capacities) were extracted from the model's associated SIM file in the SS-D/SS-A report for all building types.

[251] Study completed field measurements of refrigerant charge and airflow over a three-year period across 4,168 split, packaged, and heat pump air conditioners.

Measure savings can be found in the non-residential summary workbook and are listed by building type and TVA weather district. The annual compressor energy (kWh) and peak load shape factors for cooling end use can be found in NonRes WS Runs Data.xls.

Measure Life:

10 years (2008 DEER)

6.2.6 Non-Residential Duct Sealing

Sources:

Database for Energy Efficiency Resources (DEER) 2008

Modera and Proctor. "A Campaign to Reduce Light Commercial Peak Load in the Southern California Edison Service Territory through Duct Sealing and A/C Tune-ups." October 2002.

California Building Energy Efficiency Standards (Title 24).

Measure Description:

This measure seeks to minimize air leakage in air-conditioning supply and return air-system ducts located in unconditioned spaces. When ducts are not sealed properly, conditioned air escapes to unconditioned spaces, forcing the HVAC system to work harder and longer. The measure described in this work paper assumes the duct is sealed to allow no more than a 15% leakage rate.

Assumptions:

The study conducted by Modera and Proctor (2002) found the average leakage before sealing was 92 cfm/ton with an average fan flow of 325 cfm/ton. This corresponds to an average 28% baseline condition leakage rate.

California Title 24[252] requires that ducts leaking 15% or more must be repaired to reduce leaks. Therefore, we assume the retrofit condition of 15% leakage.

[252] 2005 California Building Energy Efficiency Standards. http://www.energy.ca.gov/title24/2005standards/index.html.

The savings calculations are performed through DOE-2 simulations utilizing eQUEST software, with the above leakage rates as baseline (28%) and retrofit (15%) conditions. The measure savings are the difference between baseline and retrofit energy-use estimates.

Savings:

The analysis is modeled by revising the prototype buildings' air-side HVAC system parameters in eQUEST's *detailed* mode to have a "duct air loss" ratio of 0.28 (the eQUEST default is zero duct air loss); this is the baseline model. The retrofit model is defined to have 15% (duct air loss ratio of 0.15) supply air lost (leaking) from the ductwork. Supply air lost from the ductwork reduces the design supply air to the zones. Consequently, the air lost from the ductwork will change the temperature of the zone specified; therefore, the system will require more cooling. This zone must be a plenum or unconditioned space in eQUEST software.

Additionally, in the same air-side HVAC system parameters window of eQUEST, the "air loss type" parameter is adjusted to be proportional, meaning that the duct air loss will vary in proportion to the air flow through the system. These revisions are made for each of the HVAC systems modeled in each building. Due to eQUEST limitations in modeling duct sealing, this measure can be applied only to the building types that have plenum spaces and have a ducted HVAC system installed. As a result of these limitations, the following buildings do NOT include duct sealing as a measure: large big-box retail, unrefrigerated/refrigerated warehouse and grocery (no plenum spaces), and motel (ductless PTAC units installed).

Due to only a subset of building types being modeled in eQUEST's duct-sealing measure, the savings can be applied only to similar building types. Large big-box retail and motel buildings, small retail and hotel, respectively, are the applicable building types for this measure.

To calculate savings on a per-ton of cooling basis (see NonRes WS Runs Data.xls):

1. Run baseline and retrofit models.
2. Extract annual end-use category totals in kWh for all baseline and retrofit runs: Heating, cooling, and ventilation fans.
3. From SS-D/SS-A report, pull the maximum cooling load and maximum heating load in kBtuh. (See beginning of section for overview of SS-D/SS-A report use)
4. Assume an oversize factor for the rated capacity of the installed HVAC units (i.e., multiply the maximum cooling load by 1.15 and maximum heating load by 1.25). [253]

[253] Oversize factors are from ASHRAE Appendix G.

5. Convert the oversized cooling and heating load to tons.
6. Extract the peak factor from each measure run (average of top 10 hottest summer and coldest winter hours).
7. Divide the difference of the calculated peak kW savings of cooling and heating (peak kW is annual kWh x peak factor) by the average rated cooling capacity and heating capacity of the baseline and retrofit, respectively, in tons.

Measure savings can be found in the non-residential summary workbook and are listed by building type and TVA weather district.

Measure Life:

18 years (2008 DEER)

6.2.7 Non-Residential Economizer-Retrofit and Repair

Sources:

Database for Energy Efficiency Resources (DEER) 2008, www.deeresrouces.com

Measure Description:

This measure refers to air-side economizers, which save energy in buildings by using cool outside air to cool the indoor space. When the enthalpy[254] of the outside air is less than the enthalpy of the recirculated air, conditioning the outside air is more energy efficient than conditioning recirculated air. When the outside air is both sufficiently cool and sufficiently dry (depending on the climate), the amount of enthalpy in the air is acceptable, and so no additional conditioning of the outside air is needed. This portion of the air-side economizer control scheme is called *free cooling*. The economizer allows the building to use the outside air, without mechanical conditioning, to cool the space at the right conditions. The economizer opens and closes its dampers according to control specifications.

The addition of air economizers can significantly reduce cooling energy use by utilizing cool outside air instead of mechanical cooling to meet cooling loads whenever possible. This measure also includes savings estimates associated with repairing economizers that are no longer functioning correctly or optimally.

[254] Enthalpy refers to the amount of energy, heat, and pressure of a given system. In this case, the system is the outside air.

Assumptions:

The following table summarizes measure assumptions and variable values.

Table 309. Economizer Measure Assumptions

Outside Air Conditions	Baseline Condition: Retrofit	Baseline Condition: Repair	Efficient Condition: Economizer Retrofit and Repair
Maximum Outside Air (OSA) Fraction	No economizer	60%	100%
Maximum Dry Bulb Temperature		55°F	68°F

The savings calculations are performed by utilizing DOE-2 models generated by eQUEST software, with the above assumptions and variable values utilized for the baseline and efficient conditions. The enthalpy high limit is defaulted to 30 Btu/lb for all cases. This is the maximum allowable outside air enthalpy for which the economizer is enabled. The outside air dampers will return to their minimum position, which is always above the 30 Btu/lb value. The measure savings values are the difference between baseline and retrofit energy-use estimates.

Savings:

To calculate savings on a per-ton of cooling basis (see NonRes WS Runs Data.xls):

1. Run baseline and retrofit models.
2. Extract annual cooling and ventilation fan end-use category totals in kWh for all baseline and retrofit (measure) runs.
3. From SS-D/SS-A report, pull the maximum cooling load in kBtuh. (See beginning of section for overview of SS-D/SS-A report use)
4. Assume an oversize factor for the rated capacity of the installed HVAC units (i.e., multiply the maximum cooling load by 1.15).[255]
5. Convert the oversized cooling load to tons.
6. Extract the peak factor from each measure run (average of top 10 hottest summer hours).

[255] Oversize factors are from ASHRAE Appendix G.

7. Divide the difference of the calculated peak kW savings of cooling (peak kW is annual kWh x peak factor) by the rated cooling capacity.

These savings are reported by tons served and can be found in the non-residential summary workbook where they are listed by building type[256] and TVA weather district. The measure is not expected to result in peak demand savings.

In order to accurately simulate the economizer parameters listed in the table above, the model was converted to the *detailed interface* mode in eQUEST to enter the maximum outside air fraction for the economizer. In the air-side HVAC system parameters window of eQUEST, the "Outdoor Air - Vent & Economizer" window was selected. In this window, the economizer type (Outside Air Control parameter), dry-bulb high limit, enthalpy high limit, and maximum outside air (OSA) fraction can be specified for each of the systems. Separate models were calibrated for the baseline economizer repair condition and the economizer repair and retrofit efficiency measure, with the respective parameters defined.

Measure Life:

5 years for repairing an existing economizer and 10 years for installing a new economizer (2008 DEER).

6.2.8 Cool Roof

Sources:

Database for Energy Efficiency Resources (DEER 2008)

Measure Description:

This measure applies to low-slope roofs on an existing non-residential building. The cool roof must have an initial thermal emittance greater than or equal to 0.70 and a maximum initial solar absorbance of less than or equal to 0.30 (or reflectance greater than or equal 0.70). The roofing products must be tested and labeled by the Cool Roofing Rating Council (CRRC). The cool roof must be installed over a mechanically cooled space.

[256] This measure was not applicable for the unrefrigerated warehouse, as this building does not have any cooling or OSA system installed.

Assumptions:

The cool roof savings calculations are based on DOE-2.2 simulations of the prototypical building eQUEST models developed for TVA. The existing roof absorbance values modeled are from the prototypical models, and range from 0.60 to 0.88 depending on the building type and shell component. The cool roof is assumed to have a solar absorbance of 0.30 (white, semi-gloss). The energy and demand savings are normalized per one thousand square feet of cool roof area.

Table 310. Existing Prototypical Model Variable Values

Building Type	Roof U-Value	Roof Absorbance	Roof Reflectance
Small Office Building	0.053	0.6	0.4
Small Retail Building	0.053	0.88	0.12
Large Big Box Retail	0.055	0.8	0.2
Mall Department Store	0.05	0.6	0.4
Assembly	0.057	0.8	0.2
School-Primary	0.057	0.8	0.2
High School/College	0.07	0.6	0.4
University	0.057, 0.082	0.60	0.4
Full Service Restaurant	0.061	0.8	0.2
Fast-food Restaurant	0.061	0.8	0.2

Savings:

The average annual kWh savings can be found in non-residential summary workbook and are listed per thousand square feet of cool roof area, by building type, and by TVA weather district. The summer and winter peak kW savings can be found in TVA - Cool Roof Savings.xlsx, listed per thousand square feet of cool roof area, by building type, and by TVA weather district.

KEMA savings calculations were modeled using eQUEST 3.64. The process for calculating the kWh/1,000 sq. ft savings from the installation of a cool roof for each pre-retrofit case is outlined in the list below (see cool roof runs data workbook):

1. Create a retrofit model by changing the baseline prototypical model roof absorbance value to 0.30.
2. Run baseline and retrofit models.
3. Extract total end-use energy in kWh for the baseline and retrofit runs.
4. Subtract the total end-use energy of the retrofit run from the baseline run to calculate the difference in total end-use energy.

5. From LV-D report, pull the total square feet of cool roof area.
6. Divide the difference in total end-use energy by the quotient of total square feet of roof area over 1,000 to calculate the kWh savings per 1,000 square feet of cool roof area. Refer to the equation below:

$$\text{Annual kWh savings} = \frac{\text{total end use energy}_{\text{baseline}} - \text{total end use energy}_{\text{retrofit}}}{\left[\frac{\text{total square feet of cool roof area}}{1,000}\right]}$$

7. Extract the peak factor from each measure run (average of top 10 hottest summer and coldest winter hours).
8. Calculate the summer and winter peak demand savings by taking the difference of the product of total end-use energy and whole building peak factors for the baseline and retrofit runs. Refer to the equation below:

$$\text{Peak kW savings} = [\text{total end use energy x whole building peak factor}]_{\text{baseline}} - [\text{total end use energy x whole building peak factor}]_{\text{retrofit}}$$

9. Calculate kW savings per 1,000 square feet of roof area by dividing the total peak demand savings by the quotient of total square feet of roof area over 1,000.

Table 311. Average Annual kWh Savings (per 1,000 sf. of Roof)

Building Type	Chattanooga	Huntsville	Knoxville	Memphis	Nashville	Average
Assembly	145	128	132	144	125	135
Fast-food Restaurant	244	202	216	234	214	222
Full Service Restaurant	286	250	256	269	253	263
HS/College	214	166	-44	210	176	145
Large Retail	539	406	538	473	443	480
Mall Department Store	198	164	195	172	170	180
Primary School	352	295	304	337	316	321
Small Office	107	82	83	119	93	97
Small Retail	193	222	250	296	250	242
University	130	114	127	121	123	123

Measure Life:

15 years (2008 DEER)

Attachment:

TVA - Cool Roof Savings.xlsx

6.2.9 Reflective Window Film

Sources:

Database for Energy Efficiency Resources (DEER 2008)

Measure Description:

This measure applies to window film installed to reduce the solar heat gain through the affected window. Windows with a northern exposure (+/- 45 degree of true north) are not eligible. The savings are calculated per square foot of non-north-facing windows. The film must meet one of the following requirements:

- For clear, single-pane glass, the solar heat gain coefficient (SHGC) of the window film must be less than 0.39
- For clear, double-pane glass, the SHGC of the window film must be less than 0.25
- For applications that do not meet either of the previous requirements, the film must have a SHGC <= 0.47 and a visible transmittance/solar heat gain coefficient (VT/SHGC) ratio of 1.3

Assumptions:

The reflective window film measure savings calculations are based on DOE-2.2 simulations of the prototypical building eQUEST models developed for TVA. The existing single-pane (SP) windows modeled are from the prototypical models and have a U-factor of 1.23, a SHGC of 0.82, and VT of 0.90. The existing double-pane windows modeled have a U-factor of 0.55, a SHGC of 0.76, and a VT of 0.81. For the application of reflective window film on existing single-pane windows, the window is assumed to have a SHGC of 0.39 or 0.47 and a VT of 0.60 or 0.61 (as shown in the two options in the following table). For the application of reflective window film on existing double-pane (DP) windows, the window is assumed to have a SHGC of 0.25, and a VT of 0.25. These values are summarized in the following table.

Table 312. Reflective Window Film Variables

Window Variable	SP Baseline	SP Window Film	SP Window Film Alternative	DP Baseline	DP Window Film
U-Factor	1.23	1.23	1.23	0.55	0.55
SHGC	0.82	0.39	0.47	0.76	0.25
VT	0.90	0.60	0.61	0.81	0.25
VT/SHGC	1.10	1.54	1.30	1.07	1.00

Savings:

The average annual kWh savings can be found in the non-residential summary workbook and are listed per square foot of reflective window film area, by building type, and by TVA weather district. The summer and winter peak kW savings can be found in TVA - Window Film Savings.xlsm, listed per square foot of window area, by building type, and by TVA weather district.

KEMA savings calculations were modeled using eQUEST 3.64. The process for calculating the kWh/sqft savings from the installation of reflective window film for each pre-retrofit case is on a per square foot basis (see window film runs data workbook) and outlined in the list below:

- Create a double-pane baseline model by changing the window U-factor, SHGC, and VT values from the baseline values to 0.55, 0.76, and 0.81 respectively
- Create a single-pane reflective window film model by changing the single-pane baseline window SHGC, and VT values to 0.39 , and 0.60 respectively, for all windows on South, East, and West-oriented facades
- Create an alternative single-pane reflective window film model by changing the single-pane baseline window SHGC, and VT values to 0.47, and 0.61 respectively, for all windows on South, East, and West-oriented facades
- Create a double-pane reflective window film model by changing the double-pane baseline window SHGC, and VT values to 0.25, and 0.25 respectively, for all windows on South, East, and West-oriented facades
- Run baseline and retrofit models
- Extract total end-use energy in kWh for the baseline and retrofit runs
- Subtract the total end-use energy of the retrofit run from the baseline run to calculate the difference in total end-use energy
- From LV-H report, pull the square feet of window glass area for South, East, and West-oriented facades

- Divide the difference in total end-use energy by the square feet of retrofitted window glass area to calculate the kWh savings per square foot of retrofitted window glass area. Refer to the equation below:

$$\text{Annual kWh savings} = \frac{\text{total end use energy}_{\text{baseline}} - \text{total end use energy}_{\text{retrofit}}}{\text{square feet of retrofitted window glass area}}$$

- Extract the peak factor from each measure run (average of top 10 hottest summer and coldest winter hours)
- Calculate the summer and winter peak demand savings by taking the difference of the product of total end-use energy and whole building peak factors for the baseline and retrofit runs. Refer to the equation below:

$$\text{Peak kW savings} = [\text{total end use energy x whole building peak factor}]_{\text{baseline}} - [\text{total end use energy x whole building peak factor}]_{\text{retrofit}}$$

- Calculate kW savings per square foot of retrofitted window glass area by dividing the total peak demand savings by the total square feet of retrofitted window glass area

The results for the large office-building type were not as expected and may be a function of the modeling software algorithms handling a high window-to-wall ratio. Regardless, the KEMA team decided to use an alternate approach for this building type. Annual energy savings were determined by applying an average savings factor to the large office building baseline consumption. This savings factor was calculated from the annual kWh savings as a percent of the baseline, averaged over all heating and building types, except the large office, for each climate zone and baseline case (single or double-pane). Step 9 from the savings calculation list above was applied to this annual energy savings for the large office to produce annual kWh savings per square foot of retrofitted glass area. To calculate peak savings, this kWh savings per square foot value was then multiplied by the baseline model summer or winter peak savings factors.

The savings across the single pane and double pane baselines are summarized in the following tables.

Table 313. Annual kWh Savings (per Square Foot) for Reflective Window Film Applied to Existing Single-Pane Windows

Building Type	Chattanooga	Huntsville	Knoxville	Memphis	Nashville	Average
Assembly	9.4	8.7	9.5	9.5	7.2	8.9
Fast-food Restaurant	7.9	7.0	6.5	8.7	7.6	7.6
Full Service Restaurant	7.4	7.2	6.4	10.2	7.3	7.7
Hospital	21.2	20.8	31.9	18.8	16.9	21.9
Hotel	15.4	15.0	5.1	14.8	14.0	12.9
HS/College	13.0	8.4	8.4	13.4	13.7	11.4
Large Office	17.8	14.8	13.4	19.7	19.1	16.9
Large Retail	10.0	8.7	8.9	10.5	9.0	9.4
Mall Department Store	19.1	11.1	11.7	12.5	11.3	13.1
Motel	1.4	0.0	-1.1	1.1	-0.1	0.2
Primary School	9.7	9.4	6.3	10.8	9.6	9.2
Small Office	5.9	4.4	4.4	7.0	5.2	5.4
Small Retail	7.5	4.2	7.3	9.5	8.5	7.4
University	21.5	20.0	16.4	21.7	30.3	22.0

Table 314. Annual kWh Savings (per Square Foot) for Alternative Reflective Window Film Applied to Existing Single-Pane Windows

Building Type	Chattanooga	Huntsville	Knoxville	Memphis	Nashville	Average
Assembly	7.7	7.3	8.1	7.7	7.4	7.6
Fast-food Restaurant	6.6	6.0	5.5	7.2	7.0	6.5
Full Service Restaurant	6.2	5.9	5.2	8.7	5.9	6.4
Hospital	17.1	17.0	16.7	15.1	13.1	15.8
Hotel	11.4	14.9	4.9	12.9	7.1	10.2
HS/College	10.8	6.3	6.5	11.1	11.5	9.3
Large Office	14.7	12.5	11.9	16.1	16.3	14.3
Large Retail	7.7	7.2	7.2	8.3	7.4	7.6
Mall Department Store	16.4	9.1	9.7	10.3	9.0	10.9
Motel	1.4	0.4	-0.5	0.7	0.2	0.4
Primary School	8.0	7.7	7.0	8.9	8.1	7.9
Small Office	4.9	3.9	3.9	6.0	4.7	4.7
Small Retail	6.1	3.0	6.1	7.1	5.7	5.6
University	17.7	16.5	16.9	18.0	30.8	20.0

Table 315. Annual kWh Savings (per Square Foot) for Reflective Window Film Applied to Existing Double-Pane Windows

Building Type	Chattanooga	Huntsville	Knoxville	Memphis	Nashville	Average
Assembly	12.0	11.9	10.9	12.8	11.6	11.8
Fast-food Restaurant	9.9	11.3	10.5	11.8	10.0	10.7
Full Service Restaurant	8.8	9.0	8.0	10.3	9.1	9.0
Hospital	24.8	31.5	26.7	22.8	23.6	25.9
Hotel	17.4	14.6	11.4	20.6	15.2	15.8
HS/College	6.7	11.1	9.4	16.6	14.7	11.7
Large Office	18.1	19.0	16.8	24.4	21.4	20.0
Large Retail	11.5	10.2	10.5	12.3	10.6	11.0
Mall Department Store	21.1	15.4	17.7	17.5	14.3	17.2
Motel	-0.4	1.4	-2.6	2.9	1.7	0.6
Primary School	12.2	9.8	8.5	13.5	11.4	11.1
Small Office	8.0	7.1	6.9	9.9	7.6	7.9
Small Retail	9.7	6.2	9.0	11.0	9.3	9.0
University	11.5	24.1	23.3	25.7	23.4	21.6

Measure Life:

10 years (2008 DEER)

Attachment:

TVA - Window Film Savings.xlsm

6.2.10 High-Efficiency Windows

Sources:

Database for Energy Efficiency Resources (DEER 2008)

Measure Description:

This measure applies to existing single-pane windows with a U-factor of 1.23 or higher and a SHGC of 0.82 or higher, or to existing double-pane window with a U-factor of 0.55 or higher and a SHGC of 0.76. Eligible window replacements must be National Fenestration Rating Council (NFRC) certified and meet or exceed the following criteria:

- U-factor ≤ 0.30
- SHGC ≤ 0.33

Assumptions:

The high efficiency window measure savings calculations are based on DOE-2.2 simulations of the prototypical building eQUEST models developed for TVA. The existing single-pane windows modeled are from the prototypical models, and have a U-factor of 1.23, a SHGC of 0.82, and a visible transmittance (VT) of 0.90. The existing double-pane windows modeled have a U-factor of 0.55, a SHGC of 0.76, and a VT of 0.81. The high-efficiency window is assumed to have a U-factor of 0.30, a SHGC of 0.33, and a VT of 0.50. These values are summarized in the following table.

Table 316. High-Efficiency Window Variables

Window Variable	SP Baseline	DP Baseline	HE Window
U-Factor	1.23	0.55	0.3
SHGC	0.82	0.76	0.33
VT	0.90	0.81	0.50
VT/SHGC	1.10	1.07	1.52

Savings:

The average annual kWh savings can be found in the non-residential summary workbook and are listed per square foot of high efficiency window pane area, by building type, and TVA weather district. The summer and winter peak kW savings can be found in TVA - HE Window Savings.xlsm, listed per square foot of window area, by building type, and TVA weather district.

KEMA savings calculations were modeled using eQUEST 3.64. The process for calculating the kWh/sqft savings from the installation of high efficiency windows for each pre-retrofit case is outlined in the list below.

To calculate savings on a per square foot basis (see HE Window Savings.xlsx):

1. Create a double-pane baseline model by changing the window U-factor, SHGC, and VT values from the baseline values to 0.55, 0.76, and 0.81 respectively.
2. Create a high efficiency window model by changing the window U-factor, SHGC, and VT values to 0.30, 0.33, and 0.50 respectively.
3. Run baseline and retrofit models.
4. Extract total end-use energy in kWh for the baseline and retrofit runs.

5. Subtract the total end-use energy of the retrofit run from the baseline run to calculate the difference in total end-use energy.
6. From LV-H report, pull the total square feet of window glass area.
7. Divide the difference in total end-use energy by the total square feet of window glass area to calculate the kWh savings per square foot of window glass area. Refer to the equation below:

$$\text{Annual kWh savings} = \frac{\text{total end use energy}_{\text{baseline}} - \text{total end use energy}_{\text{retrofit}}}{\text{total square feet of window glass area}}$$

8. Extract the peak factor from each measure run (average of top 10 hottest summer and coldest winter hours).
9. Calculate the summer and winter peak demand savings by taking the difference of the product of total end-use energy and whole building peak factors for the baseline and retrofit runs. Refer to the equation below:

Peak kW savings = [total end use energy x whole building peak factor]baseline -[total end use energy x whole building peak factor]retrofit

10. Calculate kW savings per square foot of window glass area by dividing the total peak demand savings by the total square feet of window glass area.

The results for the large office-building type were not as expected and may be a function of the modeling software algorithms handling a high window-to-wall ratio. Regardless, the KEMA team decided to use an alternate approach for this building type. Annual energy savings were determined by applying an average savings factor to the large office building baseline consumption. This savings factor was calculated from the annual kWh savings as a percent of the baseline, averaged over all heating and building types, except the large office, for each climate zone and baseline case (single or double pane). Step 7 from the savings calculation list above was applied to this annual energy savings for large office to produce annual kWh savings per square foot of glass area. To calculate peak savings, this kWh savings per square foot value was then multiplied by the baseline model summer or winter peak savings factors.

The savings across the single pane and double pane baselines are summarized in the following tables.

Table 317. Annual kWh Savings (per Square Foot) for High Efficiency Window Replacing Single-Pane Window

Building Type	Chattanooga	Huntsville	Knoxville	Memphis	Nashville	Average
Assembly	9.4	9.4	9.2	11.3	10.0	9.9
Fast-food Restaurant	8.7	8.8	8.4	10.4	15.1	10.3
Full Service Restaurant	6.1	6.7	6.5	9.5	7.2	7.2
Hospital	23.3	9.7	13.8	15.7	12.9	15.1

Building Type	Chattanooga	Huntsville	Knoxville	Memphis	Nashville	Average
Hotel	33.4	37.2	32.0	34.7	34.6	34.4
HS/College	12.1	10.0	9.5	14.3	14.3	12.1
Large Office	22.5	22.6	21.9	25.8	28.6	24.3
Large Retail	6.7	6.7	6.5	7.8	6.9	6.9
Mall Department Store	9.3	7.8	8.3	10.5	8.6	8.9
Motel	12.4	13.0	13.3	12.4	14.3	13.1
Primary School	9.2	9.4	7.6	10.9	9.7	9.4
Small Office	10.5	11.3	11.3	12.1	12.2	11.5
Small Retail	8.3	5.9	9.0	10.4	9.5	8.6
University	15.5	14.8	16.1	17.6	26.6	18.1

Table 318. Annual kWh Savings (per Square Foot) for High-Efficiency Window Replacing Double-Pane Window

Building Type	Chattanooga	Huntsville	Knoxville	Memphis	Nashville	Average
Assembly	8.4	8.4	8.1	9.5	8.7	8.6
Fast-food Restaurant	8.7	8.9	8.4	9.8	14.4	10.0
Full Service Restaurant	6.4	6.6	6.1	7.6	6.7	6.7
Hospital	13.6	13.7	14.7	14.5	13.9	14.1
Hotel	18.9	17.2	14.4	19.6	18.2	17.6
HS/College	4.5	9.2	7.2	13.0	11.5	9.1
Large Office	14.3	15.4	14.1	18.6	18.8	16.2
Large Retail	7.3	6.7	6.6	7.8	6.8	7.0
Mall Department Store	11.0	9.0	10.3	10.7	9.4	10.1
Motel	3.2	5.5	2.7	5.4	6.1	4.6
Primary School	8.7	7.0	6.4	9.9	8.4	8.1
Small Office	7.0	7.0	6.7	8.2	7.5	7.3
Small Retail	7.6	4.7	7.6	9.0	7.9	7.4
University	5.8	15.7	15.4	17.1	15.4	13.9

Measure Life:

20 years (2008 DEER)

Attachment:

TVA - HE Window Savings.xlsm

7. Residential New-Construction Savings

7.1 New Construction, Single-Family Homes

The new construction, single-family home was created using a combination of the calibrated TVA residential prototype models developed by KEMA and the TVA EnergyRight® Program new home data. The schedule information for equipment, lighting, and domestic hot water and HVAC set points were drawn primarily from the calibrated residential prototype models. The building size, configuration, building envelope constructions, and HVAC system were initially derived from the TVA energy right spreadsheet and modified to be in accordance with IECC 2003 Single-Family Prescriptive Packages and TVA's EnergyRight® Program requirements. The baseline models were defined for two IECC 2003 weather zones, Zone 8, for most of Tennessee and Zone 7 for the Memphis area, Mississippi, and Alabama.[257] The results presented here are the same as those from the 2010 TRM. IECC 2003 may not be applicable for all TVA service area jurisdictions, but were applied here to represent a baseline. It is recognized that most of the Valley is at more recent code (Tennessee at IECC 2006). The new home program is currently being evaluated (at the time of this publication), as are code changes that have occurred. Therefore, the residential home new-construction measure savings must be updated to IECC 2009 (Alabama is in alignment with the 2009 IECC).

[257] 2003 International Energy Conservation Code (IECC), "Chapter Six: Simplified Prescriptive Requirements for Detached One- and Two-Family Dwellings and Group R-2, R-4 or Townhouse Residential Buildings"

Table 319. Single-Family Baseline Modeling Assumptions

Building Element	Model Input	Source
General		
Floor Area	2400 ft^2	EnergyRight Program - New Homes
Stories	2	
Floor to Floor Height	12 ft. 4ft Attic Space	
Envelope		
Above Grade Wall Construction	Brick on Wood Frame R-13 Batt insulation	EnergyRight Program - New Homes
Windows	Double Pane Total Assembly U = 0.49, SHGC = 0.62	EnergyRight Program - New Homes
Floor	Raised floor over crawl space R-19 insulation Zone 8 R-11 insulation Zone 7	EnergyRight Program - New Homes
Roof	Wood Frame with asphalt shingles. R-30 insulation	EnergyRight Program - New Homes
Internal Loads		
Lighting Power Density	1.30 W/ft^2	TVA model
Receptacle Equipment	0.5 W/ft^2	TVA model
HVAC System		
Design Temperatures	Cooling Design Temp - 78F Heating Design Temp - 65F	
Cooling Capacity	60kBtuhr (5 ton) unit	
Cooling Efficiency	13 SEER	EnergyRight Program - New Homes
Heating Capacity	69.5kBtuhr (5 ton) unit	
Heating Efficiency	7.7 HSPF	EnergyRight Program - New Homes
DHW System		
	Gas Water Heater - 50 gallon tank.	EnergyRight Program - New Homes

7.2 Single-Family EnergyRight® Program Requirements

There are two tiers to the EnergyRight® program, the first tier (Tier 1) requires that the new home achieve at least a 7% reduction in energy usage from the baseline home built in accordance with IECC 2003 Single-Family Prescriptive Package. The second tier (Tier 2) or EnergyRight® Platinum Certified level requires that the new home achieve a 15% or better reduction in energy consumption over the baseline home. There are various ways that the Tier1 and Tier 2savings can be achieved the following sections discuss the savings assumptions that were used by DNVGL in their DOE 2 models to compute the savings.

The single-family baseline model was used to create parametric measure runs to determine the program savings based upon the typical measures implemented through the program as provided in the EnergyRight® program savings spreadsheet.[258] The measures can be broadly categorized as follows:

- Heat pump efficiency upgrade
- Duct sealing
- Right sizing of the heat pump

The three measures listed above are typically referred to as a heat-pump efficiency improvements with quality installation and are treated as all one measure. In this case we chose to run the components individually as parametric runs so that the savings impacts of each component could be assessed. These three measures were the only ones considered for Tier 1 homes.

Tier 2 homes, in addition to all of the above measures to qualify for Tier 1, upgraded to a higher efficiency heat pump unit. Additionally, it was also necessary to improve the shell of the homes in order to achieve the 15% efficiency improvement. The shell measures included the following:

- Window upgrades
- Improved insulation
- Weatherization measures

The following sections provide a detailed description of the measures, methodology for calculating savings, and strategies that are combined to achieve the EnergyRight® Program goals for new construction single-family homes.

[258] The measures were determined using the spreadsheet entitled “er Program Values Revised Dec 28 8.xls”, which was provided by TVA.

7.2.1 Heat Pump Efficiency Upgrade

Under this measure, the heat pumps were upgraded to higher SEER and HSPF values and correctly sized. Energy savings claims may be different due to the various levels of quality installation. Proper sizing is completed according to Manual J.

The increased efficiencies for the heat pump equipment are listed in the following table. For the single-family home, two upgrades (equipment with increased efficiency) were modeled for the heat pump system.

Table 320. Single-Family Baseline and Heat Pump Upgrade [259]

	SEER	HSPF
Single-Family Baseline	14	8.2
Single-Family Upgrade Level 1	14	8.2
Single-Family Upgrade Level 2	17	8.5

Due to the residential buildings being modeled in the Detailed Interface of eQUEST, cooling EIR (electric input ratio) and heating EIR were required as inputs for the SEER and HSPF efficiencies. The modeling software defines the EIR, or 1/(Coefficient of Performance), to be the ratio of the electric energy input to the rated capacity, when both the energy input and rated capacity are expressed in the same units. The following table specifies the cooling EIR equivalent to the SEER and EER values listed in the table above.

Table 321. Model EIR Equivalent to Air Conditioner SEER/EER

	SEER	HSPF
Single-Family Baseline	0.2507	0.2742
Single-Family Upgrade Level 1	0.2300	0.2612
Single-Family Upgrade Level 2	0.1824	0.2539

7.2.2 Duct Sealing

This measure seeks to minimize air leakage in air-conditioning supply and return air system ducts located in unconditioned spaces. When ducts are not sealed properly, conditioned air escapes to unconditioned

[259] By EER unless otherwise noted.

spaces, forcing the HVAC system to work harder and longer. The measure described in this work paper assumes that the baseline duct system is sealed to allow no more than a 15% leakage rate.

The study conducted by Modera and Proctor (2002),[260] found an average leakage before sealing of 92 cfm/ton with an average fan flow of 325 cfm/ton. This corresponds to an average 15% leakage rate as the baseline condition. Beginning on October 1, 2005, new duct sealing requirements were released by the California Energy Commission Title 24 building standards for residential homes being fitted with a new central air conditioning or furnace. The California Title 24 requires that ducts leaking 15% or more must be repaired to reduce leaks. Based on this information we assume the baseline duct leakage of 15% is improved to 6%.

The analysis in eQUEST is modeled by revising the "Air-side HVAC System" parameters to have "Duct Air Loss" ratio of 0.06. This means that 0.06 fraction or 6% of the supply air is lost from the ductwork, thereby reducing the design supply air to the zones. Subsequently, the air lost from the ductwork will change the temperature of the zone specified. In eQUEST, this zone must be a plenum or unconditioned space. Additionally, in the same air-side HVAC system parameters window of eQUEST, the "Air Loss Type" parameter is adjusted to being proportional. This means that the duct air loss will vary in proportion to the air flow through the system. These revisions are made for each of the HVAC systems modeled in each building.

7.2.3 **7% Improvement Summary**

With the combination of these first two measures heat pump upgrade and duct sealing, 7% energy savings above the baseline were achieved for the single-family home for all five weather zones. The following table provides the results for each of the weather zones, and RNC Runs Data.xls contains the complete model output analysis.

[260] "A Campaign to Reduce Light Commercial Peak Load in the Southern California Edison Service Territory through Duct Sealing and A/C Tune-ups", October 2002, Modera and Proctor.

Table 322. Savings Results for Efficiency Upgrade with Duct Sealing

Region	Measure	Total kWh	Total % Savings
Chattanooga	Baseline	17,311	-
Chattanooga	Heat Pump Efficiency Upgrade 1	16,957	2%
Chattanooga	Duct Sealing	16,169	7%
Huntsville	Baseline	18,558	-
Huntsville	Heat Pump Efficiency Upgrade 1	18,192	2%
Huntsville	Duct Sealing	16,803	10%
Knoxville	Baseline	19,365	-
Knoxville	Heat Pump Efficiency Upgrade 1	18,967	2%
Knoxville	Duct Sealing	17,458	11%
Memphis	Baseline	18,000	-
Memphis	Heat Pump Efficiency Upgrade 1	17,619	2%
Memphis	Duct Sealing	16,469	9%
Nashville	Baseline	19,086	-
Nashville	Heat Pump Efficiency Upgrade 1	18,689	2%
Nashville	Duct Sealing	17,254	11%

Although the 7% improvement in performance above baseline was achieved after the efficiency upgrade and duct sealing, correctly sizing the component is required to qualify for the EnergyRight® program at the 7% level.

7.2.4 Equipment Right Sizing

The right sizing measure was modeled in accordance with TVA's All Electric Heat Pump (AEHP) inspection requirements. HVAC efficiency upgrade and weatherization measures were modeled according to TVA's EnergyRight® Program specifications for New Homes.[261] Sizing the HVAC system for a home is very important as it can improve comfort and reduce operating costs, maintenance, and energy use. Right sizing is especially important in humid climates (TVA region) as short-cycling of the air conditioning system can lead to poor humidity control. Oversized systems can also use more fan power and have more duct leakage due to higher operating duct pressures. Finally, oversized heat pumps greatly increase the summer peak electrical demand on hot days.

In order to measure the savings contributed by right sizing, we first had to size the equipment per standard baseline practice and then right sized the equipment as a measure. The first process in sizing equipment

[261] The data was taken from the "er Program Values Revised Dec 28 8.xls" spreadsheet provided by TVA.

is extracting the peak sensible cooling load from the eQUEST model .SIM file. This is the maximum load expected for the home and the equipment will need to be sized to meet this load.

The maximum cooling load for the building was 51 kBtuh and the maximum sensible cooling load was 45.9 kBtuh (assuming a 90% sensible heat ratio). Since TVA uses Manual J calculations to size equipment, it was necessary to adjust the maximum cooling load from DOE to account for differences in the two methods. The eQUEST output was increased by an adjustment factor of 20% to align our sizing with Manual J sizing requirements, and then the result was rounded up to the nearest nominal size. Following this method, a standard equipment size, a 60 kBtuh (51 kBtuh x 1.20 = 61.2 kBtuh) cooling capacity was used. The heating capacity of the heat pump was determined by multiplying the cooling capacity by the ratio of 13.9 kBtuh/12 kBtuh, which represents the average heating capacity of a heat pump over the average cooling capacity. This results in a baseline heat pump with a 69.5 kBtuh heating capacity.[262]

For the right-sizing measure, the peak loads from the eQUEST sim file were used after implementing the duct leakage measure. The right-sized equipment cooling capacity was 48 kBtuh (4 tons), which calculated to be 600 square feet/ ton. This was in accordance with TVA's current program inspection requirements that the cooling capacity does not exceed 125% of the maximum sensible cooling load in the building.[263] The heating capacity was calculated similarly to the standard sizing procedure, by applying a ratio (13.9/12) to the cooling capacity. This resulted in a heating capacity 55.6 kBtuh.

7.3 Single-Family EnergyRight® Platinum Certified 15% Improvement

In order to achieve the 15% improvement in efficiency required for the EnergyRight® Platinum Certified (ENERGY STAR) level it was necessary to include a heat pump efficiency upgrade to 17 SEER and 8.7 HSPF, as well as improved windows, insulation and weatherization measures. The following sections will provide a detailed discussion of the window, insulation, and weatherization measures, and the inputs and assumptions used to model them. The description of right sizing and heat pump upgrade are provided in Sections 1.2.4 and 1.2.1 respectively.

[262] The heating capacity was not adjusted to the nearest nominal size but was determined by the nominal cooling capacity times the heating to cooling capacity ratio (13.9/12).

[263] Also, TVA's inspection requirements indicate that the cooling load should fall within 500 to 800 square feet of conditioned living space per ton.

7.3.1 Residential Window Replacement

This parametric run involves replacing standard windows with better performing windows of the same dimensions. The performance of a window is typically measured by its solar heat-gain coefficient (SHGC) and U-value. The SHGC is a measure of the rate of radiant heat transfer through the window. As a result, a lower SHGC is desired for hotter summer seasons, but is not necessarily beneficial during the winter season. The U-value measures the conductance of heat (thermal conductivity) through a window. The window frame and assembly are important factors that contribute heavily to the overall window U-value; a frame that utilizes a material with low thermal conduction (vinyl, wood, fiber glass) will typically offer lower U-value than a metal frame. A low-e coating can be applied to the window to help reduce the U-value of assembly. A low-e coating is a microscopically thin metal-oxide layer that reduces the amount of infrared radiation traveling from the warm pane to the cool pane of the glass assembly. This results in a lower U-value as the thermal conductivity is reduced through the window. Windows with lower U-values are desired for regions with cold winter and hot summer seasons due to there being less heat transfer through the assembly.

The baseline window type is a double-pane window. Retrofit window assemblies were selectively chosen from the Efficient Windows Collaborative[264] to provide options that will realize their greatest savings based on TVA district climate. In addition, retrofit windows must meet the 2003 International Energy Conservation Code (IECC) in Tennessee for windows used in existing or new single-family buildings.[265] The following table shows the baseline window characteristics for single-family and the recommended energy-efficient window.

Table 323. Window Baseline and Retrofit Characteristics

Model Assumptions	U-value	SHGC/Shading Coefficient (SC)	Source
Baseline Window Characteristics [Double-Pane, Clear]	0.49	0.62/0.73	EnergyRight® Program New Home
New Low-E Window[266]	0.37	0.63/0.72	http://www.efficientwindows.org

[264] http://www.efficientwindows.org – The site was developed jointly by the Center for Sustainable Building Research, Alliance to Save Energy, and Lawrence Berkeley National Laboratory.

[265] Table 602.1 in Chapter 6, 2003 IECC Report.

[266] The new low E window was a Moderate-Solar-Gain Low-E tint, Argon/Krypton gas fill, Vinyl frame (0.50" air gap) double pane unit.

Baseline characteristics (U=0.49, SHGC=0.62) were used in the DOE-2 residential building models developed in eQUEST using TVA weather data. The eQUEST baseline models were then revised with the retrofit window characteristics (U= 0.37, SHGC=0.63) to estimate savings.

7.3.2 Residential Insulation (Attic, Floor, and Wall)

Residential insulation is a cost-effective way to drastically reduce heat loss through the building shell. Attic/ceiling insulation is particularly important because during heating seasons, warmer air will rise into the attic, and without insulation, can quickly transfer its heat to the roofing material and escape from the interior through natural attic ventilation. Attic/ceiling insulation significantly reduces the rate at which heat is lost through the attic/roof, thus reducing the amount of energy consumption required to keep the home at a comfortable temperature. Attic/ceiling insulation will also reduce a building's cooling load during the summer because heat transfer rates between cooler indoor air and warmer ambient and attic air will be inhibited by the insulation.

Attic/ceiling insulation, floor and wall insulation provide the same heat transfer inhibiting characteristics as their attic/ceiling counterparts; however, floor insulation usually reduces heat transfer between the assembly of the building and the earth beneath it (mainly conductive/convective heat transfer), and wall insulation reduces heat transfer to the interior space. There are several types of insulation material used in residential applications, and each material has physical characteristics that make it more suitable than others in certain situations. These characteristics are presented in more detail in the assumptions section, when insulation materials are chosen for retrofit measure options.

Floor insulation will only be applicable to manufactured homes and single-family homes having a raised floor with crawl space or basement with insulation, which represents 60 percent of the total single-family floor area. However, the models will only be run for single-family homes with a raised floor with crawl space since the population of homes with basements is relatively small.

The following table provides the baseline insulation values for single-family homes, which were taken from IECC 2003 Single-Family Prescriptive Packages. Following these requirements, there were two baselines modeled for Tennessee single-family homes (Tennessee Zone 8 insulation specifications for Nashville, Knoxville, and Chattanooga; and Tennessee Zone 7 insulation specifications for Memphis). Additionally, Huntsville, Alabama single-family homes were modeled with baseline requirements according to IECC 2003 Alabama Single-Family Prescriptive Packages for Zone 8.

Table 324. Baseline & Measure Insulation Level Model Inputs

Dwelling Type	Attic/Ceiling	Floor	Above-grade Wall
Single-Family Baseline (Zone 7 & 8)	R-30	R-19	R-13
Single-Family Envelope Measure	R-38	R-19	R-24

7.3.3 Residential Weatherization

The residential weatherization measure includes a number of weatherization applications listed below, all of which are assumed to make up this measure:

- Attic access weather-stripping
- Caulking
- Door weather-stripping
- Installation of outlet gaskets

These weatherization applications are relatively inexpensive for material and installation, and ultimately provide a decrease in a building's natural infiltration rate. Depending on the building's location in regards to climate and weather, the decreased infiltration rate of the building can reduce energy consumption for heating.

Weatherization savings will be estimated by modeling the change (reduction) in the number of air changes per hour (ACH) a building experiences due to the installation of the weatherization measures. A baseline infiltration value of 0.50 ACH will be used for single-family. A "low" infiltration rate for new/young vintage residential construction (in California) is 0.25 to 0.35 ACH (per DEER 2008). The 2008 DEER weatherization measure is based on California residential building code and is offered as a low-income measure. DEER 2005 assumes that retrofitting a building that "needed" weatherization can reduce the infiltration rate to the (DEER) standard of 0.35 ACH.

eQUEST prototype (baseline) residential building models with infiltration of 0.5 ACH were revised with the retrofit weatherization characteristics (change to infiltration rate, ACH) to an infiltration rate of 0.35 ACH.

7.3.4 EnergyRight® Home Platinum - 15% Savings Results

With the combination of the following measures: heat pump upgrade 2, duct sealing, equipment right sizing, envelope insulation, more efficient windows, and weatherization, 15% energy savings above the baseline were achieved for the single-family home. The following table shows the results for each of the weather zones, and RNC Runs Data.xls contains the complete model output analysis.

Table 325. Single-Family, Energy Right Home Platinum Modeling Results

Region	Measure	Total kWh	Total % Savings
Chattanooga	Baseline	17,311	-
Chattanooga	HP Eff Upgrade 2, and all Measures	15,041	13%
Huntsville	Baseline	18,558	-
Huntsville	HP Eff Upgrade 2, and all Measures	15,525	18%
Knoxville	Baseline	19,365	-
Knoxville	HP Eff Upgrade 2, and all Measures	16,144	19%
Memphis	Baseline	18,000	-
Memphis	HP Eff Upgrade 2, and all Measures	15,291	16%
Nashville	Baseline	19,086	-
Nashville	HP Eff Upgrade 2, and all Measures	16,010	18%

7.4 New Construction Manufactured Homes Savings

The ENERGY STAR Manufactured Homes program savings are summarized here. KEMA did modeling to assess these savings, which are reported in the monthly TVA EnergyRight & Renewable Solutions (E&RS) reports.[267] The results presented here are not from the 2010 TRM efforts, but other analysis conducted for the TVA.

7.4.1 ENERGY STAR Manufactured Homes

The energy and demand impacts for this program were calculated in late October of 2010, based only on information identifying the approximate size and annual kWh energy usage of these homes. The evaluation approach was based on DOE-2 modeling, using a proxy strip heat model.

[267] The reports have the savings as 11,947 kWh and 12,676 kWh per home for the ENERGY STAR and ENERGY STAR Plus Manufactured Home respectively.

The TMY3 weather for Nashville was used in the evaluations. Demand reductions were taken from the hourly (8,760) impact results of the DOE-2 models based on the average impacts across the ten coldest and ten hottest weekdays of winter and summer, respectively, within the coincident system demand peak period. The summer and winter coincident demands are the measure demand savings during the system peaks; the non-coincidental (NC) demand is simply the maximum hourly demand savings, regardless of time of occurrence. Both their gross and net values are shown.

The following table lists the 6 measures that were modeled and the assumptions that were applied to convert measure level savings from the model outputs to program savings based on participation rate of each measure.

Table 326. Measure Descriptions and Program Savings (per Home)

Measure Description	kWh	Summer Peak kW	Winter Peak kW	Participation Rate	Program kWh	Program Summer Peak kW	Program Winter Peak kW
Ceiling R-value = 11 to R-38	564	0.126	0.281	1.000	564	0.126	0.281
Floor over crawl space R-value = 0 to R-19	-336	-0.179	-0.265	0.000	0	0.000	0.000
Reduce CFM50 from 2500 to 1500	1,669	0.104	1.261	0.660	1,101	0.069	0.832
Increase duct insulation from 1inch to 2 inches	514	0.059	0.406	1.000	514	0.059	0.406
Replace single-pane with double-pane windows	3,606	0.452	2.154	0.570	2,055	0.257	1.228
Replace strip heat with SEER 13 HP	7,713	0.000	7.106	1.000	7,713	0.000	7.106
				Totals	11,947	0.510	9.390

8. Custom/Calculated Measure Analysis Overview

As with prescriptive energy efficiency measures, Custom Measures can be broadly categorized as either residential or non-residential measures. Generally speaking custom measures are dominated by non-residential (commercial and industrial) measure types. In this section we briefly discuss the general principles of residential custom measure analysis followed by a discussion of the non-residential custom measures analysis. The following sections provide general guidelines for energy savings calculations of custom measures as well as a discussion of specific custom measure analysis guidelines.

8.1 Residential Custom/Calculated Measure Analysis

In this section, we discuss the approach TVA and its local power companies should use to review non-deemed residential measures savings. Since most of the individual projects completed in the residential sector are too small to make it cost-effective for a specific calculation on a per project/home basis, methods should be developed to handle these measures. However, if the application is for a suite of installations across a subdivision or in a big multifamily facility and installed and/or incentivized as a part of an audit program, then one of the following methods are recommended:

- Implementers should develop a deemed savings number or methodology for measures not covered in this manual.
- Use eQUEST prototypes to calculate a deemed savings value for the measure.
- Refer to secondary sources for a savings value.
- Meter a sample of the installations of a measure (and baseline), if a calculated deemed savings value cannot be determined.
- It is important to also consider the code standards for any savings analysis and eligibility determination. For residential, the building considered is IECC 2009.

8.1.1 Ineligible Custom Residential Measures

Measures that are based on user controls are highly dictated by behavior. These measures should not receive an incentive unless proper evaluation studies prove otherwise. Additionally, measures that have a short measure life or can easily be removed from use should not be considered. Persistence is an important factor in achieving long-term savings in a cost-effective manner. The following is a list of measures that fall into this category:

- Programmable thermostats
- Intelligent surge suppressors
- Room lighting occupancy sensors (with override capability)
- Table lamps (and other plug loads that can easily be removed/replaced)

8.2 Non-Residential Custom/Calculated Measure Analysis

While prescriptive non-residential (commercial and industrial) projects use deemed energy savings for a specified set of measures, the custom (or calculated) measures provide customers and program implementers with more flexibility in the types of projects they can bring to the program, as well as customize the savings amount as appropriate for that project. Custom projects can include measures for which deemed savings are not developed or measures that are applied to complex energy-using systems. Because these custom projects are often very site-specific, there are several methods to ensure the proper savings are documented and verified for the project. Regardless of the method, the program implementer must perform additional calculations and analyses in order to quantify the savings for all custom projects. The implementation team members work with the applicant to develop and/or confirm their savings for measures eligible for a custom incentive. Refer to Section 3 for methods to calculate estimates for winter and summer peak period demand savings. This section provides a process for assisting the implementer in reviewing/calculating energy savings. There is no one correct way to calculate most custom savings; however, methods can be applied incorrectly or done inadequately for proper savings verification.

8.2.1 Savings Verification

Savings cannot be directly measured, since they represent the absence of energy use. Instead, savings are determined by comparing measured or calculated use before and after implementation of a project, making appropriate adjustments for changes in conditions. The method for developing savings estimates should be selected based on available data for the facility, the savings uncertainty (or risk of achieving the savings estimate), the proposed measurement method, and the value of incentive payment. A better savings estimate results in more realistic expectations on behalf of the customer, implementer (power provider), and TVA. However, it is just as important to consider the cost in developing a savings estimate and the precision it provides relative to its overall benefit to the utility and end user.

8.2.2 Ineligible Custom Non-Residential Measures

There are certain non-residential measures that implementers should consider as ineligible. Measures that are based on energy system user controls are highly dictated by user behavior. These measures should be incentivized with careful consideration for verifiable savings before being reported to power system planning as durable savings. However, for systems whose process capability have been altered to give high reliability, long-term savings of kW during peak power system periods should be considered when shown to be appropriate. Additionally, measures that have a short measure life or can easily be removed from use should not be considered. Persistence is an important factor in achieving long term savings in a cost-effective manner. The measures that should not be given an incentive are (exceptions may occur):

- Intelligent surge suppressors
- Table lamps (or other plug loads)
- Measures with non-verifiable savings - for example
  - Refrigerant additive
  - Power factor controllers
  - "Black box"
- No cost measures
- Decommissioning equipment, space, or buildings (i.e., shutting down is not an efficiency improvement)

However, it is important to consider that many of these measures do have potential for peak demand savings and have verifiable annual energy savings, so exceptions may be made on a case-by-case basis.

8.2.3 General Guidelines for Custom Measure Analysis

The estimate of peak demand (kW) and first year energy (kWh) savings for retrofit projects will be calculated as the difference between the pre-retrofit or "base case" system peak kW and kWh use and the post-retrofit or "efficient case" system peak kW and kWh. The first step is to define and describe the base case and efficient case system and operating conditions. The savings calculations can be done in a number of ways that will depend on the specific measure that is installed and the percentage of the total usage/demand that the savings represent.

The applicant should be asked to provide the following information for all custom projects. The implementer is expected to include the following information in its project files for evaluator review.

- Concise project description including how the equipment is used
- Production data or any other control variables if applicable
- The quantities, make, model number, and rated capacity of both the existing and the new equipment that is being installed. When appropriate, other nameplate information like operating voltage and rated full load amps

- Copies of the manufacturer's specification sheets and/or performance rating sheets and the Web site address where further technical information about the equipment performance might be found[268]
- Copies of sketches, drawings, equipment lists, or inventories that help to clarify the understanding of the process (or equipment) change and its scope
- Description of the locations where the equipment is installed or process affected
- The facility and/or process operating hours and the equipment operating schedule for each day of the week and by season if there is seasonal variation and in context of plant capacity utilization, if applicable
- Equipment load conditions for the hours the equipment typically operates
- Annotation of all assumptions or constants used in engineering calculations
- Statement that explains the baseline chosen (see the next section for more detail)

8.2.3.1 Defining the Base Case

The base case is dependent on the project. If codes or standards exist for a specific measure, then the base case is the minimum required according to codes and standards, such as ASHRAE 90.1[269] or federal standards. For example, ASHRAE provides minimum efficiency levels for HVAC equipment and Appendix G[270] as a reference guide for new construction. These efficiency values would in many cases be the baseline, especially for new construction. TVA will assume a project is replace on "burnout" or natural turnover (applicant must replace due to equipment failure, change of use, etc.), and not early replacement in almost all cases. In every situation where a choice of efficiencies is available, the base case would be code or standard minimum required; or if no code or standard is applicable, then the base case is the minimum efficiency available in the market or industry standard practice. This can include situations that are customer-specific. For example, if one chain store always installs central lighting controls at its sites, then it is their standard practice and should not be claimed as savings in this territory.

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[268] Not applicable if a process change occurs and no major equipment change out is part of the improvement.

[269] The current standard applied in the TVA territory is The International Energy Conservation Code (IECC) 2009 or ASHRAE 90.1-2007. Areas where there is no code or code from previous years, then this one is the baseline for projects claiming savings.

[270] Appendix G is a modeling protocol that is used to measure compliance with the ASHRAE 90.1 Standard. It adopts the Performance Rating Method that compares the energy use and cost of a proposed design against a baseline design.

For process improvements such as large production line changes or even more simplistic compressed air system upgrade projects,[271] the base case would be the existing equipment. If any monitoring is conducted, the base case load profile would be adjusted to match that of the post case load profile to compare rate of throughput, as appropriate to accommodate the process improvements in the calculation. However, if the project is based on a process, the standard practice, if one is available, would be considered the baseline. Otherwise, the existing process is the baseline.

8.2.3.1.1 New Construction vs. Retrofit Guidelines

This section provides a brief discussion of the process for determining when a project should be treated as a new construction project and when it should be treated as a retrofit project. This distinction is important because a new construction project and a retrofit project will have different procedures for determining the baseline.

New construction projects should utilize code baselines when applicable. For the TVA, 2009 IECC baseline is used for all new construction and major renovation projects, except for Mississippi, where the baseline is ASHRAE 2010. Incentives are offered based on the applicable new building standards regardless if the state requires building standard compliance. If there are business reasons other than efficiency improvement that motivate the system installation (i.e., added load, changed function, or the renovation of a building to meet the needs of a new occupant or of a long-term occupant wanting to update the space), building codes need to be considered.

For retrofit programs/projects other than new construction, incentives are offered based on the efficiency of existing equipment or applicable new equipment standards, for customers who choose to gain higher efficiencies with a system change-out even though simple replacement or no change would have met business needs. This is a retrofit project even if the local code requires new building standard compliance for a building permit. The following list provides some typical types of energy efficiency projects and how they are categorized:

1. **New Buildings -** New Construction - any new structure for which a building permit is required for construction.
2. **Additions -** New Construction - any change to a building that increases conditioned floor area. Conditioned space is space in a building that is either mechanically heated or cooled (including directly and indirectly conditioned space, e.g. Stairwells).

[271] However, for simple air compressor replacements (change out to more efficient unit), the baseline should be the minimum rated efficiency available in the market. If the remaining useful life of the existing equipment is less than five years, this alternate baseline should be considered.

3. **First Tenant Improvements -** New Construction- the base building has been built, but has not been built out to tenant specifications. Typically a tenant moves into a space for the first time in a recently constructed high-rise office building and installs new lighting systems, HVAC distribution systems, interior walls, and room finishes.
4. **Alteration to Existing Buildings -** New Construction or Retrofit - any change to a building's space conditioning, lighting, or envelope that is not an addition.

The following table describes whether the project should be treated as new construction or retrofit. Generally speaking the two criteria that are used are whether project space is currently occupied or unoccupied[272] and whether the building has a change in function or added load. If the space is occupied and there is no added load and no change to the building function or task, then the project can be considered a retrofit. Under all of the other scenarios presented below-added load, unoccupied space, change in function or task, and multiple systems change-out of two or more end uses, the project should be treated as new construction.

[272] When an unoccupied building is occupied, it may be considered a retrofit and not new construction if the extent of modifications does not change the amount (i.e., removing/adding equipment such as fixtures or tonnage) of equipment. This is regardless on the amount of time the space is unoccupied.

Table 327. Examples for Determining Retrofit vs. New Construction for Alterations to Existing Buildings

Equipment Replacement			
No added load	Retrofit	New Construction [273]	**1)** A building owner replaces an old package rooftop HVAC unit with a more efficient unit. **2)** A facilities manager replaces T8 fluorescent lamps with high performance T8 lamps and electronic ballasts without changing fixture location.
Load is added	New Construction		A building owner replaces an old package rooftop HVAC unit with a larger more efficient unit to accommodate a new computer room.
Single-System Change Out			
No change in building function or task - No added load	Retrofit	New Construction	**1)** The existing lighting system containing a mix of HID and T12 fixtures is replaced by a new T8 lighting system involving fixture relocation and replacement, an updated control system, and replacement of old wiring. **2)** A tenant changes all glazing from standard grey gloss to high performance glass.
No change in building function - Load is added	New Construction		**1)** A new air conditioning system is installed in an existing office building to condition a new computer room. **2)** A previously uncooled school adds an air conditioning system.
Change in building function or task	New Construction		**1)** A new retail store moves into what was previously an office space. The owner replaces the lighting system to effectively display their merchandise. **2)** A tenant in an office building moves a computer data processing group into a space previously occupied by a management group. The space's lighting system is changed to accommodate these new job tasks. This includes: all new and relocated fixtures, new wiring and new switching.
Multiple System Change Out (more than one system)			
All cases	New Construction		An existing tenant space is renovated. The tenant installs an entirely new lighting system including daylighting controls and occupancy sensors. Also, they install a new HVAC unit with all new ductwork, VAV (variable air volume) boxes, and an energy management system.

[273] For unoccupied space, any retrofit would be added load, hence this could be considered as not applicable to the replacement option.

8.2.3.1.2 Baseline Determination

Standard practice is a function of the equipment evaluated and the application (use) for a given type of equipment. Baseline selection can be customer-specific. Standard practice baseline policy should be well defined. Ideally, the policy should be based on the function of the market share of equipment by application. Baselines need to be updated on an as-needed basis when federal or state regulations impact minimum efficiency standards and on a periodic basis to keep up with the emergence of new technologies and new building practices. It may be worthwhile to conduct more formal assessments for selected technologies and/or applications. In the absence of data from a saturation/penetration study, the following is the guideline for baseline determination.

Steps for determining baseline and measure conditions

1. Thoroughly review the pre-existing conditions to support baseline selection:
    a. The age of the existing equipment and remaining useful life for the existing equipment.
    b. The working condition of the existing equipment and recent maintenance records.
    c. The ability of the existing equipment to meet service requirements, such as cooling loads or airflow (cubic feet per minute) requirements of a production system.
2. Provide strong evidence and supporting documentation that clearly demonstrates that the installed higher efficiency equipment exceeds the efficiency of standard practice:
    a. Check with sources to ensure equipment installed is energy efficient or cutting edge and not just a standard replacement or the only choice.
    b. Check to see if the installation is standard practice for the company/facility.
3. Determine the EUL of the measure,[274] providing context for evaluation of the age of the existing equipment.

For projects that are not governed by code, standard practice baseline determination is needed

For risk management of project savings and those claimed on behalf of the program, it is important to understand what the evaluator considers. The factors considered include not just the age of the existing equipment used to determine the baseline condition. There must be a preponderance of evidence based on the specific project. This includes a thorough review of pre-existing equipment, facility operating conditions, and standard industry practices before selecting the baseline condition. For process

[274] DEER, GDS report, state TRMs, RTF (http://rtf.nwcouncil.org//)

equipment where there is no code or industry standard,[275] the additional set of data collection should be considered:

- Gather data supporting standard practice assessment
- Consult manufacturer to learn about current market trends
- Verify if there are any alternative options available for the equipment, such as lower efficiency options compared to purchased equipment
- Review any research publications if available
- If more applications of similar type are available then interview all customers to learn more about industry standard practice

Some questions that should be asked to determine if there is a preponderance of evidence the measure/project could be considered as early replacement and not governed by code or industry standard:

- What are the reasons for implementing the project?
- When would the existing equipment have been replaced in the absence of the program?
- If the customer conducted an economic justification for the project, was it based on incremental cost?
- What other technologies/efficiency levels/options are considered (if any) when replacing this equipment?
- Did/will the new equipment increase production?
- Does your company/agency/organization typically replace this equipment on a regular basis or just when it fails? If on a regular basis, about how frequently?
- What is typical facility practice for these measures? Is this facility practice documented? If yes, request this document.

[275] Evaluator will discuss typical facility standard practice during M&V and NTG interviews.

- What were the typical facility practice or operation procedures for the removed equipment? For instance, what were the set points for controlling the equipment?
- What are the specifications of the removed equipment? (e.g., manufacturer and model number)?
- Will the equipment operations change after the new equipment is installed? If so, please describe.

In conclusion, baseline determination should follow a process where the default would be a code, industry standard, or market baseline. If one does not exist, then considering the customer's typical/standard practices is another option. Evaluator risk increases when existing conditions are used as baseline when a code, standard, or industry practice exists that is better than the baseline. When existing condition is used, sufficient data must be collected and documented to define the baseline appropriately.

8.2.3.1.3 Production Adjustments

Changes in production have a direct impact on total energy usage and energy savings. Production levels or related equipment and system services are normalized to an energy per unit of production basis when conducting impact calculations. To ensure consistent treatment for baseline and post-retrofit energy usage estimates, a regression analysis should be conducted to determine other variables that affect energy usage. Production levels have the most impact on pre- and post-metered usage data; however, other independent variables, such as dry bulb temperature, may impact usage. All variables that potentially may affect energy usage should be reviewed and considered for normalization in the production savings analysis (i.e., in the regression analysis).

There are two distinct paths that are applicable to production adjustments that are determined by the baseline assumptions applied to the project. The first is for projects that are early replacement projects where the existing production equipment is operating at or near its original capacity levels. Savings calculations for early replacement projects will use post-retrofit production levels, as long as the pre-retrofit system production level is not exceeded. Also, it must be determined whether or not customer operations might reasonably have been extended for the pre-existing baseline to meet higher post-retrofit production levels. If extended hours of operation are not reasonable then the production level might be capped based on the pre-existing system production rate or a rate that could be reasonably achieved during the preexisting production hours. In other words, new production shifts cannot be added to the baseline operation assumptions in order to match pre-production output to the post measure installation output.

The second path for savings calculations for all replace on burnout or natural replacement projects should be based on the post retrofit production levels. This is true as long as the baseline annual production output can be achieved within a reasonable production schedule. For example, if the normalized annual baseline production output cannot be achieved within 8,760 hours, then the annual production rate would have to be capped to that value.

8.2.3.2 Acceptable Calculation Methods

A list of acceptable energy savings calculation approaches submitted by applicants or provided by the implementer is outlined here. Each of the methods will be discussed in more detail as they apply to categories of measures in the following sections. The implementer should select the appropriate method in reviewing applicant submittals and should use standardized tools, as applicable, to help guide the analysis process. The implementation engineering team should review custom projects with each other on a regular basis to make sure a consistent and comprehensive process and rigor is followed within a program.[276]

At the preapproval stage (if this is a step in the program process),[277] if the applicant provided a well-documented approach to calculating energy savings, the implementer should first review their approach and decide if the program needs to develop its own approach for the project/measure(s) in question. Additionally, securing the proper documentation of baseline conditions for most custom projects is critical. Otherwise, the applicant's submittal will be sufficient if the program engineer can replicate their savings estimate. The implementation team should make sure applicants are aware of potential measurement/modeling requirements that could be imposed on them prior to receiving an incentive.

These savings approaches discussed here follow the 2007 International Performance Measurement and Verification Protocol (IPMVP).

8.2.3.2.1 IPMVP

MFS guidelines presented here are based on the 2007 International Performance Measurement and Verification Protocol (IPMVP). The IPMVP offers four main options:

Option A—Key Parameter Measurement/Engineering Calculations. Savings calculation is based on using short-term or continuous measurements of key operating parameter(s) and estimated values of the remaining parameters. Key performance parameters are the factors that affect the energy use and the

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[276] It is recommended that TVA coordinate meetings with all implementers (including power providers) who conduct custom analyses on projects. This will assist in cost-effective reviews, as well as, consistent methodologies to help ensure that proper savings are being reported and equity among all power providers in their requirements.

[277] It is recommended that custom measures require a "pre-approval" prior to installation to allow for the implementer to validate if the measure is eligible and set expectations for metering (if any) and incentive levels.

success of the project. Estimates can be based on manufacturer's specifications, historical data, or engineering judgment; however, documentation and/or justification of the estimated parameter(s) source is required. Estimated values can be nameplate horsepower and/or efficiency or fixture wattage.

For measures with impacts over several small systems, sub-metering may be impossible. These measures may include lighting, high-efficiency motors, wet-side economizers, primary/secondary pumping, cool roofs, and more. For these measures, an engineering calculation method is probably the simplest method to document savings.

Option B—Energy Use Measurement/Equipment or Process Sub-metering. Energy (kWh) or the proxy for energy (such as amps) is measured either by short-term or continuous metering of the baseline and retrofit to determine energy consumption. Measurements are usually taken at the device or system level.

When measures are installed that affect large individual systems or sets of equipment (for example an air compressor, chiller, process blower, or injection molding machine), sub-metering may be the best way to document the savings. This may require the installation of temporary portable monitoring equipment that measures and records the equipment power at short intervals over several days or weeks. When sub-metering is advised, the program implementers and customers will discuss the best method to both gather the additional data and extrapolate the savings for the measurement period to a full year of operation. Component sub-metering may often include observation of other variables like outside air temperature, operating hours, or production quantities during the measurement period to allow for this extrapolation. This method may be appropriate for air compressor system upgrades or chiller plant improvements. Many process-related equipment upgrades may require metering to assess the project's energy savings, such as VSD installations.

Option C— Whole-Building/Facility Metering/Billing Analysis. This option typically **i**nvolves comparing billing data recorded by a utility meter or sub-meters for the whole or partial facility, before and after project installation. Adjustments are required to account for any variables, such as weather, production, or occupancy levels. Energy savings can be determined once the variables are recognized and adjusted to match "average" conditions such using TMY weather or typical production levels. This method is only acceptable if at least hourly billing demand is available to determine peak demand savings.

For some projects, where the savings are a significant enough fraction (10% or more) of the total monthly (or annual) kWh usage or kW demand, a "bills before-bills after" approach may be used. This approach assumes that conditions are identical before and after the project, such as building occupancy levels or operating hours. In cases where this assumption is not reasonable, the program implementer may use regression or proportional analysis techniques to adjust the baseline. Baseline adjustments are necessary when comparing one period to another if significant changes have occurred, such as changes in occupancy, product throughput, weather, or other measurable independent factors. All weather-dependent data will be weather-normalized for both base case and post-implementation analyses. The program implementer may also perform site-specific billing analysis or whole metering for projects such as HVAC system upgrades, installing an energy management system, building envelope improvements, and process improvements.

Option D—Calibrated Simulation. Savings are determined using software to create a simulated model of a whole facility or sub facility. The model must be calibrated by comparing it with end-use monitoring data or billing data. Models should be built for the existing base case, base case complying with minimum standards (if applicable for the measures modeled and better information is not readily and cost-effectively available), and a case with the energy measures installed.

For measures that have building/facility/process-wide impacts or impacts across a number of systems, engineering modeling using generally accepted public domain software is acceptable to document savings.[278] Projects that include measures that interact with each other may require modeling. For example, if a project includes an EMS upgrade that controls many different points in a building, as well as volume to variable air-volume (VAV) retrofit, a building model may provide the most reasonable estimate of energy savings.

The implementer should work with the applicant so that the proper analysis is conducted, especially since building models can be costly. When using any model, the applicant must provide both the base case and post-case input files and annotate the files to clearly show how the differences between the pre- and post-retrofit systems are being simulated so that the reviewer can understand and verify the analysis.

Whole building models should be calibrated to actual energy use (electric bills) and use typical weather data. Models should be calibrated to ±10% of both monthly billed demand (kW) and monthly energy (kWh). Models that are only calibrated to monthly energy will not be acceptable because the demand savings estimates from these models can be unreliable. If interval metered data are available for the building, then an hourly calibration method that minimizes the hourly coefficient of variation (CV) between the model and the metered data would be preferred. An annual CV of 0.2 for the model would be a desired target value for calibration.

[278] If an industry-accepted model is available for a process or facility, then that calibrated model would be reviewed and deemed if acceptable or not.

Typically, a regression modeling assessment is used for this savings calculation approach to adjust for uncontrolled variables, such as weather. Models must reflect the actual systems and their operation (i.e., no defaults may be used) by using building-specific equipment.

Initial savings estimates that are submitted based on manufacturers' proprietary performance models should not be acceptable even as a preliminary screening assessment of energy savings, as they often do not allow the team to review or verify the manufacturers' calculation methods or inputs.[279] Therefore, a different approach would be required to determine energy savings.

8.2.4 Quality Control Process

The quality control (QC) process for custom projects should follow the steps provided for prescriptive measure review (Section 4.1) and the following specific details. We recommend documenting how the process flows and consider using checklists and project review templates.

For every project, the assigned implementation engineer does the application review. In this review process, the engineer will assess if the submitted analysis is sufficient for replication, as well as review if there are verifiable peak demand/annual energy savings.[280] However, for pre-review, a detailed analysis should not be required. If not, then the implementer will select a method, gather the necessary information, and calculate energy savings (via spreadsheet tool, model, or other) with applicant assistance. If a tool is available for use,[281] it provides a mechanism and consistency for the implementation teams to confirm the savings estimate at the time of the final incentive request.[282] For projects that use an existing tool or an acceptable methodology, QC includes:

- Validating the proper tool/method is used and appropriate for the measure
- Confirming that the inputs/measurements are appropriate

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[279] If they do provide transparency, then implementers should have the ability to decide if the data provided is sufficient for savings verification.

[280] It is important to consider if it is verifiable and replicable savings since many custom measures (especially control measures) are very much up to external variables and operator control that can result in an increase in demand. However, there are cases where changes in process capabilities do result in assurances for durable savings.

[281] Part of this manual or other tools developed by third parties or program providers should be used for simplification, consistency, and cost-effective review. The tool used should undergo a peer review process to validate its methodology.

[282] The list of tools is provided in Section 8.2.6. If an analysis is not available for the measure in question, the engineer reviewing the project will work together with an appropriate peer to ensure the analysis (calculation, model, or measurements) is appropriate for calculating the energy savings for the project.

In any case, a senior engineer should review a junior engineer's or a peer's analysis for both pre and final reviews. In cases where a tool/methodology is not available and a customized approach is needed, the senior engineer providing the QC must have experience with the measure in question. Program engineers should leverage senior engineers with specific expertise to not only provide added support, but to find ways to improve reviews for specific measures. One additional level of QC may include a literature review of evaluation studies to be sure the analysis can hold up in the evaluation process to help mitigate any risk.

If a project does not pass the QC process, the engineer tasked to that project must redo the analysis as directed by the peer reviewer. This will be done in conjunction with the peer reviewer until satisfaction is reached.

8.2.5 Utility/TVA Review Process

Program implementers (if a third party) should work with the utility (the MFS manager) when preparing a review of the energy and peak demand savings and should discuss the findings with the utility as appropriate. The following situations are examples when this should happen:

- New technology not previously assessed in program
- Disagreements between applicant and implementer on savings amount or potential change in incentive calculated greater than 5% due to implementer analysis
- Measurements recommended
- The potential incentive is at greater than $100,000 (projects of a certain size)

8.2.6 Reviewing Project Applications

It is recommended that programs requiring project applications with custom measures be submitted prior to project installation for review of the savings estimate and proper definition of baseline. In some cases, the program implementation team may require metering or measurements, as well as adjusting the savings estimate for the applicant based on the implementer's review of their submitted analysis. These are valuable steps that will help mitigate any reduced program impacts from the evaluation process, as well as improve customer satisfaction.[283] The savings calculations must be developed using acceptable

[283] Customers will have a reasonable expectation of their potential savings (and subsequent incentive) if there is upfront review of savings and any measurement/monitoring expectations for program participation.

engineering calculation techniques supported by site-specific operating and equipment performance documentation. In addition to a program engineer review of the savings estimates, it is strongly recommended that the implementation team also conduct a peer review for quality control as mentioned in the previous section.

Many of the steps for reviewing custom project applications are also conducted for prescriptive measures. However, significant steps in the process differ for custom projects as described here.

1. Verify all documents submitted are complete for a thorough review.
2. Perform energy and peak demand savings calculations - These calculations should use custom calculation tools if available (described below). Otherwise, the implementer should verify the applicant's calculations via engineering review. For reviews prior to project installation, it is important to clarify the savings calculation methodology required with the applicant to fully incentivize the measure.[284] For verifying savings of installed projects, it may require analyzing data collected/measured, building/process modeled, or other, as agreed upon by the parties. Additionally, if any of the parameters changed upon installation, such as equipment size, process changes, operating hours, and set points, then the savings need to be recalculated to ensure the correct savings are claimed by the program. Consistency among program engineers on the method used for calculating/verifying energy and peak demand savings should also be considered.
3. Perform pre-and/or post-monitoring, if necessary. On a case-by-case basis, the implementer should recommend measurements. If a project does not have sufficient final documentation to fully validate the energy and peak demand savings, the implementer may pursue monitoring or require the applicant to monitor as an option to document the retrofit conditions. One example is for energy/demand savings devices (such as power controllers like black boxes); Appendix Section 7.9 has MFS Test Protocols for Energy Savings Devices that could be given to the applicant to follow. Other examples may include building systems that do not have proper EMS data logging ability or complete log sheets. Some processes may require monitoring if the facility does not have tracking data, such as kWh/lb of steel melted, amp or pressure profile for an air compressor system, or operating profile for a variable load motor. However, requiring monitoring should be justifiable and should be required to ensure quality control.
4. Perform inspection - Not all custom projects should be pre- and/or post-inspected. Inspections should be conducted on all projects that exceed a certain savings amount (since risk of accurate

[284] To minimize program administrative costs and reduce risk that the project will not be installed, the implementer should use a "preliminary" calculation to reserve program funds and not a full blown building model or other costly method.

savings claims increase as savings and incentive payout increases), require adjusting baselines, incomplete or unclear application/project materials, and a technology that is not commonly installed in the implementer's program (or in TVA service area). A passing inspection is one that the quantities, nameplate data, and project description match the application. A failed inspection causes the reviewer to recalculate the energy savings and typically results in a lower savings estimate. Other reasons for a failed inspection include when the specified equipment is not installed or a specified process is not implemented as indicated; in both cases the savings calculation must be recalculated or the project does not qualify for the program.

The implementer's key role in custom projects is to review the savings estimates provided by the applicant and assess if the methodology used to develop the savings estimate is appropriate and sufficient. Using the customer supplied savings inputs, the implementer should attempt to replicate the savings estimate. It is recommended that programs have guidelines for submitting project documentation to assist in the savings calculation process. These guidelines should be provided to applicants in a policy and procedures manual and summarized in the custom application to ensure the applicant's expectations are in line with the program needs. In addition to the written guidelines, the manual includes worksheets for common custom measures to help implementers justify the energy savings for a project. These tools can also standardize the custom analysis process among all TVA program implementers. The tools can help calculate savings for the specific measures performed on a project.

The following calculation spreadsheets are available for use:

- LED lighting in refrigerated cases
- Server virtualization (simplified analysis)
- Day lighting
- Bin analysis (weather based or other independent factor)
- Lighting VSD on motor (load profile)
- Using eQUEST building prototypes (described in detail in the Appendix Section 5)
  - Equipment replacement, such as chillers or constant volume variable air volume system
  - Guest room energy management system
  - Energy management system

These tools are based on well-established engineering procedures available to calculate pre- and post-energy and demand use. One common modeling method is the "bin-method," in which the equipment pre- and post-energy requirements are identified for several fractional load "bins" (i.e., 25%, 50%, 75%, and 100% load or temperature range bins), and the pre- and post-equipment performance in each load or temperature bin is applied to the loads and hours that the system operates in the bin over the year. Other methods used are those for lighting (change in lighting density or wattage reduction), cool roofs (calculator provided by the Department of Energy), daylighting, and others. Also, the building prototypes can be used for analysis (details are provided in Appendix Section 5).

The implementers should also plan on using publicly available industry-accepted tools, as appropriate, including:[285]

- Motor Master
- Smart Pools
- Cool Roof
- ASD Master
- Air Master
- PSAT
- Air Handler
- Bin Maker
- California Custom Offering Program Savings Calculator, (http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/ief/)

The proper use of these tools is extremely important and should be assessed in the engineer or peer review. The inputs to the above models or spreadsheets must be included in the project documentation.

8.2.7 Measurements and Monitoring Requirements

For certain projects, in addition to energy and peak demand savings calculations, the program may require the applicant to conduct measurement for settlement (MFS) or measurements/metering in order to qualify for an incentive. In most cases, these requirements for measurements should be indicated in the pre-installation review process. Projects with incentives less than $25,000 should not be required to do

[285] Many of these can be found at: http://www1.eere.energy.gov/industry/bestpractices/software.html. However, it is important to understand what happens behind the scenes, Black box calculators should not be used.

metering since it may not be cost-effective. However, if data collection is simple, such as a spot measurement during an inspection or gathering data from the customer EMS or other source, then it is highly recommended to use the measurements. Additionally, the determination of metering requirements for projects that are implemented at multiple locations for the same customer should be based on the aggregate incentive, not on the individual incentive at each location. In most cases, the engineer should identify MFS needs at the pre-review stage (if applicable). Projects that may require measurements are:

- Air compressor to determine the load profile and schedule
- Voltage- or amp-reducing lighting dimmers
- Cooling plant improvements, to determine overall kW/ton, operating hours
- Process improvements
- Process loads on cooling systems
- Devices that have only manufacturer claims but no third party study or no data are available to support savings values (which may be the case in most industrial retrofits)
- Energy savings devices (such as power factor controllers) where savings are based on manufacturer statements or case studies where no third party review by a recognized industry representative (such as utility) has been submitted (such as the plan provided in Appendix Section 7.9).

Projects that most likely will not require monitoring:

- Lighting upgrades[286]
- Measures that use calculation spreadsheet tools that do not indicate any measurements needed
- Measures where billing analysis is appropriate, i.e., savings greater than 10% of annual whole premise consumption where baseline adjustments are not needed
- Daylighting, window film, and other envelope measures

[286] Programs may elect to do operating hour metering if savings exceed $50,000 in combined prescriptive and custom lighting retrofits and if there is a concern about the deemed hours and coincident factor being representative of the project's potential savings impacts.

If a project requires metering, the implementers or applicants should consider using the International Performance Measurement and Verification Protocol (www.ipmvp.org/download.html) to develop an MFS plan, if necessary (summarized in Section 8.2.3.2.1). The program staff should review this plan with the applicant to weigh the proposed extent of MFS and the costs required to perform the tests. The MFS plan should indicate the extent to which the final incentive will be conditional on MFS activities performed after the project is completed. The applicant must provide the necessary information for the program to do its verification. Any data collection the applicant does must be according to an approved program plan. As a rule of thumb, the cost of any measurements generally should not exceed 10% of the incentive amount and be cost-effective in balancing risk and budget.

8.2.8 Reviewing and Developing a Measurement (MFS) Plan

In some cases, the implementer will require applicants to do measurements for establishing the baseline and/or verifying the energy savings. The activities that are a part of MFS include data gathering, meter installation, developing methodologies, using acceptable estimates, computing with measure data, and reporting. This section provides guidelines for quantifying the energy savings and the peak demand reduction resulting from a project.

8.2.8.1 Plan Elements

A measurement plan should include certain elements for consideration and are discussed in this section.

Proposed Energy Savings Calculation Methodology

The MFS plan must contain proposed savings calculation methodology that will be used to evaluate the savings. The calculation methodology should be agreed upon by M&PA staff and implementation staff before the metering is installed. In order to make an informed decision about the adequacy of the plan, certain measure-specific and site-specific information must be provided in a clear and concise manner. First and foremost, the measure description must be provided so that the baseline or pre-installation conditions are clearly defined as well as the post measure condition. A brief description of how savings will be achieved should also be provided along with the energy savings calculation that will be used to measure savings. Finally, an overview of the data elements to be used in the analysis should be included that contains the components provided in **Error! Reference source not found.**. This table shows the sample data elements for the pre-metering period. A similar table should also be provided for the post-metering period. Alternatively a column could be added to indicate the measurement period, i.e., pre- or post-installation.

Table 328. Sample Data Element Table for Pre-Installation Period

Measurement Description	Units	Measurement Type	Measurement Interval	Duration	Number of Observations
Chilled water pump power	kWh	Interval true power	15-minutes	21 days	2016
Compressor Motor Operation	On/Off	Event transition	Continuous	21 days	NA
Chilled Water Flow	GPM	Instantaneous	5-minute	21 days	6,048
Chilled Water Temperature	°F	Instantaneous	5-minute	21 days	6,048
Production Output	Tons	Interval output	Daily	21 days	21

Plan for Capturing Operational Diversity

Every measurement plan should account for the operational diversity of equipment or measure being monitored so that an accurate estimate of annual consumption and energy savings can be made. Short-term metered data that are unadjusted for operational diversity tend to overstate consumption and energy savings. At a minimum, facility staff should be interviewed to obtain annual operating schedules, facility shutdown periods, production shutdown periods, and maintenance schedules. The preferred method for annualizing consumption and savings would be to use Supervisory Control and Data Acquisition (SCADA) system data that captures annual operating schedules directly. Interval whole-premise metered data can also be used to capture shutdown periods and seasonal variations in production schedules.

Data Adequacy Review

The MFS plan should also include an analysis of the data inputs to make sure they are sufficient to support the energy savings calculation method that will be used. This is particularly relevant to production measures that utilize sub-hourly interval power data, but then only have monthly production data to support regression model analysis of savings. In this case, two weeks of pre-installation and two weeks of post-installation data are simply not adequate to support a production based regression model. The plan must identify the data streams that will be used to calculate savings and ensure that the metering period is long enough to support the planned data analysis method.

Short-Term vs. Continuous Metering

When measurements are required, the frequency ranges from short-term to continuous, depending on the expected variations in the load (hence savings). If equipment operation is expected to vary, then measurements should occur over a period that covers at least the operating range expected to occur during summer and winter system peak hours. The period should also measure the low and high loads of the equipment. In some cases, if there is justification, the measurement period can be shortened or conducted at another period of time that is not during the peak period. Shortening or changing the measurement period would be justified only if the action taken does not impact or enhances the accuracy of measurement of equipment operation.

Short-term metering can be conducted using data loggers. The equipment for short-term metering needs to be accurate within ± 5% of full scale. The short-term metering equipment must be calibrated against the spot-metering equipment by taking spot-metering readings at the same time. Thus, short-term metering equipment must be installed at the same time spot-metering readings are being taken. Data loggers must record readings on intervals of 5 minutes or less unless integrated energy, average power measurements, or on/off transition data are being recorded.

Monitoring is intended to provide an estimate of annual equipment operating hours and/or load. The duration and timing of the installation of "time of use" monitoring have a strong influence on the accuracy of operating hour measurements. Time of use monitoring should not be installed during holiday or vacation periods. If a holiday or vacation falls within the time of use monitoring installation period, the duration should be extended for as many days, if necessary.

For situations in which operating hours might vary seasonally or according to a scheduled activity, such as in HVAC systems, it may be necessary to collect data during different times of the year. Examples of monitoring intervals are once a month for each season or one random month during each performance year. The MFS plan submitted with the project application must indicate the timing and length of monitoring.

Sampling

Sampling across a single program must meet a confidence level of 90% and precision level of 10%. Sampling across single or multiple project sites can be done only if the equipment/process sampled has the same usage groups, ownership, occupancy, functional use, and energy and/or peak demand use patterns. Sample selection and results of metering for the entire sample should be summarized in a tabulated format.

Implementer Approval

If measurements are required, a review is recommended of the measurement plan to ensure that any metering and analysis will be done in a consistent manner across all projects in the program and with a level of accuracy acceptable to all parties.

8.2.9 Incremental Measure Cost

Some programs limit project incentive based on a percentage of their project cost or project payback period without the incentive.[287] When project eligibility is based on project payback period, it is important to consider the incremental measure cost (IMC). The program team must help develop the estimate of costs. In order to calculate the incremental measure costs, the project cost estimates provided by the applicant can be used, as well as additional cost data from the contractor or equipment supplier where possible to help augment the cost assessment.

The Summit Blue Measure Cost study (developed for California as a part of the DEER study) gives specific directions for determining measure cost basis. There is also a study by the Regional Technical Forum that provides good guidance, too.[288] The study developed a cost basis designator to define whether an incremental or full cost basis is appropriate for each measure. The incremental cost methodology is used as much as possible. When a measure is an early replacement, a full measure cost is always warranted; whereas for the same measure, when it is a replace-upon-burnout, an incremental measure cost is merited because less efficient alternatives are available.

According to the Summit Blue study, the cost basis is used in defining when it is appropriate to use incremental and full costs. The cost basis is derived from (a) the application (retrofit, replace on burnout, or new) and (b) whether displacing existing technology, installing in absence, or is an alternative to a competing technology. In general, new construction[289] and replace on burnout measures use the incremental equipment cost. For retrofit measures, the full cost is typically used as the incremental measure cost, such as in the case where a customer installs a new technology such as an LED fixture in place of a high intensity discharge fixture. This methodology for calculating incremental measure cost is consistent with the approach that other utilities use.

The incremental cost includes subtracting from the project cost any costs that would have been incurred by the applicant to achieve all of the project benefits other than those resulting in the incentivized energy savings. The cost to be subtracted is typically based on the cost of similar equipment or materials that have a standard energy efficiency rating. In some cases, the full measure cost is considered the incremental measure cost.

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[287] Project payback period equals the project cost divided by the energy cost savings.

[288] http://rtf.nwcouncil.org/subcommittees/measurecost/

[289] New construction incremental measure cost is complicated and an investigation on the specific TVA's needs should be considered. Accurate calculations of the total resource cost (or other cost-effectiveness metrics) or incentives should be the driver for the need of a proper incremental measure cost or not.

Incremental Measure Cost = New Equipment Material and Installation Cost - Existing (or Baseline) Equipment Material and Installation Cost

In most cases, the installation cost is the same, therefore, the IMC is:

Incremental Measure Cost = New Equipment Material Cost - Existing (or Baseline) Equipment Material Cost

8.2.10 Effective Useful Life

The measure life in most cases should be equivalent to the effective useful life (EUL). This value is important to verify since capturing measure life cycle savings provides valuable power planning data, as well as help determine the avoided cost for the projects. The EUL can be defined as an estimate of the average number of years that a measure is installed under a program, and is in place, operable, and achieving the savings estimated for the first year. The implementer should first review the deemed measure list for measure life that may be applicable to the custom measure(s). Otherwise, many sources are available for measure life such as the DEER study (www.deeresources.com), evaluation reports, and California Energy Efficiency Policy Manual (www.cpuc.ca.gov), Regional Technical Forum (rtf.nwcouncil.org/), and state TRMs.[290]

8.3 Specific Custom Measure Guidelines

The following sections describe how these basic savings estimation principles and submittal project/review requirements may apply to certain project types or technologies. Prior to doing specific reviews, it is important to assess if summer and/or winter peak savings are achievable and reliable. Reviewing and replicating submitted values is always necessary. An implementer should recalculate savings if the applicant used a questionable methodology and an alternative methodology that provides a more accurate savings estimate can be used. Appendix Section 7 provides some detailed MFS guidelines on the following end uses/technologies:

- Lighting
- Constant speed motors

[290] If in the rare case, the early replacement option is considered as a baseline, the remaining useful life of the replaced equipment must be considered. The savings of existing equipment replaced is only evaluated for the RUKL and the EUL minus RUL number of years is used to calculate the remaining lifetime savings using code or standard practice baseline.

- Variable load motors (variable speed drives)
- Chiller replacement
- Generic variable load/process
- Energy savings device

8.3.1 Custom Lighting Measures

Note that some of the most common lighting measures are included in the list of prescriptive measures. If the program does not have these measures as prescriptive (deemed), then the following approach for reviewing the project is provided. When reviewing a lighting application, the first step is to make sure the application does not have deemed measures, since typically using deemed values (even if not accurate for that specific project) is a cost-effective approach to verifying savings.

The following information should be provided with custom lighting measures. If the information is not provided, then the implementer must require these data from the applicant prior to reviewing the project application. This manual includes a worksheet (TVA Lighting Worksheet.xls) that can be used with lighting projects and should help customers provide the information in the appropriate format and savings calculations. Using deemed savings values is preferable, unless lighting operating hours have been verified for the project, and a detailed space by space lighting audit is provided with actual fixture wattages.[291] Standard fixture wattage tables used by TVA's implementer or published by other states/programs are sufficient. Details on conducting lighting measurements (MFS) are provided in Appendix Section 7.4. If there is operating hour data from lighting measurements then TVA should collect these data to update the deemed measure operating hours assumptions, as appropriate.[292]

- Project description - for example, Replace 200 - 400 Watt hi-bay HID lighting fixtures in the warehouse with 220 suspended 6-lamp high output T8 fixtures equipped with daylight controls.
- Provide a detailed lighting inventory that includes the following:
  - Location (e.g., area and aisle number)
  - Existing and new fixture description
  - Existing and new fixture wattage

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[291] Implementer should assess the audit is sufficient in place of deemed savings.

[292] TVA should consider reviewing past projects that had lighting operating hours monitored to update the deemed operating hours used in Section 5.2.1.

  - Existing and new fixture quantity
  - Existing and new controls
  - Existing and new annual operating hours (different if installing controls)
  - Interior or exterior fixtures
- Provide the electrical plan sheet that shows the existing and proposed lighting layout or a reflected ceiling plan and the lighting fixture schedule, when available.
- The use of standard "default" fixture wattages is acceptable. If the fixture type being installed is not on the table, specification sheets showing the wattage of all fixtures must be provided with the lighting inventory.

Use the following general equations to calculate the savings. The spreadsheet tool is sufficient for determining the savings amount for the final incentive payment.

(Note: In the case of new construction projects, the base case lighting kW will be the maximum wattage per square foot x square footage that would be allowable by the applicable energy code. This can be referred to as the lighting power density method.)

Base Case Lighting kW = (Base case fixture quantity x Base case fixture wattage) / (1000 Watts/kW)

Post Retrofit Lighting kW = (Post retrofit fixture quantity x retrofit fixture wattage) / (1000 Watts/kW)

Annual kWh Savings = (Base Case Lighting kW x base case annual operation hours) - (Post Retrofit Lighting kW x post retrofit annual operation hours)

Peak kW Savings = (Base Case Lighting kW - Post retrofit Lighting kW) x Coincidence Factor

Coincidence factor indicates the fraction of fixtures that is typically operating during the peak period. These values are extracted from the building prototype models developed (and described in Appendix Section 2). These factors are by building type and weather zone, summarized below.

Table 329. Lighting Peak Coincidence Factors[293]

	Central		Eastern	
Building Type	**Summer**	**Winter**	**Summer**	**Winter**
Assembly	0.550	0.270	0.510	0.290
Education - College/Secondary	0.461	0.551	0.383	0.674
Education - Primary School	0.240	0.160	0.220	0.340
Education – University	0.592	0.548	0.530	0.617
Grocery (Large)	0.906	0.811	0.895	0.894
Grocery (Small)	0.540	0.540	0.540	0.540
Health/Medical	0.679	0.652	0.618	0.755
Lodging – Hotel	0.170	0.240	0.260	0.240
Lodging – Motel	0.140	0.200	0.210	0.200
Manufacturing - Bio/Tech	0.758	0.794	0.758	0.794
Manufacturing - Light Industrial	0.758	0.794	0.758	0.794
Municipal	0.547	0.429	0.452	0.602
Office – Large	0.687	0.589	0.586	0.720
Office – Small	0.672	0.576	0.573	0.704
Other	0.700	0.488	0.655	0.607
Refrigerated Warehouse	0.560	0.050	0.460	0.390
Religious	0.349	0.324	0.321	0.488
Restaurant - Fast-Food	0.650	0.580	0.650	0.640
Restaurant - Sit-Down	0.770	0.120	0.770	0.220
Retail - Mall Department Store	0.720	0.300	0.680	0.570
Retail - Single-Story, Large	0.770	0.290	0.770	0.580
Retail – Small	0.990	0.390	0.880	0.810
Service	0.862	0.454	0.759	0.703
Storage – Air Conditioned	0.860	0.150	0.710	0.650
Storage - Unconditioned	1.000	0.330	0.790	0.650
Industrial/Warehouse 1-shift**	0.758	0.794	0.758	0.794
Industrial/Warehouse 2-shift**	0.831	0.977	0.831	0.977
Industrial/Warehouse 3-shift**	0.993	0.999	0.993	0.999

293 One asterisked items are sourced from the Northeast Energy Efficiency Partnership lighting load shape tool. "C&I Lighting Load Shape Project FINAL Report", prepared for the Regional Evaluation Measurement and Verification Forum, a project facilitated by Northeast Energy Efficiency Partnerships (NEEP), KEMA, Inc., July 2011. Two asterisked items are from a northeast metering study. The manufacturing building types assume the peak factors used for one-shift industrial buildings.

HVAC interactive effects are building type dependent and can be used for quantifying lighting savings. These values are different for annual energy savings and peak kW savings. These values are also extracted from the building prototypes. However, if the lighting is not in conditioned space, the HVAC interaction effect is 1.0. The values are provided in the following table. The calculations for savings then look like the following equations:

KWh reduction = (kW base case - kW post retrofit) * Hours * Interactive Effects

kW peak load reduction = (kW base case - kW post retrofit) * Interactive Effects * Coincident Diversity Factor

Table 330. Lighting Energy Interactive Effects[294]

Building Type	Chattanooga	Huntsville	Knoxville	Memphis	Nashville
Assembly	1.208	1.200	1.177	1.220	1.186
Education - College/Secondary	1.291	1.280	1.255	1.289	1.259
Education - Primary School	1.231	1.231	1.195	1.251	1.212
Education – University	1.358	1.364	1.338	1.351	1.332
Grocery (Large)	1.264	1.267	1.25	1.312	1.284
Grocery (Small)	1.264	1.267	1.250	1.312	1.284
Health/Medical	1.323	1.316	1.315	1.333	1.319
Lodging - Hotel	1.118	1.07	1.048	1.116	1.096
Lodging - Motel	0.985	0.982	0.931	1.021	0.966
Manufacturing - Bio/Tech	1.000	1.000	1.000	1.000	1.000
Manufacturing - Light Industrial	1.000	1.000	1.000	1.000	1.000
Municipal	1.083	1.075	1.083	1.083	1.075
Office - Large	1.394	1.378	1.39	1.415	1.409
Office - Small	1.109	1.106	1.077	1.14	1.097
Other	1.038	1.033	1.038	1.038	1.032
Refrigerated Warehouse	1.625	1.626	1.620	1.634	1.634
Religious	1.146	1.134	1.146	1.146	1.135
Restaurant - Fast-Food	1.192	1.184	1.165	1.201	1.174

[294] Asterisked items are sourced from the Northeast Energy Efficiency Partnership lighting load shape tool.

Building Type	Chattanooga	Huntsville	Knoxville	Memphis	Nashville
Restaurant - Sit-Down	1.235	1.216	1.195	1.237	1.2
Retail - Mall Department Store	1.474	1.424	1.423	1.408	1.388
Retail - Single-Story, Large	1.29	1.278	1.26	1.292	1.269
Retail - Small	1.191	1.179	1.163	1.204	1.172
Service	1.109	1.101	1.109	1.109	1.099
Storage - Conditioned	1.191	1.179	1.163	1.204	1.172
Storage - Unconditioned	1.000	1.000	1.000	1.000	1.000
Industrial/Warehouse 1-shift	1.000	1.000	1.000	1.000	1.000
Industrial/Warehouse 2-shift	1.000	1.000	1.000	1.000	1.000
Industrial/Warehouse 3-shift	1.000	1.000	1.000	1.000	1.000

Table 331. Lighting Summer Demand Interactive Effects[295]

Building Type	Chattanooga	Huntsville	Knoxville	Memphis	Nashville
Assembly	1.379	1.375	1.369	1.372	1.371
Education - College/Secondary	1.446	1.434	1.414	1.399	1.388
Education - Primary School	1.416	1.416	1.374	1.439	1.394
Education – University	1.469	1.419	1.374	1.439	1.415
Grocery (Large)	1.375	1.35	1.356	1.356	1.362
Grocery (Small)	1.375	1.350	1.356	1.356	1.362
Health/Medical	1.378	1.364	1.361	1.371	1.371
Lodging - Hotel	1.367	1.403	1.342	1.418	1.497
Lodging - Motel	1.326	1.382	1.321	1.38	1.387
Manufacturing - Bio/Tech	1.000	1.000	1.000	1.000	1.000
Manufacturing - Light Industrial	1.000	1.000	1.000	1.000	1.000
Municipal	1.163	1.163	1.163	1.163	1.163
Office - Large	1.564	1.475	1.564	1.486	1.484
Office - Small	1.419	1.406	1.401	1.406	1.403
Other	1.087	1.087	1.087	1.087	1.087

[295] Asterisked items are sourced from the Northeast Energy Efficiency Partnership lighting load shape tool.

Building Type	Chattanooga	Huntsville	Knoxville	Memphis	Nashville
Refrigerated Warehouse	1.711	1.712	1.705	1.72	1.72
Religious	1.273	1.273	1.273	1.273	1.273
Restaurant - Fast-Food	1.362	1.358	1.35	1.365	1.356
Restaurant - Sit-Down	1.351	1.264	1.346	1.349	1.348
Retail - Mall Department Store	1.503	1.446	1.473	1.443	1.447
Retail - Single-Story, Large	1.346	1.34	1.312	1.34	1.339
Retail - Small	1.353	1.315	1.35	1.33	1.328
Service	1.199	1.199	1.199	1.199	1.199
Storage - Conditioned	1.353	1.315	1.35	1.33	1.328
Storage - Unconditioned	1.000	1.000	1.000	1.000	1.000
Industrial/Warehouse 1-shift	1.000	1.000	1.000	1.000	1.000
Industrial/Warehouse 2-shift	1.000	1.000	1.000	1.000	1.000
Industrial/Warehouse 3-shift	1.000	1.000	1.000	1.000	1.000

Lighting Controls

When lighting controls are installed, it is assumed that operating hours are reduced. Reducing the run time does not necessarily save on peak demand. The implementer must carefully assess and consider requiring monitoring to verify peak savings. Using the power adjustment factors[296] from ASHRAE 90.1 (provided in the following table) may be sufficient as a peak savings factor, as well as an energy savings factor. Further studies (measurements) are needed to confirm this assumption, but may be used for projects where metering is not cost-effective.

Table 332. Power Adjustment Factors for Lighting Controls

Lighting Control Type	Power Adjustment Factor
Light switch	1
No Controls	1
Daylight controls (DC) - continuous dimming	0.7
DC - multiple-step dimming	0.8
DC - ON/OFF	0.9
Occupancy sensor (OS)	0.7

[296] The savings percentage for the baseline kW or kWh is the 1 - power adjustment factor or the post retrofit operating hours are the pre retrofit operating hours times the power adjustment factor.

Lighting Control Type	Power Adjustment Factor
OS w/DC - continuous dimming	0.6
OS w/DC - multiple-step dimming	0.65
OS w/DC - ON/OFF	0.65

The following table provides some maximum thresholds to be considered for savings assumptions for lighting occupancy sensors in the following space types.297 This table may be updated based on evaluation work being conducted currently in the Northeast.

Table 333. Potential Occupancy Sensor Savings by Space Type

Space Type	% Savings
Assembly	45
Break room	25
Classroom	30
Computer Room	35
Conference	35
Dinning	35
Gymnasium	35
Hallway	25
Hospital Room	45
Industrial	45
Kitchen	30
Library	15
Lobby	25
Lodging (Guest Rooms)	45
Open Office	15
Private Office	30
Process	45
Public Assembly	35
Restroom	45
Retail	15
Stair	25
Storage	45

[297] This table is from PG&E's custom program manual as part of the M&V guidelines (www.pge.com). The percentages are in line from a Lighting Research Center study, http://www.lrc.rpi.edu/resources/pdf/dorene1.pdf .

Space Type	% Savings
Technical Area	35
Warehouses	45
Other	15
Parking Garage	15

Other Guidelines

When reviewing custom lighting projects, the reviewer will consider:

- Operating hours are typically the operating hours of the facility except as noted below. If the lighting is on a different operating schedule from the facility, consider using lighting or power data loggers to document the fixture operating hours.
  - Exit signs and emergency lighting and many hallway and stairway fixtures are typically on 24 hours per day, 7 days per week; therefore use 8,760 hours per year for a project that involves these technologies that fall outside of the prescriptive program.
  - In order to provide more accurate operating hours, consider dividing the fixtures into usage groups-offices, common areas, restrooms, conference rooms, etc.-to define operating hours by usage group.
- Pre-retrofit and post-retrofit operation hours are often the same. However, if the project includes the installation of control technologies such as occupancy sensors, timers, etc., new (lower) hours of operation usually result. Justification for the lower hours should be provided and documented.
- Installing a lower wattage lamp of the same type should not be considered as an eligible measure unless it can be established that the replacement fixture is more efficient or efficacious (i.e., the lumens per watt) than the fixture that it replaces.
- The review will check for inconsistencies between the quantities of fixtures used in the savings calculation, shown in the invoice documentation and the observed quantities of fixtures in the post-inspection. The reviewer should make sure that the applicants clearly differentiated between fixtures and lamps in their counts and provided backup documentation the installed equipment for the specific project. The Implementer should follow up with the applicant to ensure that any differences are resolved.

New Construction

For new construction, savings should be based on improvement above IECC 2009 standard, as shown in the following table (except for Mississippi where baseline code is ASHRAE 2010).

Table 334. 2009 IECC Lighting Density Standard (Watts per Square Foot)[298]

Building Area Type	LPD (W/ft^2)	Building Area Type	LPD (W/ft^2)
Automotive Facility	0.9	Multifamily	0.7
Convention Center	1.2	Museum	1.1
Courthouse	1.2	Office	1.0
Dining: Bar Lounge/Leisure	1.3	Parking Garage	0.3
Dining: Cafeteria/Fast-food	1.4	Penitentiary	1.0
Dining: Family	1.6	Performing Arts Theater	1.6
Dormitory	1.0	Police/Fire Station	1.0
Exercise center	1.0	Post Office	1.1
Gymnasium	1.1	Religious Building	1.3
Health-care clinic	1.0	Retail	1.5
Hospital	1.2	School/University	1.2
Hotel	1.0	Sports Arena	1.1
Library	1.3	Town Hall	1.1
Manufacturing Facility	1.3	Transportation	1.0
Motel	1.0	Warehouse	0.8
Motion Picture Theater	1.2	Workshop	1.4

A whole building or space-by-space approach may be used to determine savings. The baseline required densities for different building and space types are shown in the following table.

[298] In cases where both a common space type and a building specific type are listed, the building specific space type shall apply.

Table 335. Baseline Lighting Density by Building and Space Types (Watts per Square Foot)

Common Space Type	LPD (W/ft^2)	Building Specific Space Types	LPD (W/ft^2)
Office-Enclosed	1.1	**Gymnasium/Exercise Center**	
Office-Open Plan	1.1	Playing Area	1.4
Conference/Meeting/Multipurpose	1.3	Exercise Area	0.9
Classroom/Lecture/Training	1.4	**Courthouse/Police Station/Penitentiary**	
For Penitentiary	1.3	Courtroom	1.9
Lobby	1.3	Confinement Cells	0.9
For Hotel	1.1	Judges Chambers	1.3
For Performing Arts Theater	3.3	**Fire Stations**	
For Motion Picture Theater	1.1	Fire Station Engine Room	0.8
Audience/Seating Area	0.9	Sleeping Quarters	0.3
For Gymnasium	0.4	Post Office-Sorting Area	1.2
For Exercise Center	0.3	Convention Center-Exhibit Space	1.3
For Convention Center	0.7	**Library**	
For Penitentiary	0.7	Card File and Cataloging	1.1
For Religious Buildings	1.7	Stacks	1.7
For Sports Arena	0.4	Reading Area	1.2
For Performing Arts Theater	2.6	**Hospital**	
For Motion Picture Theater	1.2	Emergency	2.7
For Transportation	0.5	Recovery	0.8
Atrium—First Three Floors	0.6	Nurse Station	1.0
Atrium—Each Additional Floor	0.2	Exam/Treatment	1.5
Lounge/Recreation	1.2	Pharmacy	1.2
For Hospital	0.8	Patient Room	0.7
Dining Area	0.9	Operating Room	2.2
For Penitentiary	1.3	Nursery	0.6
For Hotel	1.3	Medical Supply	1.4
For Motel	1.2	Physical Therapy	0.9
For Bar Lounge/Leisure Dining	1.4	Radiology	0.4
For Family Dining	2.1	Laundry—Washing	0.6
Food Preparation	1.2	Automotive—Service/Repair	0.7
Laboratory	1.4	**Manufacturing**	
Restrooms	0.9	Low (<25 ft Floor to Ceiling Height)	1.2
Dressing/Locker/Fitting Room	0.6	High (>25 ft Floor to Ceiling Height)	1.7
Corridor/Transition	0.5	Detailed Manufacturing	2.1
For Hospital	1.0	Equipment Room	1.2
For Manufacturing Facility	0.5	Control Room	0.5

Common Space Type	LPD (W/ft^2)	Building Specific Space Types	LPD (W/ft^2)
Stairs—Active	0.6	Hotel/Motel Guest Rooms	1.1
Active Storage	0.8	Dormitory—Living Quarters	1.1
For Hospital	0.9	**Museum**	
Inactive Storage	0.3	General Exhibition	1.0
For Museum	0.8	Restoration	1.7
Electrical/Mechanical	1.5	Bank/Office—Banking Activity Area	1.5
Workshop	1.9	**Religious Buildings**	
Sales Area	1.7	Worship Pulpit, Choir	2.4
		Fellowship Hall	0.9
		Retail [For accent lighting, see 9.3.1.2.1(c)]	
		Sales Area	1.7
		Mall Concourse	1.7
		Sports Arena	
		Ring Sports Area	2.7
		Court Sports Area	2.3
		Indoor Playing Field Area	1.4
		Warehouse	
		Fine Material Storage	1.4
		Medium/Bulky Material Storage	0.9
		Parking Garage—Garage Area	0.2
		Transportation	
		Airport—Concourse	0.6
		Air/Train/Bus—Baggage Area	1.0
		Terminal—Ticket Counter	1.5

The whole building method is appropriate for an entire building interior or an entire occupancy in a multi-occupancy building. The space-by-space method is slightly more complicated but can be used for any type of lighting system or occupancy type. If this approach is used for one portion of a multi-occupancy building, and the building area method is used for another, then trade-offs are not permitted between the two building occupancies. Only one method may be selected. If the space-by-space method is selected, IECC standards cannot be exceeded within the spaces that do not qualify. If this approach is used, no other method which considers lighting in any manner may be applied to obtain an incentive for a new construction building.

To calculate savings, the following is the approach to use:

1. Determine the design maximum for the approach used.
2. Determine if project has a lower lighting-power-density (LPD) lower than the design maximum. If it does, then the project qualifies for an incentive.
3. The difference in lighting density between the specified design and the IECC 2009 standard is the basis of the savings. This value is then multiplied by the appropriate coincident factor and interactive effects for the peak demand savings.
4. Peak demand savings (kW) = Coincidence factor x Interactive effects x (IECC Standard LPD - Design LPD) x Square footage / 1000W/kW.

8.3.2 Custom HVAC Measures

Note that some of the common HVAC measures are included in the list of prescriptive measures. When reviewing an HVAC application, the first step is to make sure the application does not qualify for a prescriptive measure. The application should include the requirements as listed in Section 8.2.3. Then it is critical to assess if there are summer and/or winter peak demand savings. Many control measures, such as variable speed control, demand-based ventilation control, and EMS, may not have peak demand savings and must be scrutinized to ensure these measures are relevant. Common custom measures that may be applied for under the custom HVAC category might include:[299]

- Chiller replacement
- VSD on HVAC motors, >200 hp
- Water-side economizer, also known as, "free cooling" (e.g., plate and frame heat exchanger, closed-loop tower, or "glycooler")
- Exhaust heat recovery equipment (heat exchangers)
- Constant volume to variable volume water or air distribution
- Variable-speed control of centrifugal equipment (other than HVAC fans or pumps) that are throttled by less efficient means
- Control upgrades or EMS programming changes

[299] NOTE: There may be instances that the HVAC motor will operate at full load or controls resulting in no change in usage at certain instances of time resulting in no peak demand savings.

- CO2- or occupancy-based (demand-based) ventilation controls

Most (but not all) HVAC system measures are weather-dependent.[300] As such, the preferred methods of estimating energy savings are building or system models that integrate local weather conditions with system loads and performance or “temperature bin” models. A bin model is the most common method for calculating savings.

This section includes several acceptable methods for providing the savings analysis for HVAC measures. In all cases, it is important to document the pre- and post-retrofit conditions thoroughly. For most projects, the analysis will need to be calibrated and adjusted to reflect the weather variances, occupancy variations, or internal load changes. Standard analysis tools or the use of eQUEST building prototypes for many HVAC measures are available. These tools provide a mechanism and consistency to confirm the savings estimate at the time of the final incentive request.[301] If a measure does not have a prescribed method, the engineer should use a custom method (such as, whole building modeling or sub-metering) to calculate the project’s energy savings. Appendix Section 7 provides measurement guidance details for various approaches for HVAC.

Implementers may also use other standard analysis techniques to calculate project savings:

- Building models that are publicly available and well documented, such as eQUEST, Energy Plus and DOE-2 are recommended for measures with building-wide or interactive effects. Proprietary vendor programs like Trane, Trace and Carrier HAP may be accepted with appropriate documentation, but without good documentation, these models cannot be utilized and offer little confidence in the results.[302]

- ASHRAE-based simplified calculation methodologies including the bin methods are usually useful to estimate the savings of many weather-dependent strategies such as economizer systems (water and air), heat recovery, ventilation control, or even VAV conversions. These methods can be easily calculated in a spreadsheet format so that the underlying assumptions can be easily followed. In many cases, for retrofit projects, the existing building energy use and energy use patterns can provide the basis for calibration for these methods.

[300] Some buildings requiring conditioning due to high internal loads are less weather-dependent.

[301] If an analysis is not available for the measure in question, the engineer reviewing the project will work together with an appropriate peer to ensure the analysis (calculation, model, or measurements) is appropriate for calculating the energy savings for the project.

[302] It is recommended to duplicate savings estimates using other tools. The applicant must provide sufficient information for the implementer to do so.

- Simple spreadsheet analysis may be used for certain stand-alone retrofits such as carbon monoxide sensors for parking garages.

- For certain projects, a monitoring/metering approach may be the best means to document savings. In these cases, the base case condition might also require monitoring. Be sure to consider pre-project measurements prior to reserving funds. The following are some suggested parameters for measuring pre- and post-retrofit:

  - Power (kW) and energy (kWh)
  - Air flows, temperatures, water flows
  - Outdoor temperatures and humidity (may be available from other sources)
  - Building activity (people, hours, etc.)

HVAC system upgrades need to be compared to a code baseline (ASHRAE Appendix G) that is compliant with IECC 2009, except for Mississippi where the code baseline is ASHRAE 2010, applied to both process and comfort projects.

8.3.3 Custom Building Envelope Measures

Common custom measures that may be applied for under this category include:

- Window treatments like external or internal shading

- Window film

- Insulation

- Cool roof

- Door or window opening treatments that reduce infiltration

Accurately estimating envelope improvement measure energy savings is often difficult because their impacts involve a high degree of system and interactive effects. The best way to estimate the impacts of envelope treatments is to use a whole building model as described in the previous section. These models provide the opportunity to describe the pre- and post-retrofit insulation and surface characteristics and do an excellent job of including the whole system and any interactive effects. The applications should at minimum include the information described in Section 8.2.3.

However, setting up a whole building model to estimate the savings for envelope improvements is often not practical. There is a number of simplified degree-day or weather-based bin analysis methods that are sufficient to estimate the impacts of these measures. These methods are described in detail in the ASHRAE handbooks. ASHRAE combined with local weather data files will provide most of the information and calculation procedures necessary to estimate savings resulting from building envelope measures. Some of the more common methodologies have been put into spreadsheet format that are available commercially online. DOE and some states have supported the development of analytical tools that are useful in isolating the savings for various envelope improvements. Some examples are listed below:

- The Cool Roof Rating Council (http://www.coolroofs.org/) publishes a tool that is useful in estimating the impacts of roof insulation and treatments. The performance characteristics of and properties of various coatings and materials are also provided.
- TVA building prototypes

8.3.4 Custom Process and Refrigeration Measures

Some typical measures that may fall into this category are:[303]

- "Tower-free cooling" for process cooling (e.g., plate and frame heat exchanger and closed-loop tower or "glycooler")
- Waste heat recovery equipment (heat exchangers)
- Variable-speed control of centrifugal equipment (such as fans or pumps) that are throttled by less efficient means
- Higher efficiency or improved-control process equipment (improvement in energy intensity per widget)
- Floating head pressure controls for industrial refrigeration
- Upgrade of a refrigeration compressor
- Air compressor improvements[304]

[303] NOTE: Some of these measures need to be assessed for the particular application if there will be peak demand savings.

Prior to conducting an analysis of the savings, the reviewer must make sure the measure will result in peak demand savings. There are several methods that can be used to document energy and peak savings for process measures. Section 8.2.3 provides more details on the documentation requirements. Nearly all process measures will require some degree of monitoring or measurements or hourly log observations to establish the load profile for the equipment, the energy and peak demand use, and the savings, which are then extrapolated to a full-year period. In all cases, it is important to consider any seasonal, weekly, or monthly variations in operation. Section 8.2.3 provides guidelines on production adjustments needed when considering a process improvement. The following are methods how measurements can be used to extrapolate to a full year of energy use. In some cases, a regression analysis is used to provide the method for extrapolation.

- **Short-term, pre- and post-retrofit measurements extrapolated by production.** Energy and peak demand use for process systems can often (but not always) be related to production output. One method to document annual savings is to compare the pre- and post-retrofit systems over a representative production period, which may include multiple shifts, and then extrapolate the results to a full year. The method is as follows:
  - Determine the pre-retrofit system kWh and peak kW per unit of production per shift/production run/equipment cycles, as appropriate.
  - Determine the post-retrofit kWh and peak kW per unit of production per shift/production run/equipment cycles, as appropriate.
  - Adjust the baseline using the post-retrofit production levels (if production levels are lower than pre-retrofit).
  - Extrapolate to a full year by multiplying the difference by the annual production.
- **Short-term measurements extrapolated by shifts or operating time.** In some cases the energy and/or peak demand use does not relate to production, but to equipment operating time or availability. In this case the savings are similar to the above except the time in days or number of shifts is the factor used to extrapolate the savings to the full year.

- **Short-term monitoring extrapolated to a year.** A short term pre- and post-monitoring of at least two weeks can be carried out and the results extrapolated to a full year based on time and for the peak period. The difference is then multiplied by the ratio of annual hours to the monitored hours.

[304] In many cases Air Master Plus available via http://www1.eere.energy.gov/industry/bestpractices/software_airmaster.html can be used to assess air compressor savings. It may be required to do pre and post metering of air flow, pressure and/or amps or kW. Air compressor analysis needs to be customized on a per project basis.

- **Post-retrofit, energy/peak demand monitoring and calculated base case energy/peak demand, extrapolated to a full year.** This method is useful when the performance or efficiency of the base case equipment is known but the load profile was not monitored prior to the project. This method often applies to compressed air systems or large refrigeration systems. In this case, the post-retrofit system power and output (cfm or tons) is measured for a period of two weeks or more. The base case power for the same period is then calculated by multiplying the output by the base case equipment performance. The savings are then extrapolated to full year by extrapolating based on the projected loading pattern.

8.3.5 Using TVA Building Prototypes

Most of the building prototypes were completed using the eQUEST wizard mode. Therefore, some of the measures described above can be modeled using the building prototypes. This option could be beneficial for calculating energy savings for projects that have smaller energy savings potential, but require complicated and expensive analysis. Using this approach can allow "shortcuts" to building modeling. However, it must be clearly documented for the evaluator and the applicant that this savings value is not specific to the site and can be treated similarly to the assumptions made with deemed savings estimates. Appendix Section 5 provides the steps for using this approach for certain measures. Measures that may fall under this category are EMS upgrades, new EMS installation, envelope improvements, constant volume to VAV conversion, and whole chiller plant upgrades.