**Work Paper SCE13RN026**

**Revision 0**

**Southern California Edison Company**

**Advanced Refrigeration Control for Walk-In Coolers and Walk-In Freezers**

# At-a-Glance Summary

|  |  |
| --- | --- |
| ****Applicable Measure Codes:**** | RF-52451 Advance Refrigeration Control Cooler  RF-93614 Advance Refrigeration Control Freezer |
| **Measure Description:** | This measure installs advanced controls on refrigeration systems for walk-in coolers and freezers. The measure must continuously monitor the following data: evaporator coil temperature, space temperature, evaporator fan use, defrost element use, and compressor use. The controller must optimize operation of the evaporator fans, defrosting system and compressors |
| **Base Case Description:** | Refrigeration systems for walk-in coolers and freezers without advanced control. |
| **Energy Impact Common Units:** | Cap-Tons |
| **Energy Savings :** | Refer to Excel Calculation Attachment |
| **Gross Measure Cost ($/unit)** | Refer to Excel Calculation Attachment |
| **Measure Incremental Cost ($/unit):** | Refer to Excel Calculation Attachment |
| **Effective Useful Life (years):** | GrocWlkIn-WevapFMtrCtrl: 16 years |
| **Measure Application Type:** | Retrofit Add-On (REA) |
| **Net-to-Gross Ratios:** | All-Default<=2yrs: 0.7 |
| **Important Comments:** | Energy savings credit can only be taken if the existing evaporator fans operate continuously at constant volume, except during defrosting; existing defrosting’s controlled by timer.  This work paper document does not contain a data set in conformance with the 4/1/14 CPUC Ex Ante Database Specification; SCE will provide that data set separately. |

# Document Revision History

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Workpaper and Revision # | Tech. Revision | MM/DD/YY | Author/Affiliation | Summary of Changes |
| SCE13RN026.0 | No | 3/7/2014 | Yin Yin Wu/BASE Energy, Inc | Original Workpaper |
| No | 3/7/2014 | Andres Fergadiotti/SCE | Work paper updated for the reporting period, effective 7/1/14 – 12/31/14. |

# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

Advanced Refrigeration Control technology monitors operating conditions of major components of a refrigeration system and adjusts the system parameters driven by a real time expert system. The control algorithm optimizes the system performance by adapting to actual changing conditions that result in: 1) decreasing compressor cycle 2) decreasing defrost cycle, 3) decreasing evaporator fan run cycle, and 4) decreasing temperature & humidity fluctuations. The main benefits are improved system efficiency, stable humidity & temperature and substantial energy savings. This measure incents customers for installing expert system controllers to walk in coolers and freezers at commercial retail facilities and applies to both low temperature (“freezer” – below 32°F) and medium temperature (“cooler” – above 32°F).

Table 1 Measure Names

|  |  |
| --- | --- |
| Solution Code | Measure name |
| RF-52451 | Advanced Refrigeration Control Cooler |
| RF-93614 | Advanced Refrigeration Control Freezer |

This measure applies to non-residential buildings that utilize a walk-in cooler or a walk-in freezer. The measure is applicable to any commercial retail facility, including (but not limited to) supermarkets, grocery stores, hotels, restaurants and convenience stores. The facility must install a programmable logic controller to continuously monitor and control various refrigeration components to achieve desired space conditions. Details of requirements are outlined below:

* The installed advanced refrigeration control must include a programmable logic controller that meets the following requirements:
  + The advanced controller will override control of the compressors, evaporator fans, defrosting, and setpoint temperature,
  + Sense the evaporator coil temperature and space temperature, and
  + Continuously monitor these temperatures and evaporator fan, defrosting and compressor use.
* Requirements of the control of the evaporator fans:
  + The evaporator fans are controlled by cycling fans on/off.
  + The advanced control can delay the evaporator fans operation. Once the space temperature setpoint is reached, the compressors may be turned off but the evaporator fans can stay on as long as cooling can be extracted from the cooling coil.
  + The minimum duty cycle is 0.1 (i.e. 6 minutes run time per hour if no load).
  + The evaporator fans are turned off during defrosting
* Requirements of the control of defrosting system:
  + Defrosting is controlled based on demand,
  + Initiated based on coil temperature/demand, and
  + Terminated based on temperature.
* Requirements of the control of compressors:
  + The controller has the option to define the differential temperature, which is the difference between the space temperature setpoint and the temperature that enables the refrigeration cycle.
  + The compressor is enabled when the space temperature increases and reaches setpoint plus differential.
* This measure cannot be used in conjunction with either evaporator fan control or defrost by demand control.
* Energy savings credit can only be taken if the existing evaporator fans operate continuously at constant volume, except during defrosting; existing defrosting’s controlled by timer.
* The walk-in freezer setpoint is under 32 °F, and the walk-in cooler setpoint is above 32 °F.
* The advanced refrigeration control must be installed by an authorized product representative, where the installer can verify that the advanced control is compatible with the refrigeration system so that they do not degrade system performance.
* Must install an advanced controller on refrigeration system of an existing walk-in cooler or freezer to decrease energy consumption by optimized control.

**Market Applicability:**

This measure applies to walk-in storage for both medium temperature (“cooler” – above 32°F) and low temperature (“freezer” – below 32°F) refrigeration systems. Calculations for both low and medium temperature walk-in freezers and coolers are carried out for all California climate zones.

## 1.2 Technical Description

The advanced refrigeration controller is a programmable logic controller that optimizes the refrigeration operation based on real-time monitored data. The advanced controller continuously monitors the following data:

* Evaporator coil temperature,
* Space temperature,
* Evaporator fan use,
* Defrost element use, and
* Compressor use.

The controller optimizes operation of the evaporator fans, defrosting system and compressors. Detailed discussions of the optimized operation are listed below.

* The controller cycles evaporator fans on/off based on cooling demand instead of running the fans continuously. Cycling the fan reduces the evaporator fans’ operation, resulting in electrical energy savings.
* The controller controls defrosting based on demand instead of timer control. The defrosting system is activated by demand and it is terminated based on temperature. This optimized control will reduce the defrosting operation, resulting in less heat gain to the space.
* The reduced evaporator fans operation and defrost time will reduce the heat gain to the space, resulting in reduced compressor cycling.
* The real time monitoring system will result in a tighter control of space temperature, thus preventing over cooling the space. This optimization will reduce the compressor operation.

Installing the advanced refrigeration controller will reduce operations of the evaporator fans, defrosting and compressors, resulting in electrical energy savings.

## 1.3 Measure Application Type

The Base Case of this work paper is considered to be the refrigeration system without advanced control for coolers and freezers. The Measure Case is considered to be adding the advanced control on the existing refrigeration system. Therefore, the measure application type is considered to be retrofit add-on (REA).

## 1.4 Measure and Base Case Cost Effectiveness Data

### 1.4.1 DEER Measure and Base Case Analysis

The Database for Energy Efficient Resources (DEER) 2014 does not address advanced refrigeration control for walk-in coolers and walk-in freezers.

DEER does not address installing advanced controllers on refrigerated walk-in coolers and freezers for data monitoring, evaporator fan control, defrosting control and compressor control. DEER does contain measure D03-210 which addresses evaporator fan control of Walk-in coolers and Freezers. This measure differs from the advanced refrigeration controller which is the subject of this work paper. No other DEER measures address advanced refrigeration controllers.

Table 2 DEER Difference Summary

|  |  |
| --- | --- |
| DEER Difference Summary Table | |
| Modified DEER Methodology | Yes |
| Scaled DEER Measure | No |
| DEER Building Prototypes Used | Yes |
| Deviation from DEER | DEER does not include the measure of installing advanced refrigeration controllers |
| DEER Version | DEER 05, DEER 2014 |
| DEER Run ID and Measure Name (Sample) | N/A |

**Net to Gross**

The NTG value was obtained from the “DEER2011\_NTGR\_2012-05-16.xls” on the DEER website as required by Version 5 of the California Public Utilities Commission (CPUC) Energy Efficiency Policy Manual [351]. The relevant NTGR for this measure is shown in Table 3 below.

Table 3 Net-to-Gross Ratio

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| NTGR\_ID\* | Description\* | Sector\* | BldgType\* | ProgDelivID | NTG\* |
| All-Default<=2yrs | All other EEMs with no evaluated NTGR; new technology in program for 2 or fewer years | All | Any | All | 0.7 |

\*Denotes that the column is taken from the DEER NTG Table.

**Installation Rate**

The installation rate (IR) is identified in the calculation attachment. This value is obtained from the support table available in READi. Currently there is no final version on the installation rate table. To address appropriate selection of the installation rate the date of the work paper will serve as the last date checked for updated IR values. The installation rate varies by end use, sector, technology, application, and delivery method. The relevant IR values for this measure are shown in Table 4 below.

Table 4 Installation Rate

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| GSIA\_ID\* | Description\* | Sector\* | BldgType\* | ProgDelivID | GSIAValue\* |
| Def-GSIA | Default GSIA values | Any | Any | Any | 1 |

**Spillage Rate**

Spillage rate will also be applied to measures however the values will not be tracked in the workpapers. The spillage rate will be tracked in an external table to be supplied to the Energy Division.

**READi Technology Fields**

To support the development of the ED ex ante tables, select fields from the ex-ante database will be identified in the work paper. For a full set of values associated with the measures in the work paper refer the Excel calculation template.

Table 5 READi Tech IDs

|  |  |
| --- | --- |
| READi Field Name | Values included in this work paper |
| Measure Case UseCategory | Commercial Refrigeration |
| Measure Case UseSubCats | Refrigerated Equipment |
| Measure Case TechGroups | Refrigerant Storage |
| Measure Case TechTypes | Walk-in Cooler / Walk-in Freezer |
| Base Case TechGroups | Refrigerated Storage |
| Base Case TechTypes | Walk-in Cooler / Walk-in Freezer |

### 1.4.2 Codes and Standards Analysis

Table 6 Code Summary

|  |  |  |
| --- | --- | --- |
| Code | Applicable Code Reference | Effective Dates |
| N/A | N/A | N/A |

**Title 24 (2013):** These measures do not fall under Title 24.

**Title 20 (2014):** These measures do not fall under Title 20.

### 1.4.3 Non-DEER Study Review

According to the CEUS [424], refrigeration is one of the primary electric end uses at a statewide level (13%), after interior lighting (29%), and cooling (15%). The CEUS [424] study further suggests that under the SCE commercial sector, the highest overall electric end-use in terms of energy intensities are interior lighting (3.97 kWh per square foot), followed by cooling (2.31), refrigeration (1.77), and ventilation (1.55).

The measure of installing advanced controllers in walk-in coolers and freezers is also evaluated in the following studies:

* *Adaptive Refrigerator and Freezer Controls for Commercial Applications, San Diego Gas and Electric Company, Emerging Technologies Program, Project ID ET11SDEGEC, November 23, 2012.*
* *Evaluation of an Internet-Based Refrigeration Monitoring and Control System, Southern California Edison, Design & Engineering services, December 4, 2009.*
* *Adaptive Refrigeration controls Study– Commercial & Industrial Systems, National Energy & Conservation, 2010 and 2011.*
* *Technical Analysis Study & Verification Report for Refrigeration Controls, Sponsored by EnergyTrust of Oregon, Inc., August 23, 2011.*

### 1.4.4 Measure and Base Case Effective Useful Life

DEER14 update documentation provides EUL and RUL information to be used for the 2015 program cycle extension on [www.deeresources.com](http://www.deeresources.com). The DEER documentation “Summary of EUL-RUL Analysis for the April 2008 Update to DEER” provides the RUL value as a flat 1/3 of the EUL value. The RUL value will only be applied to the first baseline period for retrofit measures that have applicable code that will affect the energy savings. In all other installation types and retrofit with no applicable code that affects the energy savings, the RUL is not applicable to either the first or second baseline period.

To obtain the EUL value the DEER14 update documentation, EUL\_Summary\_10-1-08.xls [213], was consulted. Table 5 below identifies the value/methodology used for the measures in this work paper.

Table 7 DEER14 EUL Value/Methodology

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| READi EUL ID | Market | Enduse | Measure | EUL (Years) | RUL (Years) |
| GrocWlkIn-WevapFMtrCtrl | Non-Residential | Refrigeration | Advanced Refrigeration Controls\* | 16.0 | 5.3 |

\* EUL of the Evaporator Fan Controller for Walk-In Coolers measure is used for this work paper.

# Section 2. Energy Savings & Demand Reduction Calculations

## 2.1 Electric Energy Savings Estimation Methodologies

The following assumptions were made for the calculations of this work paper:

* The building simulation models were generated for a Grocery Store with multiplex-compressor systems for the refrigeration walk-in coolers and freezers. Single-compressor systems are less efficient than multiplex-compressor systems. According to the DEER Report [26], single-compressor systems were typically designed prior to 1980. To be conservative, it is assumed that the generated energy savings for this work paper will also be applied to walk-in cooler and freezer with single-compressor systems. The refrigeration compressors and condensers are considered to be outdoor and not included as internal load in the building simulation.
* This work paper is applied to walk-in coolers and freezers located inside a space which has space cooling (and space heating). The unit energy savings is represented per ton of rated capacity of the walk-in cooler and freezer. The building simulation models were generated for a Grocery Store. Since the heat gain of a cooler/freezer mainly depends on the temperature maintained for the cooler/freezer and the surrounding space temperature, it is assumed that the building types would not have significant impact on the energy savings. Thus, the resulting savings for Grocery Store is applied to all other building types considered in this work paper with weighted building vintages. The assumption has been verified through sensitivity analysis. Refer to the end of this section for Sensitivity Study on other building types.

The energy savings for this work paper is based on installing controllers on the existing refrigeration system on medium temperature walk-in coolers and low temperature walk-in freezers. The walk-in coolers and freezers are applicable to, but not limited to, grocery stores. A set of sensitivity analyses for two additional building types (Fast Food Restaurant and Small Retail) at two extreme weather conditions for one Building Vintage are performed. Refer to the end of this section for discussion.

The baseline of this work paper is the refrigeration system with no advanced control. Installing advanced control on the refrigeration system will reduce the evaporator fans’ operating hours, optimize defrost control, and stabilize space temperature, resulting in savings on the refrigeration cooling load.

The measures are weather sensitive and the building energy simulation tool eQuest was used to determine the annual impacts of different climate zones. The built-in, DEER building prototypes of grocery store were used for the simulations. The DEER building prototypes consider multiplex-compressor systems as the refrigeration type. The baseline models consider no control on the evaporator fans, defrosting by timer control and no optimized control of the compressors. Inputs of the DEER building prototypes have been reviewed and some components are modified in the baseline models. Details of the modified baseline components are discussed below:

* The baseline evaporator fans operate at constant volume continuously.
* The design evaporator fan power is modified since the built-in power rating is much lower than typical rating identified from typical walk-in coolers, and values provided in a Department of Energy (DOE) study for supermarket walk-in energy consumption. Based on the DOE study for commercial refrigeration [128], the power consumption is 2.3 W/ft2 for walk-in freezers, and 3.3 W/ft2 for walk-in coolers.
* The floor to ceiling height is modified to be 8 ft.
* Since the current eQuest version does not have defrosting input option for walk-in freezer, the defrosting power consumption is included as part of the internal energy input power to the walk-in freezer. According to the DOE study for commercial refrigeration [128], the electric defrost power consumption is 25 W/ft2 with a duty cycle of 4% for walk-in freezer.

The proposed models are generated by modifying the baseline model with advanced refrigeration control. Details of the modified components in the measure models are discussed below:

* The proposed evaporator fans are controlled by on/off cycling. Refer to the DEER [26] measure ID D03-210 for details of the simulation methodology for evaporator fan control on walk-in coolers and freezers.
* Implementing the advanced refrigeration control will optimize the space temperature control, resulting in savings in the refrigeration compressors. Based on measurement and verification in various pilot studies [440] [441] [442] of implementing the advanced refrigeration control in walk-in coolers and freezers, the measured room temperatures were maintained to be higher with the advanced control. This practice is included in the measure models by modifying the suction temperature setpoints of the refrigeration system.
* The proposed defrosting in a walk-in freezer is controlled by demand. The reduced defrosting electrical energy consumption is modified in the internal energy input power in the freezer.

The modified components to the DEER prototypes are summarized in Table 7 below.

**Table 7 Summary of Modified Components to the DEER Prototypes**

|  |  |  |
| --- | --- | --- |
| **Component** | **Freezer** | **Cooler** |
| **Baseline Model** | | |
| Evaporator Fan Control | Constant Volume | Constant Valume |
| Design Evaporator Fan Power1 | 0.000328 kW/cfm | 0.000867 kW/cfm |
| Floor to Ceiling Height | 8 ft | 8 ft |
| Internal Energy Input Power2 | 19,900.6 Btu/hr | N/A4 |
| **Proposed Model** | | |
| Supply Fan Control | Cycling | Cycling |
| Suction Temperature Setpoint3 | -21°F | 15°F |
| Internal Energy Input Power2 | 18,514.1 Btu/hr | N/A4 |

1 Modified based on the W/ft2 power consumption [128], freezer or cooler area and total design supply flow rate in the DEER prototype.

2 Electrical power consumption of defrosting is included to the internal energy input power in the freezer model.

3 The proposed model considers a 3 oF suction temperature increase for the freezer, and a 1 oF suction temperature increase for the cooler based on measured space temperature from various pilot studies.

4 No electric defrosting system considered for walk-in coolers.

Once the base case and measure case model simulations were completed, the energy savings could be determined. Comparing the total electrical energy consumption of both models, the total energy savings were determined. The unit energy savings, in kWh/ton for electricity, were calculated by dividing the total energy savings by the total cooling capacity of the refrigeration system.

Once the unit energy savings were determined for each vintage and climate zone, the weighted average savings for each climate zone was determined for each building type. DEER2008 Commercial Building Weights per vintages were used to calculate the weighted average savings for each climate zone. The weighted average savings were calculated for the following building types: Grocery, Food Store, Restaurant-Sit Down, Restaurant-Fast Food, Retail-Multistory Large, Retail-Single-Story Large, and Retail-Small. The weighted average savings of all the aforementioned building types were calculated for all 16 climate zones associated with each of the following three utility companies: Southern California Edison (SCE), Pacific Gas and Electric (PGE), and San Diego Gas & Electric (SDGE). Savings summary for all utility companies can be seen in Attachment - A.

**Discussion of Sensitivity Study**

This workpaper is applicable to building types listed in **Table 7**. The energy savings evaluated by the eQuest DEER prototype is based on the building type of Grocery. A sensitivity study is included to validate the savings estimated for other building types. The sensitivity study includes eQuest simulation runs for a Fast Food Restaurant and a Small Retail in two extreme climate zones (climate zones 1 and 15) for both measures.

According to the eQuest Refrigeration Manual [443], a refrigeration fixture experiences heat gains from the surrounding exterior space depending on the space temperature and humidity ratio. Therefore, the Fast Food Restaurant and Small Retail eQuest models with a walk-in cooler and a walk-in freezer were created by modifying the following components to the Grocery prototype model based on the DEER prototypes of Fast Food Restaurant and Small Retail:

* cooling and heating design temperatures,
* occupancy schedule profile,
* area per person,
* cooling and heating temperature setpoint schedules, and
* fan schedule.

As a result, the study shows that the savings estimated by the Fast Food Restaurant and Small Retail models are within 3% discrepancy compared to savings estimated by the Grocery models for the same building vintage. Refer to Attachment - C for details of eQuest modifications and savings outputs on the Fast Food Restaurant and a Small Retail models.

## 2.2. Demand Reduction Estimation Methodologies

Since the refrigeration system is expected to be operating at full capacity during peak demand period, no demand reduction is expected for this measure.

## 2.3. Gas Energy Savings Estimation Methodologies

The natural gas energy savings is estimated based on the eQuest building simulation outputs. Please refer to Section 2.1 for details of the eQuest models. Once the base case and measure case model simulations were completed, the energy savings could be determined. Comparing the total natural gas energy consumption of both models, the gas energy savings were determined. The unit energy savings, in therm/ton for natural gas, were calculated by dividing the total energy savings by the total cooling capacity of the refrigeration system. Once the unit energy savings were determined for each vintage and climate zone, the weighted average savings for each climate zone was determined for each building type.

Note that implementing the advanced refrigeration control will result in a tighter control of space temperature, thus preventing over cooling the coolers and freezers. As a result, there is a minimal impact to the surrounding space when the doors of the coolers and freezers are open. Based on the eQuest simulation output, implementing the advanced refrigeration control will not affect the natural gas consumption for coolers, and it will result in minimal gas savings for freezers.

Hours of operation on both Base and Measure cases were assumed to be 8760 hours – “Always On”

# Section 3. Load Shapes

The difference between the base case load shape and the measure load shape would be the most appropriate load shape; however, only end-use profiles are available. Therefore, the closest load shape chosen for this measure is the Refrigeration. See Table 9 for a list of all Building Types and Load Shapes. See the KEMA report [31] for a more thorough discussion regarding the load shapes for this measure.

Table 9 Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| Building Type | E3 Alt. Building Type | Load Shape |
| Grocery | Grocery\_Store | Refrigeration |
| Restaurant - Fast-Food | Fast\_Food\_Restaurant | Refrigeration |
| Restaurant - Sit-Down | Sit\_Down\_Restaurant | Refrigeration |
| Retail - Multistory Large | Retail - Multistory Large | Refrigeration |
| Retail - Single-Story Large | Retail - Single-Story Large | Refrigeration |
| Retail - Small | Retail - Small | Refrigeration |

# Section 4. Base Case & Measure Costs

## 4.1 Base Case Cost

The base case considers the walk-in coolers and freezers with no advanced refrigeration controller. Therefore, no cost is associated with the base case at time of purchase ($0.00).

## 4.2 Measure Case Cost

The measure case considers implementing advanced refrigeration control on walk-in coolers and freezers. Based on cost data obtaining from various pilot studies, the average implementation cost, including material and installation costs, is $2,190 per controller for applying to a freezer or cooler.

## 4.3 Gross and Incremental Measure Cost

### 4.3.1 Gross Measure Cost

For **REA** GMC is represented by the equation below:

*GMC = Measure Equipment Cost + Measure Labor Cost = $2,190*

### 4.3.2 Incremental Measure Cost

For REA there exists no base case to compare the measure to, as in the case of an economizer added to a HVAC system. Adding the economizer is the energy efficient measure and the base case is the absence of an economizer therefore there truly is no base case cost. Because of this, for **REA**, IMC is represented by the equation below:

*IMC = Measure Equipment Cost + Measure Labor Cost =* $2,190

Based on cost data obtained from various pilot studies [440] [441] [442], the average implementation cost, including material and installation costs, is $2,190 per controller for applying to a freezer or cooler.

# Attachments

1. 

1. 

# References



[351]

[424]

[213]

[26]

[128]

[440]

[441]

[442]

[443]

[426]

# Appendix A – SCE/ED Application Types

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| SCE Program Type | ED Application Type | 1st Baseline Savings | 2nd Baseline Savings | 1st Baseline Cost | 2nd Baseline Cost | 1st Baseline Life | 2nd Baseline Life |
| New | New Construction (Nc) | Above Code/Standard | N/A | Incremental Cost | N/A | EUL | 0 |
| Replace on Burnout (ROB) | Replace on Burnout (Rob)/Normal Replacement (NR) | Above Code/Standard | N/A | Incremental Cost | N/A | EUL | 0 |
| Retrofit (RET) | Early Replacement (ER) | Above Cust. Existing | Above Code/Standard | Full Cost | Incremental Cost | RUL | EUL-RUL |
| Retrofit – First Baseline Only (REF) | Early Replacement RUL (ErRul) | Above Cust. Existing | N/A | Full Cost | N/A | EUL | 0 |
| Retrofit Add-on (REA) | N/A | Above Cust. Existing | N/A | Full Cost | N/A | EUL | 0 |