Work Paper SCE17HC011

**Revision 0**

**Southern California Edison**

**Air Filter Alarm**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Measure Codes** | AC-98098 |
| **Measure Description** | Air filter alarm which signals upon high system pressure (e.g., dirty filter). Energy savings are due to forced air unit (FAU) system operating at near design system pressure. |
| **Base Case Description** | Source: Forced air unit (FAU) and air distribution system without Air Filter Alarm. |
| **Units** | Sensor |
| **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** | Source: HVAC-FlowCtrl-AirFiltCtrls – 5 years |
| **Measure Installation Type** | Retrofit Add-on (REA) |
| **Net-to-Gross Ratio** | Source: Res-Default>2 : 0.55 |
| **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 | 12/2/2016 | Ramon Yll-Prous/TRC Energy Services | - New template update for 2017 program year  - Values updated using the DEER READI tool  - Costs updated based on online retailers  - Updated DEER operating hours and DEER design tonnage |

# Commission Staff and Cal TF Comments

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Rev** | **Party** | **Submittal Date** | **Comment Date** | **Comments** | **WP Developer Response** |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

Cal TF website: <http://www.caltf.org/>

# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

This work paper details the values used to forecast the impacts of installing an air filter alarm to reduce residential space conditioning energy usage. Since homeowners are very likely to change all air filters in their homes at the same time, it is assumed that only one air filter alarm per home is needed.

An air filter alarm in the form of a hardware that accounts for the differential pressure difference on the filter media notifies the user by means of a sound signal or other signals, that the filter must be cleaned or replaced with a new one. The air filter alarm is attached to the blower side of a forced air unit (FAU) air filter. As dirt accumulates on the air filter, more pressure, and therefore energy, is required to move air through the filter. Once excessive dust and particulate buildup begins obstructing the air filter, air is forced through the alarm, which emits a tone that notifies the homeowner to change or clean the filter. This will reduce the amount of time an FAU is operated with a dirty filter, and therefore, lower fan energy consumption for both the heating and cooling seasons.

**Base, Standard, and Measure Cases**

|  |  |
| --- | --- |
| **Case** | **Description of Typical Scenario** |
| Measure | Air Filter Alarm Controls |
| Existing Condition | Air Filter without Alarm Controls |
| Code/Standard | Air Filter without Alarm Controls |
| Industry Standard Practice | N/A |

Measures and Codes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Codes** | | | | **Measure Name** |
| SCG | SDG&E | SCE | PG&E |
|  |  | AC-98098 |  | Air Filter Alarm Controls |

Measure requires that baseline FAU system is not equipped with air filter alarm controls and/or pressure sensor indicating air pressure drop or high pressure across air filter.

## 1.2 Technical Description

The measure is intended to save energy by operating distribution fan in the Forced Air Unit at a lower system (static) pressure or operating distribution fan near the system design (static) pressure. Air filtration systems are used in forced-air heating, ventilating, and air-conditioning (HVAC) systems to protect occupants and to provide adequate indoor air quality, but they influence HVAC energy consumption – where the power draw by the fan is proportional to the pressure increase across the fan and the airflow rate.

## 1.3 Installation Types and Delivery Mechanisms

This measure if offered through the Financial Support / Giveaway delivery method.

Delivery method is:

* REA for existing buildings, as in these buildings it is an add-on to a standard forced air unit.

**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 |

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: Giveaway | 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** |
| Giveaway | The program provides customers with energy efficiency equipment or services for free. |

## 1.4 Measure Parameters

### 1.4.1 DEER Data

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 | No |
| DEER Operating Hours | No |
| DEER eQUEST Prototypes | No |
| DEER Version | No |
| Reason for Deviation from DEER | Measure is not available in DEER |
| 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** |
| Res-Default>2 | All other EEM with no evaluated NTGR; existing EEM with same delivery mechanism for more than 2 years | Res | Any | Any | 0.55 |

**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**

Per latest ESPI guidance, the EUL for this REA measure is the shorter of the RUL of the base equipment OR the EUL of the add-on component or device. For this measure the RUL of the base equipment is equal to the EUL of the add-on component; hence, the EUL of the add-on component or device is adopted. 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-FlowCtrl-AirFiltCtrls | Air Filter Alarm | Res | HVAC | 5 | 1.67 |

### 1.4.2 Codes and Standards Analysis

There are no applicable Code and/or Regulations on measure

Code Summary

|  |  |  |
| --- | --- | --- |
| **Code** | **Reference** | **Effective Dates** |
| Title 24 (2016) | N/A | N/A |
| Title 20 (2015) | N/A | N/A |
| DOE | N/A | N/A |

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

## 1.6 Data Quality and Future Data Needs

N/A

# Section 2. Calculation Methodology

The calculations discussed in this section are based on the following assumptions:

* Air filters collect dirt at a constant rate.
* Increased energy needed to move air through a dirty filter has a linear correlation to the amount of dirt on the air filter surface.
* The FAU in a home operates during both heating and cooling.
* The fan is sized to match the air conditioner tonnage.

## 2.1 Energy Savings Estimation Methodologies

### 2.1.1 Calculating Additional Power Due to Dirty Air Filter

The percentage increase in power requirements due to a dirty air filter was calculated with Equation 1:

Equation 1



where ΔP = percentage increase in power due to dirty air filter,

Pdirty = power consumption with dirty air filter,

Pclean = power consumption with clean air filter.

The power drawn by the fan motor is derived from Equation 2 as a function of measured current and voltage.

Equation 2

P = *IV* cos (ϴ)

where P = power measured in watts,

I = current measured in amps-rms,

V = voltage measured in volts-rms,

cos (ϴ) = power factor of the fan motor.

An Arizona State University study [411] measured the current drawn by a fan pushing air through a clean and a dirty air filter. These values can be used in Equation 2:

* Clean filter: 415 mA of current

Pclean = 0.415 *V* cos(ϴ)

* Dirty filter: 430 mA of current

Pdirty = 0.430 *V* cos(ϴ)

Therefore the percent increase in power from Equation 1 is:



*where the ratio of the terms is assumed to be one.*

Since the voltage and power factor are constants, the difference in the energy consumption between the clean and dirty filters may be expressed as a simple percentage. The dirty air filter consumed 3.61% more energy than the clean air filter. The amount of dirt accumulation on the filter measured is not known, and no pressure drop measurements were taken. Thus, this work paper conservatively assumes that this percent increase occurs at the time the filter would be changed without a filter alarm, i.e., 11 months on average [[[1]](#endnote-1)]. When calculating energy savings, the value used is the average percent increase for the months between a recommended filter change and when an actual filter change occurs.

### 2.1.2 Calculating Percentage of Annual Operating Hours with Dirty Air Filter

In addition to the assumption dirt collects on a filter at a constant rate, the following information is considered to determine annual operating hours with a dirty air filter.

* A two month recommended change interval; based on an average of industry suggestions shown in the Air Filter Change Interval attachment and
* An 11 month actual change interval; based on an informal survey of homeowners shown in the attachment [2].

Both of these points are shown in following figure

**Annual Operating Hours with Dirty Filter**

1

2

3

4

5

6

7

8

9

10

11

12

**Months**

**Dirt Accumulation**

Recommended   
Filter Change

Dirt   
Accumulation

Actual  
Filter Change

0

Hours Operating  
w/Dirty Filter

Illustration of Dirty Filter Operational Hours

If dirt build-up on an air filter progresses in a linear fashion over time, as shown in the figure above, then the total energy consumption increase over time is:

Equation 3:



### 2.1.3 Calculating Annual Operating Hours

Annual system operating hours were estimated using DEER’s Residential building prototype for all climate zones. DEER operating hours are shown in table below.

Annual FAU Operating Hours by Climate Zone

|  |  |
| --- | --- |
| Climate Zone | Annual Operating Hours |
| 6 | 1,647 |
| 8 | 2,275 |
| 9 | 2,399 |
| 10 | 2,705 |
| 13 | 2,966 |
| 14 | 2,794 |
| 15 | 5,141 |
| 16 | 1,083 |

### 2.1.4 Calculating Energy Savings

The annual energy savings may be derived using Equation 3 and a standard motor power draw calculation to arrive at Equation 4:

Equation 4



*where*,

kWhsavings = annual energy savings per FAU,

P = power blower motor (kW),

ΔP = percentage increase in power due to dirty air filter,

hweighted = annual operating hours of blower motor,

Mlf = Motor Load Factor, and

R = percentage installed (installation rate).

The following values are used to calculate energy savings:

* Mlf = 85% motor load factor
* R = 47% air filter alarm installation rate [412]
* hweighted annual operating hours of blower motor; see following blower motor table

The maximum percentage increase in power due to a dirty air filter was estimated in Section 2.1.1 as 3.61%. However, some increased energy consumption occurs between the time a clean filter is installed and the recommended replacement time.

Following table summarizes the linear increase over the 11 months average air filter replacement interval. The average power increase from months three through eleven, 2.30%, is used as a conservative value for ΔP.

Increased Power Use Over Time

|  |  |
| --- | --- |
| **Month** | **% Increase in Power  Due to Dirty Filter** |
| 0 | 0.00 |
| 1 | 0.33 |
| 2 | 0.66 |
| 3 | 0.98 |
| 4 | 1.31 |
| 5 | 1.64 |
| 6 | 1.97 |
| 7 | 2.30 |
| 8 | 2.63 |
| 9 | 2.95 |
| 10 | 3.28 |
| 11 | 3.61 |

The blower motor power was calculated using following equation:

Equation 5



Average system tonnage for each climate zone was found using DEER measure RE-HV-ResHP-14p0S-8p6H. The CFM per ton and Watts per CFM figures are average values for residential furnace fans. For more information see attachment [2]. The results are summarized in table below.

Blower Motor Power

|  |  |  |  |
| --- | --- | --- | --- |
| **Climate**  **Zone** | **Cooling**  **Tons** | **CFM (at 400 CFM/Ton )** | **P kW (at 0.51 W/CFM)** |
| 6 | 2.64 | 1057 | 0.54 |
| 8 | 2.41 | 962 | 0.49 |
| 9 | 2.75 | 1100 | 0.56 |
| 10 | 3.22 | 1289 | 0.66 |
| 13 | 3.05 | 1218 | 0.62 |
| 14 | 3.70 | 1478 | 0.75 |
| 15 | 4.10 | 1639 | 0.84 |
| 16 | 2.70 | 1078 | 0.55 |

The annual energy savings for Climate Zone 6 using Equation 4 are estimated as:

P = 0.54 kW

ΔP = 2.30%,

hweighted = 1,647 hours,

Mlf = 85%, and

R = 47%.



The annual energy savings are shown in table below for each climate zone. Note that since the FAU runtime and air-conditioning sizing is on a per home basis, the annual energy savings is per home. The detailed calculations are provided in the attachment [2].

Annual Energy Savings by Climate Zone.

|  |  |
| --- | --- |
| Climate Zone | Annual Energy Savings  (kWh per Home) |
| 6 | 4.08 |
| 8 | 5.13 |
| 9 | 6.18 |
| 10 | 8.17 |
| 13 | 8.47 |
| 14 | 9.68 |
| 15 | 19.75 |
| 16 | 2.74 |

## 2.2 Demand Reduction Estimation Methodologies

Demand reduction was estimated using the following equation as a function of design fan power, power consumption variations of the fan between clean filter and dirty filter states, and installation rate.

Equation 6



*where*,

kWreduced = demand reduction per FAU,

P = power of blower motor,

ΔP = fractional increase in power due to dirty air filter, and

R = fraction of air filter alarms installed (installation rate).

The demand reduction is estimated for Climate Zone 6 using Equation 6 as follows:



Demand Reduction by Climate Zone.

|  |  |
| --- | --- |
| Climate Zone | Peak Demand Reduction  (kW) |
| 6 | 0.00291 |
| 8 | 0.00265 |
| 9 | 0.00303 |
| 10 | 0.00355 |
| 13 | 0.00336 |
| 14 | 0.00408 |
| 15 | 0.00452 |
| 16 | 0.00297 |

For full details, see the attachment [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** |
| Residential Single Family | Reduce\_Cooling\_Load-Ret | Misc.\_Commercial |
| Residential Multi-Family | Reduce\_Cooling\_Load-Ret | Misc.\_Commercial |
| Residential Mobile Home – Double-Wide | Reduce\_Cooling\_Load-Ret | Misc.\_Commercial |

# Section 4. Costs

## 4.1 Base Case Cost

The assumed base case has no air filter alarm. Therefore the base case cost is zero.

## 4.2 Measure Case Cost

This work paper assumes that only one air filter alarm is installed per home and that the homeowner will change the FAU filter (or all FAU filters) at the same time. Additionally, this work paper assumes that the homeowner installs the air filter alarm. For this reason, the labor cost is assumed to be $0.

Per Measure Case Cost documentation gathered using 2016 online retail information on air filter alarm providers, the average of the material cost was estimated to be in the order of $7.17. Refer to attachment [3] for more information on the costs used.

## 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/NEW | 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** |
| AC-98098 | REA | $7.17 | $7.17 | N/A |

# Attachments

1. 

1. 

1. 

# References



[49]

[195]

[411]

[412]

1. [↑](#endnote-ref-1)