Work Paper SCE13CS004

**Revision 2**

**Southern California Edison**

**Demand Controlled Ventilation + Demand Based Fan Control**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Measure Codes** | AC-78024; AC-48434; AC-54324; AC-69533; AC-79846; AC-19064; AC-89067 AC-80394; AC-94320; AC-90554; AC-39965; AC-60564; AC-58732; AC-70983 |
| **Measure Description** | This work paper contains two measures:  1. Add demand controlled ventilation (DCV) to mechanical systems in buildings that do not utilize this control strategy.  2. Add demand controlled ventilation (DCV) and fan cycling to mechanical systems in fitness centers that do not utilize this control strategy. |
| **Base Case Description** | HVAC units with economizers. |
| **Units** | kWh/ton-yr, kW/ton-yr, therms/ton-yr |
| **Energy Savings** | Refer to Excel Calculation Attachment |
| **Full Measure Cost ($/unit)** | Refer to Excel Calculation Attachment |
| **Incremental Measure Cost ($/unit)** | Refer to Excel Calculation Attachment |
| **Effective Useful Life** | 10 Years |
| **Measure Installation Type** | Retrofit fit add-on(REA) |
| **Net-to-Gross Ratio** | 0.85 & 0.6, Please refer to Section 1.4.1 for more details. |
| **Important Comments** | This work paper has a complementary Ex Ante Database data set that will be provided in a separate submission to the California Public Utilities Commission (CPUC). |

# Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Rev** | **Date** | **Author** | **Summary of Changes** |
| 0 | 05/24/12 | Ricardo Sfeir/BASE Energy | This is the original work paper for the 2013-14 bridge period. All data used in the work paper from the previous cycle work paper WPSCNRCS0004.2 has been transposed to this new template. Saving methodologies and numbers have not been changed. |
| 1 | 4/30/14 | Kar Ying Thomas Chan/BASE Energy | * This work paper updated all building models to be 2013 Title-24 compliance. * This work paper also combined the fan cycle measure for the fitness centers from work paper SCE13CS011.0. * Updated peak demand savings based on DEER2014 Peak-Demand period definitions * Updated the model weather files per DEER2014 CZ2010 weather data files * Work paper updated for reporting period, effective 07/01/14-12/31/14 |
| 2 | 01/26/16 | Ajay Wadhera/Solaris | -New template update for 2016 program year  -WP effective from 1/1/2016 thru 12/31/2016  -No value modifications |

# Commission Staff and Cal TF Comments

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Rev** | **Party** | **Submittal Date** | **Comment Date** | **Comments** | **WP Developer Response** |
|  |  |  |  |  |  |
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Cal TF website: <http://www.caltf.org/>

# Section 1. General Measure & Baseline Data

## Measure Description & Background

This work paper contains two energy efficiency measures:

Demand Control Ventilation (DCV) – This measure adds DCV to buildings that currently do not utilize this HVAC control strategy.

Demand Control Ventilation + Demand Based Fan Control – This measure adds both DCV and fan cycling controls for the fitness centers that currently do not utilize this HVAC control strategy.

The base case for this work paper is:

For buildings with HVAC systems have fully functional air-side economizers that do not utilize demand controlled ventilations.

For fitness centers with HVAC systems have fully functional air-side economizers that do not utilize demand controlled ventilations and demand-based fan cycling controls.

**Base, Standard, and Measure Cases**

|  |  |
| --- | --- |
| **Case** | **Description of Typical Scenario** |
| Measure | Add Demand side ventilation and demand based fan cycling control to existing HVAC controls |
| Existing Condition | Fully functional air side economizers with no demand side ventilation and fan cycling controls |
| Code/Standard | N/A |
| Industry Standard Practice | N/A |

Measures and Codes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Codes** | | | | **Measure Name** |
| SCG | SDG&E | SCE | PG&E |
| N/A | N/A | AC-78024 | N/A | Demand Control Ventilation (Movie Theater) |
| N/A | N/A | AC-48434 | N/A | Demand Control Ventilation (Community Center) |
| N/A | N/A | AC-54324 | N/A | Demand Control Ventilation (Convention Center) |
| N/A | N/A | AC-69533 | N/A | Demand Control Ventilation (Fitness Center)– 24 hour |
| N/A | N/A | AC-79846 | N/A | Demand Control Ventilation (Fitness Center)– 17 hour |
| N/A | N/A | AC-19064 | N/A | Demand Control Ventilation (Fitness Center)– 24 hour – Heat Pump |
| N/A | N/A | AC-89067 | N/A | Demand Control Ventilation (Fitness Center)– 17 hour – Heat Pump |
| N/A | N/A | AC-80394 | N/A | Demand Control Ventilation (Museum) |
| N/A | N/A | AC-94320 | N/A | Demand Control Ventilation Control\* |
| N/A | N/A | AC-90554 | N/A | Demand Control Ventilation Control – Heat Pump\*\* |
| N/A | N/A | AC-39965 | N/A | Demand Control Ventilation + Demand Based Fan Control (Fitness Center) Control – 24 hour (PSZ-AC) |
| N/A | N/A | AC-60564 | N/A | Demand Control Ventilation + Demand Based Fan Control (Fitness Center) Control – 17 hour (PSZ-AC) |
| N/A | N/A | AC-58732 | N/A | Demand Control Ventilation + Demand Based Fan Control (Fitness Center) Control – 24 hour (PSZ-HP) |
| N/A | N/A | AC-70983 | N/A | Demand Control Ventilation + Demand Based Fan Control (Fitness Center) Control – 17 hour (PSZ-HP) |

\* All other building types. Refer to Table in Section 2

\*\* Solution Code AC-90554 (Heat Pump) only applies to building types: “Restaurant - Fast Food” and “Restaurant – Sit Down”.

**Measure Eligibility**

Both DCV and demand based fan control require installation of CO2 sensor(s) and new sequences of operation on the existing HVAC systems. Demand based fan controls also include short-term fan cycling during very low occupancy periods based on CO2 concentration. Both measures shall include alarms on high CO2 concentration levels and operating limits to limit short-term fan cycling durations and number of events in compliance with 2013 Title-24 [355] regulation.

The minimum ventilation shall be in compliance with the applicable Codes regardless of the actual occupancy or CO2 concentration level.

**Measure Implementation**

Implementation for DCV shall include the installation of CO2 sensors, controllers, and new sequence of operations. Both measures shall be executed by programming the existing unitary DDC controller (if available and granted control point capacity is available) or by installing a new DDC controller. The new unitary DDC controllers shall be consistent and compatible with existing DDC controllers, protocol, and energy management system in the building. The measure (including but not limited to installation of CO2 sensors, controllers, and new sequence of operation) shall comply with all applicable codes and regulations including but not limited to California Title-24 2013 [355], CMC, and NEC.

## 1.2 Technical Description

This measure adds demand controlled ventilation (DCV) to existing buildings that currently do not utilize this HVAC control strategy. The measure saves energy by modulating the amount of fresh air delivered to the building based upon the level of CO2 in each individual room within the building. Reducing unnecessary ventilation air will realize savings by reducing the amount of cooling and/or heating energy needed for the HVAC units.

The target market participants for this measure are high-occupancy areas with high occupancy changes such as conference rooms and other types of assembly areas. Ventilation for these types of buildings is based on the 2013 Title 24 Requirements [355]. Since these types of rooms experience fluctuations in their occupancy over the course of a day or a week, the ventilation may be reduced at times of reduced occupancy. This measure aims to address these systems by installing demand control ventilation on existing economizers. These CO2 sensors typically are installed within the space and can also be as part of the thermostat. The output of the detector will be used to determine what level of fresh air ventilation is required. The rooftop unit’s outdoor intake will be allowed to close to minimum when less ventilation is required thus reducing unwanted heating or cooling loads.

Demand based fan control adds fan cycling controls to HVAC systems of the fitness centers. With fan cycling, it saves energy by slightly reducing fan operation when occupancy in the building is limited and there are no cooling and/or heating requirements in the space. While the 2013 California Building Energy Efficiency Standards requires [355] that ventilation be continuous during normally occupied hours, some exceptions allow for the ventilation to be disrupted for short times. Refer to Section 1.4.2 Codes and Standards Analysis for detailed discussion.

## 1.3 Installation Types and Delivery Mechanisms

The Installation Type is Retrofit Add-On.

**Installation Type Descriptions**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Installation Type** | **Savings** | | **Life** | |
| 1st Baseline (BL) | 2nd BL | 1st BL | 2nd BL |
| Retrofit Add-on (REA) | Above Customer Existing | N/A | EUL | N/A |

The delivery / incentive method is Financial Support – Direct Install.

Details are based upon contractual agreements with implementers receiving payments to provide the direct installation services.

A delivery mechanism is a delivery method paired with an incentive method. Delivery mechanisms are used by programs to obtain program participation and energy savings.

**Delivery Method Descriptions**

|  |  |
| --- | --- |
| **Delivery Method** | **Description** |
| Financial Support | The program motivates customers, through financial incentives such as rebates or low interest loans, to implement energy efficient measures or projects. |

**Incentive Method Descriptions**

|  |  |
| --- | --- |
| **Incentive Method** | **Description** |
| Direct Install | The program implements energy efficiency measures for qualifying customers, at no cost to the customer. |

## 1.4 Measure Parameters

### 1.4.1 DEER Data

This specific measure is not included in the Database for Energy Efficient Resources (DEER) Version 2014 [386]. Although there is an over-ventilation measure in DEER 2005 [26], it is not a good representation of the technology being evaluated in this document.

DEER Difference Summary

|  |  |
| --- | --- |
| **DEER Item** | **Used for Workpaper?** |
| Modified DEER methodology | No |
| Scaled DEER measure | No |
| DEER Base Case | No |
| DEER Measure Case | No |
| DEER Building Types | Yes |
| DEER Operating Hours | Yes |
| DEER eQUEST Prototypes | Yes |
| DEER Version | N/A |
| Reason for Deviation from DEER | DEER does not contain this measure. |
| DEER Measure IDs Used | N/A |

**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.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **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 |
| Com-Default-HTR-di | All other EEM with no evaluated NTGR; direct install to hard-to-reach only. | Com | Any | DirInstall | 0.85 |

Note that for the direct install delivery mechanism, a distinction between hard to reach and non-hard to reach markets will be made on a project by project basis. This work paper shows the NTG associated with a hard to reach direct install delivery mechanism and the non-residential defaulted NTG value, where in fact, a measure offered through direct install and is not “hard to reach” will receive a default NTG value.

This work paper includes measures that are offered via direct install activities into hard-to-reach (HTR) customer facilities. “Final Resolution E-4700”, dated December 18, 2014, defines specific criteria to classify customer facilities as HTR and also states that two criteria are sufficient to identify HTR customers if one of the criteria met is the geographic criteria.

SCE’s Commercial Direct Install program delivers free and low cost energy efficiency hardware retrofits through installation contractors to reduce peak demand and energy savings for small and medium commercial customers. The barriers for customer participation include limited capital resources, lack of expertise and understanding of the understanding of the benefits of energy efficiency, a suspicion of the “free offer” and its legitimacy, and language and cultural barriers. The program also addresses the ongoing concern with “split incentives”, where the customer is not the owner of the property, and therefore, lack incentive to improve their energy usage. SCE’s Commercial Direct Install program will track the following three (3) customer data points to identify direct install activities in HTR customer facilities. If geography and business size criteria are satisfied, SCE will identify the customer as HTR. If geography and language criteria are satisfied, SCE will identify the customer as HTR. Other measures in the Commercial Direct Install program will receive default NTG (NTGR\_ID: Com-Default>2), unless otherwise specified in DEER.

* **Business Size** – Customer must have less than ten employees
* **Language** – Customer’s primary language spoken is not English
* **Geography** – Businesses in areas other than the United States Office of Management and Budget (OMB) Combined Statistical Areas (CSA) of the San Francisco Bay Area, the Greater Los Angeles Area and the Greater Sacramento Area or the OBM metropolitan statistical areas or San Diego County

The “Required Corrections to Measure Level Input Parameters Identified by Commission Staff per D.14-10-046 Order Paragraph 16”, dated November 3, 2014, includes additional clarification for the geographic criteria:

“Notes on OMB CSA designations:

The OMB has designated a 12-county CSA titled the San Jose-San Francisco-Oakland, CA Combined Statistical Area which includes the nine counties of Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma which border the San Francisco Bay plus the three counties of San Joaquin, Santa Cruz, and San Benito that are economically tied to the nine counties that that border the San Francisco Bay.”

The OMB definition of this CSA includes Los Angeles, Orange, San Bernardino, Riverside and Ventura counties.

The OMB definition of this CSA includes Sacramento, Yolo, El Dorado, Placer, Sutter, Yuba, and Nevada counties.”

**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.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **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.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** | **RUL (Years)** |
| HVAC-RedcOverVent | Reducing Overventilation | Com | VentAirDist | 10 | 3.3 |

### 1.4.2 Codes and Standards Analysis

Followings are excerpts from California Title-24 2013 [355].

Title 24 2013 [355], California's energy-efficiency standard, requires demand control ventilation (DCV) in all spaces where an HVAC single-zone system includes an economizer and where there is an occupant density greater than or equal to 25 people per 1,000 sq. ft., with some exceptions.

Additionally, according to the Title 24 2013 [355], Section 120.1, California's energy-efficiency standard the specific requirements must be taken into consideration:

**“Required Demand Control Ventilation**. HVAC systems with the following characteristics shall have demand ventilation controls complying with 120.1(c)4:

A. They have an air economizer; and

B. They serve a space with a design occupant density, or a maximum occupant load factor for egress purposes in the CBC, greater than or equal to 25 people per 1000 ft2 (40 square foot per person); and

C. They are either:

i. Single zone systems with any controls; or

ii. Multiple zone systems with Direct Digital Controls (DDC) to the zone level.

**EXCEPTION 1 to Section 120.1(c)3:** Classrooms, call centers, office spaces served by multiple zone systems that are continuously occupied during normal business hours with occupant density greater than 25 people per 1000 ft2 per Section 120.1(b)2B, healthcare facilities and medical buildings, and public areas of social services buildings are not required to have demand control ventilation.

**EXCEPTION 2 to Section 120.1(c)3:** Where space exhaust is greater than the design ventilation rate specified in Section 120.1(b)2B minus 0.2 cfm per ft2 of conditioned area**.**

**EXCEPTION 3 to Section 120.1(c)3:** Spaces that have processes or operations that generate dusts, fumes, mists, vapors, or gases and are not provided with local exhaust ventilation, such as indoor operation of internal combustion engines or areas designated for unvented food service preparation, or beauty salons shall not install demand control ventilation.

**EXCEPTION 4 to Section 120.1(c)3:** Spaces with an area of less than 150 square feet, or a design occupancy of less than 10 people per Section 120.1(b)2B.

***4. Demand Control Ventilation Devices***

A. For each system with demand control ventilation, CO2 sensors shall be installed in each room that meets the criteria of Section 120.1(c)3B with no less than one sensor per 10,000 ft² of floor space. When a zone or a space is served by more than one sensor, signal from any sensor indicating that CO2 is near or at the setpoint within a space, shall trigger an increase in ventilation to the space;

B. CO2 sensors shall be located in the room between 3 ft and 6 ft above the floor or at the anticipated height of the occupant’s heads.

C. Demand ventilation controls shall maintain CO2 concentrations less than or equal to 600 ppm plus the outdoor air CO2 concentration in all rooms with CO2 sensors;

**EXCEPTION to Section 120.1(c)4C:** The outdoor air ventilation rate is not required to be larger than the design outdoor air ventilation rate required by Section 120.1(b)2 regardless of CO2 concentration.

D. Outdoor air CO2 concentration shall be determined by one of the following:

i. CO2 concentration shall be assumed to be 400 ppm without any direct measurement; or

ii. CO2 concentration shall be dynamically measured using a CO2 sensor located within 4 ft of the outdoor air intake.

E. When the system is operating during hours of expected occupancy, the controls shall maintain system outdoor air ventilation rates no less than the rate listed in TABLE 120.1-A times the conditioned floor area for spaces with CO2 sensors, plus the rate required by Section 120.1(b)2 for other spaces served by the system, or the exhaust air rate whichever is greater;

F. CO2 sensors shall be certified by the manufacturer to be accurate within plus or minus 75 ppm at a 600 and 1000 ppm concentration when measured at sea level and 25°C, factory calibrated or calibrated at start-up, and certified by the manufacturer to require calibration no more frequently than once every 5 years. Upon detection of sensor failure, the system shall provide a signal which resets to supply the minimum quantity of outside air to levels required by Section 120.1(b)2 to the zone serviced by the sensor at all times that the zone is occupied.

G. The CO2 sensor(s) reading for each zone shall be displayed continuously, and shall be recorded on systems with DDC to the zone level. “

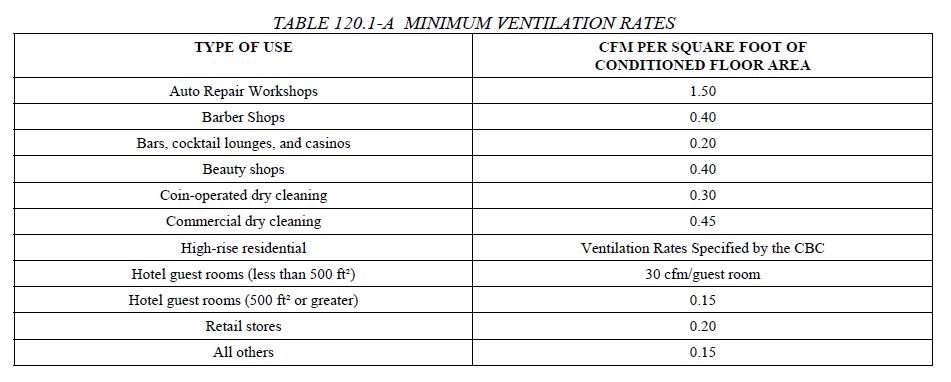
***Mechanical Ventilation*** *§120.1(b)2 and (d)*

For each space requiring mechanical ventilation the ventilation rates must be the greater of either:

1. The conditioned floor area of the space, multiplied by the applicable minimum ventilation rate from the Standards in Table 120.1-A; or

2. 15 cfm per person, multiplied by the expected number of occupants. For spaces with fixed seating (such as a theater or auditorium), the expected number of occupants is the number of

fixed seats. For spaces without fixed seating, the expected number of occupants is assumed to be no less than one-half that determined for egress purposes in the California Building Code (CBC). The Standards specify the minimum outdoor ventilation rate to which the system must be designed.

**

***Fan Cycling***

While §120.1(c)1 requires that ventilation be continuous during normally occupied hours, Exception No. 2 allows the ventilation to be disrupted for not more than 30 minutes at a time. In this case the ventilation rate during the time the system is ventilating must be increased so the average rate over the hour is equal to the required rate.

This restriction limits the duty cycling of fans by energy management systems to not more than 30 minutes at a time. In addition, when a space-conditioning system that also provides ventilation is controlled by a thermostat incorporating a fan “On/Auto” switch, the switch should be set to the “On” position. Otherwise, during mild conditions, the fan may be off the majority of the time.

## California Energy Commission Response to Demand Controlled Ventilation & Fan Cycling Methodology

The CEC provided interpretation and approval regarding the applicable 2008 Building Energy Efficiency Standards requirement for the proposed measure. In general terms, the CEC indicated that many demand response programs in California have been using the duty-cycling of air-conditioning systems as a way to reduce coincident peak demand during critical utility peak periods while maintaining acceptable indoor air quality levels, and that the proposed demand control ventilation with demand based fan control measure and controls, complies with the 2008 Energy Standards.

Further, CEC indicated that due to the fact that the installation of the measure and controls as proposed in the reviewed documentation is not considered or defined as an alteration under the Standards, there are no other applicable requirements beyond what is proposed in the measure. Attachment E includes communication with the CEC.

## ASHRAE 62.1 – 2013 Ventilation for Acceptance Indoor Air Quality

The ASHRAE 62.1 Standard specifies minimum ventilation rates and other measures intended to provide indoor air quality that is acceptable to human occupants and that minimizes adverse health effects. The Standard is intended for regulatory applications to new buildings, additions to existing buildings, and those changes to existing buildings.

In relation to this project, the Standard includes provisions for fan cycling allowing intermittent ventilation as long as the average outdoor airflow is not less than the breathing zone outdoor (prescriptive) airflow. Based on provided clarifications of the Standard, ventilation fans may be turned off for up to 30 minutes, when a zone is occupied, as long as the ventilation rate is increase during fan operation and average ventilation is maintained in compliance with the Standard. Further documentation in Section 2 details fan-cycle off durations allowed in the analysis.

Code Summary

|  |  |  |
| --- | --- | --- |
| **Code** | **Reference** | **Effective Dates** |
| Title 24 (2013) | 2013 Non-Residential Compliance Manual, Section 4-3 Ventilation Requirements | July 1st, 2014 |
| Title 24 (2013) | 2013 Building Energy Efficiency Standards, Section 120.1 – Requirement for Ventilation | July 1st, 2014 |
| Standard ASHRAE 62.1-2013 | Ventilation for Acceptable Indoor Air Quality | 2013 |

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

### 1.5.1 Non-DEER Study Review

No Non-DEER Study Review was used in the work paper.

## 1.6 Data Quality and Future Data Needs

N/A

# Section 2. Calculation Methodology

The energy savings calculation associated with implementation of demand control ventilation is based on e-Quest building energy simulations. Majority of the building models were generated using DEER software “MASControl” with the latest energy code (2013 Title-24 [355]). For the building types that were not available in “MASControl”, eQuest default models were used. Movie theaters and fitness centers were custom models developed from previous work papers (see attachments C & D for their detailed modeling descriptions). Table 8 below summarizes the building types and the methods used for generating the prototype models.

Build Types

|  |  |  |
| --- | --- | --- |
| **Building Types** | **DEER Building Type** | **Method used for Generating Building Prototypes** |
| Office Bldg, High Rise | Ofl | MASControl |
| Office Bldg, Two Story | Ofs | MASControl |
| Lodging, High Rise Hotel | Htl | MASControl |
| Relocatable Classroom | ERC | MASControl |
| K6 Elementary | Epr | MASControl |
| High School | Ese | MASControl |
| Colleges and Universities | Eun, ECC | MASControl |
| Theater | Assembly | Custom eQuest Model |
| Hospital (Inpatient) | Hsp | MASControl |
| Long-Term Care (Nursing Home) | Nrs | MASControl |
| Medical Clinic (Outpatient) | Assembly | eQuest Default Model |
| Community Center | Assembly | eQuest Default Model |
| Convention Center | Assembly | eQuest Default Model |
| Museum | Storage – Cond. | eQuest Default Model |
| Fitness Center (24/7) | Assembly | Custom eQuest Model |
| Fitness Center (17/7) | Assembly | Custom eQuest Model |
| Restaurant, Fast Food | RFF | MASControl |
| Restaurant, Full Service | RSD | MASControl |

***Note:*** *Additional building types were modeled and analyzed (Office Bldg Mid Rise, Office Bank, Preschool/Daycare, and Middle School). Results were reported in Attachment F for in case of future use.*

The type of HVAC systems used for each building type was based on eQuest default. For example, the eQuest default HVAC system for a large office building (Office Bldg, High Rise) was VAV with hot water zone reheats and chilled water cooling, so a VAV system was selected as the baseline HVAC system for the large office building type. For the type of HVAC system that was used in each building type, please refer to the attached eQuest models. For movie theaters, single-zone packaged air-cooled air conditioning equipment was used. For fitness centers, single-zone furnace heating packaged unit and heat pump equipment was used.

**Modeling Assumptions and Calculation Methods**

All models were generated through either MASControl 3.00.19 or eQuest 3.65 default models with default values, except for theaters and fitness centers. A description of the assumed occupancy profile applied to theaters, 17-hr fitness centers and 24-hr fitness centers is included in sections below. For a full description, see Attachments C & D at the end.

**All Building Types (Except Movie Theater and Fitness Centers)**

* These building types were generated using “MASControl 3.00.19.
* Energy savings were calculated using the built-in DCV function in eQuest (except for fitness centers which utilizes logged data and minimum outside air schedule and will be explained the next section).
* Base-case models utilize the eQuest default ventilation (without DCV control) as shown in Figure 1 below.



Figure 1 - eQuest Default Ventilation - Base Model

* Parametric run was used to modify the base-case model to generate a measure-case model.
* Measure-case models utilize the eQuest built-in DCV function as shown in Figure 2 below:

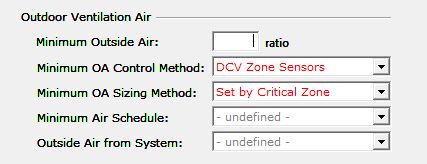


Figure 2 – eQuest DCV Control – Measure Model

* DCV was applied to all the building’s HVAC units regardless of what was their system type.
* Energy savings were calculated by running the two models then compare the differences in energy consumptions for the base-case and measure-case model.

**Movie Theater**

* The existing DCV measure for movie theaters from Revision 0 was used as the basis for modeling.
* A typical multiplex movie theater with five screening rooms with lobby was modeled.
* In the eQuest model, each screening rooms was about 3000 square feet with an average of 120 seats.
* Each screening rooms and the lobby had their own roof-top packaged units with economizer.
* Demand Controlled Ventilation would be installed on units that serve the screening rooms and the lobby. Areas that are not part of the screening room were treated as lobby area.
* For the purposes of evaluating energy and demand savings, there were two methods available. One option was to develop an average occupancy that takes into account the variance over different screening rooms; the other option was to develop a separate occupancy schedule for each screening room in the complex.
* The second option was used for this evaluation, since it was a better resemblance of a real world situation where each screening room (and the lobby) is controlled separately by individual unit (See Attachment D for detailed of the screening rooms and lobby occupancies).
* Parametric run in eQuest was used to evaluate the base-case and measure-case models.
* Energy savings were calculated using the built-in DCV function in eQuest.
* Base-case models utilized the default ventilation as shown in Figure 3 below.

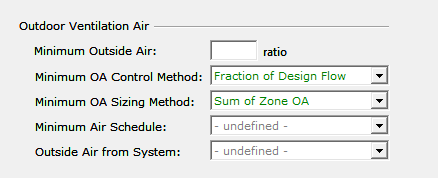


Figure 3 – Base Case Ventilation Input

* Measure-case models utilized a DCV function in eQuest as shown in Figure 4 below.

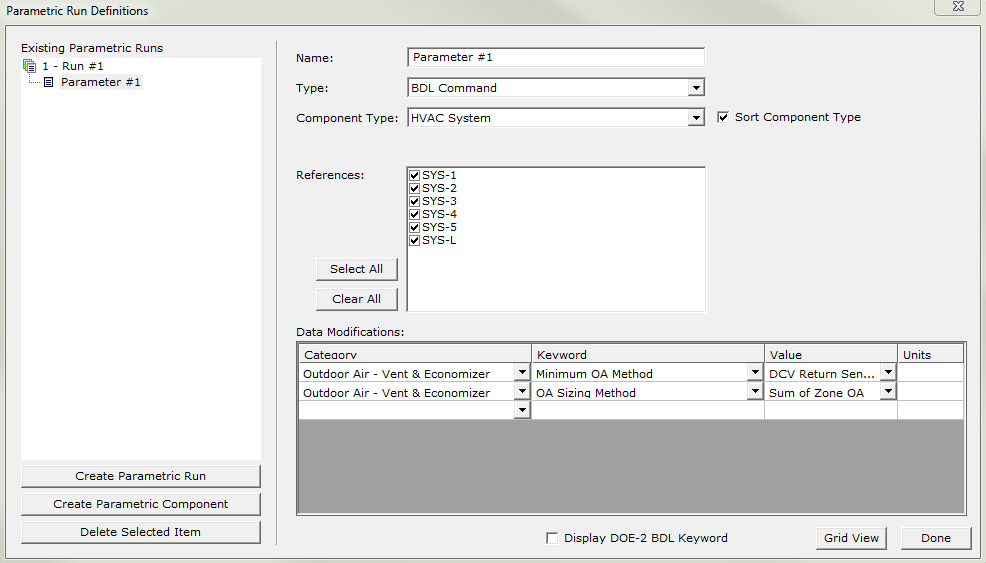


Figure 4 – Measure Case Ventilation Input

* The base-case and measure-case data were then used to estimate the potential energy savings.
* The ventilation flow rates for each zone for the measure-case were verified to meet the code minimum requirement of 0.15 cfm/ft².

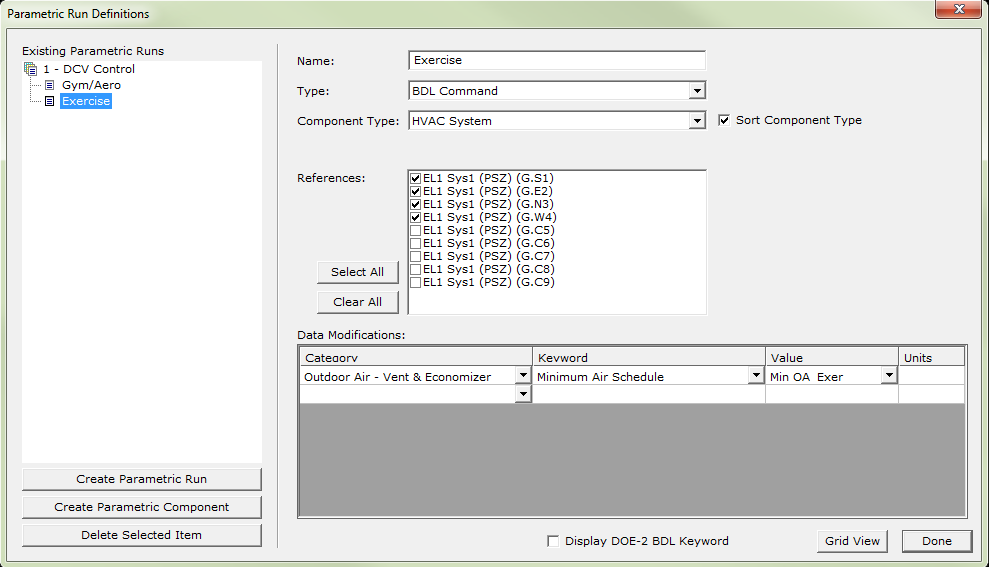
**17-Hr and 24-Hr Fitness Centers**

* The existing DCV measure of 24-hr and 17-hr fitness center from Revision 0 was used as basis for modeling.
* The occupancy profiles were extracted from the hourly clock-in data acquired from a chain fitness center customer. To be conservative, the recorded maximum occupancy of 295 was considered to be the occupancy capacity in the analysis.
* Gym: the space typically used for basketball or racket ball activities.
* Aerobics: the area where group exercise classes, such as step, kick-boxing, yoga, zumba dancing, weights training…etc. are offered; this area is very densely populated during the group sessions; and
* Exercise Areas, which is the open area with equipment, such as treadmills, elliptical trainer, and weight equipment.
* The total area of the fitness center model was 50,000 square feet. The base zoning outline was as follows: The Gym’s area was 10,600 square feet. The Aerobics area was 16,000 square feet. The Exercise area is 23,400 square feet. The building height was 20 feet. The Aerobics and Gym have adiabatic walls. Each zone had a single-zone HVAC system.
* The internal heat gain was 1800 Btu/h-person (Adjusted for male and female).
* The lighting load was 1.0 watt per square feet. The equipment load only applied to exercise area and it is 1.0 watt per square foot. The temperature set points are 75oF Cooling and 72oF Heating.
* HVAC parameters were listed in Attachment C.
* The ventilation flow rate for each zone was verified to meet the code minimum requirement of 0.15 cfm/ft².
* Savings from Demand Control Ventilation was done by running two eQuest models. A parametric run with the proposed minimum outside air schedule is modeled on top of each base-case model to generate the measure-case model. The base and measure data were then used to estimate the potential energy savings.
* Base-case models utilize the default ventilation (without DCV control) as shown in Figure 5 below.



Figure 5 – Base Case Ventilation Input

* Measure-case models utilize minimum outside schedule for ventilation in eQuest parametric run as shown in Figure 6 below.

Figure 6 – Base Case Ventilation Input

**Fan Cycling Control Strategy (Fitness Centers Only)**

Assumptions and methodologies used in fan cycling were based on work paper SCE13CS011.

This control strategy is based on ASHRAE Standard 62.1 2013 - Ventilation for Acceptable Indoor Air Quality, both allowing short-term interruption of ventilation granted the average ventilation levels are maintained equal to prescriptive limits. This strategy requires ventilation rates to be increased over the prescriptive rates during fan operation.

Prescriptive ventilation requirements defaulted by the energy model (as per the Energy Standards) average 0.33 – the fraction of outdoor air to total system flow. This value represents the average prescriptive ventilation to be maintained during fan operation and to be met if introducing fan cycling.

The fan cycling control strategy is optimized during mild weather conditions when economizer operation is maximized. Contrary, this control strategy is limited (in some cases prohibited) during extreme weather conditions when economizing operation is limited and ventilation rates are controlled by occupancy (e.g., DCV).

For the energy savings simulation, based on economizer operation expected for fitness centers’ occupancy and prescriptive ventilation rates, it is conservatively estimated that fan cycle-off operation will accumulatively approximate to no more than 2 hours per day (or 11.8% of daily operation) on the 17-hr fitness center and 3 hours per day (or 12.5% of daily operation) on the 24-hrs fitness center. These fan cycle-off accumulative durations comply with ASHRAE Standard 62.1-2013, but slightly exceed those in the Code limiting every event to no more than 5 minutes (or 8.3% of daily operation).

Based on economizer operation and demand controlled ventilation presumed for this occupancy, it is expected that on average, prescriptive ventilation limits will be met by the measure and control strategy.

Demand controlled ventilation and fan cycling are both occupancy and weather dependent. In all cases, time and durations for fan off-cycle shall be project specific and determined per ASHRAE Standard 62.1-2013 in compliance with the Energy Standards.

eQuest models for the fitness centers with fan cycling were identical to the ones described in previous section, but with the following updates:

* Additional parametric parameters were added to simulate the fan cycling for the measure-case, see Figure 7 below.

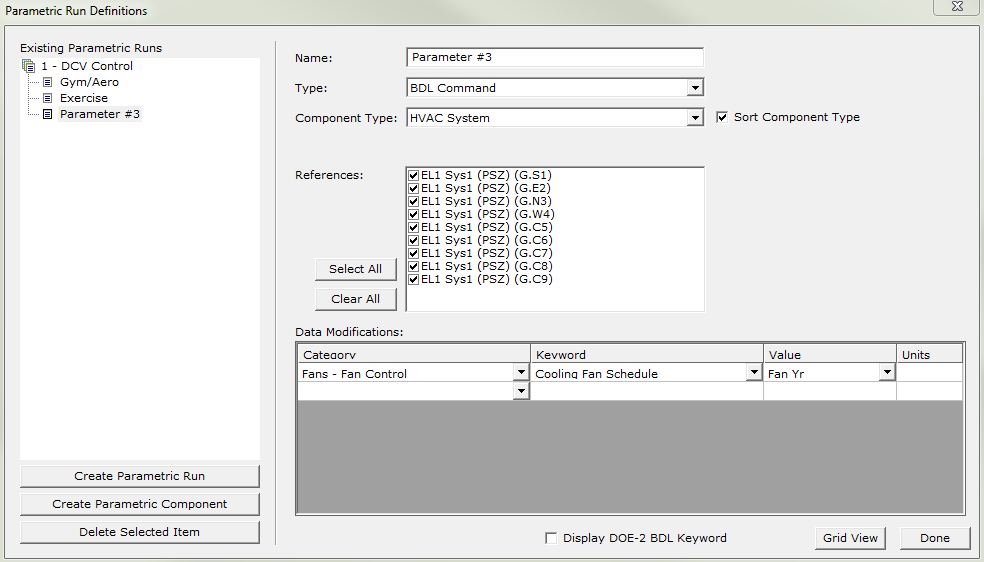


Figure 7 – Parametric Input for Fan Cycling

* Base-case fan control is shown in Figure 8 below.

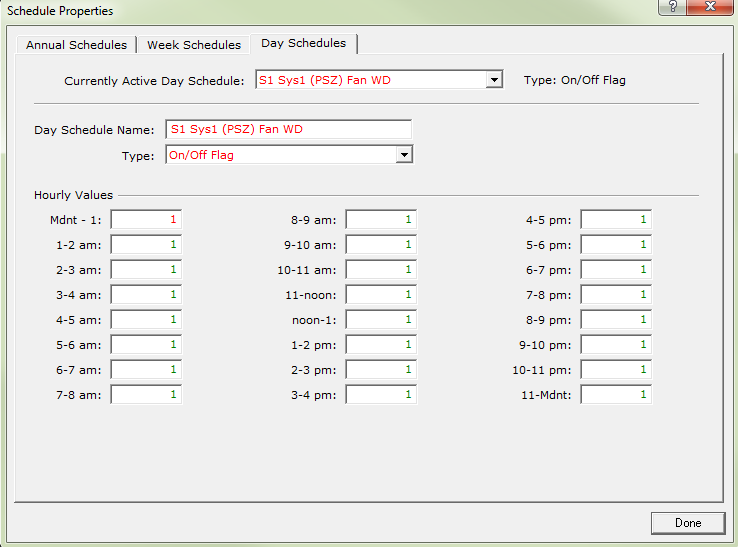


Figure 8 – Base Case Fan Control

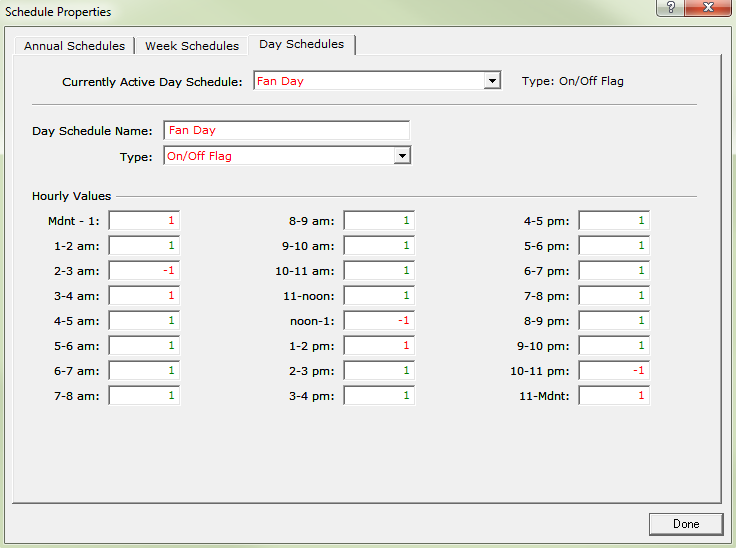
* Measure-case fan control is shown in Figure 9 below.

Figure 9 – Measure Case Fan Control

**2013 Title-24 Code Updates**

For the building types that utilized eQuest default models, and the eQuest models from previous work papers, the baseline energy code was 2008 Title-24 [208]. To update these models to meet the 2013 Title-24 [355], some of the parameters were manually edited in eQuest. Attachment H, “SummaryOfCodeChanges\_T24 C08-C13.xlsx”, outlined the changes of the 2013 code from the 2008 code. As an example, the economizer high limit shut-off was 70°F for climate zone 6 in 2008 Title-24 [208], but the high limit was 71°F for the same climate zone in 2013 Title-24 [355]; therefore, in these eQuest models, the value was manually updated to 71°F. Same approach was used for all other parameters in the eQuest models. Figure 10 below shows the economizer high limit for an economizer in climate zone 6.

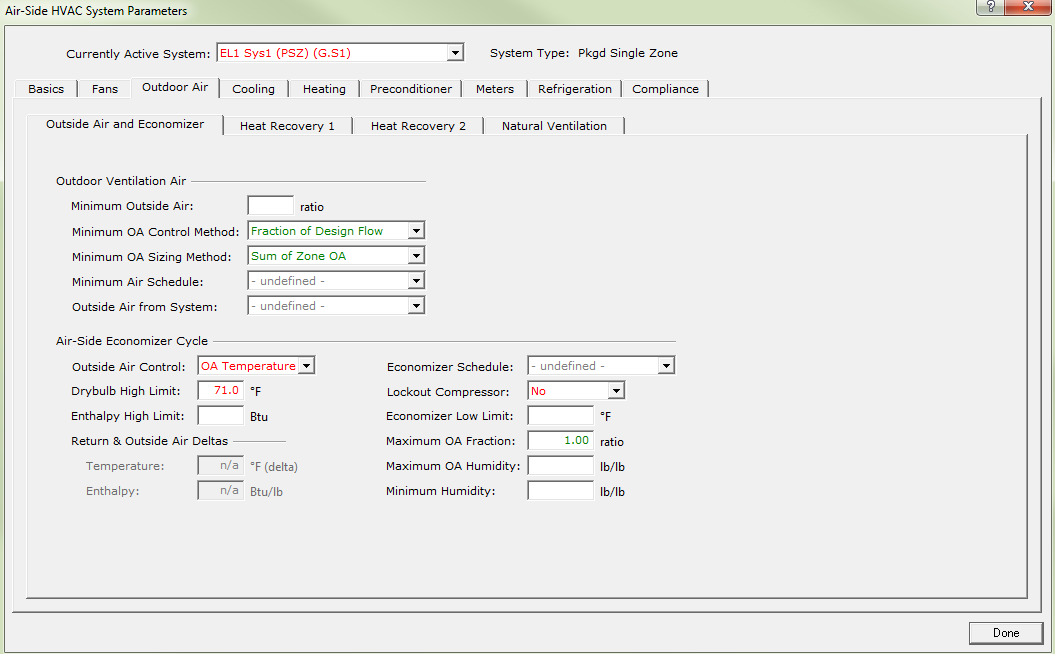


Figure 10 – Economizer High Limit (2013 Title-24, Climate Zone 6)

**Energy Savings**

Energy savings were extracted from eQuest. A sample energy savings list for a 2-Story Office Building in Climate Zone 6 is listed in table below.

**Energy Savings for 2-Story Office Building (Ofs)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Climate Zone** | **Tonnage** | **Base Energy Consumption**  **a [kWh]** | **Measure Energy Consumption [kWh]** | **Energy Savings**  **[kWh/ton]** |
| 6 | 20 | 97,357 | 97,287 | 3.5000 |
| 8 | 23 | 100,310 | 100,157 | 6.6521 |
| 9 | 26 | 101,958 | 101,692 | 10.2307 |
| 10 | 25 | 103,763 | 103,304 | 18.3600 |
| 13 | 24 | 105,625 | 104,947 | 28.2500 |
| 14 | 24 | 105,562 | 104,829 | 30.5416 |
| 15 | 28 | 124,790 | 123,240 | 55.3571 |
| 16 | 18 | 92,030 | 91,934 | 5.3333 |

For calculation methodology, please refer to [Equation 1]. For the complete list, please refer to Attachment A & F.

[Equation 1]







**Demand Reduction Calculations**

The peak demand reduction from demand control ventilation was calculated to be the difference between the base case peak demand and the measure peak demand. The peak demand is considered to be the average demand between 2 p.m. and 5 p.m., for the three consecutive weekday period as defined by DEER for the same year of different climate zones. Table below shows the DEER Peak-Demand period definitions for the climate zones of this work paper.

Demand for 2-Story Office Building (Ofs) during DEER Peak Hours

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Climate Zone** | **Month** | **Date** | **Weekday** | **Peak Temperature °F** | **Ave Temperature °F** |
| 6 | September | 1 | Tuesday | 102 | 77.1 |
| 8 | September | 1 | Tuesday | 90 | 73.9 |
| 9 | September | 1 | Tuesday | 105 | 79.8 |
| 10 | September | 1 | Tuesday | 107 | 86.6 |
| 13 | July | 8 | Wednesday | 108 | 86.7 |
| 14 | August | 26 | Wednesday | 105 | 86.8 |
| 15 | August | 25 | Tuesday | 112 | 97.5 |
| 16 | July | 8 | Wednesday | 90 | 78.8 |

Electrical demands for each model is extracted from eQuest hourly results (see Attachment G for the hourly electrical demand for a 2-Story Office Building in Climate Zone 6). Table below summarizes the demands of the example during the DEER peak hours.

Demand for 2-Story Office Building (Ofs) during DEER Peak Hours

|  |  |  |  |
| --- | --- | --- | --- |
| **Date** | **Time** | **Base Demand**  **[kW]** | **Measure Demand**  **[kW]** |
| 9/1 | 2:00 pm – 3:00 pm | 36.4346 | 36.3844 |
| 9/1 | 3:00 pm – 4:00 pm | 37.7918 | 37.7685 |
| 9/1 | 4:00 pm – 5:00 pm | 34.2666 | 31.1168 |
| 9/2 | 2:00 pm – 3:00 pm | 36.0166 | 35.9605 |
| 9/2 | 3:00 pm – 4:00 pm | 34.3075 | 34.2715 |
| 9/2 | 4:00 pm – 5:00 pm | 28.2829 | 26.2894 |
| 9/3 | 2:00 pm – 3:00 pm | 34.1677 | 34.1033 |
| 9/3 | 3:00 pm – 4:00 pm | 33.6689 | 33.6327 |
| 9/3 | 4:00 pm – 5:00 pm | 27.0441 | 25.402 |
| **Average** | | **33.5534** | **32.7699** |

A sample demand reduction list for a 2-Story Office Building in Climate Zone 6 is listed in table below.

Demand Reduction for 2-Story Office Building (Ofs)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Climate Zone** | **Tonnage** | **Base Peak Demand**  **[kW]** | **Measure Peak Demand**  **[kW]** | **Demand Reduction**  **[kW/ton]** |
| 6 | 20 | 33.553 | 32.770 | 0.03915 |
| 8 | 23 | 35.411 | 34.653 | 0.03296 |
| 9 | 26 | 42.054 | 40.196 | 0.07146 |
| 10 | 25 | 42.772 | 41.249 | 0.06092 |
| 13 | 24 | 41.422 | 39.949 | 0.06138 |
| 14 | 24 | 41.698 | 40.342 | 0.05650 |
| 15 | 28 | 48.875 | 46.662 | 0.07904 |
| 16 | 18 | 30.969 | 30.588 | 0.02117 |

[Equation 2]







# Section 3. Load Shapes

The ideal load shape for net benefits estimates would represent the difference between the base case and measure case. The closest load shapes that are applicable to the measures in this work paper are listed in the table below.

Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Load Shape** | **E3 Alternate Building Type** |
| Assembly | Reduce\_Cooling\_Load-Ret | Large\_Office |
| Education - Primary School | Reduce\_Cooling\_Load-Ret | Small\_Office |
| Education - Secondary School | Reduce\_Cooling\_Load-Ret | Small\_Office |
| Education - Relocatable Classroom | Reduce\_Cooling\_Load-Ret | Small\_Office |
| Education - University | Reduce\_Cooling\_Load-Ret | College\_University |
| Health/Medical - Hospital | Reduce\_Cooling\_Load-Ret | College\_University |
| Health/Medical - Nursing Home | Reduce\_Cooling\_Load-Ret | Small\_Office |
| Lodging – Hotel | Reduce\_Cooling\_Load-Ret | Hotel\_Motel |
| Office – Large | Reduce\_Cooling\_Load-Ret | Large\_Office |
| Office – Small | Reduce\_Cooling\_Load-Ret | Small\_Office |
| Restaurant – Fast Food | Reduce\_Cooling\_Load-Ret | Small\_Office |
| Restaurant – Sit Down | Reduce\_Cooling\_Load-Ret | Small\_Office |
| Storage - Conditioned | Reduce\_Cooling\_Load-Ret | Misc.\_Commercial |

# Section 4. Costs

Direct install programs record their actual purchase and installation costs associated with their HVAC systems.

## 4.1 Base Case Cost

For this measure category, the base case cost is assumed to be zero because these are discretionary modifications (Retrofit-Add On) to the customers’ existing equipment. Their alternative is to make no changes to their existing system.

## 4.2 Measure Case Cost

SCE directly utilizes one or more contractors as part of the program. The actual cost can vary by contractor, the date in which the work occurred, and by the volume of business. Contractor costs are confidential information and are based upon contractually agreed upon pricing as established in their purchase order with SCE; therefore, the SCE program tracking system is the only source for this data.

## 4.3 Full and Incremental Measure Cost

**Full and Incremental Measure Cost Equations**

|  |  |  |  |
| --- | --- | --- | --- |
| **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| REA | MEC + MLC | MEC + MLC | N/A |

MEC = Measure Equipment Cost; MLC = Measure Labor Cost

BEC = Base Case Equipment Cost; BLC = Base Case Labor Cost

**Full and Incremental Costs**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure** | **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| Demand Control Ventilation (Movie Theater) | REA | N/A | N/A | N/A |
| Demand Control Ventilation (Community Center) | REA | N/A | N/A | N/A |
| Demand Control Ventilation (Convention Center) | REA | N/A | N/A | N/A |
| Demand Control Ventilation (Fitness Center)– 24 hour | REA | N/A | N/A | N/A |
| Demand Control Ventilation (Fitness Center)– 17 hour | REA | N/A | N/A | N/A |
| Demand Control Ventilation (Fitness Center)– 24 hour – Heat Pump | REA | N/A | N/A | N/A |
| Demand Control Ventilation (Fitness Center)– 17 hour – Heat Pump | REA | N/A | N/A | N/A |
| Demand Control Ventilation (Museum) | REA | N/A | N/A | N/A |
| Demand Control Ventilation Control\* | REA | N/A | N/A | N/A |
| Demand Control Ventilation Control – Heat Pump\*\* | REA | N/A | N/A | N/A |
| Demand Control Ventilation + Demand Based Fan Control (Fitness Center) Control – 24 hour (PSZ-AC) | REA | N/A | N/A | N/A |
| Demand Control Ventilation + Demand Based Fan Control (Fitness Center) Control – 17 hour (PSZ-AC) | REA | N/A | N/A | N/A |
| Demand Control Ventilation + Demand Based Fan Control (Fitness Center) Control – 24 hour (PSZ-HP) | REA | N/A | N/A | N/A |
| Demand Control Ventilation + Demand Based Fan Control (Fitness Center) Control – 17 hour (PSZ-HP) | REA | N/A | N/A | N/A |

# Attachments

# 

B. 

C. 

D. 

E. 

F. 

G. 

H. 

# References



[26]

[208]

[355]

[386]