Work Paper PGE3PREF116
Add Doors to Open Med Temp Cases
Revision 2

PECI

EnergySmart Grocer

Add Doors to Open, Medium-Temperature Cases

Measure Code RA01, HA09
PECI

1/1/2016

At-a-Glance Summary

Applicable Measure Codes:	**RA01, HA09**
Measure Description:	Retrofit Add On of glass doors to medium temperature open vertical refrigerated display case.
Energy Impact Common Units:	Len-ft (length, feet) Display case length in feet
Base Case Description:	PECI. Existing open vertical MT refrigerated display case. Case may or may not have night covers in place.
Base Case Energy Consumption:	PECI kWh per foot of case varies across climate zones.
Measure Energy Consumption:	PECI kWh per foot of case varies across climate zones.
Energy Savings (Base Case – Measure)	PECI kWh per foot of case varies across climate zones.
Costs Common Units:	Per Len-ft (length, feet) Display case length in feet
Base Case Equipment Cost ($/unit):	PECI REA: $0
Measure Equipment Cost ($/unit):	PECI REA: $456.31 / Len-ft
Gross Measure Cost ($/unit)	Source: Project Bids as seen by 3rd party implementer, PECI. REA: $521.55 / Len-ft
Effective Useful Life (years):	Source: DEER2016 15 years. 5 years. RefgWrhs-Cond
Measure Application Type:	Retrofit Add On (REA)
Net-to-Gross Ratios:	Source: DEER2016 0.60, Com-Default>2yrs
Important Comments:	This is an “original” work paper from the PG&E and CPUC point of view. However, it is based on the work paper titled “Vertical Refrigerated Case, Medium Temperature: Open to Closed” with file name “WP_PECIREF_PGE604_R0 110701” by Michele Friedrich and Eric Mullendore of PECI.

Document Revision History

Revision #	Revision Date	Section-by-Section Description of Revisions	Author (Company)
Revision 0	06/08/2012	Original work paper	James Anthony, P.E., Engineering Manager, PECI
Revision 1	04/28/2014	Updated savings data according to new climate zone weather files. Formatting updated per PG&E guidelines	Brian Owens, PECI Danielle Geers, PECI
Revision 2	03/07/2016	Updated to the latest ex ante format 2016.	Linda Wan, PG&E

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Section 1. General Measure & Baseline Data

1.1 Product Measure Description & Background

The measure, addressed in this work paper, is retrofitting glass doors onto medium-temperature, open-vertical, refrigerated display cases (also known as open multideck cases). Such display cases are heavily represented in a typical supermarket and can also be found in a variety of other food retail settings such as smaller grocery stores and some large convenience stores. They can be self-contained systems with a refrigeration compressor and condenser built into the case structure, but more commonly they are served by remote compressors and condensers. In supermarkets, the remote compressors are generally arranged into combined suction groups described as a multiplex system.

Program Restrictions and Guidelines

This is a Retrofit Add On (REA) measure.

Terms and Conditions:

Requirements:

- Must add glass doors to an existing open–vertical, medium-temp display case.

Exclusions:

- Total lighting power in the case after the retrofit may not exceed total lighting power in the existing case.
- No anti-sweat heat may be present in the glass doors or door mounting.

Additional Details:

- Rebate paid based on linear feet of door installed.

Market Applicability

This measure is intended for grocery stores and supermarkets (GRO). It is a Retrofit Add On measure. This work paper provides energy savings that vary by climate zone and are applicable to all vintages. The recipient of the rebate is downstream. The rebate will reduce the simple payback period of the measure to a feasible level that can be implemented by the consumer. Without the rebate, the simple payback period is too high, making the measure difficult to implement without financial assistance.

1.2 Product Technical Description

The measure, addressed in this work paper, is retrofitting glass doors onto medium–temperature, open-vertical, refrigerated display cases (also known as open multideck cases). Such display cases are heavily represented in a typical supermarket and can also be found in a variety of other food retail settings such as smaller grocery stores and some large convenience stores. They can be self-contained systems with a refrigeration compressor and condenser built into the case structure, but more commonly they are served by remote compressors and condensers. In supermarkets, the remote compressors are generally arranged into combined suction groups described as a multiplex system.

Though air curtains are used to reduce the infiltration of non-refrigerated air into the case, infiltration of warm air and moisture is responsible for 70-80% of the refrigeration load on open-vertical refrigerated display cases.[1] Several studies have shown that this infiltration, and thus the total refrigeration load, can be significantly reduced by adding double-paned glass to the existing case.[2,3,4,5]

In addition to retrofitting the doors and door frames, the measure may require changes to the refrigeration system serving the affected display case(s). These changes *may* include but are not limited to: replacing the expansion valve and/or EPR, adjusting the evaporator temperature/pressure set point, resizing refrigeration piping, replacing the flood back valve on the condenser, resizing the coil/piping on applicable heat reclaim systems, and replacing or removing compressors. All of these potential changes stem from the significant reduction in the overall refrigeration load. Due to the complexity in determining which system alterations will be required at a particular site in order to maintain optimum system performance, a refrigeration contractor with design experience should be consulted before proceeding with the retrofit.

1.3 Measure Application Type

This is a Retrofit Add On (REA) measure: adding an EE feature or new equipment to a unit to make it more efficient.

The refrigerated display cases exist as the baseline. The measure adds a door to these existing refrigerated display cases in order to make the existing refrigerated display cases more energy efficient.

The DEER Measure Cost Data Users Guide found on www.deeresources.com under *DEER2011 Database Format* hyperlink, DEER2011 for 13-14, spreadsheet *SPTdata_format-V0.97.xls*, defines the terms as follows:

Table 1 Measure Application Type[6]

Identifies the measure application type in the Measure Implementation table in DEER2011.

Code	Description	Comment
REA	Retrofit Add On	*Single baseline (above pre-existing, full measure costs required*

1.4 Product Base Case and Measure Case Data

The base case for the customer savings estimate is a medium–temperature, open-vertical refrigerated display case. The supply air temperature is 32°F. The coil capacity is 1,600 Btu/hr/ft of case. The case has two rows of T8 lighting in the canopy (16W/ft of case) and 10W/ft of evaporator coil fan electric use. The case uses off-cycle defrost, with 4 defrost cycles/day. One measure in each climate zone includes the use of night covers for 6 hours/night in the base case while the other does not. Additional details about the refrigeration system serving the display case are described in Section 0.

There are no currently applicable code requirements beyond the customer base case.

1.4.1 DEER Base Case and Measure Case Information

The data cited by DEER is not applicable to this measure because this measure does not employ the same technology or use. These differences are explained with each data variable table in this section.

The DEER Measure ID D03-206 is also intended to represent retrofitting glass doors to medium-temperature, open-vertical refrigerated display cases. It differs from the measures discussed in this work paper in several key ways. The DEER measure assumed that additional lighting and anti-sweat heaters (ASH) would be installed as part of the retrofit. The measures, discussed in this work paper, specifically excludes adding such equipment load as stated in the Terms and Conditions, located in section 1.1 Product Measure Description & Background. Additionally, the DEER measure does not allow for night covers in the base case. Because night covers have gained in market acceptance since the DEER team modeled the refrigeration measures and because significant savings potential still exists for cases with existing night covers, this work paper has specific measure iterations to account for night covers in the base case.

Differences in the model used in this work paper and the DEER model:

1) The DEER models have a reduced case evaporator coil capacity to match the smaller load found after the measure has been implemented. Evaporator coil adjustments are not part of the retrofits currently being offered on the market so coil capacity was not changed in the models used to develop this work paper.
2) The DEER models represent a store with two multiplex refrigeration systems. The models developed in support of this work paper represent a mix of multiplex and stand alone compressors for the refrigeration system. The ratio of compressors for each system is based on market data collected during California EnergySmart Grocer program implementation (n=4,550). Additional details in Section 0.
3) The DEER models reduce the differential temperature from the supply to the return air in the display case from the base to the measure case. The models, used to develop this work paper, have a reduced approach temperature between evaporator coil and supply air in the measure case runs instead. This phenomenon occurs as a result of the coil being designed to meet a significantly larger load. The oversized coil supplies air to display case that is closer to the coil temperature than it did before the retrofit occurred.
4) This work paper has two base cases. The first is equivalent to DEER base case. The second uses a reduced infiltration schedule for 6 hours at night time to model night covers in use.
5) The models used to develop this work paper used test data by SCE Research and Thermal Test Center (RTTC) and an ASHRAE research project to inform the models for changes in display case infiltration, conduction and refrigeration load for open cases versus cases with doors. Additional details in Section 0
6) The DEER models increased the lighting W/ft and added ASH to the retrofit doors. The terms and conditions of this measure do not allow ASH to be used and requires that total lighting power remains the same or decreases. The models used in this work paper maintain a consistent auxiliary load between the base case and measure runs.

Net-to-Gross Ratio

The NTG values were obtained using the DEER READI tool. The relevant NTG values for the measures in this work paper are in the table below.

Table 2 Net to Gross Ratio

NTGR ID	Description	Sector	BldgType	Measure Delivery	NTGR
Com-Default>2yrs	All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years	Com	Any	Any	0.6

Spillage Rate

Spillage rates are not tracked in work papers; they are tracked in an external document which will be supplied to the Commission Staff.

Installation Rate

The IR values were obtained using the DEER READI tool. The relevant IR values for the measures in this work paper are in the table below.

Table 3 Installation Rate

GSIA ID	Description	Sector	BldgType	ProgDelivID	GSIAValue
Def-GSIA	Default GSIA values	Any	Any	Any	1

Effective and Remaining Useful Life

The EUL and RUL values were obtained using the DEER READI tool. DEER defines the RUL as 1/3 of the EUL value. The RUL value is only applicable to the first baseline period for an RET measure with an applicable code baseline. The relevant EUL and RUL values for the measures in this work paper are in the table below.

Table 4 Effective and Remaining Useful Life

EUL ID	Description	Sector	UseCategory	EUL (Years)	RUL (Years)
RefgWrhs-Cond	Refrigeration Upgrades (Condenser) - Refg Warehouse	Com	HVAC ProcRefrig	15	5

1.4.2 Codes & Standards Requirements Base Case and Measure Information

Federal standards exist for refrigerated cases produced on or after January 1st, 2012. These standards limit the total energy consumption of the units when tested under conditions outlined in ARI Standard 1200-2006.[7] For medium–temperature, vertical-open cases designed for use with remote condensers, the maximum-energy consumption in kWh/day is equal to 0.82*DisplayArea (ft2)+4.07.[8] For medium-temperature, vertical-open cases with integrated condensers and compressors, the maximum energy consumption in kWh/day is equal to 1.74*DisplayArea (ft2)+4.71.[9]

These standards are not applied to the analysis presented in this work paper as they apply only to new equipment. Such equipment is not expected to significantly influence the typical base case condition until the codes have been in place for several years.

Title 20: These measures do not fall under Title 20 of the California Energy Regulations.

Title 24: These measures do not fall under Title 24 of the California Energy Regulations.

Federal Standards: These measures do not fall under Federal DOE or EPA Energy Regulations.

1.4.3 EM&V, Market Potential, and Other Studies – Base Case and Measure Case Information

Numerous studies have been conducted on the energy savings associated with the measures described in this paper. One commonly cited study, conducted by researchers at Southern California Edison's Research and Thermal Test Center, found that after retrofitting doors on an open display case the cooling load attributable to infiltration was reduced by 68%.[10] This conclusion was based on lab testing conducted with static ambient temperature and humidity levels. The retrofit differed from the measure described in the paper because the added doors included anti-sweat heaters, which introduce an additional cooling load on the refrigeration system.[11]

Another report, based on lab testing, concluded that the cooling load of open cases decreased 66% versus cases without doors or night covers and 53% when compared to an open case with night covers in place at night.[12]

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) paid for a research project (RP-1402) to compare energy and sales results of open multi-deck vs. reach-in case for medium temperature applications.[13] The display cases tested held alcoholic beverages and dairy and were located in 2 stores in Kansas. The report summary showed an 18% reduction in energy, using calculated compressor savings and measured refrigeration load. Even though this research compared a new open multi-deck case to a new reach-in case, not adding doors to an existing open multideck case, many of the measurements that were taken are valid for comparison to values used in this work paper including: 1) mean door open time for the reach-in case was 12 sec, occurring 6 times an hour; 2) average lighting power = 0.014 kW/ft in the open case; 3) average fan power = 0.009 kW/ft in the open case; and 4) supply to return air delta temp = 10°F for the open case and 2°F for the reach-in case.

The State of California Air Resources Board has estimated that adding doors to all viable open vertical refrigerated display cases in the state would reduce energy consumption by more than 1,000 GWH, or 5% of the total energy consumption attributed to the grocery sector.[14]

1.4.4 Assumptions and Calculations from other sources—Base and Measure Cases

1.4.5 Time-of-Use Adjustment Factor

We are required by CPUC decision 06-06-063 dated June 29, 2006 to apply time-of-use (TOU) adjustment factors on residential A/C and commercial A/C (packaged and split-system direct-expansion cooling) measures only.   Since this is not an A/C measure, the TOU adjustment factor is 0. Additionally, if a measure is assigned a DEER08 load shape, i.e. the load shape starts with "DEER:" the TOU assigned to that measure should also be zero.

The specific values and results are summarized in
Table 5.

Table 5 TOU Adjustment Factors

Measure	kW_{AC}	kW_{Total}	%
Add Doors to Cases	0	0	0

Section 2. Calculation Methods

2.1 Electric Energy Savings Estimation Methodologies

The energy savings for this measure were determined by using detailed computer simulations based on the eQUEST Refrigeration Version 3.61/DOE-2.2R energy analysis program. The program calculates hour-by-hour building and refrigeration system energy consumption over an entire year (8760 hours) using CEC's Title 24 weather data for a representative city in each CEC-defined climate zone. Model outputs and the associated calculations are available in Appendix A.

This section describes the modeling methodologies and inputs to DOE2.2R as well as results of a sensitivity analysis to the model inputs.

2.1.1 Model Description

The base case model is designed to be representative of existing grocery building stock in California. Figure 1 displays the general site layout and orientation.

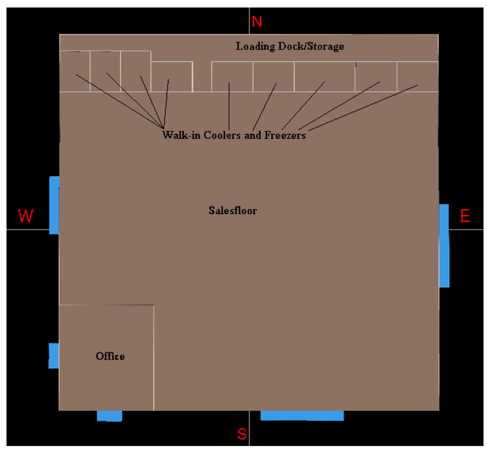

Figure 1 - eQuest Model

The model shares many building and space characteristics with the DEER 2005 grocery models as evident from Table 6, which lists a number of basic input values and their source.

Table 6 Basic eQUEST Model Characteristics

Building Characteristic	Input Value	Source
Area	50,000 ft^2	DEER 2005 Grocery Model
Shell (Walls, Windows, Roof)	Construction and 1978-85 vintage insulation	DEER 2005 Grocery Model
Lighting Power Density	2.0 Watts/SF	DEER 2005 Grocery Model, NREL[15] and T24 Code
Miscellaneous Equipment	0.5 Watts/SF	NREL[15]
Whole Building Infiltration	0.07 CFM/SF	DEER 2005 Grocery Model
Sales floor HVAC System Type	Package Variable Volume Variable Temperature set to Constant Volume	DEER 2005 Grocery Model
Sales Floor Cooling Capacity	Annual cooling peaks *1.15 - rounded up to the nearest 5 tons with	Engineering judgment

	minimum size of 20 tons	
Sales Floor Heating Capacity	Annual heating peaks * 1.2 - rounded up to the nearest 100,000 BTU	Engineering judgment
Sales Floor Design Supply Air	37,200 CFM (equal to 0.85CFM/ft^2)	Engineering judgment
Outside Air	15 CFM per person	ASHRAE standard 62
Refrigeration System	Mix of multiplex and stand-alone compressors, air-cooled condensers in most climate zones. Described in Appendix B.	Audit Data from EnergySmart Grocer Program
Occupancy schedule	Varying throughout day with peak occupancy at 125 ft^2 per person	NREL[15]

The primary-building system impacted by the measure is the refrigeration system with secondary impacts on the HVAC system. Accordingly particular attention was paid to ensuring that the modeled refrigeration system represented the arrangements common to the current grocery building stock and that the HVAC system was adequately sized to maintain a store temperature of 70^o F. This temperature setpoint represents the average temperature recorded by ADM & Associates in their work preparing the 2010 High Impact Measure (HIM) report on door gaskets.[16] A detailed description of refrigeration system model is in Appendix B.

The whole-building EUI of the base case models averaged 177 kBtu/yr-ft^2. One analysis of the CBECS data from 2003 found an average EUI of 203.6 kBtu/yr-ft^2 for grocery sites within ASHRAE climate zone 3, which covers most of California.[17] Another analysis of the same data done by Oakridge National Laboratory in support of the ASHRAE standard 100 -2006 revision[18] show grocery median values in ASHRAE climate zone 3b and 3c as 163-169 kBtu/yr-ft^2 and 178 kBtu/yr-ft^2, respectively.

2.1.2 Model Refrigeration System

The display cases impacted by the measure are modeled with remote compressors and air-cooled condensers, with the exception of Climate Zones 15 and 16 where an evaporative-cooled condenser was used in the model. There was no modeling of integral units, i.e. display cases with compressor and condenser contained within case. The majority of the open vertical cases are on a suction group connected to a multiplex compressor system, with the minority served by a stand-alone compressor in a condensing unit, i.e. a packaged compressor and condenser. PECI industry experience indicates multiplexes make up a majority of the targeted market for this measure therefore multiplexes were used for the measure modeled refrigeration systems. A survey of EnergySmart Grocer auditors and grocery store design engineers found that 90% of stand-alone refrigeration compressors are in condensing units and 10% are with remote compressors. The stand alone systems modeled for this work paper used only compressors in condensing units with 1 fan. Additional details of the refrigeration system are outlined in Appendix B.[24]

2.1.3 Model Measures

A sensitivity analysis was completed to quantify the magnitude of effect of key input variables for the modeled measures. Key input variables were chosen with minimum, maximum and typical ranges obtained from research papers, discussions with manufacturers, display case specification sheets and grocery store design engineers. The max and min values are not absolute max and min values but approximate the top 10% and the bottom 10% on a distribution graph. Table 7 shows the display case model minimum, typical and maximum values and source for each of the values that were changed between the base case and post-implementation versions of the model.

Table 7 Model Sensitivity Analysis Changes

Variable	Min Value	Typical Value	Max Value	Source
Supply Air Temp (deg F) (base/post)	28/24	32/28	37/33	Display case Manufacturer Specifications/SCE report[19]
Night covers (base only)	Reduce infiltration to 0.6 for 6 hrs/night	No reduction	–	SCE report[20]
Case light density (W/ft) (base/post)	8/16 16/11	16/16	48/48 16/29.8	Display case Manufacturer Specifications/LED specs
Case fan demand (W/ft) (base=post)	5	10	15	Display case Manufacturer Specifications
Increase Suction temperature (deg F) (post only)	4	0	–	SCE report[21], display case with doors manufacturer specs
Anti-Sweat heaters (W/ft) (post only)	–	0	16.8	door manufacturer specifications, frame heat
Coil Capacity (BTU/hr-ft) Infiltration (BTU/hr-ft) Conduction/Radiation (BTU/hr-ft) (base/post)	1100 896/195 143/46.2	1600 1331/324 208/67.2	2000 1679/427 260/84.0	Display case Manufacturer Specifications, SCE[22] and ASHRAE RP-1402 report[13]

A parametric analysis was conducted in CA climate zone 3, using eQUEST/DOE-2.2R, changing one variable at a time, holding all other variables constant (with the exception of coil capacity/infiltration/conduction that were varied together to depict different case styles). The values displayed in

Table 8 Sensitivity Results **Error! Reference source not found.** are the savings values obtained from subtracting the DOE-2.2R whole building energy use in the measure case from the DOE-2.2R whole building energy use in the base case. For base case variable sensitivity, the measure energy use is from the expected typical measure value and for measure variable sensitivity the base case energy use is from the typical value.

Table 8 Sensitivity Results

Variable	Electric Savings (kWh/ft-yr)	Change from typical (%)	Gas Savings (therm/ft-year)	Total Energy Savings (kBTU/ft-yr)	Change from typical (%)
typical	476		56.3	7,257	
min case supply temp (28 F)	500	-5%	57.9	7,496	-3%
max case supply temp (37 F)	441	7%	54.0	6,905	5%

min lights, base (1 row T8)	416	13%	57.6	7,174	1%
max lights, base (6 rows T8)	732	-54%	53.6	7,859	-8%
LED vertical lights, post	515	-8%	55.9	7,351	-1%
T8 vertical lights, post	367	23%	57.5	7,002	4%
min fan (5 watts/ft)	477	0%	56.6	7,287	0%
max fan (15 watts/ft)	476	0%	56.2	7,243	0%
night covers, base	432	9%	50.9	6,560	10%
increase SST, post (+4 F)	504	-6%	58.9	7,611	-5%
add ASH to frame, post	304	36%	58.8	6,917	5%
max lights base = max light post	480	-1%	56.3	7,268	0%
min lights base=min lights post	479	-1%	56.9	7,323	-1%
min coil capacity (1100 BTU/hr-ft)	499	-5%	58.7	7,570	-4%
max coil capacity (2000 BTU/hr-ft)	473	1%	56.1	7,225	0%
nightcovers base, ASH post	259	45%	53.4	6,220	14%

Based on the sensitivity analysis results, lighting power in the base and measure cases, the presence of night covers and the presence of anti-sweat heat in the measure case were identified as key measure variables.

Several manufacturers stated that most retrofits include a switch to more efficient LED case lighting but not an overall increase in lighting power density, so the Terms and Conditions state that the post-case lighting power cannot exceed the pre-case lighting power. Additionally, two of the three manufacturers interviewed stated that their products did not contain anti-sweat heat in the door or mullion. It was decided to specifically prohibit door and frame heat in the measure terms and conditions as it does not appear necessary in medium temperature applications and negatively impacts energy savings. The limitations on lighting power and anti-sweat heat are outlined in the program terms and conditions in Section 1.2.

Night covers are present in a large number of existing open refrigerated display cases. In order to encourage the market to achieve the deeper savings available through retrofitting doors to such cases while accounting for the more efficient base case, two measures were created for each climate zone. The first iteration is based on the energy savings compared to a base case without night covers in place. The second iteration is based on the energy savings compared to a base case where night covers are in place. The model for night covers assumes that they are deployed for 6 hours a night.

Table 9 displays the final input value and source for each of the values that were changed between the base case and post-implementation versions of the model. The changes were made to 80 ft of display case attached to a multiplex system and 40 ft of display case attached to a single compressor system in a condensing unit as identified in Appendix B.

Table 9 Model Changes Pre/Post

Base Case Input	Input Value	Source
Night covers (base case #2)	Multiply infiltration by 0.6 for 6 hrs	SCE Report[22] and assumption that store is open 16 hrs/day and stocked for 2 hrs/day.20
Case Infiltration Load (Btu/hr-ft)	1,331	Calculation: = coil capacity - light load- motor load - conduction and radiation load.
Case Conduction and Radiation Load (Btu/hr-ft)	208	SCE report[24] and ASHRAE refrigeration handbook show 13% of load.22
Evaporator Coil to Air dT (F)	8	Manufacturer Specification, typical
Discharge Air Temperature (F)	32	Manufacturer Specification, typical for dairy, deli and beverage open multideck cases
Defrost frequency (#/day)	4	Manufacturer Specification
Post Case Input	**Input Value**	**Source**
Case Infiltration Load (Btu/hr-ft)	324	Calculation: = 30% base case load - light load- motor load - conduction and radiation load. ASHRAE research[11] and SCE report[24] both measured 70% reduction in load.1322
Case Conduction and Radiation Load (Btu/hr-ft)	67	SCE report[24] shows 14% of load for cases with doors. Load is 30% * base case load.22
Evaporator Coil to Air dT (^oF)	4	Reduction dT because now coil is oversized. SCE measured 6^{o}F reduction[24].22
Discharge Air Temperature (^oF)	28	Reduction in air temperature because now coil is oversized. Assume same coil temperature.
Defrost frequency (#/day)	2	Engineering assumption. Reduction of moist air requires less defrost.

The base case and post-implementation models for each climate zone are identical with the exception of the changes detailed above.

2.1.4 Final Electrical Energy Savings Calculation

The energy savings value was calculated as the difference between the annual whole building electrical consumption output values in the base case and the post-implementation models. The difference was divided by the number of units of measure implementation that were modeled.

Equation 1

$$\text{Electric Savings}\left[\frac{\text{kWh}}{\text{unit}}\right]=\frac{ElectricUse_{BASECASE}-ElectricUse_{POST}}{UnitCount}$$

Example Calculation: $478.0\left[\frac{kWh}{unit}\right]=\frac{1{,}551{,}985.0kWh-1{,}494{,}631.0kWh}{120\ ft\ of\ case}$

Where:

Electric Savings =	The annual electric savings achieved per unit of implemented measure.
$ElectricUse_{BASECASE}$=	The annual electric consumption in the base case model.
$ElectricUse_{POST}$=	The annual electric consumption in the post-implementation model.
UnitCount=	The total number of feet of refrigerated display case for which the measure was modeled in a particular model. Always equal to 120 ft.

2.2 Demand Reduction Estimation Methodologies

The demand savings were derived from the same models that were used to develop the energy savings values. They were calculated as the difference between the peak power demand in the base case and the post-implementation model during the CPUC defined peak demand period for each climate zone. These peak demand periods have been adjusted for the 2009 weather data that was used for modeling. The total difference was divided by the number of units of measure implementation that were modeled.

Equation 2

$$\text{Demand Savings}\left[\frac{\text{kW}}{\text{unit}}\right]=\frac{Peak_{BASECASE}-Peak_{POST}}{UnitCount}$$

Example Calculation: $0.0567\left[\frac{kW}{unit}\right]=\frac{216.6667kW-209.8667kW}{120\ ft\ of\ case}$

Where:

Demand Savings =	The demand savings achieved at the electric system’s peak demand as defined by the CPUC per unit of implemented measure.
$Peak_{BASECASE}$=	The average whole-building power demand occurring during the CPUC’s defined peak period for the appropriate climate zone in the base case model.
$Peak_{POST}$=	The average modeled whole-building power demand occurring during the CPUC’s defined peak period for the appropriate climate zone in the post-implementation model.

2.3 Gas Energy Savings Estimation Methodologies

The gas savings value was calculated as the difference between the annual whole building gas consumption in the base case and the post-implementation models. The difference was divided by the number of units of measure implementation that were modeled.

Equation 3

$$Gas\ Savings\left[\frac{therms}{unit}\right]=\frac{GasUse_{BASECASE}-GasUse_{POST}}{UnitCount}$$

$$\text{Example Calculation: } 59.7667\left[\frac{therms}{unit}\right]=\frac{39{,}832.0000 therms-32{,}660.0000 therms}{120\ ft\ of\ case}$$

Where:

Gas Savings =	The annual gas savings achieved per unit of implemented measure.
$GasUse_{BASECASE}$=	The annual gas consumption in the base case model.
$GasUse_{POST}$=	The annual gas consumption in the post-implementation model.

Section 3. Load Shapes

3.1 Base Case Load Shapes

The base case load shape follows a typical commercial refrigeration load shape. This load shape closely follows outside temperatures, with the highest load associated with high outside temperatures and the smallest load associated with cooler outside temperatures. Figure 2 - Base Case Daily Load Profiles displays the load profile of the base case models used for Climate Zone 3 over the course of a typical day in July.

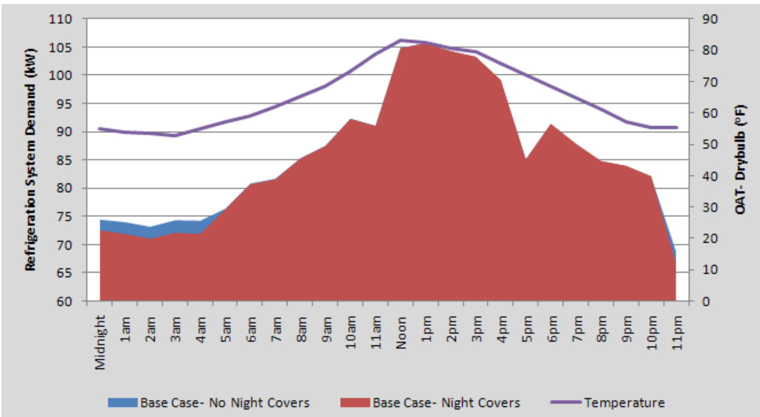

Figure 2 - Base Case Daily Load Profiles

3.2 Measure Load Shapes

For purposes of the net benefits estimates in the E3 calculator, what is required is the load shape that ideally represents the difference between the base equipment and the installed energy efficiency measure. This difference in load profile is what is called the Measure Load Shape and is the preferred load shape for use in the net benefits calculations.

The E3 Calculator contains a fixed set of load shapes selections that are the combination of the hourly avoided costs and the load shape data that was available at the time of the tool's creation. In the E3 Calculator, the load shape that most closely fits this measure is the 'Commercial Refrigeration' load shape because a majority of the savings are the direct result of a consistent infiltration cooling load reduction on the site's refrigeration system. The infiltration reduction should parallel the energy use of the base case load shape. One exception is that the savings during night hours (11p-5a) are reduced when night covers are in place in the base case. Figure 3 - Measure Savings Daily Load Profile displays the modeled measure savings profile for each of the measures in Climate Zone 3 over the course of a July day.

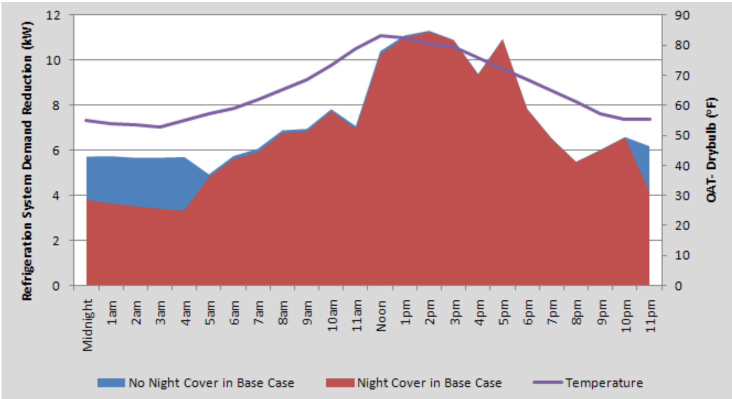

Figure 3 - Measure Savings Daily Load Profile

Section 4. Base Case & Measure Costs

4.1 Base Case(s) Costs

The addition of doors to an existing refrigerated case is a Retrofit Add On (REA) measure. As such, there are no applicable base case costs.

Table 10 Base Case Cost

Measure Code	**Measure Application Type**	**Baseline**	**Equipment Cost**	**Labor / Installation Cost**	**Maintenance / Other Cost**	**Total Base Case Cost**
RA01	REA	Existing Vertical Refrigerated Display Case	$0.00	$0.00	$0.00	$0.00
HA09	REA	Existing Vertical Refrigerated Display Case w/ Night Covers	$0.00	$0.00	$0.00	$0.00

All costs are noted as $ per measure unit

4.2 Measure Case Costs

The following Measure Application Type is appropriate to this measure. The Measure Case Costs are:

Table 11 Measure Case Cost

Measure Code	**Measure Application Type**	**Measure**	**Equipment Cost**	**Labor / Installation Cost**	**Maintenance / Other Cost**	**Total Measure Case Cost**
RA01	REA	Vertical Ref Case, Med. Temp: Open to Closed (Retrofit)	$456.31	$65.24	$0.00	$521.55
HA09	REA	Vertical Ref Case, Med. Temp: Open w/ Night Covers to Closed (Retrofit)	$456.31	$65.24	$0.00	$521.55

All costs are noted as $ per measure unit

The direct measure implementation costs were developed using quotes from several projects where the described measure was proposed.[25] Where the costs deviated from one source to another, an average value was used. The costs of labor and materials are not shown as individual line items on the bids. A separate estimation of labor hours and cost was developed for each measure component. The cost of materials is calculated as the full project cost less the estimated labor cost.

The measure material costs include: doors, door frames, LED lighting, shelving, a new expansion valve, and some additional new piping. The doors, door frames, lighting and shelving is generally sold as a package by the vendor. Based on three quotes from two vendors, these materials average $350.55/ft of case. If required, the expansion valve and piping will generally be installed by a refrigeration contractor working in coordination with the door supplier/installer. The assumptions used to generate the costs for these refrigeration components is that each 8ft refrigerated case will require a new expansion valve and 50 feet of new copper piping. These assumptions are consistent with PECI's discussions with a major refrigeration services contractor. The refrigeration components add $139.16/foot of case that it retrofitted. The total materials cost is $456.31/ft of case.

The labor includes time to scope the project, install the doors, alter the refrigeration system, and commission the refrigeration system controls to ensure proper system performance. The installation of the doors and lighting is generally included in the bid from the door vendor. The labor for these activities is estimated to cost $35.24/ft of case. Additionally a refrigeration contractor must often retrofit several system components and commission the applicable controls to maintain performance. Assuming a billable rate of $90/hr and 40 total labor hours for a store with 120 feet of case being retrofitted, this labor amounts to $30/ft of case. The total labor for the implementation of the measure is $65.24/ft of case.

The total measure cost, including all labor and materials required to retrofit the doors and ensure that the refrigeration system is in good functioning order, is $521.55/ft of case. This value does not change when night covers are in place in the base case.

4.3 Incremental & Full Measure Costs

4.3.1 Full Measure Cost

Full Measure Cost is the cost to install an energy efficient measure per the CPUC calculators. This definition implies a different meaning depending on the Measure Application type.

This measure's Measure Application type is REA for a single baseline period, so the Full Measure Cost (FMC) is represented by the equation below:

FMC = Measure Equipment Cost + Measure Labor Cost

FMC =$456.31 per Len-ft + $65.24 per Len-ft = $521.55 per Len-ft

Table 12 Base Case and Measure Cost

Measure ID	Measure Application Type	Base Case Total Cost	Measure Case Total Cost	Gross Measure Case Cost
RA01	REA	$0.00	$521.55	$521.55
HA09	REA	$0.00	$521.55	$521.55

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[22] Ibid., pp. 676-679.
[24] PECI Grocery Model Refrigeration Base Case Description. Attached as Appendix B
[25] Measure costs were estimated by averaging project costs from five MT case door project invoices. These quotes contain confidential customer information. They are archived at PECI as PGE3PREF116_Costs.zip, and are available for auditing

Appendix A. Model Refrigeration System Detail

Appendix A 160611.docx