Work Paper SCE17HC052

**Revision 0**

**Southern California Edison**

**Fan Delay (Cycle Off) Controller for Residential Air Conditioners**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Measure Codes** | AC-20510 – Fan Delay (Cycle Off) Controller for Residential Air Conditioners |
| **Measure Description** | Residential central HVAC system with evaporator fan delay (cycle off) controller based on a manual prescribed time or using a built-in logic to delay the evaporator fan cycle off time. The built-in control logic is based on equipment (compressor and fan) operation and cycling to improve HVAC system efficiency. |
| **Base Case Description** | Residential central HVAC system with standard fan controls and operation without manual or logic-based evaporator fan delay (cycle off) controller to improve HVAC system efficiency. |
| **Units** | Unit |
| **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** | 5 years (HV-ResAC) |
| **Measure Installation Type** | Retrofit Add-On (REA) |
| **Net-to-Gross Ratio** | 0.55 (DEER NTGR ID: Res-Default>2) |
| **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 | 10/08/2018 | Steve Sidletsky/BASE Energy  Ram Dharmarajan/Lincus | - This workpaper is an update of SCE13HC052.2  -New template for 2019 program year.  - Calculation update using the latest Residential DEER prototypes (via MASControl2).  - The energy savings are now calculated ‘per unit’ as opposed to the ‘per ton’ in the previous workpaper.  -Update all 16 CA Climate Zones with CTZ2010 weather.  - Measure costs updated per market assessment and 2018 RS Means Data.  -Both authors contributed to key sections of this Workpaper and are listed as co-authors. |

# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

This work paper outlines the energy savings achieved from the retrofit add-on of an evaporator fan delay controller (FDC) device onto a residential single-family, multi-family or double-wide mobile home split-system air conditioner.

Although, a fan delay controller has a small penalty for running the evaporator fan during the fan delay periods, net energy savings are realized by utilizing the residual liquid refrigerant in the evaporator and delaying the start of the next cooling cycle. Estimated demand and energy savings for this measure are estimated using latest DOE-2.3/eQUEST residential prototypes and evaluation findings from SCE’s ET11SCE1130 study [Attachment 1].

**Base, Standard, and Measure Cases**

|  |  |
| --- | --- |
| **Case** | **Description of Typical Scenario** |
| Measure | Residential central HVAC system with an evaporator fan delay (cycle off) controller based on a manual prescribed time or using a built-in logic to delay the evaporator fan cycle off time. The built-in control logic is based on equipment (compressor and fan) operation and cycling to improve HVAC system efficiency. |
| Existing Condition | Residential central HVAC system with standard fan controls and operation without manual or logic-based evaporator fan delay (cycle off) controller to improve HVAC system efficiency. |
| Code/Standard | N/A |
| Industry Standard Practice | Residential central HVAC system with standard fan controls and operation without a manual or logic-based evaporator fan delay (cycle off) controller. |

Measures and Codes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Codes** | | | | **Measure Name** |
| SCG | SDG&E | SCE | PG&E |
|  |  | AC-20510 |  | Fan Delay (Cycle Off) Controller for Residential Air Conditioners |

**Eligibility requirements**:

* This measure only applies to central residential split-system air conditioning units with an indoor evaporator coil. The baseline air conditioning system cannot have built-in delay controller and/or device capable of delaying fan operation. Please note that some of the smart thermostats, if not all, already have the fan delay controller.
* This work paper only allows the installation of an automated (logic-based) fan delay controllers, unless the manually-set time-delay fan controller is set and commissioned by a trained (and SCE approved) contractor.
* This measure can be installed in single family, multi-family, and double-wide mobile homes in all climate zones.
* Installation shall comply with all latest applicable regulations, code, and standards including but not limited to the California Energy Standards Title-24, Title-20, and NEC.
* Fan delay controllers used for optimizing and improving heating efficiency including those for gas furnaces cannot be incentivized under this workpaper.
* Installations of “manual fan delay controllers” shall be supported by proof and acknowledgment (e.g., Incentive application or similar) indicating that the installation was performed, completed, and commissioned by an approved contractor.

## 1.2 Technical Description

A typical residential AC unit cycles off both the compressor and the evaporator fan, if the thermostat setpoint temperature is met. When the compressor and evaporator fan are cut off in response to the thermostat control, the evaporator coil is still partially flooded with the liquid refrigerant. This residual liquid refrigerant can be used to provide space cooling optimizing and improving system efficiency. This can occur by running the evaporator fan for a short time after the compressor cycles off, referred to as “fan delay time”. After the compressor stops running, the evaporator fan continues running to circulate the indoor air across the evaporator coil to provide additional sensible cooling. Additional sensible cooling provided during the fan delay period postpones the start of the next cooling cycle. The reduction in cooling period results in energy savings, mitigating the penalty as a result of the increased run time of the fan.

There are two types of commercially available add-on fan delay controllers. One type has built-in logic to delay the evaporator fan cycle-off time based on compressor and/or evaporator fan cycling. The control logic directly correlates fan delay periods with compressor run times.

The other type of fan delay controller is a manual evaporator fan delay (cycle-off) controller, which typically extends evaporator fan operation for 0 to 90 seconds after the compressor has turned off. This measure only allows the installation of a fan delay controller with a built-in logic. Fan delay controllers with a manually prescribed delay time are allowed only when installed and commissioned by an approved HVAC contractor.

## 1.3 Installation Types and Delivery Mechanisms

The installation type is Retrofit Add-On (REA).

The delivery method is Financial Support – Down-Stream Incentive - Deemed; and Financial Support-Direct Install. The savings are reported on a per household basis.

**Installation Type Descriptions**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Installation Type** | **Savings** | | **Life** | |
| 1st Baseline (BL) | 2nd BL | 1st BL | 2nd BL |
| Retrofit Add-on (REA) | Above Customer Existing Baseline | N/A | EUL\_HOST/3 capped at the EUL of the add-on equipment | 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 | 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. |
| Down-Stream Incentive | The customer installs qualifying energy efficient equipment and submits an incentive application to the utility program. Upon application approval, the utility program pays an incentive to the customer. Such an incentive may be deemed or customized. |

## 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 | Yes |
| DEER Measure Case | No |
| DEER Building Types | Yes |
| DEER Operating Hours | Yes |
| DEER eQUEST Prototypes | Yes |
| DEER Version | DEER 2017 |
| Reason for Deviation from DEER | The measure does not exist in DEER.  DEER Prototypes are used and modified to determine the baseline. |
| DEER Measure IDs Used | N/A |

**Net-to-Gross Ratio**

The NTG values were obtained using the DEER READI tool v2.5.1. 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 v2.5.1. 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 v2.5.1 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. Note that this measure assumes an EUL based on the RUL of the HVAC system affected by the REA measure as described below. The EUL of the measure is capped at the remaining useful life of High Efficiency Air Conditioner, which is third of 15 years (EULHOST/3 where EULHOST is 15 years).

The EUL ID HVAC-EMS (Energy Management System) was reviewed which has the same EUL and RUL values of 15 and 5 years respectively. But, HVAC-EMS applies only to the Commercial Sector and HV-ResAC was the closest EUL ID in the Residential Sector.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** | **RUL (Years)** |
| HV-ResAC | High Efficiency Air Conditioner (package and split systems) | Res | HVAC | 5 | N/A |

### 1.4.2 Codes and Standards Analysis

There are currently no federal, state, or regional codes that impact fan delay controllers for residential air conditioners. However, Chapter 4, Article 4, Section 1605.1(c), Table C.3 of California’s Title 20 (2018) [319] code requires split system air conditioners installed after January 1, 2015 to have a minimum SEER rating of 14.0.

In order to be conservative in the energy savings, an efficiency rating of SEER 15.0 was used to establish the baseline energy usage for this measure.

Code Summary

|  |  |  |
| --- | --- | --- |
| **Code** | **Reference** | **Effective Dates** |
| Title 24 (2016) | N/A | N/A |
| Title 20 (2018) | N/A | N/A |

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

### 1.5.1 ET11SCE1130 Report: Effects of Delaying Evaporator Fan Cycle Off Time for Residential Air-Conditioning Units

Southern California Edison (SCE) conducted an Emerging Technology (ET) study (ET11SCE1130) [Attachment 1] where it tested a nominal 3-ton split air-conditioning unit in a laboratory setting. The test unit was equipped with an air-cooled condenser and a single speed compressor. This combination of components is representative of one of the most common configurations of air-conditioning units found in residential applications.

The measure evaluation portion of the testing included the installation of the two types of commercially available add-on fan delay controllers. The two fan delay controllers allowed the fans to run after the compressor was shut off, but one ran for a prescribed period of time while the other had a built-in logic to delay for a period of time based off of the compressor’s run time.

The study was limited to cooling savings and excluded evaluation of gas and/or electric (heat pump) heating savings. Findings from referenced study suggest that electrical energy savings potentials on technology varied as a function of Part Load Ratios (PLR) of the cooling systems. The findings from this ET study were used in conjunction with modified DEER prototypes to compute the energy savings for this measure.

## 1.6 Data Quality and Future Data Needs

N/A

# Section 2. Calculation Methodology

This section provides the step by step calculation methodology used for estimating the electrical energy savings and peak demand savings for a residential air conditioner with a FDC.

1. DEER Prototypes are downloaded from MASControl2 v1.1.21, the latest version of MAS Control with prototypes for the residential sector.
2. The prototypes are downloaded for all the following building types where the measure is eligible for all sixteen climate zones.

|  |  |
| --- | --- |
| **Eligible building type DEER Anonym** | **Building Description** |
| DMo | Residential Mobile Home |
| SFm | Residential Single Family |
| MFm | Residential Multi-Family |

1. This measure is applicable to all the vintages. However, for the analysis done in this workpaper only vintage 2007 is considered. This is because, as per DEER2014 Energy Impact Weights Tables; the median building vintage weight corresponds to vintage 2003 for all the three buildings types DMo, SFm and MFm. In order to be conservative, the vintage of 2007 (one above the median) is used exclusively for the purpose of energy savings analysis and ‘2006-2009’ is selected in the MASControl2 tool.
2. The HVAC system selected in MASControl2 is ‘rDXGF’. The case option selected in the tool is ‘Measure’ and the measure to be simulated is ‘RE-HV-ResAC-lt45k Btuh-15S’.
3. This section briefly describes the downloaded DEER prototype for each of the building type in more detail. This is necessary in order to understand how the energy savings are calculated later and normalized per household.

Residential Mobile Home – Each model has two units, one in the North-South orientation while the other is in the East-West orientation. The tonnage of the HVAC system in each unit is constant across all 16 climate zones at 3.5 tons per unit. Other than the orientation, the units are exactly the same in all aspects.

Residential Single Family - Each model has four units, two in the North-South orientation while the other two are in the East-West orientation. Each type of orientation has a one-story unit and a two-story unit. The one-story units differ from the two-story units with respect to the cooling and heating capacities. The average tonnage across all units and climate zones for Single Family building type is 2.97 tons.

Residential Multi Family - Each model has two systems, one in the North-South orientation while the other is in the East-West orientation. Each type of system has two stories and seven units on each story. Therefore, each multi-family DEER model prototype has a total of 28 units with 14 units in each orientation. The average tonnage across all units and climate zones for Multi Family building type is 1.02 tons.

1. The following table summarizes the modification made to the downloaded DEER prototypes to account for standard residential conditions.

|  |  |  |  |
| --- | --- | --- | --- |
| **Building Type** | SFm | MFm | DMo |
| **Climate Zones** | All 16 Climate Zones | All 16 Climate Zones | All 16 Climate Zones |
| **Vintage** | 2007 | 2007 | 2007 |
| **Weather** | CZ2010 | CZ2010 | CZ2010 |
| **HVAC System Type** | RESYS2 - Residential with cycling furnace and cycling air-conditioner (and currently supported in DOE2.3) | RESYS2 - Residential with cycling furnace and cycling air-conditioner (and currently supported in DOE2.3) | RESYS2 - Residential with cycling furnace and cycling air-conditioner (and currently supported in DOE2.3) |
| **HVAC System Efficiency** | SEER15 | SEER15 | SEER15 |
| **Cooling Electric Input Ratio** | 0.2322 | 0.2322 | 0.2322 |
| **Fan Design kW/cfm** | 0.000580 | 0.000580 | 0.000580 |
| **Fan EIR=f(PLR)** | TwoSpeedFan | TwoSpeedFan | TwoSpeedFan |
| **Temperature Setpoints** | 77.0 deg. F (cooling); 70.0 deg. F (heating) | 77.0 deg. F (cooling); 70.0 deg. F (heating) | 77.0 deg. F (cooling); 70.0 deg. F (heating) |
| **Average System (Cooling) Capacity** | 35.61 kBtu/hr (SFm) | 12.22 kBtu/hr (MFm) | 41.99 kBtu/hr (DMo) |
| **MASControl2 Tech ID Sample** | SFm-wCZ01-v2007-rDXGF-tn-SplitAC1Sp-S15 | MFm-wCZ01-v2007-rDXGF-tn-SplitAC1Sp-S15 | DMo-wCZ01-v2007-rDXGF-tn-SplitAC1Sp-S15 |

1. Weather data files corresponding to CZ2010 was used to run the eQuest simulations. The baseline energy consumption was established using Building Energy Simulation software eQuest v3.65 (DOE2.3). Following each simulation, hourly report blocks were generated, and four hourly variables were captured from the eQuest simulations on an annual basis: Total Cooling Load (Btu/hr), Condensing Unit Energy (kWh), Supply (indoor) Fan Energy (kWh), and AC Total Cooling Capacity (Btu/hr). An hourly report block is generated for each unit in a DEER prototypes. For example, a DMo simulation has 2 units and generates 2 hourly report blocks; a MFm simulation has a total of 28 units and generates 28 hourly report blocks.
2. This workpaper is limited to cooling savings and excludes the evaluation of gas/electric heating savings. Therefore, only the Supply Fan Energy specific to cooling purposes is incorporated in the Total Baseline AC Energy Usage. The following equation is used to compute the Total Baseline AC Energy Usage:

**Equation 1**

For a sample calculation, consider a single-family home in climate zone 6 with a single story, N-S orientation at 5:00 PM on September 17. The Total Baseline AC Energy Usage is:

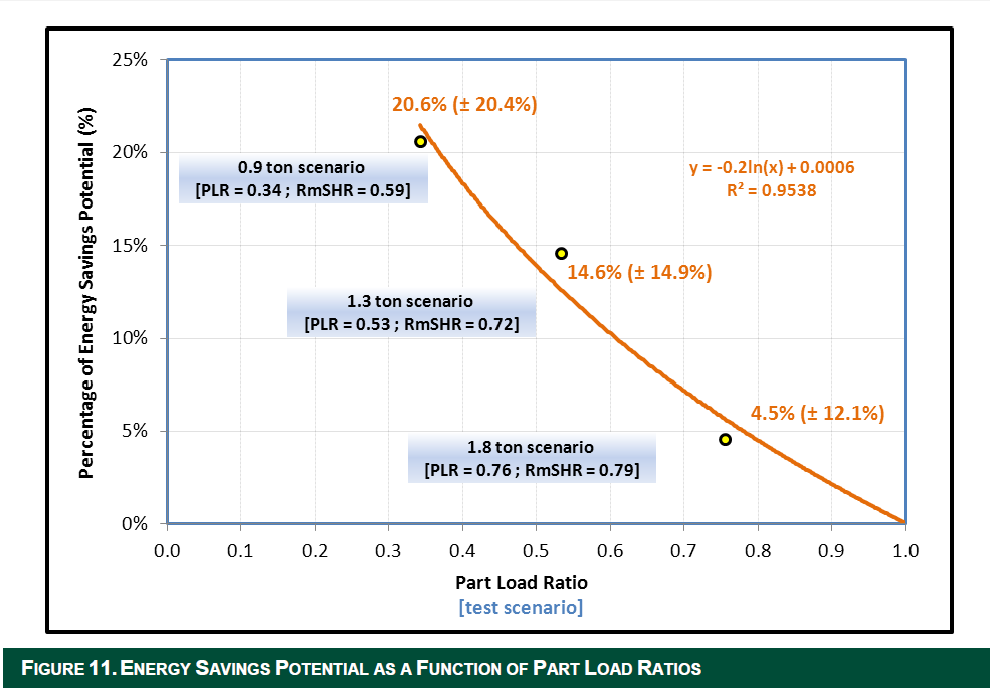
For details, please refer to Attachment 4.

1. Approach for evaluating energy and demand saving potentials on the measure leverages SCE’s ET11SCE1130 study [Attachment 1] which evaluated the feasibility and the potential electrical demand and energy savings due to fan delayed (cycle-off) periods for a central residential A/C unit. Findings from referenced study suggest that electrical energy savings potentials on technology varied as a function of fan delayed periods and Part Load Ratios.
2. The part load ratio (PLR) for each hour was determined by equation 2:

**Equation 2**

For a sample calculation considered in Step 8, PLR:

1. The following figure (Figure 1) from the ET Study [Attachment 1] plots the Percentage of Energy Savings against the Part Load Ratio. The logarithmic curve fit relation is listed on the top right of the figure below.



**Figure 1**

1. Once the Part Load Ratio (PLR) is obtained using equation 2, equation 3 applies the logarithmic curve fit of percentage of energy savings versus part load ratio determined from laboratory testing.

**Equation 3**

For a sample calculation considered in Step 8, hourly energy saving is:

The result from equation 3 is AC energy savings for each hour. This number is summed for all hours of the year to obtain the total energy savings. Each zone has a separate split AC-system based on how the DEER prototypes are modeled and results are obtained for each zone.

Reiterating, there are 2 systems (N-S, E-W orientations) in double-wide mobile homes, 4 systems in single-family homes (single-story, two-story, two orientations), and 28 systems in multi-family homes (two-story buildings with 14 units, two orientations). The results obtained for each of the building prototypes are averaged to obtain one representative savings number per building type. This averaged savings number obtained is the kWh/year saved per unit for each respective building type and climate zone.

1. Demand savings are evaluated using ex-ante DEER2014 peak demand definition and procedures. As per step 10, the hourly values of AC energy savings were available for 8,760 hours, demand reduction was calculated by summing the total AC energy savings consumed during the peak demand period for the specific summer weekday periods respective to each climate zone, 2:00 PM to 5:00 PM. The total energy consumption during this period was then divided by nine, the number of peak hours, as shown in equation 4. This is repeated for each zone and all the obtained peak demand reduction values are averaged resulting in one kW reduction value for each building type and climate zone.

**Equation 4**

Refer to the following attachments for detailed energy savings and demand reduction calculations.

* SCE17HC052.0 A2 - Annual Energy Savings\_FDC SFM \_2018.xlsx (**available upon request due to size**)
* SCE17HC052.0 A3 - Annual Energy Savings\_FDC MFM\_2018.xlsx (**available upon request due to size**)
* SCE17HC052.0 A4 - Annual Energy Savings\_FDC DMO\_2018.xlsx (**available upon request due to size**)

# 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 – Double-Wide Mobile Home | DEER:HVAC\_EFF\_AC | RES |
| Residential – Multi-Family | DEER:HVAC\_EFF\_AC | RES |
| Residential – Single Family | DEER:HVAC\_EFF\_AC | RES |

# Section 4. Costs

## 4.1 Base Case Cost

For REA measures, there is no base case cost as the measure is being added onto the existing host equipment.

## 4.2 Measure Case Cost

The measure equipment material cost was determined by contacting manufacturers of commercially available logic based FDCs. As per the manufacturers, the average price was $50 per controller. The details of the make, model, and cost of the controllers can be found in SCE17HC052.0 Cost References.xlsx [Attachment 6]. The measure labor cost was determined from 2018 RS Means Electrical Cost Data Handbook [504]*.* Based on the experience of SCE programs, the installation process including all pre and functional checks takes about 1 hour. The average labor cost is determined to be $78/hour based on 2018 RS Means under low voltage controllers.

Measure Case Cost= Measure Equipment Cost + Measure Labor Cost

= $50 + $78

= $128/unit

## 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** |
| AC-20510 | REA | $128 | $128 | N/A |

# Attachments

1. SCE17HC052.0 A1 - ET11SCE1130 ET Study
2. SCE17HC052.0 A2 - Annual Energy Savings FDC SFM \_2018.xlsx (**available upon request due to size**)
3. SCE17HC052.0 A3 - Annual Energy Savings FDC MFM\_2018.xlsx (**available upon request due to size**)
4. SCE17HC052.0 A4 - Annual Energy Savings FDC DMO\_2018.xlsx (**available upon request due to size**)
5. SCE17HC052.0 A5 - Calculation template
6. SCE17HC052.0 A6 – Cost References
7. SCE17HC052.0 A7 – Sample eQuest BES files

# References

