**Work Paper PGE3PREF127**

**Add Doors to Open Walk-in Cooler**

**Revision # 3**

**PECI**

**EnergySmart Grocer**

**Add Doors to Open Walk-in Cooler**

**Measure Code R160, HB30**

**EnergySmart Grocer, PECI**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Applicable Measure Codes:** | **R160, HB30** |
| **Measure Description:** | Add Doors to Walk-in Cooler |
| **Energy Impact Common Units:** | Len-ft  Linear ft. of display case |
| **Base Case Description:** | Source: PECI  Medium temp walk-in reach-in open display cases (without doors) |
| **Base Case Energy Consumption:** | Source: PECI  State the base case energy consumption. |
| **Measure Energy Consumption:** | Source: PECI calculations  Varies. See at a glance measure list. |
| **Energy Savings (Base Case – Measure)** | Source: PECI calculations  Varies. See at a glance measure list. |
| **Costs Common Units:** | Len-ft |
| **Base Case Equipment Cost ($/unit):** | Source: PECI  REA: $0.00 |
| **Measure Equipment Cost ($/unit):** | Source: PECI  REA: $716.43 |
| **Gross Measure Cost ($/unit)** | REA: $815.38 |
| **Measure Incremental Cost ($/unit):** | Source: PECI  REA: $815.38 |
| **Effective Useful Life (years):** | Source: PECI  REA: 12 years |
| **Measure Application Type:** | Retrofit Add On |
| **Net-to-Gross Ratios:** | Source: Deer2011\_NTGR\_2012-05-16  0.60 |
| **Important Comments:** |  |

# Work Paper Approvals

The following Manager(s) approved this workpaper through the PG&E Electronic Data Routing System under Routing Requisition # \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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| --- |
|  |
| **Grant Brohard**  Manager, Technical Product Support |
| **Carolyn Weiner**  Principal, CES Products and Programs |

# Document Revision History

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Revision #** | | **Revision Date** | | **Section-by-Section Description of Revisions** | **Author (Company)** | |
| **Revision 0** | | **08/08/08** | | **Original work paper** | **James Anthony (PECI))** | |
| **Revision 1** | | **09/18/08** | | **Added clearer language regarding costs.** | **James Anthony (PECI)** | |
| **Revision 2** | | **06/12/12** | | **Update to incorporate new work paper format.**  **Update calculation to reflect new EER and FLH value and methodology.**  **Update calculations to have separate baseline for standard motors and energy efficient motors.** | **James Anthony, P.E,**  **Engineering Manager**  **(PECI)** | |
| **Revision 3** | **04/28/14** | | **Updated formatting per PG&E guidelines** | | | **Danielle Geers, PECI**  **Jason Ochs, PECI** |

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# Section 1. General Measure & Baseline Data

## 1.1 Product Measure Description & Background

***Program Restrictions and Guidelines***

**Terms and Conditions:**

* The baseline case — a medium-temperature, open, refrigerated display case, conjoined with a medium-temperature walk-in cooler — must install doors to enclose the open-display-case area and remove the display-case evaporator fans. Baseline display lighting may not exceed the efficiency level of T8 fluorescent lamps. The baseline evaporator fan motors must be shaded pole.
* Existing case evaporator coils, fans, and lighting must be removed.
* New reach-in doors must have T8 or more efficient lighting and frame heaters, but no anti-sweat heaters.

***Market Applicability:***

This is a retrofit addition measure that is targeted at grocery stores with existing walk-in reach-in refrigerated display cases that are exposed to the grocery sales floor space. The rebate encourages the grocer to add this technology to decrease the infiltration of the refrigerated space making they refrigeration system more energy efficient.

This paper contains savings for the grocery building type, 5 building vintage categories and 15 California climate zones.

***1.2 Product Technical Description***

The base case is a refrigerated open display case, attached to a Walk In and exposed to the sales floor. The measure consists of removing the existing medium temperature open refrigerated display cases, their evaporator coils, T8 linear fluorescent lighting, and fan motors and replacing them with new reach-in doors that have no fans, no evaporator coils, T8 lighting or better, and frame heaters but no anti-sweat door heaters. The majority of the savings are due to the reduction of sales-space-heat infiltration as a result of installing the case door. Additionally, the reduced infiltration load allows for the case evaporator fans to be removed, resulting in a reduced auxiliary load.

## 1.3 Measure Application Type

The delivery method for this measure is downstream prescriptive rebate.

The Measure Application Type for this measure is Retrofit Add On (REA). In this measure, an existing refrigerated open case attached to a Walk In is removed and doors are added to the walk-in space in order to decrease the load on the refrigeration system thereby making it more efficient.

The DEER Measure Cost Data Users Guide, version 2.01 found on www.deeresources.com under DEER2011 Database Format hyperlink, DEER2011 for 13-14, spreadsheet SPTdata\_format-V0.97.xls, defines the term as follows:

Table 1 Measure Application Type

*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

### 1.4.1 DEER Base Case and Measure Case Information

At the time of this work paper this measure does not exist in DEER 2014 or any preivous versions.

### 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.[[1]](#endnote-1) 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.[[2]](#endnote-2) 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.[[3]](#endnote-3)

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

There are no M&V or other studies which directly apply to these measures. However, some M&V exists for a similar measure for adding doors to refrigerated display cases (as opposed to walk-in/reach-ins).

One commonly cited study conducted by researchers at Southern California Edison’s Research and Thermal Test Center found that after retrofitting doors to an open-display case the cooling load, attributable to infiltration, was reduced by 68%.[[4]](#endnote-4) 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.[[5]](#endnote-5)

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.[[6]](#endnote-6)

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.[[7]](#endnote-7) 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.[[8]](#endnote-8)

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

**Net-to-Gross Assumption**

The table below summarizes all applicable Net-to-Gross ratios for programs that may be used by this measure.

Table 2 DEER Net-to-Gross Ratios

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | **DEER Spreadsheet** | |
| Program Approach | NTG | File name | Cell Number |
| EnergySmart Grocer | 0.60 | DEER2011\_NTGR\_2012-05-16 | T56 |

### 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 3

Table 3 TOU Adjustment Factors

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure** | ***kWAC*** | ***kWTotal*** | **%** |
| Add Doors to Walk-in Cooler | 0 | 0 | 0 |

## 1.5 Summary of Inputs for Savings Calculations

See accompanying calculation spreadsheet “PGE3PREF127\_Add Doors to Open Walk-in Cooler\_R3\_Attachments.xlsx”.

# Section 2. Calculation Methods

Table 4 Baseline by Measure Application Type

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Application Type** | **Measure Life Basis** | **First Baseline Period: Energy Savings Baseline** | **Second Baseline Period: Energy Savings Baseline** |
| ***REA* (retrofit add on)** | EUL | Customer Average Baseline | N/A |

## 2.1 Electric Energy Savings Estimation Methodologies

The electrical savings from this measure are primarily from a reduction in infiltration to the display case from the sales area due to the addition of doors. The doors prevent the infiltration of the store’s sales floor area into the refrigerated space of the case. This allows for the removal of the case evaporator coils and fans; further lowering the auxiliary load. The annual electric savings was determined using the equation below:

Equation - Annual Electric Savings Equation



where kWhbase is found using the equation:

Equation - Base Case (Walk-in/Reach-in Case without Door) Annual Electric Energy Used



kWhee (the energy efficient annual electric energy used) is found using **Equation 2** above, but with energy efficient values.

The variables for Equation 2 are defined as follows:



FLH = annual compressor system full-load hours[[9]](#endnote-9)

= annual average compressor system efficiency

Waux = case auxiliary loads (W/ft)

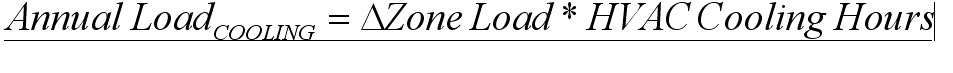
Lcase = case length (ft), length of 12 ft was used in all calculations

DF = age/condition degradation factor[[10]](#endnote-10)

In performing the above calculations, it was assumed the heat load absorbed by the case evaporator is transferred to the walk-in evaporator coils and that the refrigeration system that served the cases is identical to the refrigeration system that serves the walk-in. See note 11 for basis of the calculations in **Equation 1** and **Equation 2**.[[11]](#endnote-11)

The additional HVAC cooling required is because of the inadvertent convective and radiant cooling effect the open case’s evaporators provided to the store’s sales floor (during the warmer months) from not having doors installed on the walk-in reach-in case. As the store’s HVAC system was aided by this inadvertent cooling, after implementation of this measure the HVAC system will have to provide this cooling.





|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Where | |  |  | |
| HVAC cooling | = Annual energy needed for HVAC cooling (kWh) | | | |
| Annual Load cooling | = Annual heat rejected by HVAC for cooling (Btu) | | | |
| EER HVAC cooling | =Energy Efficiency Ratio for the HVAC cooling system (Btu/h / W )Citation 14 | | | |
| 1000 | =conversion from Watts to kW | | | |
| Delta Zone Load | =Difference in Base Case Zone Load and Energy Efficient Case Zone Load (Btu/h) | | |

## 2.2. Demand Reduction Estimation Methodologies

Peak demand electric energy reduction was found using the equation:

Equation - Annual Peak Demand Energy Savings



where HVAC Powercooling found using the equation:

Equation -Additional Power Consumed by Air Conditioning



where EERHVACcooling = energy efficiency ratio for the HVAC cooling system (Btu/h / W)[[12]](#endnote-12)

## 2.3. Gas Energy Savings Estimation Methodologies

This measure includes HVAC interactive effects savings.

In addition to electric energy savings, there is also an annual gas savings (therms) benefit to this measure. This is from the heating requirement the HVAC system had (during the cooler months) when the case’s evaporators were providing cold air to the sales floor from not having doors installed. These savings were found during the same modeling as noted above.

Annual Gas Savings:



Where:

|  |  |
| --- | --- |
| HVAC heating | = Annual energy needed for HVAC heating (therms) |
| 100,000 | = Conversion form Btu to therms |
| Gas Efficiency | = Efficiency of HVAC heating |
| Annual LoadHeating | = Annual heat needed to offset refrigeration system heat sink (Btu) |



# 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 1 - 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 - 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 (11 PM-5 AM) are reduced when night covers are in place in the base case. Figure 2 - 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 - Measure Savings Daily Load Profile

# Section 4. Base Case & Measure Costs

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Application Type** | **Measure Life Basis** | **First Baseline Period Full Measure Cost (RUL)** | **Second Baseline Period Full Measure Cost (EUL – RUL)** |
| ***REA (Retrofit Add on)*** | EUL | Calculated as Full Gross Measure Cost | N/A |

## 4.1 Base Case(s) Costs

The following Measure Application Type is appropriate to these measures. The Base Case Costs are:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| ***Measure Code*** | **Measure Application Type** | **Baseline** | **Equipment Cost** | **Labor / Installation Cost** | **Maintenance / Other Cost** | **Total Base Case Cost** |
| R160 | REA | Existing Walk-in Reach-in Case w/o Door, Standard Fan Baseline | $0.00 | $0.00 | $0.00 | $0.00 |
| HB30 | REA | Existing Walk-in Reach-in Case w/o Door, Energy Efficient Fans Baseline | $0.00 | $0.00 | $0.00 | $0.00 |

*All costs are noted as $ per measure unit*

## 4.2 Measure Case Costs

The direct measure implementation costs were developed using quotes from several projects where the described measure was proposed.[[13]](#endnote-13) 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 following Measure Application Type is appropriate to these measures. The Measure Case Costs are:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| ***Measure Code*** | **Measure Application Type** | **Measure** | **Equipment Cost** | **Labor / Installation Cost** | **Maintenance / Other Cost** | **Total Measure Case Cost** |
| R160 | REA | Add Door – Standard Fan Baseline | $716.43 | $98.95 | $0.00 | $815.38 |
| HB30 | REA | Add Door – Efficient Motor Baseline | $716.43 | $98.95 | $0.00 | $815.38 |

*All costs are noted as $ per measure unit*

## 4.3 Incremental & Full Measure Costs

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Application Type** | **Full Measure Cost**  **(RUL Period/First Baseline)** | **Full Measure Cost**  **(EUL-RUL Period/ Second Baseline)** | **Incremental Measure Cost** |
| REA | Measure Equipment Cost  +Measure Labor Cost | N/A | Measure Equipment Cost + Measure Labor Cost |

### 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 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 =$716.43 per Len-ft + $98.95 per Len-ft = $815.38 per Len-ft

### 4.3.2 Incremental Measure Costs

Incremental Measure Cost is the premium cost to install an energy efficient measure over a standard efficiency measure or code baseline measure. While IMC has a straightforward definition depending on the Measure Application Type, the equation does vary.

This Measure Application Type is REA. There is no base case to which to compare the measure, so the Incremental Measure Cost (IMC) is represented by the equation below:

IMC = Measure Equipment Cost + Measure Labor Cost

IMC = $716.43 per Len-ft + $98.95 per Len-ft = $815.38 per Len-ft

**Summary Table for Section 4**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Measure ID** | **Measure Application Type** | **Base Case Total Cost** | **Measure Case Total Cost** | **Full Measure Case Cost** | **Incremental Measure Cost** |
| R160 | REA | $0.00 | $815.38 | $815.38 | $815.38 |
| HB30 | REA | $0.00 | $815.38 | $815.38 | $815.38 |

## References:

1. Code of Federal Regulation. 2010. Title 10, Volume 3, Chapter II, Part 431, Subpart C. p. 409. [↑](#endnote-ref-1)
2. Ibid. p. 411. [↑](#endnote-ref-2)
3. Ibid. [↑](#endnote-ref-3)
4. Faramarzi, R., B. Coburn, R. Sarhadian, Rafik. 2002. Performance and Energy Impact of Installing Glass Doors on an Open Vertical Deli/Dairy Display Case. *ASHRAE Transactions: Symposia*, pp. 676-677. [↑](#endnote-ref-4)
5. Ibid., p. 678. [↑](#endnote-ref-5)
6. Lindberg, U., M. Axell, P. Fahlen. 2010. Vertical Display Case Cabinets without and with Doors. *Sustainability and Cold Chain Conference at Cambridge University*, p. 5. [↑](#endnote-ref-6)
7. Fricke, B.A. and B.R. Becker. 2009. “Comparison of Vertical Display Cases: Energy and Productivity Impacts of Glass Doors Versus Open Vertical Display Cases”, Final report to ASHRAE Technical Committee 10.7. [↑](#endnote-ref-7)
8. State of California Air Resources Board. 2009. Inventory of Direct and Indirect GHG Emissions from Stationary Air Conditioning and Refrigeration Sources, with Special Emphasis on Retail Food Refrigeration and Unitary Air Conditioning, CARB Agreement No. 06-325, p. 74. [↑](#endnote-ref-8)
9. The value of Full Load Hours (FLH) are derived from hourly reports from parametric DOE2.2r modeled peak refrigeration load, and the total annual suction load. The FLH value shown represents the average across the many different refrigeration system types and climate zones that apply to this measure. See file “FLH EER pivot” for the excel calculation, and see file “Explanation of FLH for PG&E & CPUC.doc” for further explanation.

    [↑](#endnote-ref-9)
10. Degradation factor = 0.98, this considers an average system age of 5 years. The values that influence DF are as follows: refrigeration system age; HVAC age; condenser cleanliness/condition; and whether or not an evaporative or air cooled condenser is installed. [↑](#endnote-ref-10)
11. Basis for calculations:

    a. The heat load absorbed by the case evaporator is transferred to the walk-in evaporator coils.

    b. The refrigeration system that served the cases is identical to the refrigeration system that serves the Walk-in.

    c. The evaporator fans for the walk-in run 8760 hours per year.

    d. Installing the door removes the additional 800 Btu/h/ft load on the Walk-in that is required while the walk-in reach-in case is present.

    e. The heat load presented by the Equipment Manufacturer is multiplied by the case length or number of doors to find the "case load" in the energy savings calculations

    f. The case has standard fans, 1 row of standard canopy lighting, and an additional "optional" row of canopy lighting.

    g. The HVAC system will need to increase its cooling load and the heating system will be able to reduce its heating load, both by the difference of the zone load (infiltration of heat and air from the sales area) between the base case and the energy efficient case. [↑](#endnote-ref-11)
12. HVAC Cooling EER value obtained from ASHRAE 90.1 2004. [↑](#endnote-ref-12)
13. See file “Add doors to Walk-in cost data.xls” for table of all the costs communicated by Dave Rogers [↑](#endnote-ref-13)