Work Paper SCE17PR008

**Revision 1**

**Southern California Edison**

**Process Fan VSD**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Measure Codes** | PR-19147, PR-19148 |
| **Measure Description** | Add a variable frequency drive to an existing process fan (3 hp to 75 hp) |
| **Base Case Description** | Non-HVAC and non-refrigeration fan used for exhaust, ventilation, pressurization, or other process |
| **Units** | Horsepower (hp) |
| **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** | 6.67 years (DEER EUL ID: ProcDist-Motor\_Spd) in accordance with Draft Resolution [510] |
| **Measure Installation Type** | Retrofit Add-on (REA) |
| **Net-to-Gross Ratio** | 0.6 for Com-Default>2yrs, Ind-Default>2yrs, Agric-Default>2yrs |
| **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 | 10/25/2016 | Ramon Yll-Prous/TRC | * This work paper is an update of SCE13PR008.2 * New template update for 2017 program year * Updated costs based on 2015 RSMeans * Savings scaled based on update DEER operating hours * Updated the EUL value in accordance with Draft Resolution E-4807 [510] |
| 1 | 3/24/2017 | Lake Casco/TRC | Following updates were made based on CPUC “DISPOSITION FOR WORKPAPERS COVERING PROCESS FAN VSD”   * Split measure into two solution codes based on fan HP. * Update savings based on CPUC disposition values. The savings values are effective between 1/1/2017 through 6/30/2017 * Updated cost per new solution codes. |

# 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

## 1.1 Measure Description & Background

The measure case is a variable speed drive (VSD) on an existing process fan.

The base case is an existing process fan with rated motor capacity between 3 hp and 75 hp. The base case fan will either operate continuously or have on/off controls.

**Base, Standard, and Measure Cases**

|  |  |
| --- | --- |
| **Case** | **Description of Typical Scenario** |
| Measure | Variable speed drive (VSD) on an existing process fan |
| Existing Condition | Process fan with rated motor capacity between 3 hp and 75 hp |
| 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** | **PR-19147** | **N/A** | 3 HP to 5 HP Variable Speed Drive on Process Fan Control |
| **N/A** | **463775** | **PR-19148** | **PR002** | Greater than 5 HP to 75 HP Variable Speed Drive on Process Fan Control |

At the time of this workpaper revision both SDG&E and PG&E do not plan on offering the 3 to 5 HP solutions in their current programs.

The existing fan shall meet the following requirements:

* Must not be a HVAC or refrigeration fan.
* May be used for exhaust, ventilation, pressurization, or other process applications. Air compressor systems are not eligible.
* Must have a motor horsepower rating ≥ 3 hp and ≤ 75 hp because savings for motors below 3 hp are minimal and do not justify the cost of a VSD retrofit. For SDG&E and PG&E, motor horsepower rating must be >5 hp and ≤ 75 hp.
* Must operate continuously or be manually operated with an ON/OFF control switch. Two-speed fans do not qualify.

This measure is applicable only to the following building types:

* Manufacturing - Bio/Tech
* Manufacturing - Light Industrial

## 1.2 Technical Description

VSD control: The demand on process fans is often variable, so 100% speed fan operation is not always required. A VSD enables the fan to operate at a reduced speed during part load conditions in order to match the demand; typically there are sensors in the system, which send control signals to the VSD. This saves energy due to the cubic nature of the fan affinity laws. Fan power is proportional to the fan speed, e.g. operating at half speed theoretically requires only one-eighth of the power draw at full speed. Depending on the system, there may be minimum and maximum speed requirements that apply, e.g. minimum speed of 30%.

## 1.3 Installation Types and Delivery Mechanisms

The delivery methods are:

* Financial Support – Down-Stream Incentive – Deemed
* Partnership – Down-Stream Incentive – Deemed

The program/install type is Retrofit Add-On (REA).

**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 | The program motivates customers, through financial incentives such as rebates or low interest loans, to implement energy efficient measures or projects. |
| Partnership | The program implements projects through a partnership between the utility and an institutional, government, or community-based organization. |

**Incentive Method Descriptions**

|  |  |
| --- | --- |
| **Incentive Method** | **Description** |
| 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

This specific measure is not included in the Database for Energy Efficient Resources (DEER) Version 2017.

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 | Yes |
| DEER eQUEST Prototypes | No |
| DEER Version | N/A |
| Reason for Deviation from DEER | DEER does not contain this type of 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 |
| Ind-Default>2yrs | All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years | Ind | Any | Any | 0.6 |
| Agric-Default>2yrs | All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years | Ind | Any | Any | 0.6 |

**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 in accordance with Draft Resolution E-4807 [510].

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** | **RUL (Years)** |
| ProcDist-Motor\_Spd | Variable Speed Drive on Process Fan Control | Com | Process | 6.67 | 0 |

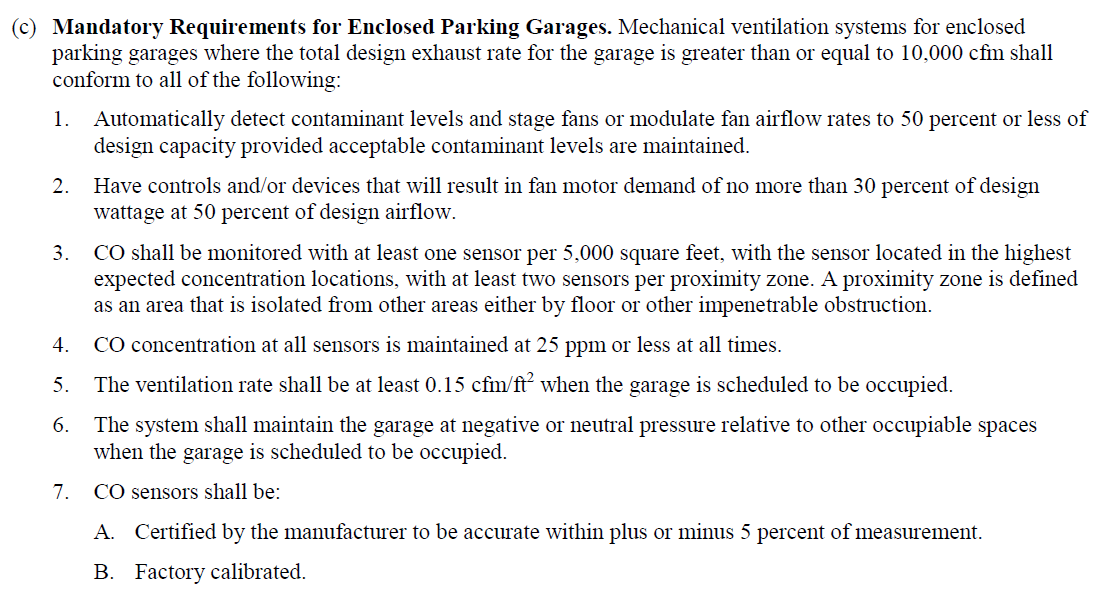
### 1.4.2 Codes and Standards Analysis

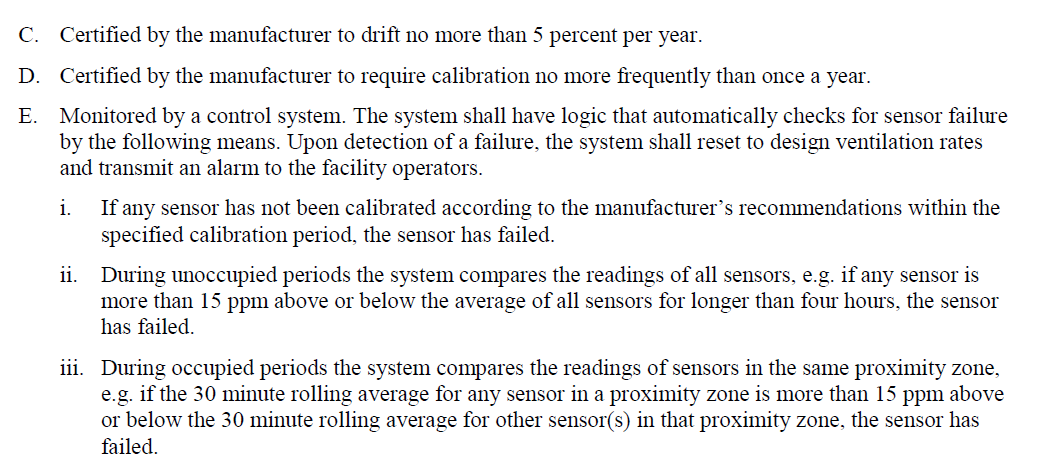
Title 24 (2016), Section 120.6 [496] provides the following mandatory requirements for covered processes:

* 120.6(a)3 Evaporators:

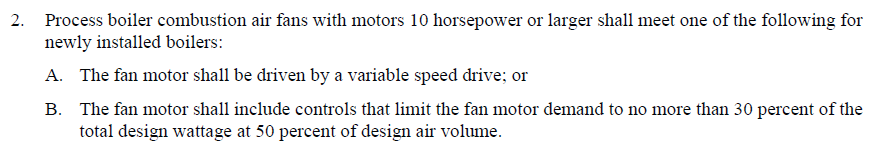
|  |
| --- |
|  |

* 120.6(c) Enclosed Parking Garages:





* 120.6(d)2 Boilers:



* 120.6(e) provides requirements for air compressor systems, but air compressor systems are not covered in this work paper.

The Title 24 (2016) requirements mentioned above do not affect this work paper because they apply to new systems only. The Process VSD measure is an add-on to an existing system and therefore does not trigger Title 24.

Code Summary

|  |  |  |
| --- | --- | --- |
| **Code** | **Reference** | **Effective Dates** |
| Title 24 (2016) | Section 120.6 Mandatory Requirements for Covered Processes | January 1, 2017 |

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

### 1.5.1 Non-DEER Study Review

No studies were used in this work paper. The SCE Online Application Tool was used.

## 1.6 Data Quality and Future Data Needs

N/A

# Section 2. Calculation Methodology

This measure achieves energy savings and demand reduction by enabling a process fan to operate more efficiently at part load conditions. Savings do not vary by climate zone or building type.

**CPUC Disposition: DISPOSITION FOR WORKPAPERS COVERING PROCESS FAN VSD (3/2/17)**

The table below displays savings provided by the CPUC for this workpaper. The disposition breaks down the previous measure into two measures with different sizes of fans: 3 to 5 hp and greater than 5 to 75 hp. These savings are valid between 1/1/17 and 6/30/17, at which point SCE will provide an approved updated workpaper methodology and savings. The table below shows the savings for the two size categories.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Workpaper Values** | | **Disposed Values** | | **Difference from Workpaper Claimed Average** | | | |
| **HP** | **kW, Adj Hours** | **kWh, Adj Hours** | **kW, Adj Hours** | **kWh, Adj Hours** | **kW, %** | **kW, diff** | **kWh, %** | **kWh, diff** |
| 5 | 0.387948 | 672.9163 | **0.38795** | **672.90** | 111% | 0.04 | 111% | 68.26 |
| 7.5 | 0.362546 | 624.111 |  |  |  | 0.01 |  | 19.46 |
| 10 | 0.347248 | 599.2668 |  |  |  | 0.00 |  | -5.39 |
| 15 | 0.360237 | 623.2278 |  |  |  | 0.01 |  | 18.57 |
| 20 | 0.342052 | 592.889 |  |  |  | -0.01 |  | -11.77 |
| 25 | 0.348807 | 604.6825 |  |  |  | 0.00 |  | 0.03 |
| 30 | 0.342052 | 594.6195 |  |  |  | -0.01 |  | -10.04 |
| 40 | 0.337073 | 584.4092 |  |  |  | -0.01 |  | -20.25 |
| 50 | 0.343091 | 596.5529 |  |  |  | -0.01 |  | -8.10 |
| 60 | 0.329784 | 573.6057 | For >5 HP to 75 HP | |  | -0.02 |  | -31.05 |
| 75 | 0.334951 | 584.9237 | **0.34478** | **597.83** | 98.9% | -0.01 | 98.9% | -19.73 |
| Claimed Average | 0.34871 | 604.65 |  |  |  |  |  |  |

Please see Attachment 7 for the disposition describing the savings.

Annual Energy Savings and Demand Reduction

*The table below shows the savings approved from 1/1/17 until 6/30/17.*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Solution Code** | **Measure name** | **Building Type** | **Annual Electric Savings (kWh/HP/year)** | **Demand Reduction (kW/HP)** | **Effective Date** |
| PR-19147 | 3 HP to 5 HP Variable Speed Drive on Process Fan Control | Manufacturing - Bio/Tech, Manufacturing - Light Industrial | 672.90 | 0.38795 | **1/1/17 to 6/30/17** |
| PR-19148 | Greater than 5 HP to 75 HP Variable Speed Drive on Process Fan Control | Manufacturing - Bio/Tech, Manufacturing - Light Industrial | 597.83 | 0.34478 | **1/1/17 to 6/30/17** |

**Previous Analysis**

The calculation methodology described below should be ignored. The savings are based on CPUC disposition values noted in the table above.

**Online Application Tool**

The Fan Systems Upgrade Tool in SCE’s Online Application Tool is a preferred calculation tool for the Statewide Customized Offering. It allows the user to input a baseline fan system and calculate the savings associated with the installation of a VSD on the fan drive motor. This software tool uses information from the FSAT (Fan System Assessment Tool created under the direction of the DOE) in conjunction with fan affinity laws; see Attachment 4 for the Fan Systems Upgrade Tool documentation. See the equation below for the relationship between fan power (P) and speed (n):

Savings were modeled for eleven different baseline fan systems, using NEC standard motor sizes (5 hp, 7.5 hp, 10 hp, 15 hp, 20 hp, 25 hp, 30 hp, 40 hp, 50 hp, 60 hp, 75 hp). Inputs were used to create a typical process fan system. Centrifugal fans are more common for process fans due to their size advantage, and were therefore assumed as the baseline fan type. Since process fans are not weather dependent, the savings will not vary among climate zones. For simulation purposes only, Los Angeles was selected as a typical city, and since the calculations are not dependent on climate zone, the results are applicable to all climate zones. Fan static pressures vary widely by application and the Fan Tool allows for a range from 0-35“ Wg to be chosen. An average static pressure of 5“ Wg was assumed because process fans vary from exhaust fans that can have less than 1“ Wg static pressure to large dust collection fans that can have around 10“ Wg static pressure. Brake horsepower (BHP) is equal to flow times pressure. For each run, BHP is held constant because energy savings are normalized over hp. Energy savings are not affected by the chosen pressure since the CFM was adjusted in the simulations to keep the BHP constant. CFM was determined using specification sheets from a fan manufacturer (see Attachment 5). For each motor, the BHP was calculated for each of the eleven baseline fan systems, and a fan was selected that best met both the BHP and the 5“ Wg static pressure assumption (see Attachment 6). The appropriate CFM was then identified from the specification sheets and used for the maximum and design flow software inputs. CFM selected will be consistent across various manufactures since the specific fan type being modeled was chosen because it is the typical type used for process fan. As such the fans efficiency and operating points will not vary significantly across different manufacturers. Based on the specified CFM and pressure, fan efficiency was calculated using the following equation:



Since the CFM changed based on hp, the fan efficiency varied with each run. The motor efficiency was set to the minimum efficiency allowed per NEMA standards [357]. Nominal motor and fan revolutions per minute (RPM) were chosen to be 1800 since most motor process applications are expected to utilize this RPM. Initially, the software model was run at different RPMs; however, the results were consistent. As such, 1800 RPM was kept as a constant input. The tool was then run at an assumed 70% average flow. 70% loading was chosen as the midpoint of a range between which savings would be minimal at the high end and the motor would be considered oversized at the low end. The Fan Systems Upgrade tool defaults for VFD full load efficiency and minimum operating speeds were used for the proposed system. DEER17 was used to determine the 2920 operating hours per year for the Manufacturing – Light Industrial building type.

For each of the software runs, the following inputs were kept constant:

* Fan System Type: Centrifugal
* Number of Fans: 1
* Location/City: Los Angeles CO (Los Angeles)
* Exhaust Fan? : No
* Estimate Ambient Air Temperature? : No
* Inlet Air Temperature: 85 oF
* Sys. Total Static Press. @ Max Flow: 5.0 “Wg
* Fan Type: Centrifugal Airfoil DIDW
* Control Type: Centrifugal On/OFF
* Drive Type: Std. V-Belt Drive
* Fan Speed: 1800 rpm
* Total Static Pressure: 5“ Wg
* Speed (RPM): 1800
* Service Factor: 1.15
* FL Speed: 1790
* Enclosure: ODP
* Annual Operating Hours: 2920
* VFD Full Load Efficiency: 96%
* VFD Minimum Operating Speed: 50%

The Fan tool yielded kWh/year energy savings and kW peak demand, which were divided by hp ratings to obtain specific energy savings (kWh/hp/year and kW/hp) and then averaged. The original work paper used DEER11 operating hours of 3372 hours/year, so the savings were scaled for the DEER17 Manufacturing Light Industrial building type, for existing buildings in SCE Climate zones (Com-Indoor-LF lighting type) by a factor of 2920/3372. The table below shows the energy savings from the measures covered in this work paper.

# 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** |
| Manufacturing - Bio/Tech | Industrial | Industrial |
| Manufacturing - Light Industrial | Industrial | Industrial |

# Section 4. Costs

## 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. The alternative is to make no changes to their existing system.

## 4.2 Measure Case Cost

The measure cost was obtained using data from the 2015 edition of RS Means Electrical Cost Data. RSMeans covers VFDs from 3 hp to 75 hp [498]. The total cost from RSMeans for each drive was divided by the rated HP to get a normalized cost. These were then averaged to get an overall $/hp for each size range. The labor costs were calculated similarly to the total costs. Material costs per hp was taken as the difference between total cost and labor cost.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Solution Code** | **Description** | **Average Material $/HP** | **Average Labor $/HP** | **Average Install $/HP** |
| PR-19147 | 3 HP to 5 HP Variable Speed Drive on Process Fan Control | $453.13 | $136.25 | $589.38 |
| PR-19148 | Greater than 5 HP to 75 HP Variable Speed Drive on Process Fan Control | $184.71 | $38.29 | $223.00 |

See Attachment 2 for more details.

## 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** |
| PR-19147 | REA | $589.38 | $589.38 | N/A |
| PR-19148 | REA | $223.00 | $223.00 | N/A |

# Attachments

1. SCE17PR008.1 A1 – Calculation Template\_Final.xlsx
2. SCE17PR008.1 A2 - Cost Calculation Tool.xlsx
3. SCE17PR008.1 A3 - Fan Upgrade Tool Runs.zip
4. SCE17PR008.1 A4 - SCE Online Tool Documentation.docx
5. SCE17PR008.1 A5 - Greenheck Fan Specs.pdf
6. SCE17PR008.1 A6 - Fan Operation Points.xlsx
7. SCE17PR008.1 A7 - ProcessFanVSDDisposition-1March2017FINAL.docx

# References

References\_12122016\_100741.xlsx

[357] NEMA Premium Product Scope and Nominal Efficiency Levels

[496] 2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings (Title 24)

[498] RSMeans Electrical Cost Data 2015

[510] 2015 SCE Ex Ante Adjustments.xlsx