Work Paper PGE3PAGR117

Revision 8

Agricultural Ventilation Fans

10/12/2017

At a Glance Summary

Applicable Measure Codes:	**H207**	**H208**	**H209**
Measure Description:	Ventilation fans or Box fans for 24-in to26-in retrofit	Ventilation fans or Box fans for 36in retrofit	Ventilation fans or Box fans for 48in retrofit
Energy Impact Common Units:	Per Fan		
Base Case Description:	Low Efficiency Ventilation Fan	Low Efficiency Ventilation Fan	Low Efficiency Ventilation Fan
Base Case Energy Consumption:	Source: Ensave Calculations	Source: Ensave Calculations	Source: Ensave Calculations
Measure Energy Consumption[6]:	Source: Ensave Calculations	Source: Ensave Calculations	Source: Ensave Calculations
Energy Savings ((Base Case – Measure) x Interactive Effects)	Source: Ensave Calculations	Source: Ensave Calculations	Source: Ensave Calculations
Costs Common Units:	Per Fan		
Base Case Equipment Cost ($/fan):	$350	$420	$670
Measure Equipment Cost ($/fan):	$650 Source: Ensave DEEP Data	$720 Source: Ensave DEEP Data	$800 Source: Ensave DEEP Data
Measure Incremental Cost ($/fan):	$300 Source: Ensave DEEP Data	$300 Source: Ensave DEEP Data	$130 Source: Ensave DEEP Data
Effective Useful Life (years):	10 years, Proposed: Agr-VentFan (Agr-VSDWellPump) Source: Interviews with manufacturers (see Section 1.6)		
Measure Application Type:	ROB		
Net-to-Gross Ratios:	NTGR = 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” Source: DEER 2014		

Document Revision History

Revision 0	Date	Original short form work paper.	Author (Company)
Revision 1	4/4/08	Updated for initial DEEP 2009-2011 Submission.	EnSave, Inc.
Revision 2	5/16/08	Updated to standard Long Form.	EnSave, Inc.
Revision 3	8/25/08	Updated with new NTG and equipment costs.	EnSave, Inc.
Revision 4	2/6/2012	Revised to include circulation fans tested with "Thrust Test" procedure. Values in Tables 3 and 4 are based on fans tested by Bess Labs as of December 2011.	EnSave, Inc.
Revision 5	6/8/12	Updated work papers for 2013-2014.	EnSave, Inc.
Revision 5	8/29/12	M Tiemens replaced BCR (bldg type), AV (bldg vintage), and All (climate zone) with Any; extracted embedded reference.	Mark Tiemens, PG&E
Revision 6	5/9/2014	Updated to new compliance template. Aligned costs with Excel file	Mark Tiemens, PG&E
Revision 7	2/29/2016	Updated to 2016 ex ante format. No values or savings were changed. Proposed EUL ID = Agr-VentFan of 10 years.	Linda Wan, PG&E
Revision 8	10/12/2017	Retiring measure code H210 effective 12/31/2017. No changes on the remaining three measure codes (H207, H208, H209).	Randy Kwok, PG&E

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Section 1. General Measure & Baseline Data

1.1 Product Measure Description & Background

These measures encourage installation of high efficiency agricultural ventilation fans instead of standard efficiency fans. These fans are box, panel, or basket fans and are sometimes designated as Low Volume High Speed (LVHS) to distinguish them from High Volume Low Speed (HVLS) fans. In Dairy facilities in California, these fans are used primarily to cool cows. They are often used in conjunction with water sprayers or misters to enhance evaporative cooling. These measures are downstream.

1.2 Product Technical Description

Airflow is measured in Flow (cubic feet per minute, cfm). Fan efficiency is measured in units of cfm per Watt (cfm/W). Additionally since 2007/2008 the test method was changed such that airflow is measured in Thrust (pounds force, lb_f) for circulation fans. Fan efficiency is measured in units of lb_f per kilowatt (lb_f /kW) and is referred to as "Thrust Efficiency Ratio".

1.3 Measure Application Type

Table 1 - Measure Application Type[1]

Identifies the measure application type in the Measure Implemenation table in DEER2014.

Code	Description	Comment
ER	Early retirement	*Measure is more efficient than code/std; Dual baseline, full measure costs required*
ROB	Replace on Burnout	*Single baseline (above code), incremental or full costs*
NC	New Construction	*Single baseline (above code), incremental or full costs*
REA	Retrofit Add On	*Single baseline (above pre-existing), full measure costs required*

This measure is considered Replace on Burnout (ROB) as there is only a single baseline used for savings evaluation.

1.4 Product Base Case and Measure Case Information

1.4.1DEER Base Case and Measure Case Information

Net-to-Gross ratio for this workpaper is based on DEER2014, READI tool v 2.3.0.

Table 2 below shows the description of the applicable Net-to-Gross ratio for this measure.

Table 2 - Net-to-Gross Ratios

NTGR_ID	Description	Sector	NTGR	Documentation
Agric-Default>2yrs	All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years	Ag	0.6	2011 DEER Update Report - Section 15 Table 15-3 T58

Spillage rates are not tracked in work papers; they are tracked in an external document which will be supplied to the Commission Staff.

The IR value was obtained using the DEER READI tool. The relevant IR value for the measures in this work paper is in the table below:

Table 3 - Installation Rate

GSIA ID	Description	Sector	BldgType	ProgDelivID	GSIAValue
Def-GSIA	Default GSIA values	Any	Any	Any	1

Measure Effective Useful Life (EUL) is 10 years for all fan sizes. EUL is the same for Retrofit (RET), Replace on Burnout (ROB), and New Construction (NEW). Source: Interviews with manufacturers. Through the course of the 2004-2005 SCE Ventilation program, EnSave interviewed over 60 fan manufacturers and dealers asking them, among other things, for the typical life of a new ventilation fan installed in a livestock (cows, chickens, etc.) facility.

Table 4 - Effective and Remaining Useful Life

EUL ID	Description	Sector	UseCategory	EUL (Years)	RUL (Years)
Propose: Ag-VentFan*	Air Conditioners (air-cooled, split and unitary)	Ag	HVAC	10	3.33

*Currently using EUL ID Agr-VSDWellPump as a placeholder until the proposed EUL ID is approved.

1.4.2 Codes & Standards Requirements Base Case and Measure Information

There is no applicable state or federal codes that dictate or restrict the energy saving potential of this measure.

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

There is no known EM&V studies have been completed for this measure.

1.4.4 Assumptions and Calculations from other sources—Base and Measure Cases

There are no further data or calculations provided for the support of the measures in this workpaper.

Section 2. Calculation Methods –

2.1 Energy Savings Estimation Methodologies

2.1.1 Pre 2007/2008 fans

EnSave derived its savings calculation utilizing fan efficiency testing results from the Bioenvironmental and Structural Systems Laboratory[2] (BESS Lab) ventilation fan testing facility at the University of Illinois, using the following test specifications:

- AMCA/ANSI 210-99 (equivalent to ASHRAE 51-1999)
- ASABE S565 Oct 2005

Baselines for ventilation fans were figured using the following procedure: BESS lab data was arranged in lists by fan size and sorted in ascending order by cfm/W. The lowest 10 %* of fans for each size were averaged for cfm and Watts. The wattage was multiplied by 1.10* to derive the baseline wattage for new fans. This wattage was further multiplied by 1.10* to derive baseline wattage for retrofit fans. The average cfm for the lowest 10% of fans was then divided by these baseline wattages to derive the baseline cfm/W. To be eligible for a rebate, a fan must have been tested by BESS Lab to the specifications listed above, and must meet a minimum allowable cfm/W which is roughly equal to the 40th percentile. This value is a tradeoff between trying to encourage the highest practical efficiencies and still allowing most manufacturers to have at least one offering within the accepted range. The results are shown in the following table:

Table 5 - Fan Efficiencies

Fan Size	Baseline cfm/W (Retrofit)	Baseline cfm/W (New)	Minimum Allowable cfm/W
24" – 26"	8.2	9.0	14.0
36"	12.6	13.9	20.4
48"	15.8	17.4	21.9

* Choosing the lowest 10% of the population is based on the assumption that many manufacturers of inefficient fans often do not have their fans tested by BESS Lab. The additional reduction factor of 1.1 is based on the assumption that even manufacturers who do test their fans often do not have their less efficient fans tested. The final reduction factor of 1.1 is based on the assumption that older fans in the field are less efficient due to wear, damage, dirt, and corrosion.

To calculate savings, the actual cfm and cfm/W of the fan is obtained from the BESS Lab data, and the annual hours of operation is obtained directly from the customer.
The kWh savings is then calculated as follows:

Baseline Fan Wattage = (cfm of Fan being installed) / (cfm/W of baseline, from table)

New Fan Wattage = (cfm of Fan being installed) / (cfm/W of new fan) (from BESS lab data)

Annual kWh Savings = (Baseline Fan Wattage – New Fan Wattage) * Annual Hours of Operation / 1,000

kW Savings = Annual kWh Savings / Annual Hours of Operation

For purposes of estimating the number of installations for input to the E3 calculator, the assumed cfm for each fan size is found from the average of the BESS lab data. The hours of operation were assumed to be 2,175 based on results from the Southern California Edison 2005 Agricultural Ventilation Fan Efficiency Program.

Table 6 - Fan Energy Savings

Fan Size	Average cfm	Assumed Hours of Operation	Gross kWh Savings	Gross kW Savings
24" – 26" (Retrofit)	6,600	2,175	725	0.333
36" (Retrofit)	11,500	2,175	759	0.349
48" (Retrofit)	22,300	2,175	855	0.393
24" – 26" (New)	6,600	2,175	570	0.262
36" (New)	11,500	2,175	573	0.264
48" (New)	22,300	2,175	573	0.263

Example: 48" Fan, New Installation, 22,300 cfm, 2,175 hours

Baseline Fan Wattage = 22,300 cfm / 17.4 cfm/W = 1,281 W

New Fan Wattage = 22,300 cfm / 21.9 cfm/W = 1,018 W

Annual kWh Savings = (1,282 W – 1,018 W) * 2,175 hrs / 1,000 = 573 kWh

kW Savings = (1,281 W– 1,018 W) / 1000 = 0.263 kW

Note: BESS lab currently conducts fans tests using a new protocol typically referred to as a "Thrust Test" (AMCA/ANSI 230-99). This test can accommodate fans that cannot be tested to the traditional BESS lab test, such as basket fans, and is specifically aimed at circulation fans, as opposed to exhaust fans. This new test measures the thrust generated by a fan and calculates a cfm (denoted as ccfm for calculated cubic feet per minute) by assuming a uniform air velocity across the face of the fan. This ccfm does not match the cfm measured by the traditional spec. Also, most manufacturers have not yet released their results for this test to the public. So, at this time, new energy efficiency metrics cannot be generated, however it might be possible to do so prior to the start of the next cycle for the Dairy Energy Efficiency Program. This update is presented in Section 3 below.

2.1.2 Post 2007/2008 Circulation Fans

EnSave derived its savings calculation utilizing fan efficiency testing results from the Bioenvironmental and Structural Systems Laboratory (BESS Lab) ventilation fan testing facility at the University of Illinois, using the following test specification:

- AMCA/ANSI 230-99

Baselines for ventilation fans were figured using the following procedure: BESS lab data was arranged in lists by fan size and sorted in ascending order by lb_f /kW. The lowest 10 %* of fans for each size were averaged for lb_f and kW. The wattage was multiplied by 1.10* to derive the baseline wattage for new fans. This wattage was further multiplied by 1.10* to derive baseline wattage for retrofit fans. The average lb_f for the lowest 10% of fans was then divided by these baseline wattages to derive the baseline lb_f /kW. To be eligible for a rebate, a fan must have been tested by BESS Lab to the specification listed above, and must meet a minimum allowable lb_f /kW which is roughly equal to the 40th percentile. This value is a tradeoff between trying to encourage the highest practical efficiencies and still allowing most manufacturers to have at least one offering within the accepted range. The results are shown in the following table:

Table 7 - Fan Efficiencies

Phase	Fan Size diameter (inches)	Baseline lb_f/kW (New)	Baseline lb_f/kW (Retrofit)	Minimum allowable lb_f/kW
Single	24-26	7.6	6.9	10.9
Single	36	12.0	10.9	17.6
Single	48	16.1	14.6	23.0
Three	24-26	12.0	10.9	15.4
Three	36	12.5	11.4	18.8
Three	48	16.7	15.2	23.4

* Choosing the lowest 10% of the population is based on the assumption that many manufacturers of inefficient fans often do not have their fans tested by BESS Lab. The additional reduction factor of 1.1 is based on the assumption that even manufacturers who do test their fans often do not have their less efficient fans tested. The final reduction factor of 1.1 is based on the assumption that older fans in the field are less efficient due to wear, damage, dirt, and corrosion.

To calculate savings, the actual lb_f and lb_f /kW of the fan is obtained from the BESS Lab data, and the annual hours of operation is obtained directly from the customer. The kWh savings is then calculated as follows:

Baseline Fan Wattage = [(lb_f of Fan being installed) / (lb_f /kW of baseline, from table)] x (1000W/kW)

New Fan Wattage = [(lb_f of Fan being installed) / (lb_f /kW of new fan)] x (1000W/kW) (from BESS lab data)

Annual kWh Savings = (Baseline Fan Wattage – New Fan Wattage) * Annual Hours of Operation / 1,000 kW Savings = Annual kWh Savings / Annual Hours of Operation

For purposes of estimating the number of installations for input to the E3 calculator, the assumed lb_f for each fan size is found from the average of the BESS lab data. The hours of operation were assumed to be 2,175 based on results from the Southern California Edison 2005 Agricultural Ventilation Fan Efficiency Program.

Table 8 - Fan Energy Savings

				New		Retrofit	
Phase	**Fan Size diameter (inches)**	**Average lb_f**	**Assumed Hours of Operation**	**Gross kWh Savings**	**Gross kW savings**	**Gross kWh Savings**	**Gross kW savings**
Single	24-26	5.2	2175	451	0.207	602	0.277
Single	36	10.3	2175	594	0.273	782	0.360
Single	48	23.0	2175	932	0.429	1,251	0.575
Three	24-26	8.0	2175	320	0.147	466	0.214
Three	36	11.0	2175	641	0.295	826	0.380
Three	48	24.1	2175	899	0.413	1,208	0.556

Example: Single Phase 48" Fan, New Installation, 23 lb_f, 2,175 hours

Baseline Fan Wattage = (23 lb_f / 16.1 lb_f/kW) x 1,000 = 1,429 W

New Fan Wattage = (23 lb_f / 23 lb_f/kW) x 1,000 = 1,000 W

Annual kWh Savings = (1,429 W – 1,000 W) * 2,175 hrs / 1,000 = 932 kWh

kW Savings = (1,429 W– 1,000 W) / 1000 = 0.429 kW

2.2. Demand Reduction Estimation Methodologies

Fans are typically operating during peak times (summer weekdays, 2:00 PM to 5:00 PM), therefore their Peak Coincidence factor should be 1.0

Section 3. Load Shapes

3.1 Base Cases Load Shapes

The base case load shape is the same as the measure load shape.

3.2 Measure Load Shapes

The Agricultural Load Shape is applicable to this measure and was used in the E3 calculator.

Section 4. Base Case & Measure Costs

4.1 Base Cases Costs

For calculation purposes, because this is a retrofit program, there is no base case cost associated with these measures. Only the full cost (measure equipment plus labor cost) was considered.

Base case costs include the cost of the low or standard efficiency fan, mounting hardware, and installation labor.

4.2 Measure Costs

Measure costs include the cost of the high efficiency fan, mounting hardware, and installation labor.

4.3 Incremental & Full Measure Costs

For calculations replace on burnout (ROB) project type was used.

Full Measure costs are applicable to retrofit (RET) projects. Incremental costs are applicable to new construction (NEW) and replace on burnout (ROB) projects.

Table 9 - Ventilation Fans Costs

Fan Size diameter (inches)	Measure cost (Materials)	Installation and labor cost	Gross Measure Cost (total)
36	$ 614	$200	$814
50-52	$740	$338	$1,078

Value: $1,078 per 50”- 52” fan installed. The measure cost is derived as the average cost taken from a sample of 18 installations in DEEP 2006-2012, NYSERDA, and New York Disaster Relief Program.

Note: Material costs from sample were found to be $740 per 50”- 52” per fan installed. Labor and installation costs from sample were found to be $338.

Value: $814 per 36” fan installed. The measure cost is derived as the average cost taken from a sample of 4 installations and estimates in DEEP 2006-2012 and survey of California installers.

Note: Material costs from sample were found to be $614 per 36” fan installed. Labor and installation costs from sample were found to be $200.

Data used to determine average costs is found in referenced Excel file.[3]

References

[1] The DEER Measure Cost Data Users Guide found on www.deeresources.com under *DEER2011 Database Format* hyperlink, DEER2011 for 13-14, spreadsheet *SPTdata_format-V0.97.xls.*

[2] http://www.bess.uiuc.edu/,
University of Illinois, Department of Agricultural and Biological Engineering
332 Agricultural Engineering Sciences Building
1304 W. Pennsylvania Avenue, Urbana, Illinois 61801

[3] "Measure Cost Data" – Measure cost information from DEEP 2006-2012, NYSERDA, New York Disaster Relief Program, and surveyed California installers [provided as separate Excel document].