Third Party Workpaper Submittal Process and Respect for Intellectual Property and Innovation

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John Walsh[2], President, GreenFan® Inc.
Sudip Kundu[3], Esq. Kundu PLLC

Ex Parte Meeting with Sandy Goldberg Advisor to Commissioner Clifford Rechtschaffen
November 28, 2017

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[1] Robert Mowris, M.S. Civil Engineering, B.S. Mechanical Engineering, B.S. Education, owns 7 U.S. patents, 34 years energy efficiency experience, 300 EM&V studies, published 70 papers, and 5 years worked with Dr. Arthur Rosenfeld.

[2] John Walsh, B.S. Electrical Engineering, owns 7 U.S. patents, 35 years experience designing embedded systems, robotics, training simulators, telecommunications, fiber optics, neural science and manufacturing.

[3] Sudip Kundu, J.D. and B.S. Electrical Engineering, 12 years experience with IP patent law practicing before U.S. District Courts, U.S. International Trade Commission, U.S. Court of Appeals, and U.S. Patent and Trademark Office.

Presentation Overview

- Page 43 of proposed decision encourages PAs to accept third party (3P) workpapers (WPs) with no requirement to submit 3P WPs or respect IP
- 3Ps need permission to submit proprietary workpapers directly to CPUC for Ex Ante Review to protect IP and avoid lost opportunities
- 3P workpapers (WPs) for new technologies require no ratepayer funding, reduce lost opportunities, increase cost effectiveness, and help double energy efficiency savings by 2030

Non-DEER Workpapers D.12-05-015 OP 144

"PG&E, SCE, SDG&E, and SCG shall:

(1) Use due diligence when developing proposed ex ante values to represent expected kWh and therm savings, costs, and EUL;

(2) Undertake research, in collaboration with CPUC, as required, to establish reasonable expected values; and

(3) Pilot promising new technologies and use results of research undertaken during the piloting period to improve ex ante values."

Issues with Current Workpaper Process

- Due diligence, collaboration and pilot programs are either inconsistent or missing
- Only IOUs can submit workpapers which creates insurmountable barriers for new proprietary technologies and programs
- Any or all IOUs can veto innovative new technologies or programs simply by inaction
- Lack of respect for intellectual property, emerging technologies, and 3P proprietary workpapers significantly hampers innovation

Workpaper Intellectual Property Issues

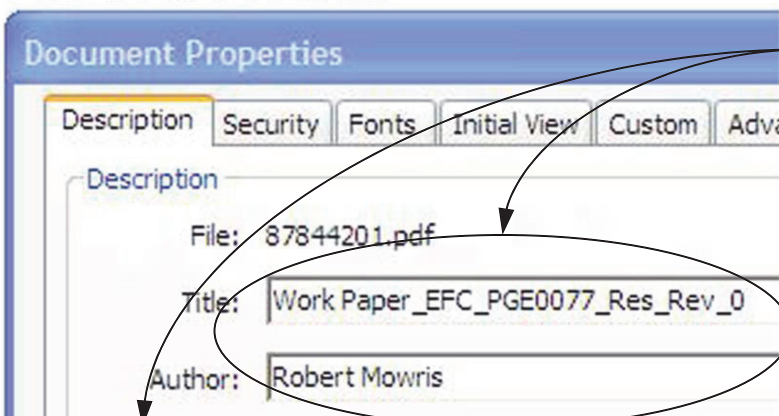
- Proprietary 3P workpapers are protected by copyrights, trademarks and patents enumerated by US Constitution Article I, Section 8, Clause 8
- Derivative workpapers for commercial gain impacting market for original 3P workpapers are not “fair use” per Copyright Law (17 U.S.C. § 102)
- False descriptions and dilution are forbidden under 15 U.S. Code § 1125 per Lanham Act
- Reporting lower prices is an issue under Sherman Act and Federal Trade Commission Act

Experience Submitting 3P Workpapers

- Verified® published two 3P workpapers (WPs) PGE0077 (3-16-12) and SCG0077 (4-04-12) which were plagiarized by SDG&E WPSDGEREHC0024 (10-25-12) and SCE15HC052 (8-24-12)
- Plagiarizing copyrighted work by SDG&E constitutes copyright infringement
- Plagiarized workpapers can induce infringement and create confusion and uncertainty
- Unauthorized workpapers potentially infringe on U.S. copyrights, trademarks, and patents

SDG&E WPSDGEREHC004 Infringes Copyright of 2012 Verified® Workpapers

WPSDGEREHC0024 Revision # 0	Work Paper PGE0077 Revision # 0
San Diego Gas & Electric	Verified, Inc.
Energy Efficiency Engineering	
California HVAC Upgrade: Efficient Fan Controller (EFC) – Residential	**California HVAC Upgrade: Efficient Fan Controller (EFC) – Residential**
	March 16, 2012



1. Removed original author and title, altered tables and footer identifying "i-O-Stat HVAC AAA EFC" products not tested by Verified® Inc. on pages i, v, vi, 25, 26, 29 and 30.
2. 2012 Verified® workpapers are protected by copyrights TX 8-187-702 and TX 8-247-614 and derivative, condensed, or incomplete expressions are illegal under 18 U.S.C. § 2319(b)
3. Potential infringement of Efficient Fan Controller® (5,163,211 and EFC® (5,198,335) registered trademarks and U.S. patents US8763920, US9438933, US9500386, US9671125 US 9797405

i-O-Stat HVAC AAA EFC SDG&E Work Paper Copy v October 25, 2012
San Diego Gas & Electric.

SCE SCE15HC052 Infringes on Copyrights, Trademarks, Patents

Work Paper SCE15HC052
Revision 2

Southern California Edison

1. Potential infringement of Efficient Fan Controller® (5,163,211 and EFC® (5,198,335) registered trademarks
2. Potential infringement of copyright (8-187-702 and 8-197-614)
3. Potentially inducing patent infringement of US8763920, US9438933, US9500386, US9671125 US 9797405

Efficient Fan Controller for Residential Air Conditioners and Furnaces

4. Potential misrepresentation with "Furnaces" on cover but reporting zero heating savings (33 U.S. Code § 931)

5. $25/unit cost based on SCE ET11SCE113 is incorrect and potentially illegal under 15 U.S. Section § 1
6. 03-21-13 Verified® EFC® SCG0077.1 and PGE0077.1 provide manufacturer cost of $50/unit per GreenFan® letter sent to SDG&E implementer on 02-07-13

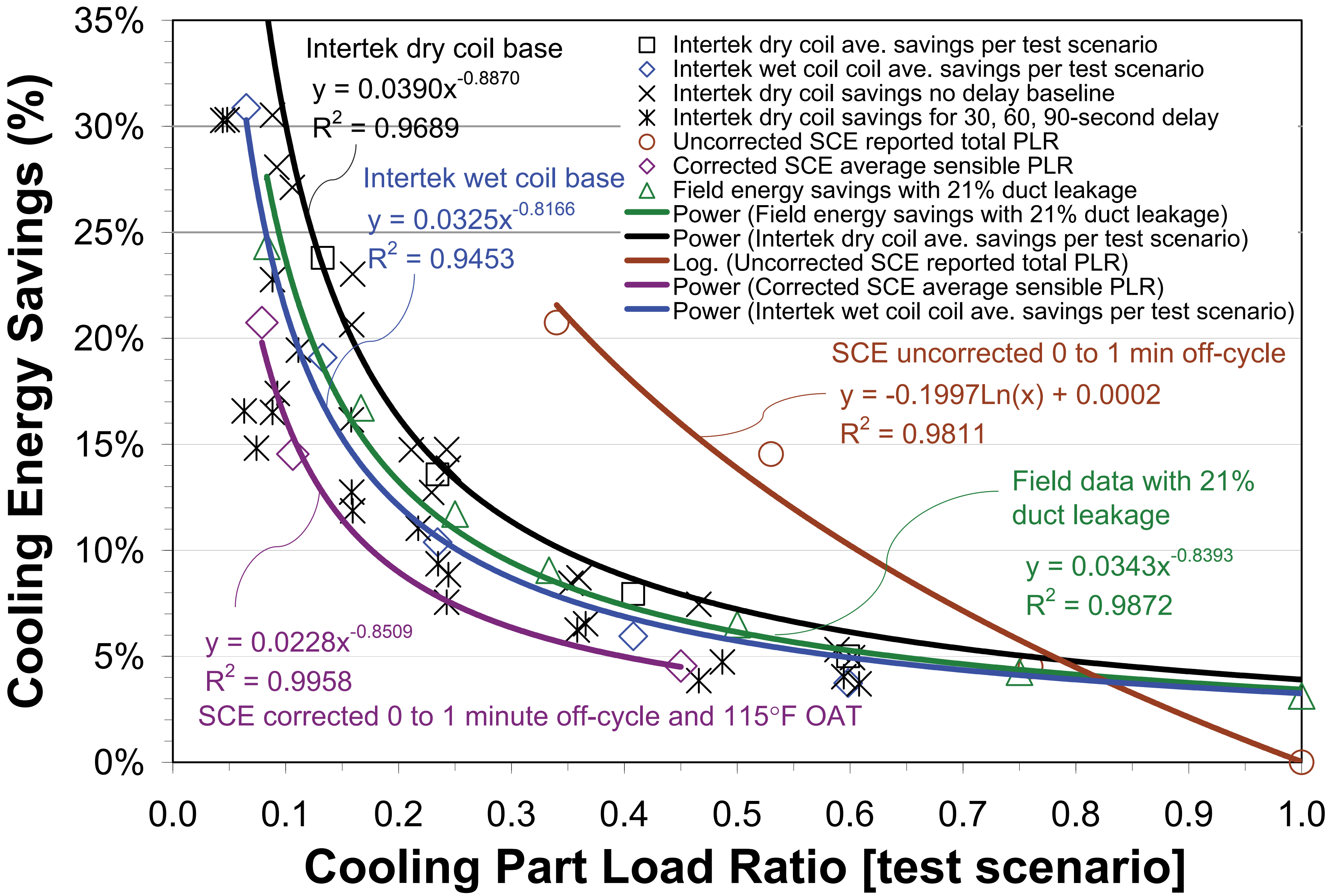
4.2 Measure Case Cost

The measure equipment material cost was determined by reviewing the purchased price for two fan delay controllers tested in the ET laboratory report [A]. The price paid was $25 per controller, plus $3.50 for shipping and handling. The price was cross-referenced with Southern California Gas Company's work paper SCG0077.0 California HVAC Upgrade: Efficient Fan Controller (EFC) – Residential, which listed the material equipment cost at $25. The controller cost is also normalized on a per-ton basis using the

EFC3P17HVC138 versus SCE15HC052 WP

- On 7-20-16, SDG&E asked GreenFan® to prepare updated 3P EFC3P17HVC138 WP costing $500,000
- On 5-9-17, SDG&E refused to submit "proprietary" EFC® WP due to "unreasonably high savings"
- EFC® WP IP is patented, trademarked, copyrighted and EFC3P17HVC138 cooling savings are 9 to 18% less than SCE15HC052 or WPSDGEREHC0024
- EAR is unofficially reviewing EFC3P17HVC138 WP and EFC® gas savings of 16% (per US 9797405) will help double gas heating energy savings by 2030

EFC3P17HVC138 versus SCE15HC052 WP



Recommendations

- PD ID #16114, 3.10.4, page 43, revise: “In the meantime, the program administrators are required ~~encouraged~~ to ~~accept~~ submit third party workpaper development and submissions.”
- Or replace text with: “In the meantime, third parties shall be allowed to submit their own workpapers to the CPUC for Ex Ante Review.”
- Allowing 3Ps to submit WPs directly to CPUC for Ex Ante Review will benefit ratepayers and help double EE savings by 2030 with no risks or costs

Thank you!

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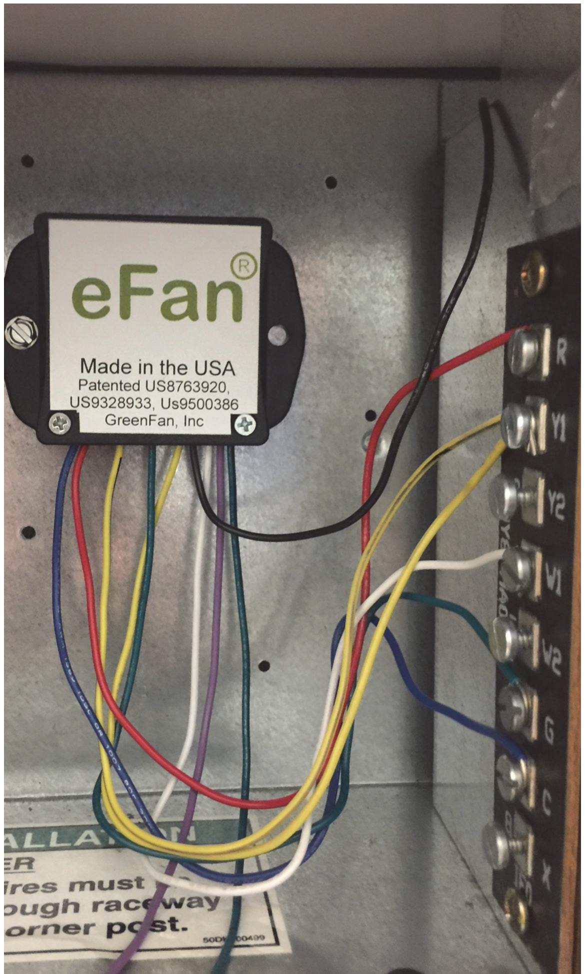

 U.S. Patent 9671125

- **GreenFan® eFAN®** patented installation process seals the economizer perimeter, measures outdoor airflow and sets dampers to optimized position for minimum outdoor airflow.

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- Patented **eFAN®** Efficient Fan Controller® technology controls fan and damper position to improve thermal comfort, delivers more heating and cooling, and prevents evaporator coil icing.
- **eFAN®** estimated energy savings are 11 to 27% for heating and 9 to 25% for cooling based on Intertek laboratory tests.
- The **eFAN®** patented AFDD and correction of supply fan control can save even more energy.
- **GreenFan®** provides a 5-year warranty and **eFAN®** lasts for the life of the HVAC equipment.
- Optional **eFAN®** patented economizer AFDD detects damper stuck open or closed, actuator faults, sensor faults, economizer faults, excess outdoor air faults per CA Title 24.

eFAN®

Commercial HVAC Efficiency

eFAN® Increases Commercial HVAC Efficiency with Advanced Efficient Fan Controller® Technology, Optimized Economizer Outdoor Airflow, and AFDD Supply Fan Control

"Your Partner for Efficient Cooling and Heating"

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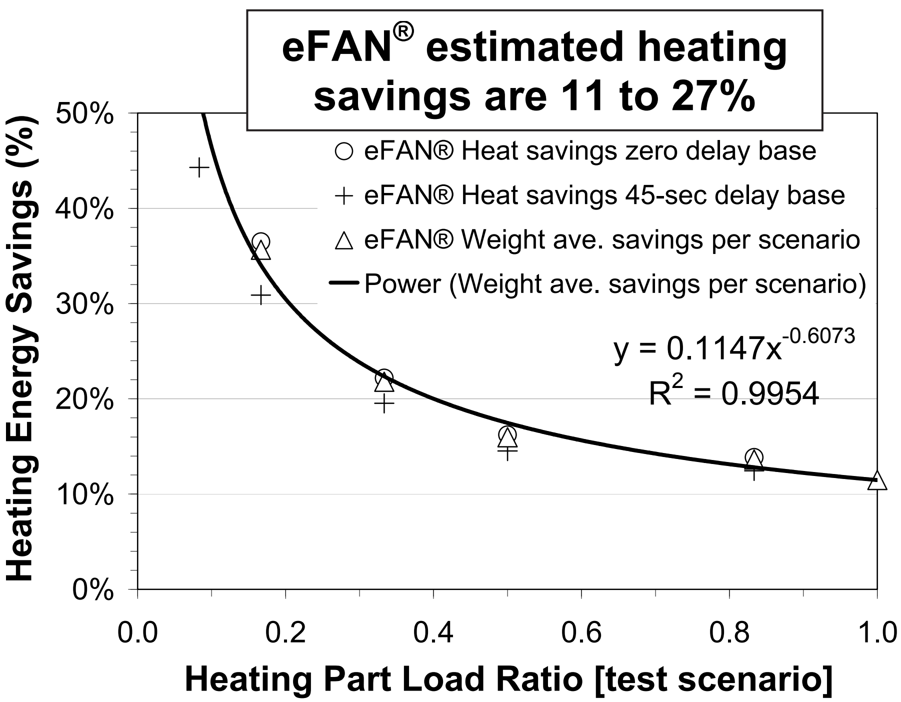
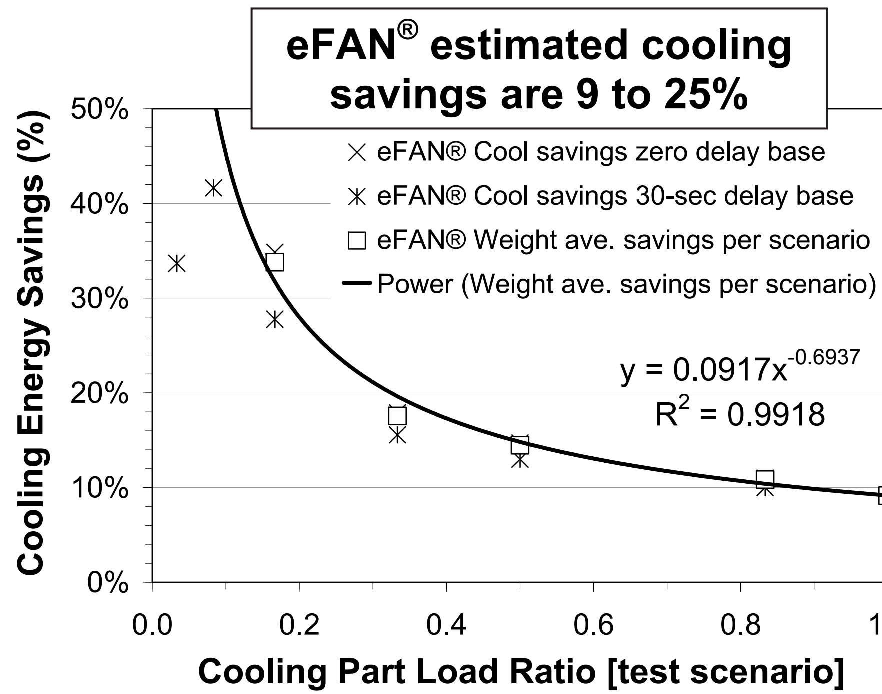
GreenFan® Patented eFAN® Increases Commercial HVAC Efficiency with Advanced Efficient Fan Controller® Technology, Optimized Economizer Outdoor Airflow, and AFDD Supply Fan Control

Intertek®† laboratory tests show eFAN® estimated heating savings are 11 to 27% based on reducing unintended outdoor airflow and delivering more heating energy from gas, heat pump or hydronic heat exchangers that would otherwise be wasted.

Intertek® laboratory tests show eFAN® estimated cooling energy savings are 9 to 25% based on reducing unintended outdoor airflow and delivering more useful evaporative cooling energy from that would otherwise be wasted and preventing evaporator coil icing.





Part Load Ratio (PLR) is the sensible cooling or heating load (Btu) divided by the steady-state sensible cooling or heating capacity of the equipment (Btu).

†Intertek is an AHRI–Certified HVAC Testing Laboratory.
U.S. Patent 9671125

Work Paper PGE0077
Revision # 0

Verified, Inc.

California HVAC Upgrade: Efficient Fan Controller (EFC) – Residential

March 21,2012

At a Glance Summary

Measure Name:	Efficient Fan Controller (EFC) - Residential
Savings Impacts Energy Common Units (ECU):	Household or tons for Residential Air Conditioner (RAC) or kBtuh for Residential Gas Furnace (RGF) space heating only
Customer Base Case Description:	The customer base case heating, ventilating, and air conditioning (HVAC) system has low-speed fan operation in heating mode. After the furnace turns off the fan continues to operate for a fixed time delay of 90 seconds or the fan continues to operate based on a temperature delay which turns off the fan when the plenum temperature falls below a control threshold of 100 to 200°F depending on whether or not the temperature delay sensor is operating or set properly. In cooling mode the fan turns off when the compressor turns off (i.e., no time delay). Some customer base case systems (less than 8%) continue to operate the fan for a fixed time delay of 90 seconds after the compressor turns off.
Code Base Case Description:	The code base case HVAC system has low-speed fan operation in heating mode. After the furnace turns off the fan continues to operate for a fixed time delay of 90 seconds or the fan continues to operate based on a temperature delay which turns off the fan when the plenum temperature falls below a control threshold of 100 to 200°F depending on whether or not the temperature delay sensor is operating or set properly. In cooling mode the code base case HVAC system does not operate the fan after the compressor turns off (i.e., no time delay). Some HVAC systems (less than 8%) continue to operate the fan for a fixed time delay of 90 seconds after the compressor turns off.
Costs Common Units:	Household or tons for RAC, or kBtuh for RGF
Measure Equipment Cost ($/unit):	25
Measure Incremental Cost ($/unit):	75 (SFM, MFM, and DMO)
Measure Installed Cost ($/unit):	75 (SFM, MFM, and DMO)
Measure Load Shape:	26 = Res. Central Air Conditioning
Effective Useful Life (years):	10
Program Type:	Retrofit
TOU AC Adjustment:	100%
Net-to-Gross Ratios:	1.00
Important Comments:	DEER Vintage Weighting

E3 Calculator Data – EFC for Residential Air Conditioner (RAC) Cooling and Heating

DEER 2008 ImpactID	Measure Description	Building Type	Building Vintage	Climate Zone	Above Code Annual Electric Savings (kWh/unit)	Above Code Peak Electric Demand Reduction (kW/unit)	Above Code Annual Savings (Therms /unit)	Incremental Measure Cost ($/unit)	Effective Useful Life (years)	Net to Gross Ratio	Total Resource Cost (TRC) Test
SFM-w01-vPGx-hAC-tWt-bCAv-eMsr	EFC	SFM	PG&E Weighted	1	-24.68	0.07	40.20	75	10	1.0	3.66
SFM-w02-vPGx-hAC-tWt-bCAv-eMsr	EFC	SFM	PG&E Weighted	2	26.42	0.11	36.93	75	10	1.0	4.98
SFM-w03-vPGx-hAC-tWt-bCAv-eMsr	EFC	SFM	PG&E Weighted	3	-0.39	0.10	35.80	75	10	1.0	3.96
SFM-w04-vPGx-hAC-tWt-bCAv-eMsr	EFC	SFM	PG&E Weighted	4	54.53	0.13	28.54	75	10	1.0	4.84
SFM-w05-vPGx-hAC-tWt-bCAv-eMsr	EFC	SFM	PG&E Weighted	5	-7.32	0.07	37.65	75	10	1.0	3.89
SFM-w11-vPGx-hAC-tWt-bCAv-eMsr	EFC	SFM	PG&E Weighted	11	164.42	0.18	33.61	75	10	1.0	9.42
SFM-w12-vPGx-hAC-tWt-bCAv-eMsr	EFC	SFM	PG&E Weighted	12	97.08	0.15	32.40	75	10	1.0	6.80
SFM-w13-vPGx-hAC-tWt-bCAv-eMsr	EFC	SFM	PG&E Weighted	13	202.65	0.17	31.76	75	10	1.0	9.86
SFM-w16-vPGx-hAC-tWt-bCAv-eMsr	EFC	SFM	PG&E Weighted	16	41.14	0.14	70.95	75	10	1.0	9.09
SFM-wPGE-vEx-hAC-tWt-bCAv-eMsr	EFC	SFM	PG&E Weighted	PG&E Weighted	111.75	0.15	33.27	75	10	1.0	6.85
MFM-w01-vPGx-hAC-tWt-bCAv-eMsr	EFC	MFM	PG&E Weighted	1	-11.62	0.05	24.64	75	10	1.0	2.36
MFM-w02-vPGx-hAC-tWt-bCAv-eMsr	EFC	MFM	PG&E Weighted	2	16.48	0.07	14.79	75	10	1.0	2.19
MFM-w03-vPGx-hAC-tWt-bCAv-eMsr	EFC	MFM	PG&E Weighted	3	-2.60	0.05	14.71	75	10	1.0	1.56
MFM-w04-vPGx-hAC-tWt-bCAv-eMsr	EFC	MFM	PG&E Weighted	4	15.89	0.06	11.03	75	10	1.0	1.71
MFM-w05-vPGx-hAC-tWt-bCAv-eMsr	EFC	MFM	PG&E Weighted	5	-0.08	0.04	9.75	75	10	1.0	1.08
MFM-w11-vPGx-hAC-tWt-bCAv-eMsr	EFC	MFM	PG&E Weighted	11	80.42	0.10	16.14	75	10	1.0	4.57
MFM-w12-vPGx-hAC-tWt-bCAv-eMsr	EFC	MFM	PG&E Weighted	12	45.57	0.08	15.96	75	10	1.0	3.27
MFM-w13-vPGx-hAC-tWt-bCAv-eMsr	EFC	MFM	PG&E Weighted	13	118.64	0.10	13.44	75	10	1.0	5.20
MFM-w16-vPGx-hAC-tWt-bCAv-eMsr	EFC	MFM	PG&E Weighted	16	42.95	0.09	30.35	75	10	1.0	4.64
MFM-wPGE-vEx-hAC-tWt-bCAv-eMsr	EFC	MFM	PG&E Weighted	PG&E Weighted	51.20	0.08	14.41	75	10	1.0	3.05
DMO-w01-vPGx-hAC-tWt-bCAv-eMsr	EFC	DMO	PG&E Weighted	1	16.87	0.11	36.69	75	10	1.0	4.61
DMO-w02-vPGx-hAC-tWt-bCAv-eMsr	EFC	DMO	PG&E Weighted	2	200.56	0.20	32.44	75	10	1.0	10.35
DMO-w03-vPGx-hAC-tWt-bCAv-eMsr	EFC	DMO	PG&E Weighted	3	116.93	0.15	28.48	75	10	1.0	6.46
DMO-w04-vPGx-hAC-tWt-bCAv-eMsr	EFC	DMO	PG&E Weighted	4	243.89	0.18	25.75	75	10	1.0	10.36
DMO-w05-vPGx-hAC-tWt-bCAv-eMsr	EFC	DMO	PG&E Weighted	5	101.18	0.14	37.32	75	10	1.0	8.10
DMO-w11-vPGx-hAC-tWt-bCAv-eMsr	EFC	DMO	PG&E Weighted	11	406.57	0.28	38.64	75	10	1.0	18.37
DMO-w12-vPGx-hAC-tWt-bCAv-eMsr	EFC	DMO	PG&E Weighted	12	331.11	0.25	31.13	75	10	1.0	14.39
DMO-w13-vPGx-hAC-tWt-bCAv-eMsr	EFC	DMO	PG&E Weighted	13	499.66	0.27	29.71	75	10	1.0	18.93
DMO-w16-vPGx-hAC-tWt-bCAv-eMsr	EFC	DMO	PG&E Weighted	16	190.97	0.21	65.72	75	10	1.0	12.97
DMO-wPGE-vEx-hAC-tWt-bCAv-eMsr	EFC	DMO	PG&E Weighted	PG&E Weighted	346.33	0.24	34.59	75	10	1.0	13.63

See **Section 1.5** for baseline unit energy consumption (UEC) values.

E3 Calculator Data – EFC for Residential Gas Furnace (RGF) Space Heating Only

DEER 2008 ImpactID	Measure Description	Building Type	Building Vintage	Climate Zone	Above Code Annual Electric Savings (kWh/unit)	Above Code Peak Electric Demand Reduction (kW/unit)	Above Code Annual Savings (Therms /unit)	Incremental Measure Cost ($/unit)	Effective Useful Life (years)	Net to Gross Ratio	Total Resource Cost (TRC) Test
SFM-w01-vPGx-hGF-tWt-bCAv-eMsr	EFC	SFM	PG&E Weighted	1	-18.02	0.00	38.03	75	10	1.0	3.64
SFM-w02-vPGx-hGF-tWt-bCAv-eMsr	EFC	SFM	PG&E Weighted	2	-17.31	0.00	38.78	75	10	1.0	3.71
SFM-w03-vPGx-hGF-tWt-bCAv-eMsr	EFC	SFM	PG&E Weighted	3	-15.47	0.00	35.11	75	10	1.0	3.45
SFM-w04-vPGx-hGF-tWt-bCAv-eMsr	EFC	SFM	PG&E Weighted	4	-12.26	0.00	27.36	75	10	1.0	2.66
SFM-w05-vPGx-hGF-tWt-bCAv-eMsr	EFC	SFM	PG&E Weighted	5	-17.60	0.00	39.88	75	10	1.0	3.73
SFM-w11-vPGx-hGF-tWt-bCAv-eMsr	EFC	SFM	PG&E Weighted	11	-14.69	0.00	33.57	75	10	1.0	3.21
SFM-w12-vPGx-hGF-tWt-bCAv-eMsr	EFC	SFM	PG&E Weighted	12	-13.74	0.00	31.54	75	10	1.0	3.04
SFM-w13-vPGx-hGF-tWt-bCAv-eMsr	EFC	SFM	PG&E Weighted	13	-13.43	0.00	30.50	75	10	1.0	2.96
SFM-w16-vPGx-hGF-tWt-bCAv-eMsr	EFC	SFM	PG&E Weighted	16	-33.57	0.00	71.38	75	10	1.0	6.91
SFM-wPGE-vEx-hGF-tWt-bCAv-eMsr	EFC	SFM	PG&E Weighted	PG&E Weighted	-15.60	0.00	35.10	75	10	1.0	3.45
MFM-w01-vPGx-hGF-tWt-bCAv-eMsr	EFC	MFM	PG&E Weighted	1	-7.61	0.00	16.62	75	10	1.0	1.60
MFM-w02-vPGx-hGF-tWt-bCAv-eMsr	EFC	MFM	PG&E Weighted	2	-6.31	0.00	13.97	75	10	1.0	1.34
MFM-w03-vPGx-hGF-tWt-bCAv-eMsr	EFC	MFM	PG&E Weighted	3	-6.29	0.00	14.29	75	10	1.0	1.41
MFM-w04-vPGx-hGF-tWt-bCAv-eMsr	EFC	MFM	PG&E Weighted	4	-5.33	0.00	11.84	75	10	1.0	1.15
MFM-w05-vPGx-hGF-tWt-bCAv-eMsr	EFC	MFM	PG&E Weighted	5	-6.57	0.00	14.88	75	10	1.0	1.39
MFM-w11-vPGx-hGF-tWt-bCAv-eMsr	EFC	MFM	PG&E Weighted	11	-6.81	0.00	15.23	75	10	1.0	1.45
MFM-w12-vPGx-hGF-tWt-bCAv-eMsr	EFC	MFM	PG&E Weighted	12	-7.36	0.00	16.44	75	10	1.0	1.58
MFM-w13-vPGx-hGF-tWt-bCAv-eMsr	EFC	MFM	PG&E Weighted	13	-6.20	0.00	13.74	75	10	1.0	1.33
MFM-w16-vPGx-hGF-tWt-bCAv-eMsr	EFC	MFM	PG&E Weighted	16	-11.42	0.00	24.47	75	10	1.0	2.37
MFM-wPGE-vEx-hGF-tWt-bCAv-eMsr	EFC	MFM	PG&E Weighted	PG&E Weighted	-6.19	0.00	13.99	75	10	1.0	1.37
DMO-w01-vPGx-hGF-tWt-bCAv-eMsr	EFC	DMO	PG&E Weighted	1	-14.10	0.00	32.61	75	10	1.0	3.16
DMO-w02-vPGx-hGF-tWt-bCAv-eMsr	EFC	DMO	PG&E Weighted	2	-13.42	0.00	30.91	75	10	1.0	2.97
DMO-w03-vPGx-hGF-tWt-bCAv-eMsr	EFC	DMO	PG&E Weighted	3	-12.27	0.00	29.27	75	10	1.0	2.90
DMO-w04-vPGx-hGF-tWt-bCAv-eMsr	EFC	DMO	PG&E Weighted	4	-10.02	0.00	23.52	75	10	1.0	2.30
DMO-w05-vPGx-hGF-tWt-bCAv-eMsr	EFC	DMO	PG&E Weighted	5	-13.99	0.00	32.76	75	10	1.0	3.08
DMO-w11-vPGx-hGF-tWt-bCAv-eMsr	EFC	DMO	PG&E Weighted	11	-15.93	0.00	35.88	75	10	1.0	3.42
DMO-w12-vPGx-hGF-tWt-bCAv-eMsr	EFC	DMO	PG&E Weighted	12	-11.56	0.00	26.75	75	10	1.0	2.58
DMO-w13-vPGx-hGF-tWt-bCAv-eMsr	EFC	DMO	PG&E Weighted	13	-14.34	0.00	32.05	75	10	1.0	3.10
DMO-w16-vPGx-hGF-tWt-bCAv-eMsr	EFC	DMO	PG&E Weighted	16	-29.53	0.00	64.49	75	10	1.0	6.27
DMO-wPGE-vEx-hGF-tWt-bCAv-eMsr	EFC	DMO	PG&E Weighted	PG&E Weighted	-15.02	0.00	36.51	75	10	1.0	3.62

Document Revision History

Revision 0	**Date March 21, 2012**	**Original Submittal.** Applicable to all residential heating, ventilation, and air conditioning (HVAC) equipment. Savings are based on DEER 2008 Unit Energy Consumption by building type and climate zone and Energy Common Units (ECU) per household, per ton (RCA) or per kBtuh (RGF).

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Section 1. General Measure & Baseline Data

1.1 Measure Description & Background

This work paper provides engineering estimates of savings for upgrading Heating, Ventilating, and Air Conditioning (HVAC) equipment with an Efficient Fan Controller (EFC) to recover additional heating and cooling capacity and operate HVAC equipment at higher efficiency. The savings documented here are for the installation of a patent pending EFC that adjusts fan operation for heating based on gas valve activation time (which is a proxy for furnace operation), and fan operation for cooling based on fan run time (which is a proxy for compressor operation). The amount of time the fan operates after the furnace is off or after the compressor is off varies with the amount of time the furnace or compressor are on. The furnace run time indicates how much heat is stored in the heat exchanger. The air conditioner fan run time indicates how much cold water is condensed on the evaporator coil. Most furnaces fans operate at low speed and this reduces airflow and heating efficiency. The EFC provides high speed fan operation in heating mode to increase heating efficiency and reduce furnace run time.[1] This measure applies to HVAC systems that have a fan off time delay of less than 2 minutes in heating or cooling operation. The measure applies to standard and high efficiency furnaces and heat pumps in heating mode and air conditioners with furnaces in cooling and heating mode. The savings estimates assume a baseline temperature delay or 90 second fan time delay on heating and no time delay on cooling. Some units have a 60 to 90 second time delay on cooling. With these units the savings will be slightly lower compared to units with no existing time delay. If an HVAC unit includes a high efficiency fan motor, the savings will be higher due to lower power consumption of the fan motor. Savings for combined measures are discussed in **Table 10**.

Conventional fan controllers typically operate the ventilation fan for 0 to 90 seconds after the furnace or compressor turn off and this wastes heating and cooling energy that is not delivered to the conditioned space. The EFC recovers and delivers more heating and cooling energy to the conditioned space than is possible with conventional fan controllers. The EFC improves the efficiency of HVAC equipment by delivering additional heating or cooling capacity for a small amount of additional electric energy (kWh).

Air conditioners cool conditioned spaces by removing sensible and latent heat from the return air which reduces the supply air temperature and humidity. Latent heat is removed as water vapor is condensed out of the air due to the temperature of the evaporator coil being less than the return air dew point temperature.[2] Most evaporators are cold and wet (below 40 to 50°F) after the compressor turns off. Cooling energy left on the evaporator coil after the compressor turns off is generally wasted. The evaporator absorbs heat from the attic and cold water on the coil flows

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[1] Some newer heating systems with standard 90-second time delay do not allow high speed fan operation without switching the fan control jumper.

[2] Latent heat is the quantity of heat absorbed or released by air undergoing a change of state, such as water vapor condensing out of the air as water onto a cold evaporator coil or cold water evaporating to water vapor which will cool the air.

down the condensate drain. The EFC recovers the remaining cooling energy from evaporator coil by operating the fan after the compressor turns off to cool the conditioned space.

Most furnaces fans operate at low speed and this reduces airflow and heating efficiency. The EFC provides high speed fan operation in heating mode to increase heating efficiency and reduce furnace run time. Most furnace heat exchangers are still hot (above 135 to 210°F) after the furnace fan turns off. The EFC recovers the remaining heat energy from the hot furnace heat exchanger after the furnace turns off and delivers this heat to the conditioned space.

The EFC is a small low-voltage microprocessor controller approximately the size of a US penny. The EFC connects to the existing thermostat wires and is mounted in one of three positions: 1) behind the thermostat mounting plate, 2) between the thermostat and the thermostat mounting plate (with sufficient clearance), or 3) in a hole behind thermostat mounting plate where thermostat wires attach to thermostat.

This measure is cross cutting for use the residential market sector and available for use in the commercial sector.

The values used to forecast the measure's impacts are as follows:

- Incremental Measure Cost: $75 per air conditioner,
- Annual Energy Savings: See **Table 1** and **Table 2**,
- Demand Reduction: See **Table 1** and **Table 2**,
- Effective Useful Life: 10 years, and
- Net to Gross Ratio: 1.0 (Comprehensive Space Conditioning).

1.2 DEER Differences Analysis

The Database for Energy Efficiency Resources (DEER 2008) does not provide energy savings for the Efficient Fan Controller (EFC) measure. The cooling, heating, and ventilation Unit Energy Consumption (UEC) values for residential air conditioners (RAC) and residential gas furnaces (RGF) are based on the DEER2008 UEC values from the Measure Inspection and Summary viewer tool (MISer Version 1.10.25) and DEER (Version: DEER2008.2.2). See http://www.deeresources.com/. UEC values and DEER 2008 ImpactIDs listed in **Section 1.5** are in the embedded Excel Workbook #1 (see References Section). The DEER annual cooling and heating energy consumption are average values assuming no degradation due to excessive duct leakage, improper refrigerant charge and airflow, restrictions, non condensables, or blocked condenser coils. If the unit efficiency is degraded, the UEC will increase and this will increase the energy savings (therms, kWh and kW) beyond the estimates provided in this work paper. The annual natural gas savings (therm/yr) are based on weighted average savings of 11% (see **Table 12**). The annual electricity energy savings (kWh/yr) are based on 14.8% weighted average cooling savings and include the impact of increased ventilation energy use of 13.8% for space heating ventilation and -36.2% for space cooling ventilation.

EFC Energy and demand savings for residential air conditioning (RAC - space cooling and space heating) are shown in **Table 1**. Data are based on analysis in **Section 1.4** provided in the embedded Excel workbooks #1 and #2 in the References Section.

Table 1. EFC Energy and Demand Savings Impacts by Building Type – RAC

Building Type	Climate Zone	Vintage	Net Elec Savings (kWh/yr)	Elec Demand Savings (kW)	Annual Gas Savings (therm/yr)
Single Family	1	PG&E Weighted	-24.68	0.07	40.20
Single Family	2	PG&E Weighted	26.42	0.11	36.93
Single Family	3	PG&E Weighted	-0.39	0.10	0.34
Single Family	4	PG&E Weighted	54.53	0.13	28.54
Single Family	5	PG&E Weighted	-7.32	0.07	37.65
Single Family	11	PG&E Weighted	164.42	0.18	33.61
Single Family	12	PG&E Weighted	97.08	0.15	32.40
Single Family	13	PG&E Weighted	202.65	0.17	31.76
Single Family	16	PG&E Weighted	41.14	0.14	70.95
Single Family	PG&E Weighted	PG&E Weighted	111.75	0.15	33.27
Multi Family	1	PG&E Weighted	-11.62	0.05	24.64
Multi Family	2	PG&E Weighted	16.48	0.07	14.79
Multi Family	3	PG&E Weighted	-2.60	0.05	14.71
Multi Family	4	PG&E Weighted	15.89	0.06	11.03
Multi Family	5	PG&E Weighted	-0.08	0.04	9.75
Multi Family	11	PG&E Weighted	80.42	0.10	16.14
Multi Family	12	PG&E Weighted	45.57	0.08	15.96
Multi Family	13	PG&E Weighted	118.64	0.10	13.44
Multi Family	16	PG&E Weighted	42.95	0.09	30.35
Multi Family	PG&E Weighted	PG&E Weighted	51.20	0.08	14.41
Mobile Home	1	PG&E Weighted	16.87	0.11	36.69
Mobile Home	2	PG&E Weighted	200.56	0.20	32.44
Mobile Home	3	PG&E Weighted	116.93	0.15	28.48
Mobile Home	4	PG&E Weighted	243.89	0.18	25.75
Mobile Home	5	PG&E Weighted	101.18	0.14	37.32
Mobile Home	11	PG&E Weighted	406.57	0.28	38.64
Mobile Home	12	PG&E Weighted	331.11	0.25	31.13
Mobile Home	13	PG&E Weighted	499.66	0.27	29.71
Mobile Home	16	PG&E Weighted	190.97	0.21	65.72
Mobile Home	PG&E Weighted	PG&E Weighted	346.33	0.24	34.59

EFC Energy and demand savings for residential gas furnace (RGF - space heating only) are shown in **Table 2**. Data are based on analysis in **Section 1.4** provided in the embedded Excel workbooks #1 and #2 in the References Section.

Table 2. EFC Energy and Demand Savings Impacts by Building Type – RGF

Building Type	Climate Zone	Vintage	Net Elec Savings (kWh/yr)	Elec Demand Savings (kW)	Annual Gas Savings (therm/yr)
Single Family	1	PG&E Weighted	-18.02	0.00	38.03
Single Family	2	PG&E Weighted	-17.31	0.00	38.78
Single Family	3	PG&E Weighted	-15.47	0.00	35.11
Single Family	4	PG&E Weighted	-12.26	0.00	27.36
Single Family	5	PG&E Weighted	-17.60	0.00	39.88
Single Family	11	PG&E Weighted	-14.69	0.00	33.57
Single Family	12	PG&E Weighted	-13.74	0.00	31.54
Single Family	13	PG&E Weighted	-13.43	0.00	30.50
Single Family	16	PG&E Weighted	-33.57	0.00	71.38
Single Family	PG&E Weighted	PG&E Weighted	-15.60	0.00	35.10
Multi Family	1	PG&E Weighted	-7.61	0.00	16.62
Multi Family	2	PG&E Weighted	-6.31	0.00	13.97
Multi Family	3	PG&E Weighted	-6.29	0.00	14.29
Multi Family	4	PG&E Weighted	-5.33	0.00	11.84
Multi Family	5	PG&E Weighted	-6.57	0.00	14.88
Multi Family	11	PG&E Weighted	-6.81	0.00	15.23
Multi Family	12	PG&E Weighted	-7.36	0.00	16.44
Multi Family	13	PG&E Weighted	-6.20	0.00	13.74
Multi Family	16	PG&E Weighted	-11.42	0.00	24.47
Multi Family	PG&E Weighted	PG&E Weighted	-6.19	0.00	13.99
Mobile Home	1	PG&E Weighted	-14.10	0.00	32.61
Mobile Home	2	PG&E Weighted	-13.42	0.00	30.91
Mobile Home	3	PG&E Weighted	-12.27	0.00	29.27
Mobile Home	4	PG&E Weighted	-10.02	0.00	23.52
Mobile Home	5	PG&E Weighted	-13.99	0.00	32.76
Mobile Home	11	PG&E Weighted	-15.93	0.00	35.88
Mobile Home	12	PG&E Weighted	-11.56	0.00	26.75
Mobile Home	13	PG&E Weighted	-14.34	0.00	32.05
Mobile Home	16	PG&E Weighted	-29.53	0.00	64.49
Mobile Home	PG&E Weighted	PG&E Weighted	-15.02	0.00	36.51

1.3 Codes & Standards Requirements Analysis

There is no code or standard addressing the EFC. The measure can be retrofit to any RAC with gas furnace or heat pump having a thermostat with less than 2-minute time delay for cooling or heating or standard temperature delay for heating. The measure can also be retrofit to any RGF thermostat with less than 2-minute time delay or standard temperature delay for heating.

1.4 EM&V, Market Potential, and Other Studies

The forecast values were derived from these sources:

- Incremental (Full) Measure Cost is based on what HVAC Contractors charge for the materials, labor, and overhead to install the Efficient Fan Controller.
- Annual Energy Savings is based on the Percentage Energy Savings times the Baseline Electrical Usage as described in **Section 1.4.5** (Estimated Energy Savings).
- Percentage Energy Savings are based on Field and Laboratory Tests as described in **Section 1.4.3** (Field Test Data) and **Section 1.4.4** (Laboratory Test Data).

1.4.1 Abstract

The EFC improves on the conventional temperature or time delay relay (TDR) which will continue to operate the fan after the furnace or compressor turns off. In heating mode, the EFC micro-computer monitors gas valve activation time and determines whether or not to continue operating the fan after the furnace turns on and how long the fan should continue operating to maximize heat recovery from the heat exchanger. In cooling mode the EFC monitors fan operation and determines whether or not to continue operating the fan after the compressor turns off to transfer heat to the cold evaporator coil and recover energy stored in the form of condensed cold water on the evaporator coil to further cool the building. In cooling mode the EFC uses the evaporator coil as an evaporative cooler. The fan uses 8 to 15 times less power than the compressor and is adaptively controlled to operate based on fan run time (which is a proxy for compressor operation). Air conditioning equipment manufacturers provide an optional 1.5 minute TDR kit to improve SEER by 2 to 3%. Furnace manufacturers provide either a 1.5 minute fan time delay or a temperature delay that extends fan operation from 1 to 4 minutes by shutting off the fan when the supply air is less than 110°F. The standard furnace TDR improves AFUE by 2 to 3%. The delivered furnace efficiency improvements from EFC are shown in **Figure 1**. The EFC maximizes heating efficiency by increasing fan speed from low to high four minutes after the furnace is turned on. Standard furnace fans operate at low speed delivering less heating capacity to the conditioned space at lower efficiency compared to operating the fan at high speed. The EFC maximizes heat recovery from the heat exchanger after the furnace is turned off with an extended fan delay of 2 to 4 minutes depending on how long the furnace gas valve signal is on during the heating cycle. The EFC improves heating efficiency by 7 to 10% above standard temperature delay and 6 to 8% above standard 90-second delay. For systems with degraded temperature sensors the EFC saves 7 to 23% depending on furnace run time and ambient conditions. Savings will be greater for furnaces with degraded temperature delay. The delivered air conditioner sensible energy efficiency ratio (EER*) improvements from EFC are shown in **Figure 2**. Standard air conditioners have a 0 to 1.5 minute fan time delay. The EFC maximizes recovery of latent cooling from the evaporator after the compressor is turned off with an extended fan delay of 1.5 to 5 minutes depending on how long the air conditioner compressor is on during the cooling cycle.

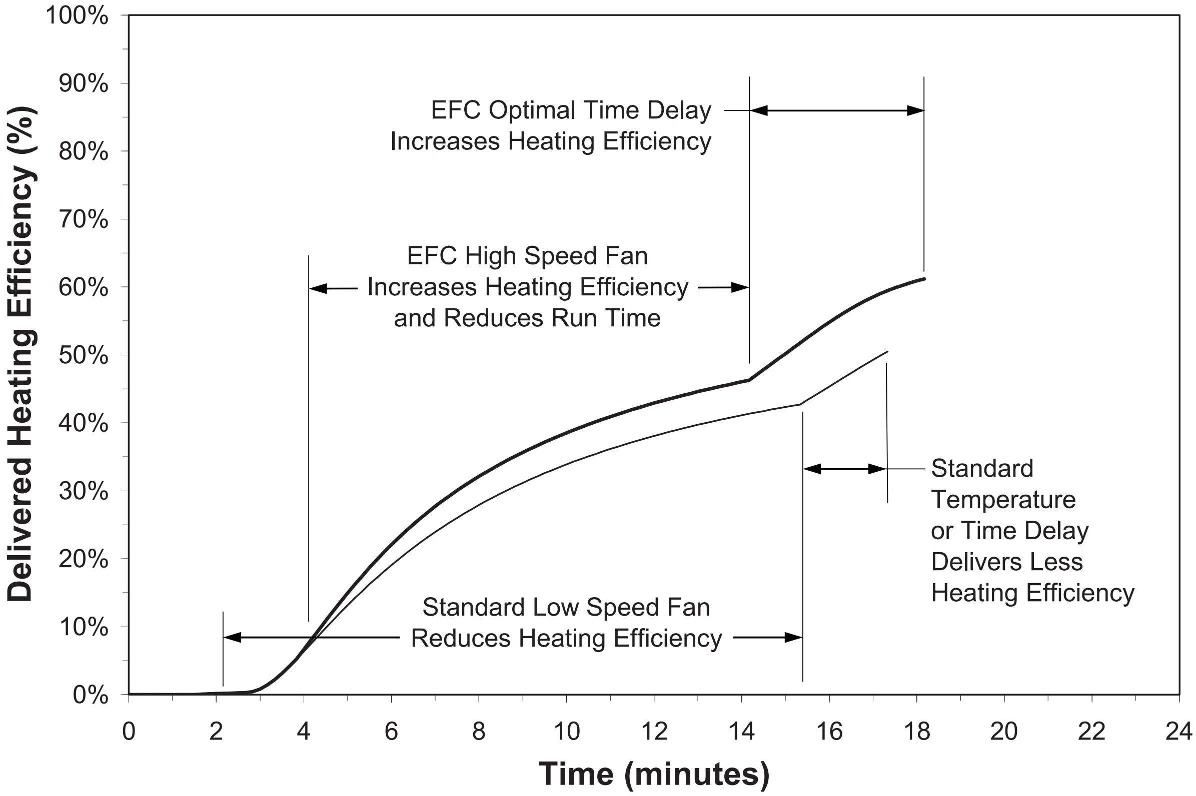

Figure 1. Heating Efficiency Improvement from EFC

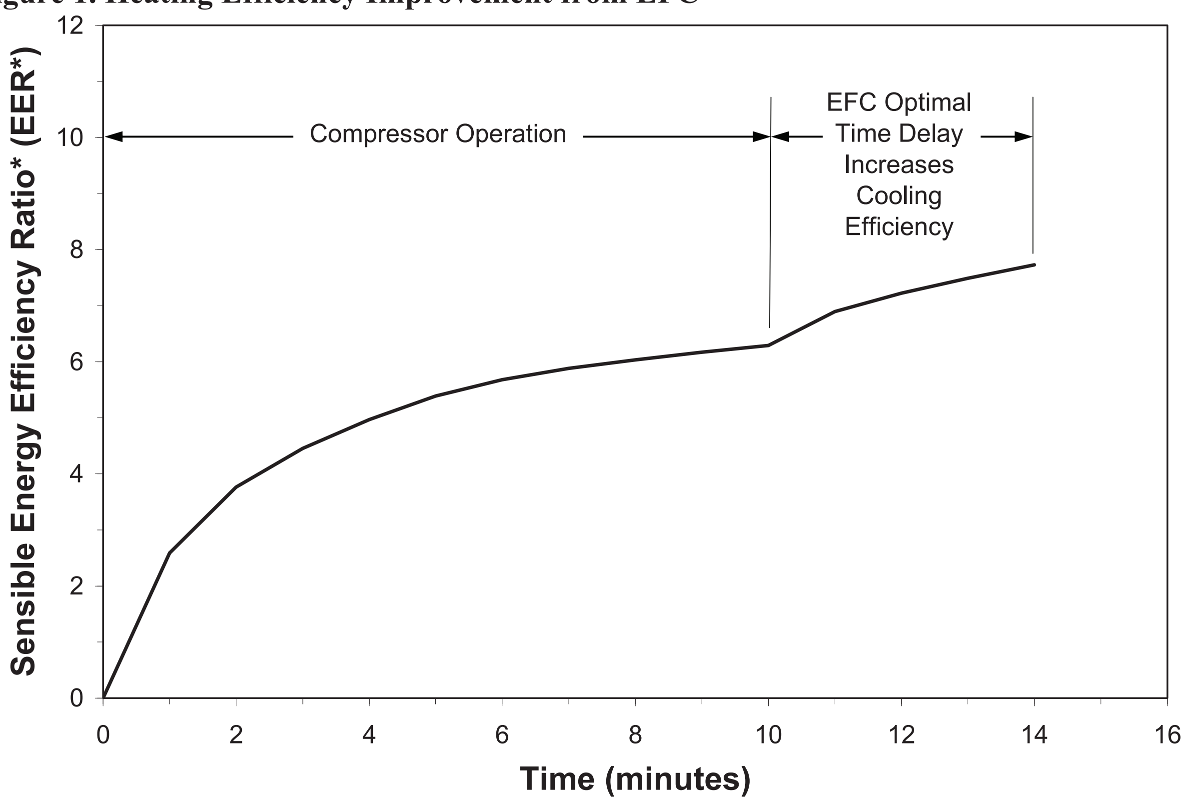

Figure 2. Air Conditioner Sensible EER* Improvement from EFC

The SEER cycling test is performed with a dry evaporator coil. In California the air conditioner condenses moisture from the air onto the cold evaporator coil. The EFC intelligently optimizes the fan operation after the compressor turns off to improve the EER and SEER. Many new air conditioning systems are installed without the standard manufacturer TDR due to market barriers (i.e., information, availability, or organizational practices) or the evaporator and condenser are replaced without replacing the furnace forced air unit (FAU).

Most furnaces operate at low fan speed with a time or temperature delay relay that stops the fan with heat left in the heat exchanger at temperatures between 100°F and 200°F. Most air conditioners do not have a fan time delay. Therefore, the EFC is applicable to all existing and new HVAC systems.

EFC units were installed at homes in California and Nevada to evaluate consumer satisfaction. Survey respondents indicated that the EFC provides more comfortable heating with an overall rating of 7.5 ± 0.18 out of 10 points. One hundred percent of survey respondents indicated that the EFC saves energy. Survey respondents indicate high satisfaction with an overall rating of 10 out of 10 points.

1.4.2 Baseline

The baseline furnace and air conditioner characteristics are provided in **Table 3**. For heating the baseline is either temperature controlled, degraded temperature controlled, or time controlled delay on the furnace fan. The estimated market share for heating system controls is as follows: 35% for properly working temperature delay, 35% for degraded temperature delay, and 30% for time delay.[3] For cooling the baseline is either no time delay or time delay of 90 seconds. The estimated market share for cooling systems with no time delay is 90% and the estimated market share for cooling systems with 90-second time delay is 10%. Furnaces having temperature delay controllers typically turn on the furnace fan at supply plenum temperatures ranging from 135 to 160°F and turn off the furnace fan at supply plenum temperatures ranging from 100 to 110°F (Carrier 1973). Over time the bi-metal temperature sensor accuracy and performance degrades and the sensors will drift up by approximately 30 to 60°F. This causes the standard temperature delay controller to not turn on the furnace fan until the plenum temperature is 140 to 160°F which can take more than 4 minutes. When the furnace turns off the degraded sensor will cause the controller to turn off the furnace fan with supply plenum temperatures still at or above 120 to 210°F. This will typically occur within 40 to 90 seconds instead of 180 to 240 seconds. Degraded bi-metal temperature sensors leave a significant amount of heat stranded in the heat exchanger (i.e., 15 to 25%). For systems with degraded bi-metal sensors the EFC can save 15 to 65% depending on furnace run time and ambient conditions. Newer heating systems are sold with adjustable time delay controllers with factory settings of 90 to 120 seconds (Carrier 2006, Lennox 1998, Lennox 1998a, Trane 2009, Rheem 2005). The 90 second time delay will turn off

[3] Most HVAC manufacturers introduced heating time delay controls with 90-second factory settings in the early 1980s. New furnaces currently sold are manufactured with 90-second time delays. Furnaces systems more than 20 years old typically have temperature delays. Approximately 50% of the older systems have degraded temperature delays due to dirt build-up or excessive supply plenum temperatures which cause the delays to drift upward by approximately 30°F to 40°F.

the furnace with supply plenum temperatures still at or above 110 to 120°F. Some newer air conditioners can have an optional time delay relay kit installed with factory settings of 90 seconds (Carrier 2006a, Carrier 2010). Most existing and new air conditioners do not have a cooling fan time delay. Therefore, the EFC is applicable to all existing and new HVAC systems. For heating, the EFC will correct for improperly operating temperature delays with degraded bi-metal temperature sensors with less material and labor cost than would be required to replace degraded temperature sensors and controllers. Increasing the heating fan speed from low and high will increase power use by approximately 18 to 21% (60 to 150W) for permanent split capacitance (PSC) motors depending on the size of the fan motor and total system static pressure. PSC blower motors that are worn out will use more power in high speed due to increased bearing friction. Worn out PSC blower motors should be replaced.

Table 3. Pre-Existing Baseline and Measure Characteristics

Pre-Existing Description	Measure Description	Estimated Market Share
Heating properly working Temperature Delay at 100 to 110°F, PSC motor	EFC High Speed Fan plus Variable Time Delay (2 to 4 minutes)	35%
Heating degraded Temperature Delay at 130 to 200°F, PSC motor	EFC High Speed Fan plus Variable Time Delay (2 to 4 minutes)	35%
Heating 90 second Time Delay, PSC motor	Variable Time Delay (2 to 4 minutes)	30%
Cooling No Time Delay, PSC Motor	Variable Time Delay (1.5 to 5 minutes)	90%
Cooling 90 second Time Delay, PSC Motor	Variable Time Delay (1.5 to 5 minutes)	5%
Cooling No Time Delay, Efficient Motor	Variable Time Delay (1.5 to 5 minutes)	3%
Cooling 90 second Time Delay, Efficient Motor	Variable Time Delay (1.5 to 5 minutes)	2%

1.4.3 Field Test Data

Field measurements and equipment accuracy are provided in **Table 4**.

Table 4. Field Measurements, Measurement Equipment, and Accuracy

Field Measurement	Measurement Equipment	Measurement Accuracy
Relative humidity (%) and temperature in degrees Fahrenheit (°F) of return and supply, thermostat, and outdoor condenser entering air	Platinum Resistance Pt100 1/3 Class B 6-channel humidity and temperature data loggers.	Temperature: 0.1°C or 0.18°F RH: ± 0.5 RH at 23°C and 10, 20, 30, 40, 50, 60, 70, 80, 90 % RH
Airflow in cubic feet per minute (cfm) across air conditioner evaporator coil	Digital pressure gauge and fan-powered flow hood, flow meter pitot tube array, and electronic balometer	Fan-powered flowhood: ± 3% Flow meter pitot tube array: ± 7% Electronic balometer: ± 4%
Total power in kilowatts (kW) of air conditioner compressor and fans	True RMS 4-channel power data loggers and 4-channel power analyzer	Data loggers, CTs, PTs: ± 1% Power analyzer: ± 1%
Total gas energy use (Btu) of furnace	Natural gas utility diaphragm flow meter	± 1% of reading
Combustion efficiency, CO	Digital combustion analyzer	Combustion efficiency: ±0.1% CO: ± 5%, O2: ±0.3%

Return and supply temperatures were measured inside the return and supply ducts either in the plenums or near the plenums. Temperature and power were measured at intervals of 10 to 60 seconds. Airflow was measured before and after making any changes to the supply/return ducts, opening vents, or installing new air filters that would affect airflow. Return and supply enthalpies were derived from the temperature measurements using standard psychrometric algorithms (REFPROP 2010). The "application" EER* is calculated from the combination of enthalpy, airflow, and power measurements. Measurements of air conditioner performance were made continuously.

The heating or cooling capacity of the HVAC system is measured as the rate of delivered heating or cooling energy per measurement interval (i.e., English units of British thermal units per hour).[4] Heating of air occurs in the heat exchanger of the furnace or heat pump. Cooling occurs in the evaporator coil of the air conditioner. The heating capacity or energy is based on the measured airflow rate, specific volume, and sensible temperature difference across the return and supply plenums. **Equation 1** provides the calculation of sensible heating energy delivered to the conditioned space by the HVAC system.

Eq. 1 $$Q_{hs} = \frac{cfm \times 60}{v} \times c_v \times (T_r - T_s)$$

Where,

Q_{hs} = sensible heating energy delivered to the conditioned space over the measurement interval (i.e., Btu/hr),
cfm = airflow rate in cubic feet per minute (cfm),
v = specific volume per pound of dry air (ft^3/lbm),
c_v = specific heat of dry air = 0.24 Btu/lbm-°F,
T_r = dry bulb temperature of return air in plenum entering the heat exchanger (°F), and
T_s = dry bulb temperature of supply air in plenum leaving the heat exchanger (°F).

The cooling capacity is based on the measured airflow rate, specific volume, and enthalpy difference across the return and supply plenums. **Equation 2** provides the calculation of total cooling energy removed from the air by the HVAC system.

Eq. 2 $$Q_c = \frac{cfm \times 60}{v} \times (h_r - h_s)$$

Where,

Q_c = cooling energy removed from the air by the HVAC system over the measurement interval (Btu/hr),
h_r = enthalpy of return air entering the evaporator coil (i.e., Btu/lbm), and
h_s = enthalpy of supply air leaving the evaporator coil (i.e., Btu/lbm).

[4] The British Thermal Unit (Btu) is the unit of heat required to raise the temperature of one pound of water one degree Fahrenheit (°F). The Btu is equivalent to 1055.06 joules or 251.997 calories.

Laboratory and field test data show that standard fan delays are insufficient to harvest available cooling stored in the evaporator and that medium fan speed and standard fan delays are insufficient to harvest available heating stored in the heat exchanger. The combustion efficiency, EFC efficiency, and standard temperature delay efficiency are illustrated in **Figure 3** and **Table 5** for an 80 AFUE gas furnace. **Equation 3** shows how the heating efficiency is calculated.

Eq. 3 $\eta = \sum_{i=0}^{t} \frac{Q_{hs\,i}}{Q_{hf\,i}}$

Where,

η = heating efficiency (ratio or %),

i = measurement interval for which data is collected ranging from 10 to 60 seconds,

t = total number of measurement intervals for the test,

$Q_{hs\,i}$ = sensible heating energy delivered to the conditioned space per measurement interval (Btu/hr), and

$Q_{hf\,i}$ = heating energy fuel input per measurement interval (Btu/hr).

The heating energy savings (S_{heat}) based on the heating efficiency improvement are calculated using **Equation 4**.

Eq. 4 $S_{heat} = \eta_{EFC} - \eta_{Base}$

Where,

S_{heat} = heating energy savings for the EFC (ratio or %),

η_{EFC} = delivered heating efficiency of the EFC with high speed fan and/or optimal time delay from 2 to 4 minutes (ratio or %), and

η_{Base} = delivered heating efficiency of the base case thermostat with temperature delay, 90-second time delay, or degraded temperature delay (ratio or %).

The rated furnace efficiency, EFC plus high speed fan (HSF) efficiency, and standard temperature delay efficiency for an 80% AFUE gas furnace is shown in **Figure 3** and **Table 5**. The furnace is turned on when the thermostat temperature is below 65°F and turned off when the thermostat temperature is above 68°F. The low speed fan requires 14.8 minutes of furnace operation to increase the thermostat temperature to above 68°F, and the baseline working temperature delay provides 4.2 minutes of additional fan operation and supply plenum fan off temperature of 99.4°F. The EFC provides high speed fan operation 4 minutes after the furnace is turned on and this increases furnace efficiency by 5.9% and reduces furnace operation by 1.1 minutes or 7.9%. The EFC provides a 4 minute time delay with high speed fan recovering slightly more energy than the standard temperature delay with fan off supply plenum temperature of 98.3°F and increased off cycle of 1%. The EFC saves 7.9% of gas heating energy and -4.6% of heating fan ventilation energy. High speed fan power is 722W or 17.8% greater than low speed fan power which is 613W.

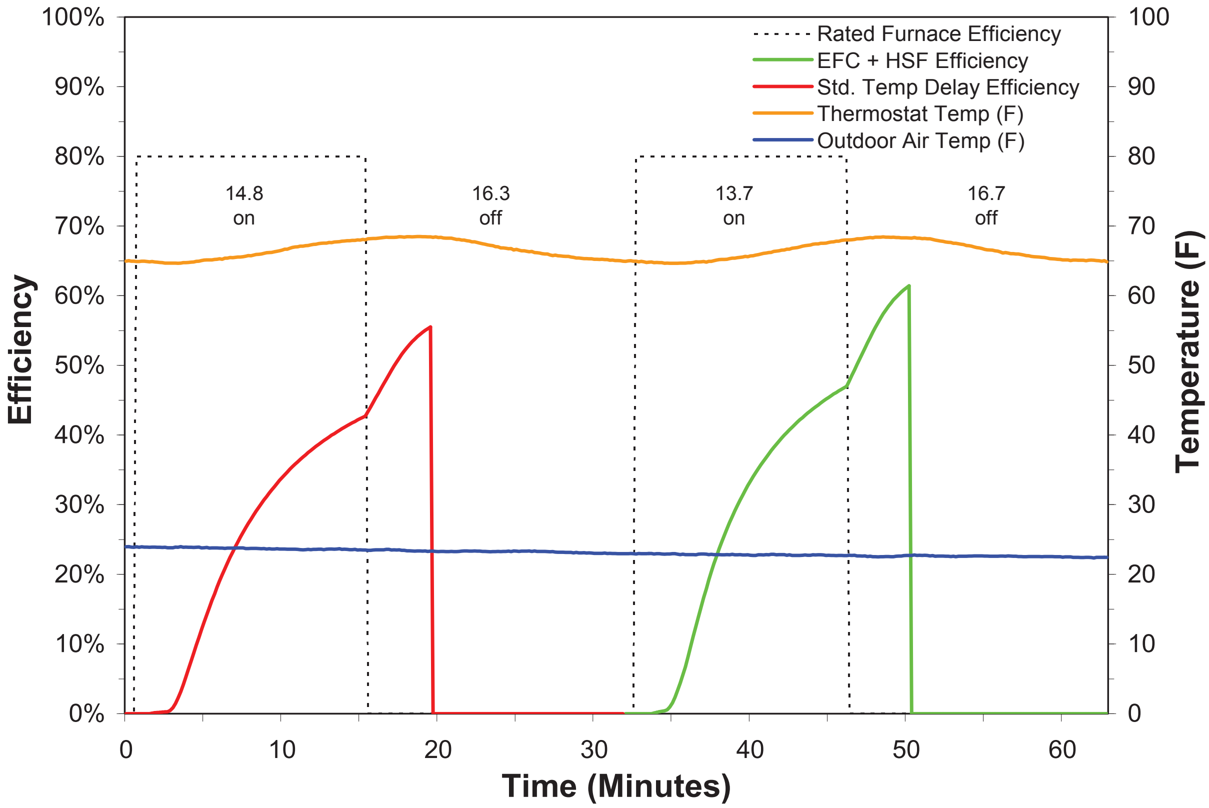

Figure 3. Heating Efficiency with EFC + HSF versus Standard Temperature Delay

Table 5. Measured Heating Efficiency from EFC + HSF vs. Standard Temp. Delay

Description	**Test 1 Baseline**	**Test 2 EFC**
Furnace On Time (minutes)	14.8	13.7
Furnace Off Cycle Time (minutes)	16.3	16.7
Fan Delay After Furnace Off (minutes)	4.2	4
EFC Additional Fan Energy (kWh/cycle)		0.009
EFC Additional Fan Energy		-4.6%
Furnace Energy Used (Btu)	-32,689	-30,118
Heat Energy Delivered to Space (Btu)	-18,147	-18,493
Delivered Efficiency	55.5%	61.4%
Savings Based on Heating Capacity (%)		5.9%
Savings from Run Time and Off Cycle (%)		9.9%
Average Savings		**7.9%**
Furnace Off Thermostat Temperature (F)	68.1	68.0
Fan Off Plenum Temperature (F)	99.4	98.3
Fan Off Supply Temperature (F)	95.7	94.0
Furnace On Thermostat Temperature before Cycle (F)	64.9	64.9

The rated furnace efficiency, EFC efficiency, and 90-second time delay efficiency for an 80% AFUE gas furnace is shown in **Figure 4** and **Table 6**. The furnace is turned on when the thermostat temperature is below 69°F and turned off when the thermostat temperature is above 72°F. The baseline time delay provides 1.5 minutes of additional fan operation and supply plenum fan off temperature of 143.9°F. The EFC provides a 4 minute time delay with fan off

supply plenum temperature of 97.9°F and increased off cycle by 1.2 minutes or 6.5%. The EFC saves 5.9% of gas heating energy and -14.5% of heating fan ventilation energy.

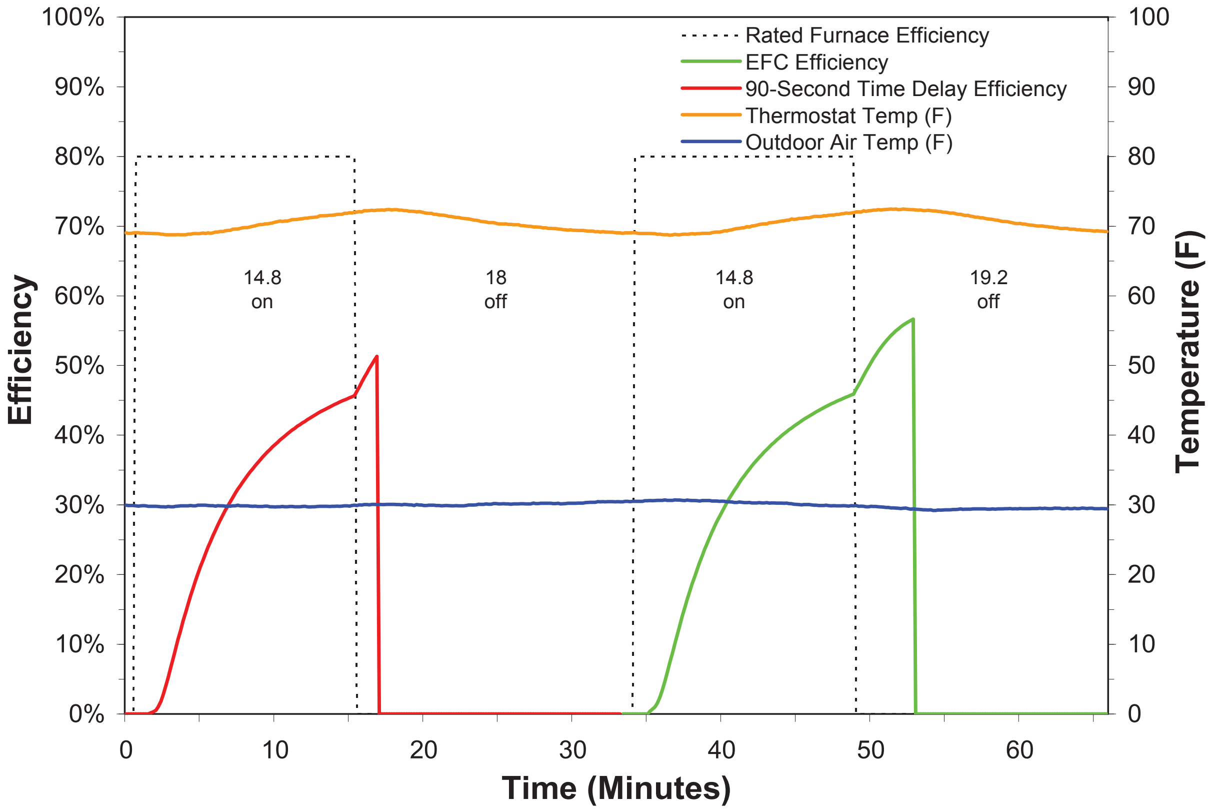

Figure 4. Heating Efficiency with EFC versus 90-Second Time Delay (Low Speed Fan)

Table 6. Measured Heating Efficiency with EFC vs. 90-Sec. Time Delay (Low Speed Fan)

Description	**Test 3 Baseline**	**Test 4 EFC**
Furnace On Time (minutes)	14.8	14.8
Furnace Off Cycle Time (minutes)	18.0	19.2
Fan Delay After Furnace Off (minutes)	1.5	4
EFC Additional Fan Energy (kWh/cycle)		0.025
EFC Additional Fan Energy		-14.5%
Furnace Energy Used (Btu)	-32,689	-32,689
Heat Energy Delivered to Space (Btu)	-16,769	-18,523
Delivered Efficiency	51.3%	56.7%
Savings Based on Heating Capacity (%)		5.4%
Savings from Run Time and Off Cycle (%)		6.5%
Average Savings		**5.9%**
Furnace Off Thermostat Temperature (F)	72.0	72.1
Fan Off Plenum Temperature (F)	143.9	97.9
Fan Off Supply Temperature (F)	116.9	97.3
Furnace On Thermostat Temperature before Cycle (F)	69.0	69.0

The rated furnace efficiency, EFC + HSF efficiency, and degraded temperature delay efficiency for an 81% AFUE gas furnace is shown in **Figure 5** and **Table 7**. For test 5 (baseline) and test 6 (EFC) the furnace is turned on when the thermostat temperature is below 68°F and turned off when the thermostat temperature is above 71°F. The low speed fan requires 8.0 minutes of

furnace operation to increase the thermostat temperature to above 71°F. The baseline degraded temperature delay provides 0.7 minutes of additional fan operation and the supply plenum fan-off temperature is 198.8°F. The EFC provides high speed fan operation 4 minutes after the furnace is turned on. This increases furnace efficiency by 7.1% and reduces furnace operation by 0.7 minutes or 8.8%. The EFC provides a 4-minute time delay with high-speed fan and the fan-off supply plenum temperature is 114.8°F. The EFC increases off cycle from 9.8 to 15.7 minutes or 60.2%. Test 6 EFC saves 24.5% of gas energy and -13.8% of heating fan ventilation energy. The high-speed fan power is 450W or 22.1% greater than low-speed fan power which is 368W.

For the test 7 (baseline) and test 8 (EFC) the furnace is turned on when the thermostat temperature is below 67°F and turned off when the thermostat temperature is above 73°F. The low speed fan requires 14.8 minutes of furnace operation to increase the thermostat temperature to above 73°F. The baseline degraded temperature delay provides 1 minute of additional fan operation and the supply plenum fan-off temperature is 206.4°F. The EFC provides high speed fan operation 4 minutes after the furnace is turned on. This increases furnace efficiency by 7.7% and reduces furnace operation by 1 minute or 6.8%. The EFC provides a 4-minute time delay with high-speed fan and the fan-off supply plenum temperature is 118.8°F. The EFC increases off cycle from 50.2 to 67.5 minutes or 34.6%. EFC test 8 saves 16.9% of gas energy and -30.5% of heating fan ventilation energy. The average savings from EFC (tests 6 and 8) versus degraded temperature delay (tests 5 and 7) are 20.7% of gas heating energy and -22.2% of heating fan ventilation energy. The high-speed fan power is 450W or 23.2% greater than low-speed fan power which is 365W.

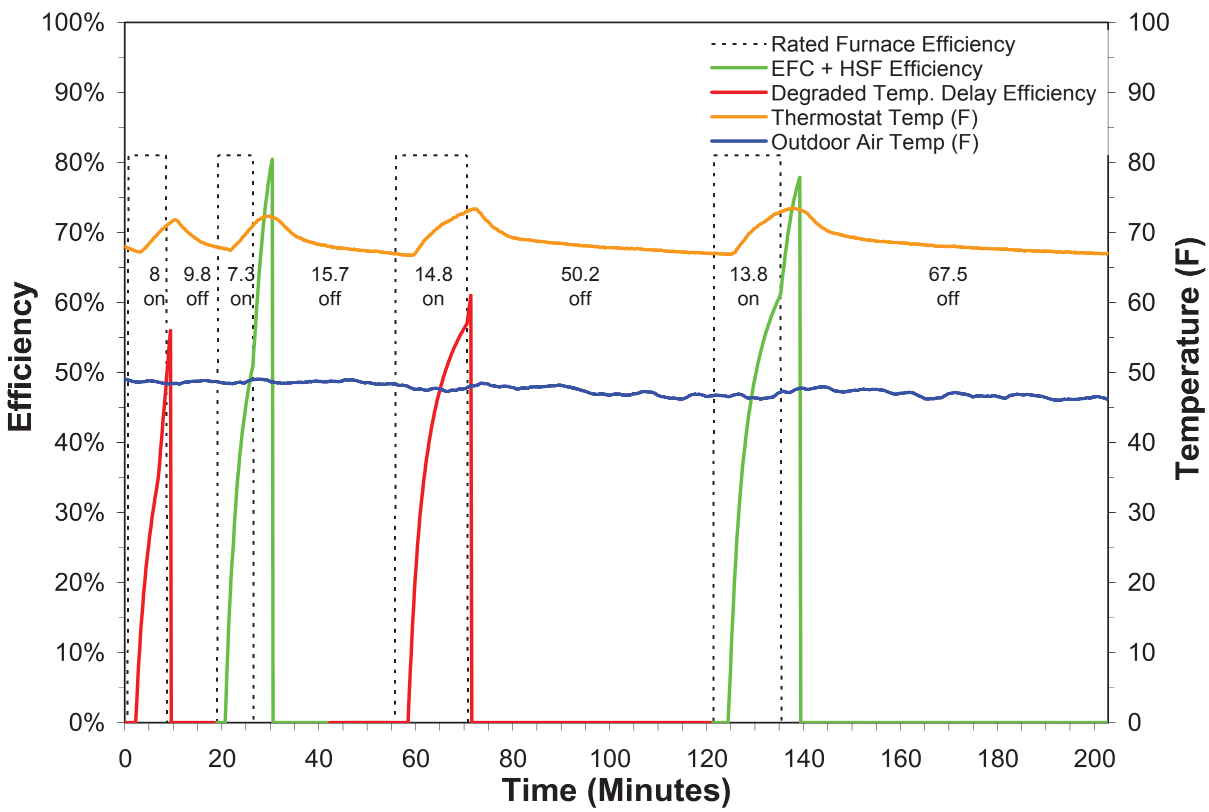

Figure 5. Heating Efficiency with EFC + HSF versus Degraded Temperature Delay

Table 7. Measured Heating Efficiency with EFC + HSF vs. Degraded Temp. Delay

Description	Test 5 Baseline	Test 6 EFC	Test 7 Baseline	Test 8 EFC	Average
Furnace On Time (minutes)	8.0	7.3	14.8	13.8	7.5%
Furnace Off Cycle Time (minutes)	9.8	15.7	50.2	67.5	46.9%
Fan Delay After Furnace Off (minutes)	0.8	4.0	1.0	4.0	
EFC Additional Fan Energy (kWh/cycle)		0.007		0.029	
EFC Additional Fan Energy		-13.8%		-30.5%	-22.2%
Furnace Energy Used (Btu)	-15,617	-14,315	-28,956	-27,004	
Heat Energy Delivered to Space (Btu)	-8,740	-11,519	-17,674	-21,033	
Delivered Efficiency	56.0%	80.5%	61.0%	77.9%	
Savings Based on Heating Capacity (%)		24.5%		16.9%	20.7%
Savings from Run Time and Off Cycle (%)		67.7%		41.3%	54.5%
Average Savings		**24.5%**		**16.9%**	**20.7%**
Furnace Off Thermostat Temperature (F)	71.1	71.2	73.1	73.0	
Fan Off Plenum Temperature (F)	198.8	114.8	206.4	118.8	
Fan Off Supply Temperature (F)	136.3	100.7	140.9	103.4	
Furnace On T-stat Temp. before Cycle (F)	68.0	68.0	67.0	67.0	

The ratio of additional electric power to operate the EFC fan compared to the standard fan is calculated using **Equation 5**.

Eq. 5 EFC Fan Energy = $S_{vent} = \dfrac{\sum_{i=0}^{m}(t_i \times P_{std\ fan\ i}) - \sum_{j=0}^{n}(t_j \times P_{EFC\ fan\ j})}{\sum_{i=0}^{m}(t_i \times P_{std\ fan\ i})}$

Where,

S_{vent} = electric residential air conditioner (RAC) or residential gas furnace (RGF) ventilation savings associated with the EFC based on field or laboratory tests (%),
t = time of measurement interval,
m = total time for EFC furnace fan operation,
n = total time for standard heating fan operation,
$P_{EFC\ fan}$ = power of heating fan with EFC (W),
$P_{std\ fan}$ = power of heating fan with standard control (W).

The test data presented in this report indicate 17.8 to 22.6% more fan energy is required for the permanent split-capacitance (PSC) motor (722W versus 613W and 450W versus 367W). A review of manufacturer product literature indicates that 20.5% more power is generally required to operate a PSC motor at high speed compared to medium speed (Lennox 1998a). In heating mode, the EFC requires 4.6% more electricity than furnace fans with standard temperature delay fan, 22.3% more electricity than furnace fans with degraded temperature delay, and 14.5% more electricity than furnace fans with 90-second time delay fan. In cooling mode, the EFC requires 37.5% more electricity than the fans with no delay and 19.3% more electricity than fans with 90-second time delay fan. The additional electricity required to operate the EFC fan is 13.8% in heating mode and 36.2% in cooling mode based on the weighted average of temperature and time delay market share (see **Table 12**).

Field measurements of the cooling sensible energy efficiency ratio (EER*) and total power (kW) for an air conditioner with a standard no time delay on the fan are shown in **Figure 6** and **Table 8**. The average cooling efficiency improvement from the EFC compared to the standard no TDR unit is 14.5% +/- 2% based on these measurements. The field tests were conducted with average air conditioner run times of 16.5 minutes and average EFC fan time delay times of 5 minutes. The EFC additional fan energy is 30.6% in cooling mode.

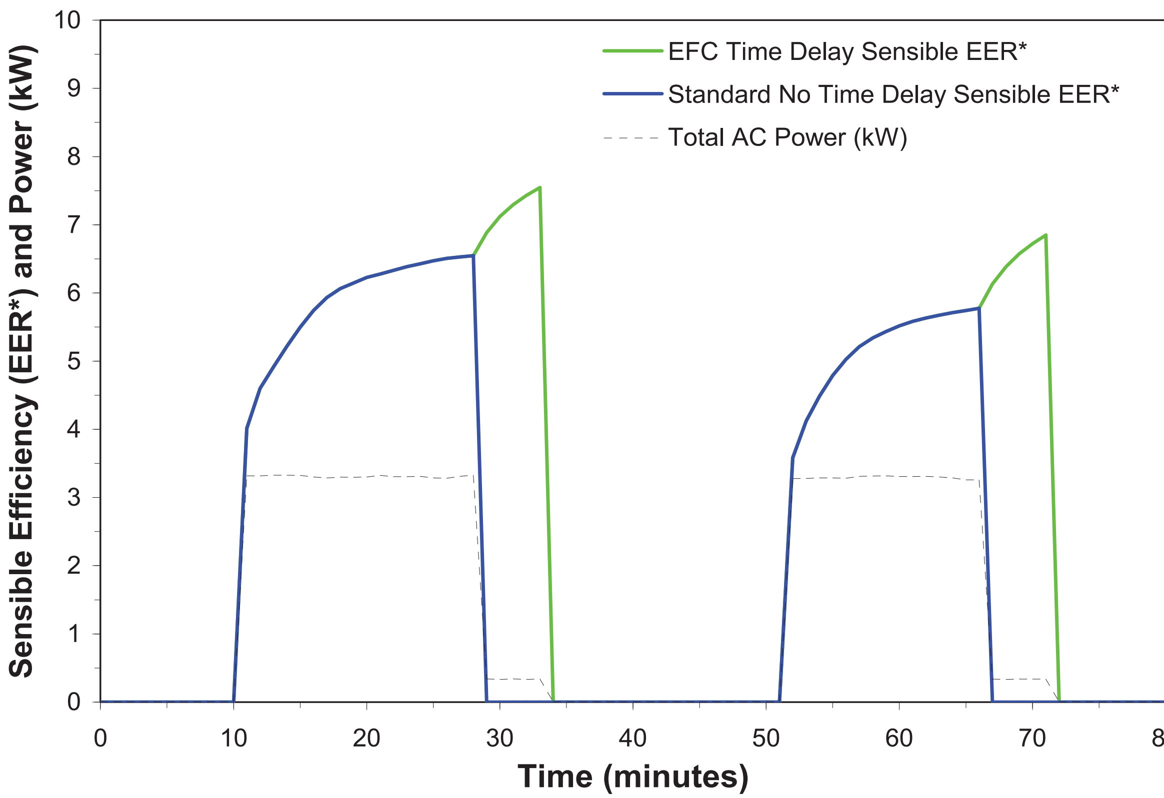

Figure 6. Field Tests Cooling Sensible EER and Power EFC versus no Time Delay

Table 8. Field Tests of Air Conditioner EFC versus No Time Delay

Description	Test 9	Test 10	Average
Compressor On Time (minutes)	18	15	16.5
EFC Delay After Compressor Off (minutes)	5	5	5
EFC Additional Fan Energy (kWh/cycle)	0.03	0.03	0.03
Std. Delay After Compressor Off (minutes)	0	0	0.00
EFC Additional Fan Cooling Energy	-27.8%	-33.3%	-30.6%
Std. AC Energy (kWh)	0.99	0.82	0.91
Standard Cooling Delivered (Btu)	6,497	4,752	5,625
Std. 90-Sec. Delay Cool Efficiency	6.55	5.77	6.16
EFC AC Energy (kWh)	1.02	0.85	0.94
EFC Cooling Delivered (Btu)	7,703	5,828	6,766
EFC Cooling Efficiency	7.55	6.85	7.20
Cooling Efficiency Improvement	**13.3%**	**15.7%**	**14.5%**

Field measurements of the cooling sensible energy efficiency ratio (EER*) and total power (kW) for an air conditioner with a 90-second time delay on the fan are shown in **Figure 7** and **Table 9**.

The average cooling efficiency improvement from the EFC compared to the 90-second TDR is 9.5% +/- 1.3% based on the field measurements. The field tests were conducted with average air conditioner run times of 16.5 minutes and average EFC fan time delay times of 5 minutes. The EFC additional fan energy is 19.6% in cooling mode.

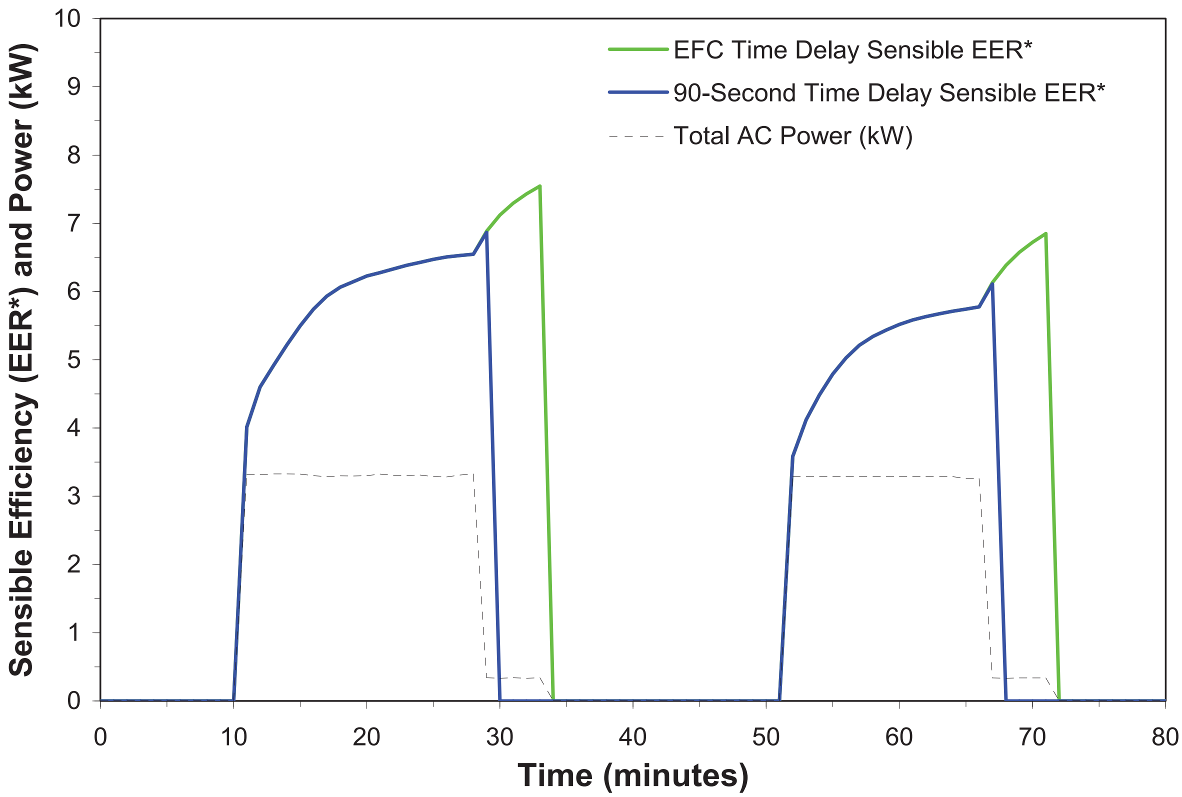

Figure 7. Field Tests Cooling Sensible EER and Power EFC versus 90-second TDR

Table 9. Field Tests of Air Conditioner EFC versus 90-Second TDR

Description	**Test 11**	**Test 12**	**Average**
Compressor On Time (minutes)	18	15	16.5
EFC Delay After Compressor Off (minutes)	5	5	5
EFC Additional Fan Energy (kWh/cycle)	0.02	0.02	0.02
Std. Delay After Compressor Off (minutes)	1.5	1.5	1.50
EFC Additional Fan Cooling Energy	-17.9%	-21.2%	-19.6%
Std. AC Energy (kWh)	1.00	0.83	0.91
Standard Cooling Delivered (Btu)	6,881	5,091	5,986
Std. 90-Sec. Delay Cool Efficiency	6.89	6.14	6.51
EFC AC Energy (kWh)	1.02	0.85	0.94
EFC Cooling Delivered (Btu)	7,703	5,828	6,766
EFC Cooling Efficiency	7.55	6.85	7.20
Cooling Efficiency Improvement	**8.7%**	**10.4%**	**9.5%**

1.4.4 Laboratory Test Data

The amount of moisture converted to sensible cooling is dependent on the airflow and the length of time the fan runs at the end of the compressor cycle. **Figure 8** and **Table 10** show laboratory

test data from Southern California Edison from the embedded Excel Workbook #2 in tab "SCE Data Fig7-8", Column O is the Cycle Sensible EER (see References Section). The sensible EER improvement decreases with increasing compressor run time from 22.2% for 5-minute run time to 6.2% for 30 minute compressor run time. The EFC adjusts the length of the time delay from 1.5 to 5 minutes based on the fan run time which is a proxy for the compressor run time. The average cooling efficiency improvement from the EFC compared to the standard unit is 15.3% +/- 5.7% based on these measurements. These savings are comparable to the average cooling efficiency improvement of 14.5% +/- 2% for the EFC compared to no time delay based on field measurements (see **Table 8**). **Figure 9** and **Table 11** show the same data set but with the baseline having a 90 second time delay. The average cooling efficiency improvement from the EFC compared to the 90-second delay is 8.1% +/- 2.4%. These savings are comparable to the average cooling efficiency improvement of 9.5% +/- 1.3% for the EFC compared to the 90-second delay based on field measurements (see **Table 9**).

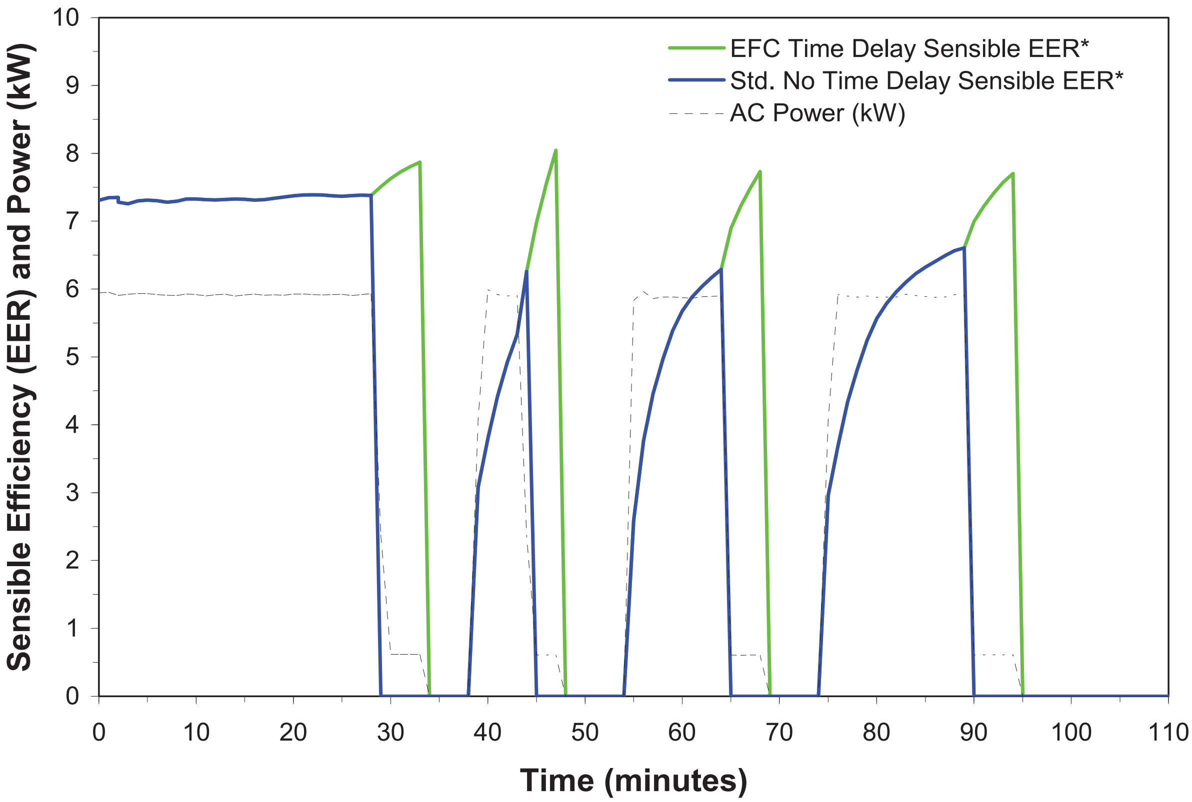

Figure 8. Laboratory Tests of Air Conditioner EFC versus No Time Delay

Table 10. Laboratory Tests of Air Conditioner with no Time Delay

Description	Test 13	Test 14	Test 15	Test 16	Average
Compressor On Time (minutes)	30	5	10	15	17.5
EFC Delay After Compressor Off (minutes)	5	3	4	5	4.25
EFC Additional Fan Energy (kWh/cycle)	0.05	0.03	0.04	0.05	0.04
Std. Delay After Compressor Off (minutes)	0	0	0	0	0.00
EFC Additional Fan Cooling Energy	-16.7%	-60.0%	-40.0%	-33.3%	-37.5%
No Time Delay AC Energy (kWh)	2.96	0.50	0.98	1.44	1.73
No Time Delay Cooling Delivered (Btu)	21,838	3,146	6,167	9,538	12,492
No Time Delay Application Sensible EER*	7.38	6.26	6.29	6.61	6.82
EFC AC Energy (kWh)	3.04	0.53	1.02	1.49	1.79
EFC Cooling Delivered (Btu)	23,917	4,288	7,893	11,507	11,901
EFC Application Sensible EER*	7.87	8.04	7.73	7.70	7.84
EFC Cooling Savings	**6.2%**	**22.2%**	**18.7%**	**14.2%**	**15.3%**

Source: Based on Southern California Edison data.

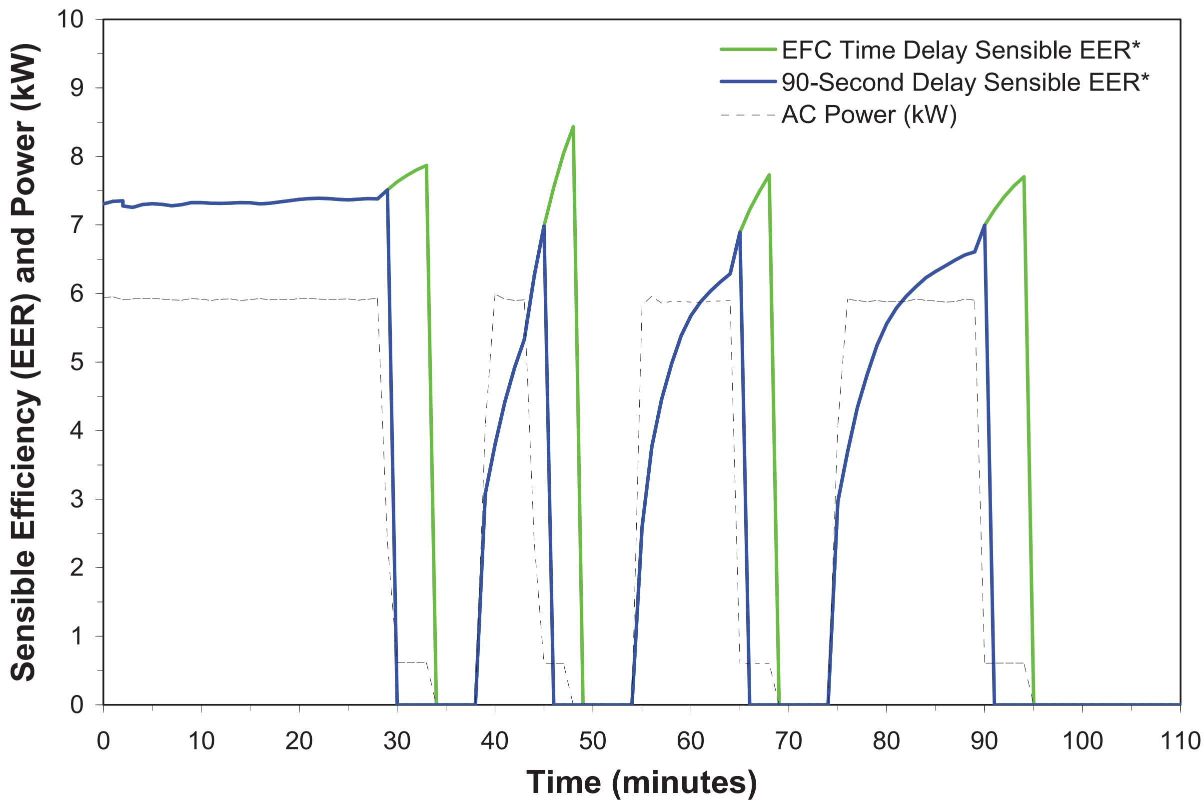

Figure 9. Laboratory Tests of Air Conditioner with EFC versus 90-Second Time Delay

Table 11. Laboratory Tests of Air Conditioner with EFC and 90-Second Time Delay

Description	Test 17	Test 18	Test 19	Test 20	Average
Compressor On Time (minutes)	30	5	10	15	17.5
EFC Delay After Compressor Off (minutes)	5	3	4	5	4.25
EFC Additional Fan Energy (kWh/cycle)	0.05	0.03	0.04	0.05	0.04
Std. Delay After Compressor Off (minutes)	1.5	1.5	1.5	1.5	1.50
EFC Additional Fan Cooling Energy	-11.1%	-23.1%	-21.7%	-21.2%	-19.3%
No Time Delay AC Energy (kWh)	3.00	0.52	1.00	1.46	1.76
No Time Delay Cooling Delivered (Btu)	22,738	3,765	7,029	10,365	13,251
No Time Delay Application Sensible EER*	7.57	7.27	7.06	7.11	7.42
EFC AC Energy (kWh)	3.04	0.53	1.02	1.49	1.79
EFC Cooling Delivered (Btu)	23,917	4,288	7,893	11,507	11,901
EFC Application Sensible EER*	7.87	8.04	7.73	7.70	7.84
EFC Cooling Savings	**3.9%**	**10.7%**	**9.5%**	**8.4%**	**8.1%**

Source: Based on Southern California Edison.

Equation 6 shows how the application sensible EER* is calculated.

Eq. 6 Sensible $EER_s^* = \sum_{i=0}^{n} \frac{Q_{cs\,i}}{P_i}$

Where,

EER_s^* = application sensible energy efficiency ratio (Btu/hr-W),

$Q_{cs\,i}$ = sensible cooling energy removed from the air by the air conditioner over the measurement interval (Btu/hr),

P_i = total power to operate the air conditioner compressor, fan, and controls over the measurement interval (W).

The cooling energy savings (S_{cool}) based on cooling Sensible EER improvements are calculated using **Equation 7**.

Eq. 7 $S_{cool} = \frac{EER_s^*\big|_{EFC}}{EER_s^*\big|_{Base}} - 1$

Where,

S_{cool} = cooling energy savings for the EFC (%),

$EER_s^*\big|_{EFC}$ = EFC sensible cooling efficiency with optimal time delay from 1.5 to 5 minutes, and

$EER_s^*\big|_{Base}$ = base sensible cooling efficiency with no delay or 90-second time delay.

1.4.5 Estimated Energy Savings

The estimated space cooling and heating energy savings for each market share for the EFC are shown in **Table 12**. The savings are based on field tests and laboratory tests of furnaces and air conditioners with and without the EFC. The estimated weighted average heating energy savings are 11.8% based on field tests (see tests 1 through 8 in **Tables 5**, **6**, and **7**). In heating mode, the EFC requires 4.6% more ventilation electricity than heating systems with standard temperature delay fan and 14.5% more electricity than ventilation systems with 90-second time delay. In

cooling mode, the EFC requires 37.5% more ventilation electricity than the standard cooling system with no time delay and 19.3% more ventilation electricity than the system with 90-second time delay. The EFC heating ventilation energy savings are -13.8% (i.e., negative) based on the weighted average of temperature and time delay. The EFC cooling ventilation energy savings are -36.2% (i.e., negative) based on the weighted average of temperature and time delay. The EFC cooling savings are 14.8% based on the weighted average savings from field and laboratory tests and estimated market share.

The test data presented in this report indicate 20.6% more fan power is required at high speed compared to low speed for the permanent split-capacitance (PSC) motor for a 3-ton unit (450W high speed versus 372W low speed) and 17.8% for a 4-ton unit (722W high speed versus 613W low speed). A review of manufacturer product literature indicates 20.5% more power is required to operate at high speed during the time delay (Lennox 1998a). The weighted average ventilation electricity savings are -13.8% instead of -20.6% due to running the fan in high speed during furnace operation which reduces both furnace and fan energy consumption.

The weighted average space heating savings are calculated using **Equation 8**.

Eq. 8 $$\overline{S_{heat}} = \sum_{k=0}^{p} S_{heat_k} \times M_k$$

Where,

$\overline{S_{heat}}$ = weighted average space heating energy savings for the EFC based field tests and market share (%),

S_{heat_k} = heating energy savings for the EFC for market segment “k” (%), and

M_k = market segment “k” for the following base thermostat control market segments: working temperature delay, degraded temperature delay, or 90-second time delay (%).

The weighted average space cooling savings are calculated using **Equation 9**.

Eq. 9 $$\overline{S_{cool}} = \sum_{k=1}^{p} S_{cool_k} \times M_k$$

Where,

$\overline{S_{cool}}$ = weighted average space cooling energy savings for the EFC based on field and laboratory tests and market share (%),

S_{cool_k} = cooling energy savings for the EFC for market segment “k” (%), and

M_k = market segment “k” for the following base thermostat control market segments: no time delay PSC motor, 90-second time delay PSC motor, no time delay EC motor, 90-second time delay EC motor (%).

The weighted average RGF ventilation savings are calculated using **Equation 10**.

Eq. 10 $\overline{S_{RGF\,vent}} = \sum_{k=1}^{p} S_{RGF\,vent_k} \times M_k$

Where,

$\overline{S_{RGF\,vent}}$ = weighted average RGF ventilation energy savings associated with the EFC based on field and laboratory tests and market share (%),

$S_{RGF\,vent_k}$ = RGF ventilation savings for the EFC for market segment "k" (%), and

M_k = market segment "k" for the following base thermostat control market segments: working temperature delay, degraded temperature delay, or 90-second time delay (%).

The weighted average RAC ventilation savings are calculated using **Equation 11**.

Eq. 11 $\overline{S_{RAC\,vent}} = \sum_{k=1}^{p} S_{RAC\,vent_k} \times M_k$

Where,

$\overline{S_{RAC\,vent}}$ = weighted average RAC ventilation energy savings associated with the EFC based on field and laboratory tests and market share (%),

$S_{RAC\,vent_k}$ = RAC ventilation savings for the EFC for market segment "k" (%), and

M_k = market segment "k" for the following base thermostat control market segments: no time delay PSC motor, 90-second time delay PSC motor, no time delay EC motor, 90-second time delay EC motor (%).

Table 12. Estimated Space Heating and Cooling Energy Savings for EFC

Pre-existing Description	Measure Description	EFC Heating Savings	EFC Fan Heating Savings	EFC Fan Cooling Savings	EFC Cooling Savings	Estimated Market Share
Heating Temperature Delay at 100 to 110°F, PSC motor	EFC High-Speed Fan plus Variable Time Delay (2 to 4 minutes)	7.9%	-4.6%			35%
Heating Temperature Degraded Delay at 130 to 200°F, PSC motor	EFC High-Speed Fan plus Variable Time Delay (2 to 4 minutes)	20.7%	-22.3%			35%
Heating 90 second Time Delay, PSC motor low speed	EFC Variable Time Delay (2 to 4 minutes)	5.9%	-14.5%			30%
Cooling No Time Delay, PSC Motor	EFC Variable Time Delay (1.5 to 5 minutes)			-37.5%	15.3%	90%
Cooling Standard 90 second Time Delay PSC motor	EFC Variable Time Delay (1.5 to 5 minutes)			-19.3%	8.1%	5%
Cooling No Time Delay, Efficient Fan Motor	EFC Variable Time Delay (1.5 to 5 minutes)			-37.5%	15.3%	3%
Cooling Standard 90 second Time Delay, Efficient Fan Motor	EFC Variable Time Delay (1.5 to 5 minutes)			-19.3%	8.1%	2%
Weighted Average		**11.8%**	**-13.8%**	**-36.2%**	**14.8%**	

1.4.5 Consumer Satisfaction Study

EFC units were installed at homes in California and Nevada to evaluate consumer satisfaction. Consumers provided the following feedback after using the EFC for two months during the winter heating season from January through March 2012. Additional consumer survey responses will be obtained after the summer cooling season. Consumer satisfaction survey data are provided in **Table 13**. The average number of occupants is 3.2 +/- 0.1 and the average conditioned floor area is 2800 ft^2. Survey respondents indicated that the EFC provides more comfortable heating with an overall rating of 7.5 ± 0.18 out of 10 points. One hundred percent of survey respondents indicated that the EFC saves energy. Survey respondents indicate high satisfaction with an overall rating of 10 out of 10 points.

Table 13. Consumer Satisfaction Survey Data

Description	Average	Respondents
1. Number of Occupants	3.2 +/- 0.1	20
2. Conditioned Floor Area (ft^2)	2,800 +/- 49	20
3. Air Conditioner Average Fan Off Delay (sec)	TBD	TBD
4. Pre-Existing Average Furnace Fan Off Delay (sec)	109.6 +/- 3.3	20
5. EFC Furnace Fan Off Delay (sec)	240 +/- 2	20
6. Does the EFC provide more comfortable heating on a scale of 1 to 10? (10=more, 5=same, 1=less).	7.5 +/- 0.18	20
7. Does the EFC provide more comfortable cooling on a scale of 1 to 10?	TBD	TBD
8. Does the EFC save energy compared to not using the EFC? (% Yes)	100%	20
9. How satisfied are you with the EFC on a scale of 1 to 10? (1=Low, 10=High).	10 +/- 0	20

1.5 Baseline Unit Energy Consumption (UEC) Values

The weighted baseline unit energy consumption (UEC) values for the PG&E service territory for Single Family (SFM), Multifamily (MFM), and Double-wide Mobile (DMO) prototypical buildings and Residential Air Conditioner (RAC) with Gas Furnace (GF) HVAC system are shown in **Table 14** and Residential gas Furnace (RGF) HVAC system are shown in **Table 15**. The UEC values are from the DEER 2008.2.1 MISer (DEER 2008a). Section 2 provides engineering calculations used to develop estimates of the baseline annual cooling electric ventilation from the total baseline annual electric ventilation and the baseline annual heating electric ventilation. The baseline and energy savings should be defined in “Common energy units” rather than per household to allow for multiple EFC units to be installed at one home.

Table 14. Weighted Baseline UEC per Household –RAC with GF (DEER 2008 MISer)

DEER2008 ImpactID	PG&E Weighted Building Vintage Climate Zone	Baseline Annual Gas Heating (therm/yr)	Baseline Annual Heating Elec Ventilation (kWh/yr)	Baseline Annual Cooling Elec Ventilation (kWh/yr)	Baseline Annual Elec Cooling (kWh/yr)	Baseline Annual Elec Cooling (kW)	Baseline Annual Elec Ventilation (kW)
SFM-w01-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	1	341.3	131.0	56.0	35.9	1.017	0.181
SFM-w02-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	2	313.6	125.8	86.9	420.9	1.905	0.258
SFM-w03-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	3	304.0	112.4	66.5	197.9	1.658	0.225
SFM-w04-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	4	242.3	89.1	116.1	618.7	2.284	0.296
SFM-w05-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	5	319.7	127.9	50.4	142.2	1.266	0.180
SFM-w11-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	11	285.4	106.8	234.9	1,548.5	3.221	0.415
SFM-w12-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	12	275.1	99.9	161.4	981.3	2.700	0.338
SFM-w13-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	13	269.7	97.6	270.7	1,849.8	3.028	0.379
SFM-w16-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	16	602.4	244.0	179.6	763.8	2.534	0.337
SFM-wPGE-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	PG&E Weighted	282.5	113.4	169.2	1,104.1	2.672	0.340
MFM-w01-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	1	209.3	55.3	61.3	61.5	0.392	0.073
MFM-w02-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	2	125.6	45.9	47.2	222.0	0.722	0.095
MFM-w03-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	3	124.9	45.7	23.6	59.0	0.428	0.068
MFM-w04-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	4	93.7	38.7	35.8	194.9	0.672	0.093
MFM-w05-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	5	82.8	47.8	0.0	43.9	0.248	0.049
MFM-w11-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	11	137.0	49.5	118.5	760.1	1.301	0.167
MFM-w12-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	12	135.5	53.5	75.5	466.4	1.055	0.132
MFM-w13-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	13	114.1	45.1	147.4	1,055.7	1.308	0.164
MFM-w16-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	16	257.7	83.0	135.6	562.8	1.093	0.149
MFM-wPGE-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	PG&E Weighted	122.4	45.0	82.4	506.4	0.980	0.126
DMO-w01-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	1	311.5	102.5	116.7	377.7	2.203	0.214
DMO-w02-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	2	275.4	97.5	215.1	1,755.2	3.806	0.317
DMO-w03-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	3	241.8	89.2	143.5	1,079.5	2.968	0.249
DMO-w04-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	4	218.6	72.8	241.3	2,062.6	3.598	0.307
DMO-w05-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	5	316.9	101.6	174.4	1,029.3	2.815	0.226
DMO-w11-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	11	328.1	115.8	368.5	3,384.3	5.391	0.447
DMO-w12-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	12	264.3	84.0	304.5	2,753.0	4.800	0.388
DMO-w13-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	13	252.2	104.2	367.8	4,001.0	5.190	0.415
DMO-w16-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	16	558.0	214.6	312.0	1,939.2	4.165	0.354
DMO-wPGE-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	PG&E Weighted	293.7	109.1	310.5	2,887.8	4.717	0.389

Table 15. Weighted Baseline UEC per Household –RGF Only (DEER 2008 MISer)

DEER2008 ImpactID	PG&E Weighted Building Vintage Climate Zone	Baseline Annual Gas Heating (therm/yr)	Baseline Annual Heating Elec Ventilation (kWh/yr)	Baseline Annual Cooling Elec Ventilation (kWh/yr)	Baseline Annual Elec Cooling (kWh/yr)	Baseline Annual Elec Cooling (kW)	Baseline Annual Elec Ventilation (kW)
SFM-w01-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	1	322.9	131.0				
SFM-w02-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	2	329.3	125.8				
SFM-w03-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	3	298.1	112.4				
SFM-w04-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	4	232.3	89.1				
SFM-w05-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	5	338.6	127.9				
SFM-w11-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	11	285.1	106.8				
SFM-w12-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	12	267.8	99.9				
SFM-w13-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	13	259.0	97.6				
SFM-w16-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	16	606.1	244.0				
SFM-wPGE-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	PG&E Weighted	298.1	113.4				
MFM-w01-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	1	141.1	55.3				
MFM-w02-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	2	118.6	45.9				
MFM-w03-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	3	121.3	45.7				
MFM-w04-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	4	100.5	38.7				
MFM-w05-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	5	126.4	47.8				
MFM-w11-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	11	129.3	49.5				
MFM-w12-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	12	139.6	53.5				
MFM-w13-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	13	116.7	45.1				
MFM-w16-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	16	207.8	83.0				
MFM-wPGE-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	PG&E Weighted	118.8	45.0				
DMO-w01-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	1	276.9	102.5				
DMO-w02-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	2	262.4	97.5				
DMO-w03-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	3	248.6	89.2				
DMO-w04-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	4	199.7	72.8				
DMO-w05-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	5	278.2	101.6				
DMO-w11-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	11	304.6	115.8				
DMO-w12-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	12	227.1	84.0				
DMO-w13-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	13	272.1	104.2				
DMO-w16-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	16	547.6	214.6				
DMO-wPGE-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	PG&E Weighted	310.0	109.1				

Energy common units for RAC and RGF are shown in **Tables 16** and **17**.

Table 16. Energy Common Units for RAC HVAC System (DEER 2008 MISer)

DEER2008 ImpactID	PG&E Weighted Building Vintage Climate Zone	HVAC System	Energy Common Units 1 description	Number Energy Common Units 1
SFM-w01-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	1	RAC	tons cool cap	2.14
SFM-w02-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	2	RAC	tons cool cap	3.28
SFM-w03-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	3	RAC	tons cool cap	2.90
SFM-w04-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	4	RAC	tons cool cap	2.81
SFM-w05-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	5	RAC	tons cool cap	3.06
SFM-w11-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	11	RAC	tons cool cap	3.51
SFM-w12-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	12	RAC	tons cool cap	3.32
SFM-w13-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	13	RAC	tons cool cap	3.40
SFM-w16-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	16	RAC	tons cool cap	3.17
SFM-wPGE-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	PG&E Weighted	RAC	tons cool cap	3.27
MFM-w01-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	1	RAC	tons cool cap	1.19
MFM-w02-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	2	RAC	tons cool cap	1.46
MFM-w03-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	3	RAC	tons cool cap	1.38
MFM-w04-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	4	RAC	tons cool cap	1.31
MFM-w05-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	5	RAC	tons cool cap	1.09
MFM-w11-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	11	RAC	tons cool cap	1.84
MFM-w12-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	12	RAC	tons cool cap	1.65
MFM-w13-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	13	RAC	tons cool cap	1.71
MFM-w16-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	16	RAC	tons cool cap	1.57
MFM-wPGE-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	PG&E Weighted	RAC	tons cool cap	1.58
DMO-w01-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	1	RAC	tons cool cap	3.50
DMO-w02-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	2	RAC	tons cool cap	3.50
DMO-w03-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	3	RAC	tons cool cap	3.50
DMO-w04-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	4	RAC	tons cool cap	3.50
DMO-w05-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	5	RAC	tons cool cap	3.50
DMO-w11-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	11	RAC	tons cool cap	3.50
DMO-w12-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	12	RAC	tons cool cap	3.50
DMO-w13-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	13	RAC	tons cool cap	3.50
DMO-w16-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	16	RAC	tons cool cap	3.50
DMO-wPGE-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	PG&E Weighted	RAC	tons cool cap	3.50

Table 17. Energy Common Units for RGF HVAC System (DEER 2008 MISer)

DEER2008 ImpactID	PG&E Weighted Building Vintage Climate Zone	HVAC System	Energy Common Units 1 description	Number Energy Common Units 1
SFM-w01-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	1	RGF	kBtuh furnace	39.56
SFM-w02-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	2	RGF	kBtuh furnace	64.08
SFM-w03-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	3	RGF	kBtuh furnace	54.61
SFM-w04-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	4	RGF	kBtuh furnace	52.41
SFM-w05-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	5	RGF	kBtuh furnace	60.15
SFM-w11-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	11	RGF	kBtuh furnace	71.03
SFM-w12-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	12	RGF	kBtuh furnace	66.52
SFM-w13-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	13	RGF	kBtuh furnace	67.26
SFM-w16-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	16	RGF	kBtuh furnace	59.54
SFM-wPGE-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	PG&E Weighted	RGF	kBtuh furnace	56.56
MFM-w01-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	1	RGF	kBtuh furnace	17.47
MFM-w02-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	2	RGF	kBtuh furnace	26.09
MFM-w03-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	3	RGF	kBtuh furnace	25.73
MFM-w04-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	4	RGF	kBtuh furnace	25.42
MFM-w05-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	5	RGF	kBtuh furnace	27.98
MFM-w11-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	11	RGF	kBtuh furnace	33.89
MFM-w12-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	12	RGF	kBtuh furnace	32.62
MFM-w13-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	13	RGF	kBtuh furnace	33.40
MFM-w16-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	16	RGF	kBtuh furnace	25.99
MFM-wPGE-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	PG&E Weighted	RGF	kBtuh furnace	25.96
DMO-w01-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	1	RGF	kBtuh furnace	55.08
DMO-w02-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	2	RGF	kBtuh furnace	55.09
DMO-w03-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	3	RGF	kBtuh furnace	55.04
DMO-w04-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	4	RGF	kBtuh furnace	55.06
DMO-w05-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	5	RGF	kBtuh furnace	55.06
DMO-w11-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	11	RGF	kBtuh furnace	55.07
DMO-w12-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	12	RGF	kBtuh furnace	55.12
DMO-w13-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	13	RGF	kBtuh furnace	55.00
DMO-w16-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	16	RGF	kBtuh furnace	55.00
DMO-wPGE-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	PG&E Weighted	RGF	kBtuh furnace	55.06

Tables 18 and **19** provide baseline UEC data normalized per "Energy Common Units" (ECU), i.e., tons cooling capacity or kBtuh furnace capacity.

Table 18. Weighted Baseline UEC per ECU – RAC with Gas Furnace (DEER 2008 MISer)

DEER2008 ImpactID	PG&E Weighted Building Vintage Climate Zone	Baseline Annual Gas Heating (therm/yr-ECU)	Baseline Annual Heating Elec Ventilation (kWh/yr-ECU)	Baseline Annual Cooling Elec Ventilation (kWh/yr-ECU)	Baseline Annual Elec Cooling (kWh/yr-ECU)	Baseline Annual Elec Cooling (kW/ECU)	Baseline Annual Elec Ventilation (kW/ECU)
SFM-w01-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	1	159.17	61.09	26.11	16.76	0.474	0.085
SFM-w02-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	2	95.48	38.32	26.47	128.16	0.580	0.079
SFM-w03-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	3	104.81	38.76	22.94	68.24	0.572	0.078
SFM-w04-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	4	86.11	31.66	41.26	219.84	0.812	0.105
SFM-w05-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	5	104.46	41.80	16.46	46.47	0.414	0.059
SFM-w11-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	11	81.23	30.39	66.85	440.71	0.917	0.118
SFM-w12-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	12	82.78	30.05	48.56	295.24	0.812	0.102
SFM-w13-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	13	79.36	28.72	79.67	544.36	0.891	0.111
SFM-w16-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	16	189.82	76.88	56.59	240.68	0.798	0.106
SFM-wPGE-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	PG&E Weighted	86.34	34.66	51.71	337.50	0.817	0.104
MFM-w01-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	1	176.05	46.51	51.56	51.73	0.330	0.061
MFM-w02-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	2	85.80	31.33	32.22	151.66	0.493	0.065
MFM-w03-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	3	90.66	33.15	17.15	42.83	0.311	0.049
MFM-w04-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	4	71.72	29.64	27.37	149.18	0.514	0.071
MFM-w05-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	5	75.70	43.69	0.00	40.11	0.227	0.045
MFM-w11-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	11	74.61	26.96	64.54	413.94	0.709	0.091
MFM-w12-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	12	82.24	32.46	45.79	282.94	0.640	0.080
MFM-w13-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	13	66.67	26.35	86.13	617.01	0.765	0.096
MFM-w16-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	16	164.23	52.87	86.37	358.64	0.696	0.095
MFM-wPGE-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	PG&E Weighted	77.53	28.51	52.18	320.81	0.621	0.080
DMO-w01-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	1	89.04	29.28	33.35	107.96	0.630	0.061
DMO-w02-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	2	78.75	27.88	61.50	501.82	1.088	0.091
DMO-w03-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	3	69.14	25.50	41.03	308.66	0.849	0.071
DMO-w04-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	4	62.51	20.82	68.98	589.69	1.029	0.088
DMO-w05-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	5	90.58	29.06	49.84	294.25	0.805	0.065
DMO-w11-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	11	93.80	33.10	105.34	967.53	1.541	0.128
DMO-w12-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	12	75.58	24.03	87.05	787.11	1.372	0.111
DMO-w13-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	13	72.12	29.80	105.16	1143.99	1.484	0.119
DMO-w16-vPGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	16	159.51	61.35	89.19	554.37	1.191	0.101
DMO-wPGE-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	PG&E Weighted	83.98	31.20	88.77	825.61	1.349	0.111

Table 19. Weighted Baseline UEC per ECU – RGF Only (DEER 2008 MISer)

DEER2008 ImpactID	PG&E Weighted Building Vintage Climate Zone	Baseline Annual Gas Heating (therm/yr-ECU)	Baseline Annual Heating Elec Ventilation (kWh/yr-ECU)	Baseline Annual Cooling Elec Ventilation (kWh/yr-ECU)	Baseline Annual Elec Cooling (kWh/yr-ECU)	Baseline Annual Elec Cooling (kW/ECU)	Baseline Annual Elec Ventilation (kW/ECU)
SFM-w01-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	1	8.16	3.31				
SFM-w02-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	2	5.14	1.96				
SFM-w03-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	3	5.46	2.06				
SFM-w04-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	4	4.43	1.70				
SFM-w05-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	5	5.63	2.13				
SFM-w11-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	11	4.01	1.50				
SFM-w12-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	12	4.03	1.50				
SFM-w13-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	13	3.85	1.45				
SFM-w16-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	16	10.18	4.10				
SFM-wPGE-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	PG&E Weighted	5.27	2.00				
MFM-w01-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	1	8.08	3.16				
MFM-w02-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	2	4.55	1.76				
MFM-w03-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	3	4.72	1.78				
MFM-w04-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	4	3.96	1.52				
MFM-w05-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	5	4.52	1.71				
MFM-w11-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	11	3.82	1.46				
MFM-w12-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	12	4.28	1.64				
MFM-w13-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	13	3.49	1.35				
MFM-w16-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	16	7.99	3.19				
MFM-wPGE-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	PG&E Weighted	4.57	1.73				
DMO-w01-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	1	5.03	1.86				
DMO-w02-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	2	4.76	1.77				
DMO-w03-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	3	4.52	1.62				
DMO-w04-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	4	3.63	1.32				
DMO-w05-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	5	5.05	1.85				
DMO-w11-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	11	5.53	2.10				
DMO-w12-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	12	4.12	1.52				
DMO-w13-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	13	4.95	1.90				
DMO-w16-vPGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	16	9.96	3.90				
DMO-wPGE-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	PG&E Weighted	5.63	1.98				

1.6 Pre-Existing Baseline and Measure Effective Useful Lives

The pre-existing baseline measure characteristics are provided in **Table 3**. For heating the baseline is either temperature controlled or time controlled delay on the furnace fan. For cooling the baseline is either no time delay or time delay of 90 seconds. The baseline measure is installed inside the HVAC equipment and is dependent on the life of the equipment. The EFC measure is not installed inside the air conditioner, furnace, forced-air unit, or thermostat. Therefore, the EFC EUL is not dependent on the life of the air conditioner, furnace, FAU, or thermostat. The EFC is a small microchip approximately the size of a US penny which is installed in the wall behind the thermostat on the low-voltage wires coming from the HVAC equipment. The effective useful lifetime of the EFC is assumed to be 10 years based on the EUL of programmable thermostats (DEER 2008). However, since the EFC is solid-state its lifetime could be longer (i.e., 15 to 25 years) since there are no moving parts or parts to wear out since the product operates on low voltage without the need for a battery,

1.7 Net-to-Gross Ratios

A net to gross ratio of the EFC is 1.0 based on the EUL for comprehensive air conditioning measures.

Section 2. Engineering Calculations

The engineering calculations for annual natural gas and electricity savings and peak demand reduction are provided in the embedded Excel workbook using the following equations. The baseline annual gas heating (therm/yr) values shown in **Table 14**, column 3, and the baseline annual electric cooling (kWh/yr) values shown in **Table 14**, column 5, are taken directly from the 2008 DEER Update (DEER 2008a) for the PGE weighted vintage for each climate zone and residential air conditioner (RAC) HVAC system (includes gas furnace and air conditioner). The baseline annual heating electric ventilation (kWh/yr) values shown in **Table 15**, column 4, are taken directly from the 2008 DEER Update (DEER 2008a) for the PGE weighted vintage for each climate zone and residential gas furnace (RGF) HVAC system (excludes air conditioning). The baseline annual cooling electric ventilation values shown in **Table 14**, column 5, are calculated using **Equation 12**.

Eq. 12 $UEC_{cool\ vent} = UEC_{RAC\ vent} - UEC_{RGF\ vent}$

Where,

$UEC_{cool\ vent}$ = baseline cooling electric ventilation exclusive of heating (kWh/year),
$UEC_{RAC\ vent}$ = baseline electric ventilation for residential air conditioning including cooling and heating (i.e., furnace) from DEER 2008a (kWh/year), and
$UEC_{RGF\ vent}$ = baseline heating-only electric ventilation for residential gas furnace (RGF) excluding cooling from DEER 2008a (kWh/year).

The annual heating energy savings shown in **Table 1** for RAC are calculated using **Equation 13** and the baseline UEC values shown in **Table 14**.

Eq. 13 $ES_{EFC\ heat} = UEC_{RAC\ heat} \times \overline{S_{heat}}$

Where,

$ES_{EFC\ heat}$ = energy savings for the EFC measure for space heating (therm/year),
$UEC_{RAC\ heat}$ = baseline space heating from DEER 2008a (therm/year), and
$\overline{S_{heat}}$ = weighted average space heating energy savings associated with the EFC based on field and laboratory tests (%).

The annual net electric energy savings shown in **Table 1** are calculated using **Equation 14** and the baseline UEC values shown in **Table 14** for RAC and **Table 15** for RGF.

Eq. 14 $ES_{EFC\ cool} = [UEC_{RAC\ cool} \times \overline{S_{cool}}] + [UEC_{RAC\ vent} \times (\overline{S_{cool}} + \overline{S_{RAC vent}})] + [UEC_{RGF\ vent} \times \overline{S_{RGF vent}}]$

Where,

$ES_{EFC\ cool}$ = energy savings for the EFC measure for space cooling (kWh/year),
$UEC_{RAC\ cool}$ = baseline space cooling from DEER 2008a (kWh/year),
$\overline{S_{cool}}$ = weighted average space cooling electric energy savings associated with the EFC based on field and laboratory tests (%),
$\overline{S_{RAC vent}}$ = weighted average RAC ventilation savings associated with the EFC based on field and laboratory tests (%), and
$\overline{S_{RGF vent}}$ = weighted average RGF ventilation savings associated with the EFC based on field and laboratory tests (%).

The annual peak demand savings (PDS) shown in **Table 1** are calculated using **Equation 15** and the baseline Unit Peak Demand (UPD) values shown in **Table 14**.

Eq. 15 $PDS_{EFC} = DF \times \{[UPD_{RAC\ cool} \times \overline{S_{cool}}] + [UPD_{RAC\ vent} \times (\overline{S_{cool}} + \overline{S_{RAC vent}})]\}$

Where,

PDS_{EFC} = peak demand savings for the EFC measure (kW),
DF = diversity factor of 0.33 for space cooling assuming one-third of air conditioners are on at any given time during the peak period (dimensionless),
$UPD_{RAC\ cool}$ = baseline space cooling peak demand from DEER 2008a (kW), and
$UPD_{RAC\ vent}$ = baseline ventilation peak demand from DEER 2008a (kW).

Tables 18 and **19** provide baseline UEC data normalized per "Energy Common Units" (ECU), i.e., tons cooling capacity or kBtuh furnace capacity. ECU data are provided in **Tables 16** and **17**. These data can be used with **Equation 16** to calculate annual heating energy savings.

Eq. 16 $ES_{EFC\ heat} = UEC_{heat} \times \overline{S_{heat}} \times ECU$

Where,

ECU = Energy Common Unit per **Table 16** for RAC and **Table 17** for RGF.

The annual net electric energy savings are calculated using **Equation 17**, baseline UEC data per ECU in **Tables 18** and **19**, and ECU data in **Tables 16** and **17**.

Eq. 17 $$ES_{EFC\ cool} = \left\{[UEC_{cool} \times \overline{S_{cool}}] + [UEC_{vent} \times (\overline{S_{cool}} + \overline{S_{RAC\,vent}})] + [UEC_{vent} \times \overline{S_{RGF\,vent}}]\right\} \times ECU$$

The annual peak demand savings (PDS) are calculated using **Equation 18** and the baseline UEC data per ECU in **Tables 18** and **19**, and ECU data in **Tables 16** and **17**.

Eq. 18 $$PDS_{EFC} = \left\{DF \times \left\{[UPD_{RAC\ cool} \times \overline{S_{cool}}] + [UPD_{RAC\ vent} \times (\overline{S_{cool}} + \overline{S_{RAC\,vent}})]\right\}\right\} \times ECU$$

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DEER 2008a. DEER2008 unit energy consumption values are from the Measure Inspection and Summary viewer tool (MISer Version 1.10.25) and DEER (Version: DEER2008.2.2). See http://www.deeresources.com/.

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Workpaper_Verified_
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Work Paper SCG0077
Revision # 0

Verified, Inc.

California HVAC Upgrade: Efficient Fan Controller (EFC) – Residential

April 4, 2012

At a Glance Summary

Measure Name:	Efficient Fan Controller (EFC) - Residential
Savings Impacts Energy Common Units (ECU):	Household or tons for Residential Air Conditioner (RAC) or kBtuh for Residential Gas Furnace (RGF) space heating only
Customer Base Case Description:	The customer base case heating, ventilating, and air conditioning (HVAC) system has low-speed fan operation in heating mode. After the furnace turns off the fan continues to operate for a fixed time delay of 90 seconds or the fan continues to operate based on a temperature delay which turns off the fan when the plenum temperature falls below a control threshold of 100 to 200°F depending on whether or not the temperature delay sensor is operating or set properly. In cooling mode the fan turns off when the compressor turns off (i.e., no time delay). Some customer base case systems (less than 8%) continue to operate the fan for a fixed time delay of 90 seconds after the compressor turns off.
Code Base Case Description:	The code base case description is the same as the customer base case description (above).
Costs Common Units:	Household or tons for RAC, or kBtuh for RGF
Measure Equipment Cost ($/unit):	25
Measure Incremental Cost ($/unit):	75 (SFM, MFM, and DMO)
Measure Installed Cost ($/unit):	75 (SFM, MFM, and DMO)
Measure Load Shape:	26 = Res. Central Air Conditioning
Effective Useful Life (years):	10
Program Type:	Retrofit
TOU AC Adjustment:	100%
Net-to-Gross Ratios:	1.00
Important Comments:	DEER Vintage Weighting

E3 Calculator Data – EFC for Residential Air Conditioner (RAC) Cooling and Heating

DEER 2008 ImpactID	Measure Description	Building Type	Building Vintage	Climate Zone	Above Code Annual Electric Savings (kWh/unit)	Above Code Peak Electric Demand Reduction (kW/unit)	Above Code Annual Savings (Therms /unit)	Incremental Measure Cost ($/unit)	Effective Useful Life (years)	Net to Gross Ratio	Total Resource Cost (TRC) Test
SFM-w04-vSGx-hAC-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	4	56.14	0.13	30.94	75	10	1	4.79
SFM-w05-vSGx-hAC-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	5	-7.50	0.07	38.83	75	10	1	4.22
SFM-w06-vSGx-hAC-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	6	84.13	0.10	22.13	75	10	1	4.15
SFM-w07-vSGx-hAC-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	7	75.14	0.11	15.67	75	10	1	3.40
SFM-w08-vSGx-hAC-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	8	129.02	0.14	19.15	75	10	1	4.78
SFM-w09-vSGx-hAC-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	9	171.38	0.17	22.94	75	10	1	6.02
SFM-w10-vSGx-hAC-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	10	149.18	0.15	25.24	75	10	1	5.79
SFM-w13-vSGx-hAC-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	13	208.14	0.17	31.78	75	10	1	7.52
SFM-w14-vSGx-hAC-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	14	290.13	0.20	33.16	75	10	1	9.16
SFM-w15-vSCx-hAC-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	15	542.52	0.20	13.12	75	10	1	11.16
SFM-w16-vSGx-hAC-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	16	45.67	0.14	73.54	75	10	1	9.02
SFM-wSCG-vEx-hAC-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	SCG Weighted	158.31	0.15	24.42	75	10	1	5.85
MFM-w04-vSGx-hAC-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	4	18.08	0.06	12.42	75	10	1	1.90
MFM-w05-vSGx-hAC-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	5	-3.46	0.04	16.05	75	10	1	1.82
MFM-w06-vSGx-hAC-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	6	23.13	0.06	7.55	75	10	1	1.48
MFM-w07-vSGx-hAC-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	7	19.79	0.06	6.01	75	10	1	1.26
MFM-w08-vSGx-hAC-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	8	50.65	0.07	6.97	75	10	1	1.93
MFM-w09-vSGx-hAC-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	9	101.03	0.10	9.99	75	10	1	3.19
MFM-w10-vSGx-hAC-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	10	76.85	0.09	11.17	75	10	1	2.87
MFM-w13-vSGx-hAC-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	13	119.13	0.10	13.62	75	10	1	3.84
MFM-w14-vSGx-hAC-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	14	195.83	0.13	18.09	75	10	1	5.71
MFM-w15-vSGx-hAC-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	15	344.33	0.14	6.59	75	10	1	6.99
MFM-w16-vSGx-hAC-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	16	38.44	0.09	28.79	75	10	1	4.03
MFM-wSCG-vEx-hAC-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	SCG Weighted	92.24	0.09	9.43	75	10	1	2.93
DMO-w04-vSGx-hAC-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	4	362.96	0.22	30.60	75	10	1	10.15
DMO-w05-vSGx-hAC-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	5	107.56	0.14	39.78	75	10	1	6.55
DMO-w06-vSGx-hAC-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	6	265.75	0.13	17.34	75	10	1	6.76
DMO-w07-vSCx-hAC-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	7	236.33	0.16	14.58	75	10	1	6.13
DMO-w08-vSGx-hAC-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	8	511.41	0.23	21.16	75	10	1	11.64
DMO-w09-vSGx-hAC-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	9	408.21	0.24	20.03	75	10	1	9.92
DMO-w10-vSGx-hAC-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	10	507.25	0.25	22.25	75	10	1	11.83
DMO-w13-vSGx-hAC-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	13	502.77	0.27	30.33	75	10	1	12.67
DMO-w14-vSGx-hAC-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	14	688.20	0.32	39.97	75	10	1	16.90
DMO-w15-vSGx-hAC-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	15	962.20	0.33	18.63	75	10	1	19.16
DMO-w16-vSGx-hAC-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	16	108.69	0.14	53.45	75	10	1	7.99
DMO-wSCG-vEx-hAC-tWt-bCAv-eMsr-	EFC	DMO	SCG Weighted	SCG Weighted	512.82	0.25	22.97	75	10	1	11.92

See **Section 1.5** for baseline unit energy consumption (UEC) values.

E3 Calculator Data – EFC for Residential Gas Furnace (RGF) Space Heating Only

DEER 2008 ImpactID	Measure Description	Building Type	Building Vintage	Climate Zone	Above Code Annual Electric Savings (kWh/unit)	Above Code Peak Electric Demand Reduction (kW/unit)	Above Code Annual Savings (Therms /unit)	Incremental Measure Cost ($/unit)	Effective Useful Life (years)	Net to Gross Ratio	Total Resource Cost (TRC) Test
SFM-w04-vSGx-hGF-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	4	-12.04	0.00	27.02	75	10	1.0	2.56
SFM-w05-vSGx-hGF-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	5	-17.75	0.00	40.17	75	10	1.0	3.82
SFM-w06-vSGx-hGF-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	6	-8.42	0.00	20.01	75	10	1.0	1.91
SFM-w07-vSGx-hGF-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	7	-6.51	0.00	14.83	75	10	1.0	1.41
SFM-w08-vSGx-hGF-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	8	-7.67	0.00	17.73	75	10	1.0	1.69
SFM-w09-vSGx-hGF-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	9	-9.15	0.00	21.63	75	10	1.0	2.06
SFM-w10-vSGx-hGF-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	10	-10.14	0.00	23.64	75	10	1.0	2.25
SFM-w13-vSGx-hGF-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	13	-13.28	0.00	30.22	75	10	1.0	2.87
SFM-w14-vSGx-hGF-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	14	-14.71	0.00	33.72	75	10	1.0	3.21
SFM-w15-vSGx-hGF-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	15	-5.96	0.00	14.63	75	10	1.0	1.40
SFM-w16-vSGx-hGF-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	16	-33.94	0.00	71.57	75	10	1.0	6.76
SFM-wSCG-vEx-hGF-tWt-bCAv-eMsr	EFC	SFM	SCG Weighted	SCG Weighted	-9.31	0.00	21.65	75	10	1.0	2.06
MFM-w04-vSGx-hGF-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	4	-5.66	0.00	12.65	75	10	1.0	1.20
MFM-w05-vSGx-hGF-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	5	-5.66	0.00	12.74	75	10	1.0	1.21
MFM-w06-vSGx-hGF-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	6	-3.29	0.00	7.78	75	10	1.0	0.74
MFM-w07-vSGx-hGF-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	7	-2.61	0.00	6.05	75	10	1.0	0.58
MFM-w08-vSGx-hGF-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	8	-2.94	0.00	6.70	75	10	1.0	0.64
MFM-w09-vSGx-hGF-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	9	-3.56	0.00	8.23	75	10	1.0	0.78
MFM-w10-vSGx-hGF-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	10	-4.59	0.00	10.35	75	10	1.0	0.98
MFM-w13-vSGx-hGF-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	13	-6.24	0.00	13.83	75	10	1.0	1.31
MFM-w14-vSGx-hGF-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	14	-10.26	0.00	18.37	75	10	1.0	1.71
MFM-w15-vSGx-hGF-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	15	-2.18	0.00	4.97	75	10	1.0	0.47
MFM-w16-vSGx-hGF-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	16	-11.42	0.00	24.47	75	10	1.0	2.31
MFM-wSCG-vEx-hGF-tWt-bCAv-eMsr	EFC	MFM	SCG Weighted	SCG Weighted	-3.38	0.00	7.83	75	10	1.0	0.74
DMO-w04-vSGx-hGF-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	4	-10.02	0.00	23.52	75	10	1.0	2.24
DMO-w05-vSGx-hGF-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	5	-13.98	0.00	32.71	75	10	1.0	3.11
DMO-w06-vSGx-hGF-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	6	-6.04	0.00	14.87	75	10	1.0	1.42
DMO-w07-vSCx-hGF-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	7	-5.67	0.00	13.89	75	10	1.0	1.33
DMO-w08-vSGx-hGF-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	8	-7.07	0.00	16.80	75	10	1.0	1.60
DMO-w09-vSGx-hGF-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	9	-9.82	0.00	23.24	75	10	1.0	2.21
DMO-w10-vSGx-hGF-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	10	-10.90	0.00	25.01	75	10	1.0	2.38
DMO-w13-vSGx-hGF-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	13	-14.34	0.00	32.05	75	10	1.0	3.04
DMO-w14-vSGx-hGF-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	14	-18.74	0.00	40.97	75	10	1.0	3.88
DMO-w15-vSGx-hGF-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	15	-18.93	0.00	19.09	75	10	1.0	1.65
DMO-w16-vSGx-hGF-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	16	-29.53	0.00	64.49	75	10	1.0	6.11
DMO-wSCG-vEx-hGF-tWt-bCAv-eMsr	EFC	DMO	SCG Weighted	SCG Weighted	-30.00	0.00	27.71	75	10	1.0	2.35

Document Revision History

Revision 0	**Date April 4, 2012**	**Original Submittal.** Applicable to all residential heating, ventilation, and air conditioning (HVAC) equipment. Savings are based on DEER 2008 Unit Energy Consumption by building type and climate zone and Energy Common Units (ECU) per household, per ton (RCA) or per kBtuh (RGF).

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Section 1. General Measure & Baseline Data

1.1 Measure Description & Background

This work paper provides engineering estimates of savings for upgrading Heating, Ventilating, and Air Conditioning (HVAC) equipment with an Efficient Fan Controller (EFC) to recover additional heating and cooling capacity and operate HVAC equipment at higher efficiency. The savings documented here are for the installation of a patent pending EFC that adjusts fan operation for heating based on gas valve activation time (which is a proxy for furnace operation), and fan operation for cooling based on fan run time (which is a proxy for compressor operation). The amount of time the fan operates after the furnace is off or after the compressor is off varies with the amount of time the furnace or compressor are on. The furnace run time indicates how much heat is stored in the heat exchanger. The air conditioner fan run time indicates how much cold water is condensed on the evaporator coil. Most furnaces fans operate at low speed and this reduces airflow and heating efficiency. The EFC provides high speed fan operation in heating mode to increase heating efficiency and reduce furnace run time.[1] This measure applies to HVAC systems that have a fan off time delay of less than 2 minutes in heating or cooling operation. The measure applies to standard and high efficiency furnaces and heat pumps in heating mode and air conditioners with furnaces in cooling and heating mode. The savings estimates assume a baseline temperature delay or 90 second fan time delay on heating and no time delay on cooling. Some units have a 60 to 90 second time delay on cooling. With these units the savings will be slightly lower compared to units with no existing time delay. If an HVAC unit includes a high efficiency fan motor, the savings will be higher due to lower power consumption of the fan motor. Savings for combined measures are discussed in **Table 10**.

Conventional fan controllers typically operate the ventilation fan for 0 to 90 seconds after the furnace or compressor turn off and this wastes heating and cooling energy that is not delivered to the conditioned space. The EFC recovers and delivers more heating and cooling energy to the conditioned space than is possible with conventional fan controllers. The EFC improves the efficiency of HVAC equipment by delivering additional heating or cooling capacity for a small amount of additional electric energy (kWh).

Air conditioners cool conditioned spaces by removing sensible and latent heat from the return air which reduces the supply air temperature and humidity. Latent heat is removed as water vapor is condensed out of the air due to the temperature of the evaporator coil being less than the return air dew point temperature.[2] Most evaporators are cold and wet (below 40 to 50°F) after the compressor turns off. Cooling energy left on the evaporator coil after the compressor turns off is generally wasted. The evaporator absorbs heat from the attic and cold water on the coil flows

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[1] Some newer heating systems with standard 90-second time delay do not allow high speed fan operation without switching the fan control jumper.

[2] Latent heat is the quantity of heat absorbed or released by air undergoing a change of state, such as water vapor condensing out of the air as water onto a cold evaporator coil or cold water evaporating to water vapor which will cool the air.

down the condensate drain. The EFC recovers the remaining cooling energy from evaporator coil by operating the fan after the compressor turns off to cool the conditioned space.

Most furnaces fans operate at low speed and this reduces airflow and heating efficiency. The EFC provides high speed fan operation in heating mode to increase heating efficiency and reduce furnace run time. Most furnace heat exchangers are still hot (above 135 to 210°F) after the furnace fan turns off. The EFC recovers the remaining heat energy from the hot furnace heat exchanger after the furnace turns off and delivers this heat to the conditioned space.

The EFC is a small low-voltage microprocessor controller approximately the size of a US penny. The EFC connects to the existing thermostat wires and is mounted in one of three positions: 1) behind the thermostat mounting plate, 2) between the thermostat and the thermostat mounting plate (with sufficient clearance), or 3) in a hole behind thermostat mounting plate where thermostat wires attach to thermostat.

This measure is cross cutting for use the residential market sector and available for use in the commercial sector.

The values used to forecast the measure's impacts are as follows:

- Incremental Measure Cost: $75 per air conditioner,
- Annual Energy Savings: See **Table 1** and **Table 2**,
- Demand Reduction: See **Table 1** and **Table 2**,
- Effective Useful Life: 10 years, and
- Net to Gross Ratio: 1.0 (Comprehensive Space Conditioning).

1.2 DEER Differences Analysis

The Database for Energy Efficiency Resources (DEER 2008) does not provide energy savings for the Efficient Fan Controller (EFC) measure. The cooling, heating, and ventilation Unit Energy Consumption (UEC) values for residential air conditioners (RAC) and residential gas furnaces (RGF) are based on the DEER2008 UEC values from the Measure Inspection and Summary viewer tool (MISer Version 1.10.25) and DEER (Version: DEER2008.2.2). See http://www.deeresources.com/. UEC values and DEER 2008 ImpactIDs listed in **Section 1.5** are in the embedded Excel Workbook #1 (see References Section). The DEER annual cooling and heating energy consumption are average values assuming no degradation due to excessive duct leakage, improper refrigerant charge and airflow, restrictions, non condensables, or blocked condenser coils. If the unit efficiency is degraded, the UEC will increase and this will increase the energy savings (therms, kWh and kW) beyond the estimates provided in this work paper. The annual natural gas savings (therm/yr) are based on weighted average savings of 11% (see **Table 12**). The annual electricity energy savings (kWh/yr) are based on 14.8% weighted average cooling savings and include the impact of increased ventilation energy use of 13.8% for space heating ventilation and -36.2% for space cooling ventilation.

EFC Energy and demand savings for residential air conditioning (RAC - space cooling and heating) are shown in **Table 1**. Data are based on analysis in **Section 1.4** provided in the embedded Excel workbooks #1 and #2 in the References Section.

Table 1. EFC Energy and Demand Savings Impacts by Building Type – RAC

Building Type	Climate Zone	Vintage	Net Elec Savings (kWh/yr)	Elec Demand Savings (kW)	Annual Gas Savings (therm/yr)
Single Family	4	SCG Weighted	56.14	0.13	30.94
Single Family	5	SCG Weighted	-7.50	0.07	38.83
Single Family	6	SCG Weighted	84.13	0.10	22.13
Single Family	7	SCG Weighted	75.14	0.11	15.67
Single Family	8	SCG Weighted	129.02	0.14	19.15
Single Family	9	SCG Weighted	171.38	0.17	22.94
Single Family	10	SCG Weighted	149.18	0.15	25.24
Single Family	13	SCG Weighted	208.14	0.17	31.78
Single Family	14	SCG Weighted	290.13	0.20	33.16
Single Family	15	SCG Weighted	542.52	0.20	13.12
Single Family	16	SCG Weighted	45.67	0.14	73.54
Single Family	SCG Weighted	SCG Weighted	158.31	0.15	24.42
Multi Family	4	SCG Weighted	18.08	0.06	12.42
Multi Family	5	SCG Weighted	-3.46	0.04	16.05
Multi Family	6	SCG Weighted	23.13	0.06	7.55
Multi Family	7	SCG Weighted	19.79	0.06	6.01
Multi Family	8	SCG Weighted	50.65	0.07	6.97
Multi Family	9	SCG Weighted	101.03	0.10	9.99
Multi Family	10	SCG Weighted	76.85	0.09	11.17
Multi Family	13	SCG Weighted	119.13	0.10	13.62
Multi Family	14	SCG Weighted	195.83	0.13	18.09
Multi Family	15	SCG Weighted	344.33	0.14	6.59
Multi Family	16	SCG Weighted	38.44	0.09	28.79
Multi Family	SCG Weighted	SCG Weighted	92.24	0.09	9.43
Mobile Home	4	SCG Weighted	362.96	0.22	30.60
Mobile Home	5	SCG Weighted	107.56	0.14	39.78
Mobile Home	6	SCG Weighted	265.75	0.13	17.34
Mobile Home	7	SCG Weighted	236.33	0.16	14.58
Mobile Home	8	SCG Weighted	511.41	0.23	21.16
Mobile Home	9	SCG Weighted	408.21	0.24	20.03
Mobile Home	10	SCG Weighted	507.25	0.25	22.25
Mobile Home	13	SCG Weighted	502.77	0.27	30.33
Mobile Home	14	SCG Weighted	688.20	0.32	39.97
Mobile Home	15	SCG Weighted	962.20	0.33	18.63
Mobile Home	16	SCG Weighted	108.69	0.14	53.45
Mobile Home	SCG Weighted	SCG Weighted	512.82	0.25	22.97

EFC Energy and demand savings for residential gas furnace (RGF - space heating only) are shown in **Table 2**. Data are based on analysis in **Section 1.4** provided in the embedded Excel workbooks #1 and #2 in the References Section.

Table 2. EFC Energy and Demand Savings Impacts by Building Type – RGF

Building Type	Climate Zone	Vintage	Net Elec Savings (kWh/yr)	Elec Demand Savings (kW)	Annual Gas Savings (therm/yr)
Single Family	4	SCG Weighted	-12.04	0.00	27.02
Single Family	5	SCG Weighted	-17.75	0.00	40.17
Single Family	6	SCG Weighted	-8.42	0.00	20.01
Single Family	7	SCG Weighted	-6.51	0.00	14.83
Single Family	8	SCG Weighted	-7.67	0.00	17.73
Single Family	9	SCG Weighted	-9.15	0.00	21.63
Single Family	10	SCG Weighted	-10.14	0.00	23.64
Single Family	13	SCG Weighted	-13.28	0.00	30.22
Single Family	14	SCG Weighted	-14.71	0.00	33.72
Single Family	15	SCG Weighted	-5.96	0.00	14.63
Single Family	16	SCG Weighted	-33.94	0.00	71.57
Single Family	SCG Weighted	SCG Weighted	-9.31	0.00	21.65
Multi Family	4	SCG Weighted	-5.66	0.00	12.65
Multi Family	5	SCG Weighted	-5.66	0.00	12.74
Multi Family	6	SCG Weighted	-3.29	0.00	7.78
Multi Family	7	SCG Weighted	-2.61	0.00	6.05
Multi Family	8	SCG Weighted	-2.94	0.00	6.70
Multi Family	9	SCG Weighted	-3.56	0.00	8.23
Multi Family	10	SCG Weighted	-4.59	0.00	10.35
Multi Family	13	SCG Weighted	-6.24	0.00	13.83
Multi Family	14	SCG Weighted	-10.26	0.00	18.37
Multi Family	15	SCG Weighted	-2.18	0.00	4.97
Multi Family	16	SCG Weighted	-11.42	0.00	24.47
Multi Family	SCG Weighted	SCG Weighted	-3.38	0.00	7.83
Mobile Home	4	SCG Weighted	-10.02	0.00	23.52
Mobile Home	5	SCG Weighted	-13.98	0.00	32.71
Mobile Home	6	SCG Weighted	-6.04	0.00	14.87
Mobile Home	7	SCG Weighted	-5.67	0.00	13.89
Mobile Home	8	SCG Weighted	-7.07	0.00	16.80
Mobile Home	9	SCG Weighted	-9.82	0.00	23.24
Mobile Home	10	SCG Weighted	-10.90	0.00	25.01
Mobile Home	13	SCG Weighted	-14.34	0.00	32.05
Mobile Home	14	SCG Weighted	-18.74	0.00	40.97
Mobile Home	15	SCG Weighted	-18.93	0.00	19.09
Mobile Home	16	SCG Weighted	-29.53	0.00	64.49
Mobile Home	SCG Weighted	SCG Weighted	-30.00	0.00	27.71

1.3 Codes & Standards Requirements Analysis

There is no code or standard addressing the EFC. The measure can be retrofit to any RAC with gas furnace or heat pump having a thermostat with less than 2-minute time delay for cooling or heating or standard temperature delay for heating. The measure can also be retrofit to any RGF thermostat with less than 2-minute time delay or standard temperature delay for heating.

1.4 EM&V, Market Potential, and Other Studies

The forecast values were derived from these sources:

- Incremental (Full) Measure Cost is based on what HVAC Contractors charge for the materials, labor, and overhead to install the Efficient Fan Controller.
- Annual Energy Savings is based on the Percentage Energy Savings times the Baseline Electrical Usage as described in **Section 1.4.5** (Estimated Energy Savings).

- Percentage Energy Savings are based on Field and Laboratory Tests as described in **Section 1.4.3** (Field Test Data) and **Section 1.4.4** (Laboratory Test Data).

1.4.1 Abstract

The EFC improves on the conventional temperature or time delay relay (TDR) which will continue to operate the fan after the furnace or compressor turns off. In heating mode, the EFC micro-computer monitors gas valve activation time and determines whether or not to continue operating the fan after the furnace turns on and how long the fan should continue operating to maximize heat recovery from the heat exchanger. In cooling mode the EFC monitors fan operation and determines whether or not to continue operating the fan after the compressor turns off to transfer heat to the cold evaporator coil and recover energy stored in the form of condensed cold water on the evaporator coil to further cool the building. In cooling mode the EFC uses the evaporator coil as an evaporative cooler. The fan uses 8 to 15 times less power than the compressor and is adaptively controlled to operate based on fan run time (which is a proxy for compressor operation). Air conditioning equipment manufacturers provide an optional 1.5 minute TDR kit to improve SEER by 2 to 3%. Furnace manufacturers provide either a 1.5 minute fan time delay or a temperature delay that extends fan operation from 1 to 4 minutes by shutting off the fan when the supply air is less than 110°F. The standard furnace TDR improves AFUE by 2 to 3%. The delivered furnace efficiency improvements from EFC are shown in **Figure 1**. The EFC maximizes heating efficiency by increasing fan speed from low to high four minutes after the furnace is turned on. Standard furnace fans operate at low speed delivering less heating capacity to the conditioned space at lower efficiency compared to operating the fan at high speed. The EFC maximizes heat recovery from the heat exchanger after the furnace is turned off with an extended fan delay of 2 to 4 minutes depending on how long the furnace gas valve signal is on during the heating cycle. The EFC improves heating efficiency by 7 to 10% above standard temperature delay and 6 to 8% above standard 90-second delay. For systems with degraded temperature sensors the EFC saves 7 to 23% depending on furnace run time and ambient conditions. Savings will be greater for furnaces with degraded temperature delay. The delivered air conditioner sensible energy efficiency ratio (EER*) improvements from EFC are shown in **Figure 2**. Standard air conditioners have a 0 to 1.5 minute fan time delay. The EFC maximizes recovery of latent cooling from the evaporator after the compressor is turned off with an extended fan delay of 1.5 to 5 minutes depending on how long the air conditioner compressor is on during the cooling cycle.

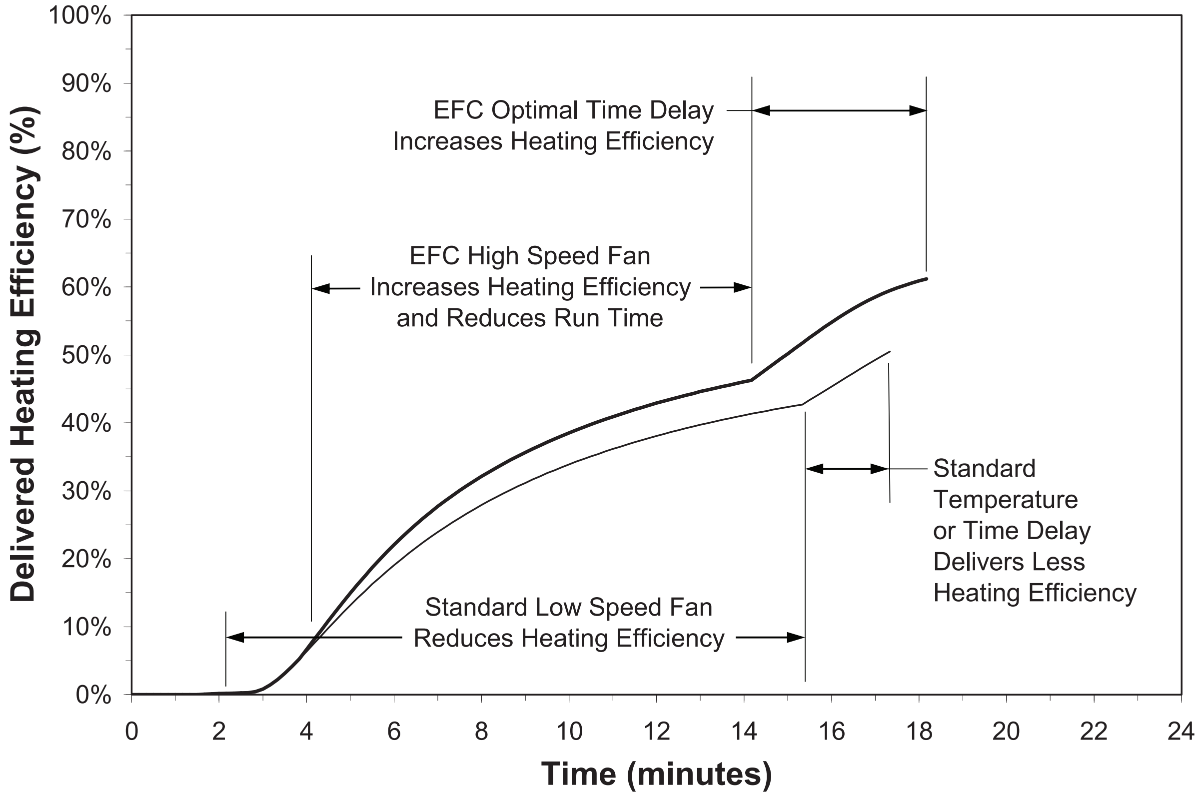

Figure 1. Heating Efficiency Improvement from EFC

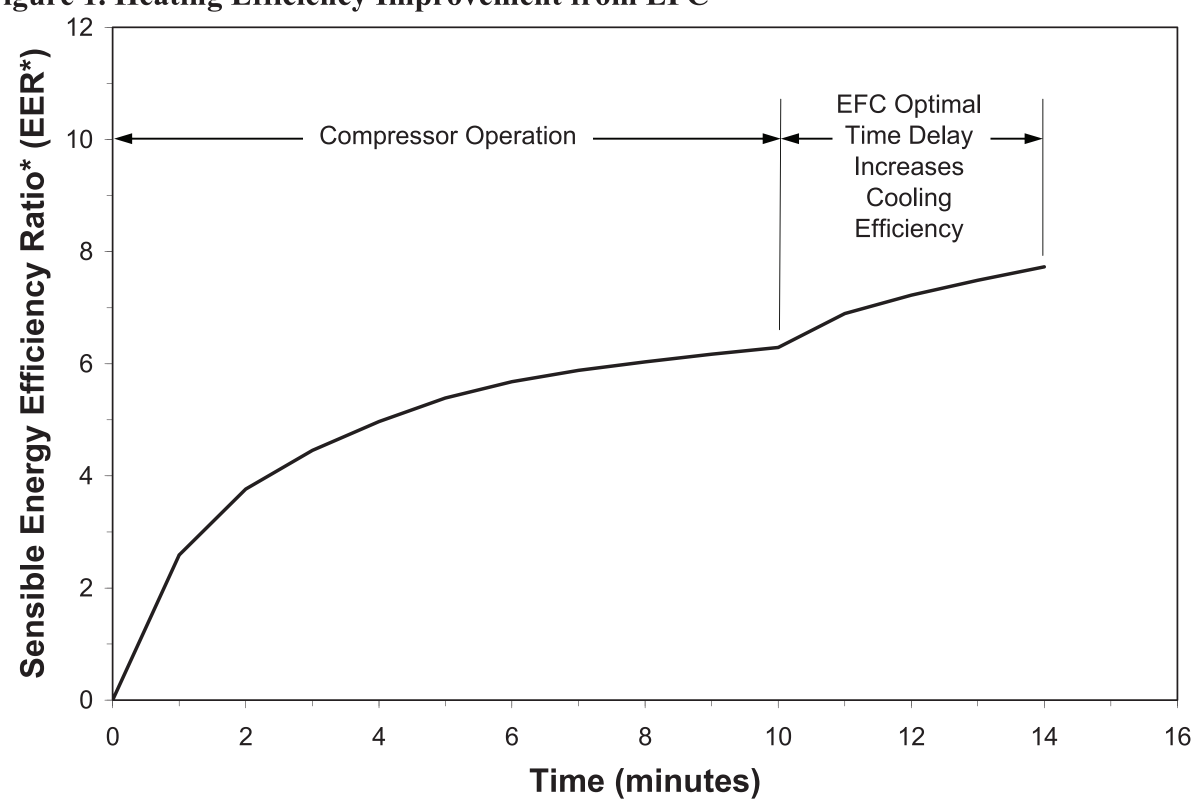

Figure 2. Air Conditioner Sensible EER* Improvement from EFC

The SEER cycling test is performed with a dry evaporator coil. In California the air conditioner condenses moisture from the air onto the cold evaporator coil. The EFC intelligently optimizes the fan operation after the compressor turns off to improve the EER and SEER. Many new air conditioning systems are installed without the standard manufacturer TDR due to market barriers (i.e., information, availability, or organizational practices) or the evaporator and condenser are replaced without replacing the furnace forced air unit (FAU).

Most furnaces operate at low fan speed with a time or temperature delay relay that stops the fan with heat left in the heat exchanger at temperatures between 100°F and 200°F. Most air conditioners do not have a fan time delay. Therefore, the EFC is applicable to all existing and new HVAC systems.

EFC units were installed at homes in California and Nevada to evaluate consumer satisfaction. Survey respondents indicated that the EFC provides more comfortable heating with an overall rating of 7.5 ± 0.18 out of 10 points. One hundred percent of survey respondents indicated that the EFC saves energy. Survey respondents indicate high satisfaction with an overall rating of 10 out of 10 points.

1.4.2 Baseline

The baseline furnace and air conditioner characteristics are provided in **Table 3**. For heating the baseline is either temperature controlled, degraded temperature controlled, or time controlled delay on the furnace fan. The estimated market share for heating system controls is as follows: 35% for properly working temperature delay, 35% for degraded temperature delay, and 30% for time delay.[3] For cooling the baseline is either no time delay or time delay of 90 seconds. The estimated market share for cooling systems with no time delay is 90% and the estimated market share for cooling systems with 90-second time delay is 10%. Furnaces having temperature delay controllers typically turn on the furnace fan at supply plenum temperatures ranging from 135 to 160°F and turn off the furnace fan at supply plenum temperatures ranging from 100 to 110°F (Carrier 1973). Over time the bi-metal temperature sensor accuracy and performance degrades and the sensors will drift up by approximately 30 to 60°F. This causes the standard temperature delay controller to not turn on the furnace fan until the plenum temperature is 140 to 160°F which can take more than 4 minutes. When the furnace turns off the degraded sensor will cause the controller to turn off the furnace fan with supply plenum temperatures still at or above 120 to 210°F. This will typically occur within 40 to 90 seconds instead of 180 to 240 seconds. Degraded bi-metal temperature sensors leave a significant amount of heat stranded in the heat exchanger (i.e., 15 to 25%). For systems with degraded bi-metal sensors the EFC can save 15 to 65% depending on furnace run time and ambient conditions. Newer heating systems are sold with adjustable time delay controllers with factory settings of 90 to 120 seconds (Carrier 2006, Lennox 1998, Lennox 1998a, Trane 2009, Rheem 2005). The 90 second time delay will turn off

[3] Most HVAC manufacturers introduced heating time delay controls with 90-second factory settings in the early 1980s. New furnaces currently sold are manufactured with 90-second time delays. Furnaces systems more than 20 years old typically have temperature delays. Approximately 50% of the older systems have degraded temperature delays due to dirt build-up or excessive supply plenum temperatures which cause the delays to drift upward by approximately 30°F to 40°F.

the furnace with supply plenum temperatures still at or above 110 to 120°F. Some newer air conditioners can have an optional time delay relay kit installed with factory settings of 90 seconds (Carrier 2006a, Carrier 2010). Most existing and new air conditioners do not have a cooling fan time delay. Therefore, the EFC is applicable to all existing and new HVAC systems. For heating, the EFC will correct for improperly operating temperature delays with degraded bi-metal temperature sensors with less material and labor cost than would be required to replace degraded temperature sensors and controllers. Increasing the heating fan speed from low and high will increase power use by approximately 18 to 21% (60 to 150W) for permanent split capacitance (PSC) motors depending on the size of the fan motor and total system static pressure. PSC blower motors that are worn out will use more power in high speed due to increased bearing friction. Worn out PSC blower motors should be replaced.

Table 3. Pre-Existing Baseline and Measure Characteristics

Pre-Existing Description	Measure Description	Estimated Market Share
Heating properly working Temperature Delay at 100 to 110°F, PSC motor	EFC High Speed Fan plus Variable Time Delay (2 to 4 minutes)	35%
Heating degraded Temperature Delay at 130 to 200°F, PSC motor	EFC High Speed Fan plus Variable Time Delay (2 to 4 minutes)	35%
Heating 90 second Time Delay, PSC motor	Variable Time Delay (2 to 4 minutes)	30%
Cooling No Time Delay, PSC Motor	Variable Time Delay (1.5 to 5 minutes)	90%
Cooling 90 second Time Delay, PSC Motor	Variable Time Delay (1.5 to 5 minutes)	5%
Cooling No Time Delay, Efficient Motor	Variable Time Delay (1.5 to 5 minutes)	3%
Cooling 90 second Time Delay, Efficient Motor	Variable Time Delay (1.5 to 5 minutes)	2%

1.4.3 Field Test Data

Field measurements and equipment accuracy are provided in **Table 4**.

Table 4. Field Measurements, Measurement Equipment, and Accuracy

Field Measurement	Measurement Equipment	Measurement Accuracy
Relative humidity (%) and temperature in degrees Fahrenheit (°F) of return and supply, thermostat, and outdoor condenser entering air	Platinum Resistance Pt100 1/3 Class B 6-channel humidity and temperature data loggers.	Temperature: 0.1°C or 0.18°F RH: ± 0.5 RH at 23°C and 10, 20, 30, 40, 50, 60, 70, 80, 90 % RH
Airflow in cubic feet per minute (cfm) across air conditioner evaporator coil	Digital pressure gauge and fan-powered flow hood, flow meter pitot tube array, and electronic balometer	Fan-powered flowhood: ± 3% Flow meter pitot tube array: ± 7% Electronic balometer: ± 4%
Total power in kilowatts (kW) of air conditioner compressor and fans	True RMS 4-channel power data loggers and 4-channel power analyzer	Data loggers, CTs, PTs: ± 1% Power analyzer: ± 1%
Total gas energy use (Btu) of furnace	Natural gas utility diaphragm flow meter	± 1% of reading
Combustion efficiency, CO	Digital combustion analyzer	Combustion efficiency: ±0.1% CO: ± 5%, O2: ±0.3%

Return and supply temperatures were measured inside the return and supply ducts either in the plenums or near the plenums. Temperature and power were measured at intervals of 10 to 60 seconds. Airflow was measured before and after making any changes to the supply/return ducts, opening vents, or installing new air filters that would affect airflow. Return and supply enthalpies were derived from the temperature measurements using standard psychrometric algorithms (REFPROP 2010). The "application" EER* is calculated from the combination of enthalpy, airflow, and power measurements. Measurements of air conditioner performance were made continuously.

The heating or cooling capacity of the HVAC system is measured as the rate of delivered heating or cooling energy per measurement interval (i.e., English units of British thermal units per hour).[4] Heating of air occurs in the heat exchanger of the furnace or heat pump. Cooling occurs in the evaporator coil of the air conditioner. The heating capacity or energy is based on the measured airflow rate, specific volume, and sensible temperature difference across the return and supply plenums. **Equation 1** provides the calculation of sensible heating energy delivered to the conditioned space by the HVAC system.

Eq. 1 $$Q_{hs} = \frac{cfm \times 60}{v} \times c_v \times (T_r - T_s)$$

Where,

Q_{hs} = sensible heating energy delivered to the conditioned space over the measurement interval (i.e., Btu/hr),
cfm = airflow rate in cubic feet per minute (cfm),
v = specific volume per pound of dry air (ft^3/lbm),
c_v = specific heat of dry air = 0.24 Btu/lbm-°F,
T_r = dry bulb temperature of return air in plenum entering the heat exchanger (°F), and
T_s = dry bulb temperature of supply air in plenum leaving the heat exchanger (°F).

The cooling capacity is based on the measured airflow rate, specific volume, and enthalpy difference across the return and supply plenums. **Equation 2** provides the calculation of total cooling energy removed from the air by the HVAC system.

Eq. 2 $$Q_c = \frac{cfm \times 60}{v} \times (h_r - h_s)$$

Where,

Q_c = cooling energy removed from the air by the HVAC system over the measurement interval (Btu/hr),
h_r = enthalpy of return air entering the evaporator coil (i.e., Btu/lbm), and
h_s = enthalpy of supply air leaving the evaporator coil (i.e., Btu/lbm).

[4] The British Thermal Unit (Btu) is the unit of heat required to raise the temperature of one pound of water one degree Fahrenheit (°F). The Btu is equivalent to 1055.06 joules or 251.997 calories.

Laboratory and field test data show that standard fan delays are insufficient to harvest available cooling stored in the evaporator and that medium fan speed and standard fan delays are insufficient to harvest available heating stored in the heat exchanger. The combustion efficiency, EFC efficiency, and standard temperature delay efficiency are illustrated in **Figure 3** and **Table 5** for an 80 AFUE gas furnace. **Equation 3** shows how the heating efficiency is calculated.

Eq. 3 $$\eta = \sum_{i=0}^{t} \frac{Q_{hs\,i}}{Q_{hf\,i}}$$

Where,

η = heating efficiency (ratio or %),

i = measurement interval for which data is collected ranging from 10 to 60 seconds,

t = total number of measurement intervals for the test,

$Q_{hs\,i}$ = sensible heating energy delivered to the conditioned space per measurement interval (Btu/hr), and

$Q_{hf\,i}$ = heating energy fuel input per measurement interval (Btu/hr).

The heating energy savings (S_{heat}) based on the heating efficiency improvement are calculated using **Equation 4**.

Eq. 4 $$S_{heat} = \eta_{EFC} - \eta_{Base}$$

Where,

S_{heat} = heating energy savings for the EFC (ratio or %),

η_{EFC} = delivered heating efficiency of the EFC with high speed fan and/or optimal time delay from 2 to 4 minutes (ratio or %), and

η_{Base} = delivered heating efficiency of the base case thermostat with temperature delay, 90-second time delay, or degraded temperature delay (ratio or %).

The rated furnace efficiency, EFC plus high speed fan (HSF) efficiency, and standard temperature delay efficiency for an 80% AFUE gas furnace is shown in **Figure 3** and **Table 5**. The furnace is turned on when the thermostat temperature is below 65°F and turned off when the thermostat temperature is above 68°F. The low speed fan requires 14.8 minutes of furnace operation to increase the thermostat temperature to above 68°F, and the baseline working temperature delay provides 4.2 minutes of additional fan operation and supply plenum fan off temperature of 99.4°F. The EFC provides high speed fan operation 4 minutes after the furnace is turned on and this increases furnace efficiency by 5.9% and reduces furnace operation by 1.1 minutes or 7.9%. The EFC provides a 4 minute time delay with high speed fan recovering slightly more energy than the standard temperature delay with fan off supply plenum temperature of 98.3°F and increased off cycle of 1%. The EFC saves 7.9% of gas heating energy and -4.6% of heating fan ventilation energy. High speed fan power is 722W or 17.8% greater than low speed fan power which is 613W.

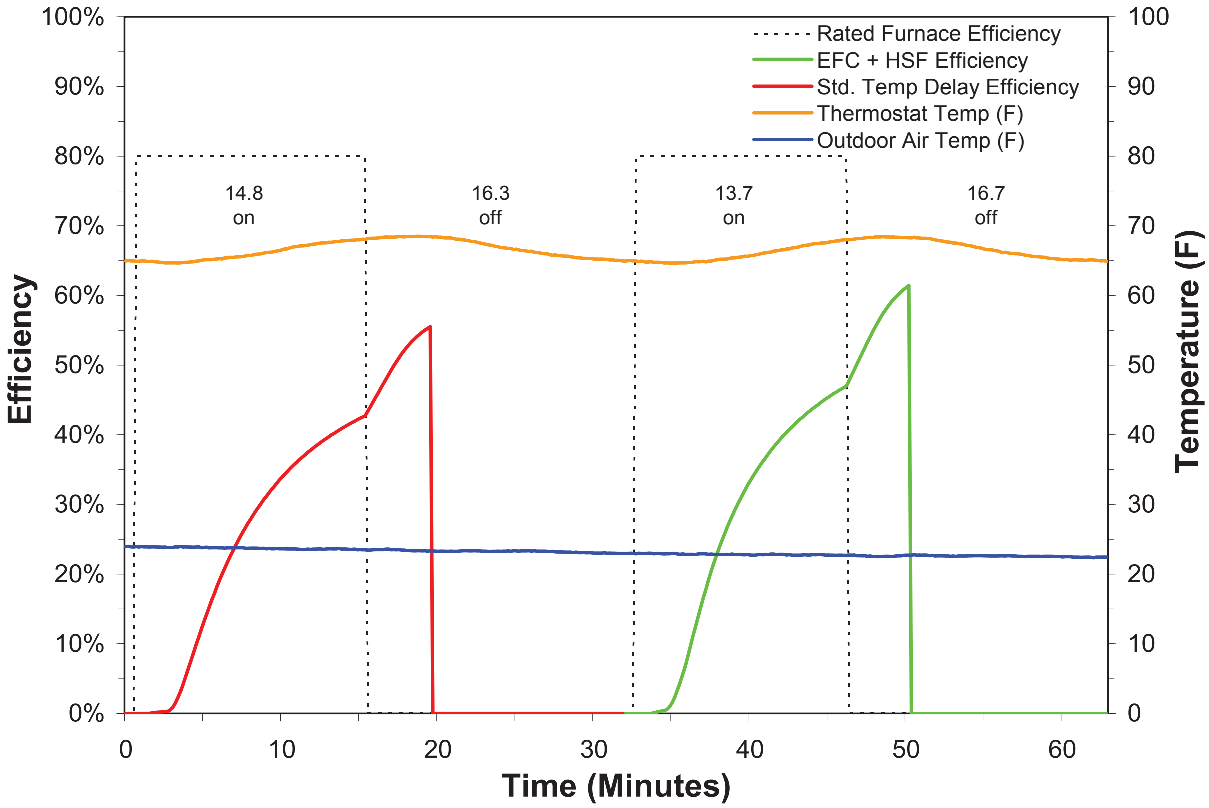

Figure 3. Heating Efficiency with EFC + HSF versus Standard Temperature Delay

Table 5. Measured Heating Efficiency from EFC + HSF vs. Standard Temp. Delay

Description	Test 1 Baseline	Test 2 EFC
Furnace On Time (minutes)	14.8	13.7
Furnace Off Cycle Time (minutes)	16.3	16.7
Fan Delay After Furnace Off (minutes)	4.2	4
EFC Additional Fan Energy (kWh/cycle)		0.009
EFC Additional Fan Energy		-4.6%
Furnace Energy Used (Btu)	-32,689	-30,118
Heat Energy Delivered to Space (Btu)	-18,147	-18,493
Delivered Efficiency	55.5%	61.4%
Savings Based on Heating Capacity (%)		5.9%
Savings from Run Time and Off Cycle (%)		9.9%
Average Savings		**7.9%**
Furnace Off Thermostat Temperature (F)	68.1	68.0
Fan Off Plenum Temperature (F)	99.4	98.3
Fan Off Supply Temperature (F)	95.7	94.0
Furnace On Thermostat Temperature before Cycle (F)	64.9	64.9

The rated furnace efficiency, EFC efficiency, and 90-second time delay efficiency for an 80% AFUE gas furnace is shown in **Figure 4** and **Table 6**. The furnace is turned on when the thermostat temperature is below 69°F and turned off when the thermostat temperature is above 72°F. The baseline time delay provides 1.5 minutes of additional fan operation and supply plenum fan off temperature of 143.9°F. The EFC provides a 4 minute time delay with fan off

supply plenum temperature of 97.9°F and increased off cycle by 1.2 minutes or 6.5%. The EFC saves 5.9% of gas heating energy and -14.5% of heating fan ventilation energy.

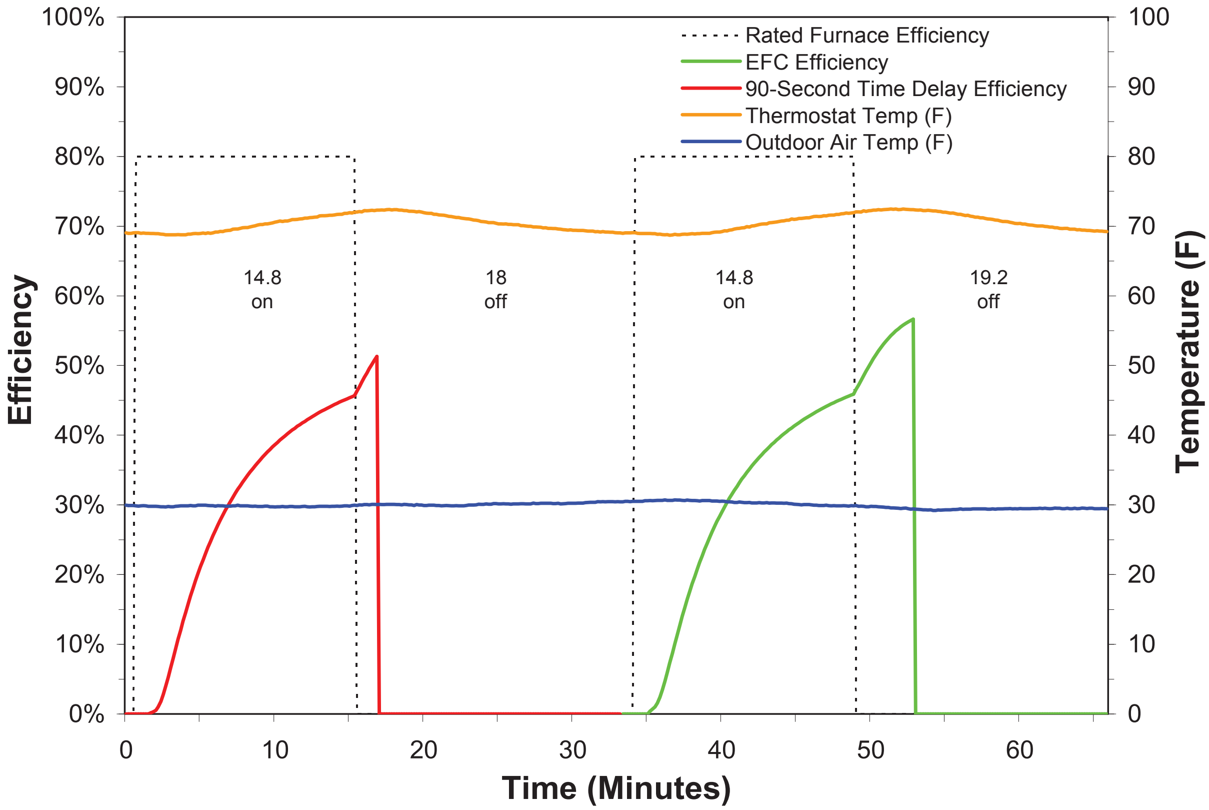

Figure 4. Heating Efficiency with EFC versus 90-Second Time Delay (Low Speed Fan)

Table 6. Measured Heating Efficiency with EFC vs. 90-Sec. Time Delay (Low Speed Fan)

Description	Test 3 Baseline	Test 4 EFC
Furnace On Time (minutes)	14.8	14.8
Furnace Off Cycle Time (minutes)	18.0	19.2
Fan Delay After Furnace Off (minutes)	1.5	4
EFC Additional Fan Energy (kWh/cycle)		0.025
EFC Additional Fan Energy		-14.5%
Furnace Energy Used (Btu)	-32,689	-32,689
Heat Energy Delivered to Space (Btu)	-16,769	-18,523
Delivered Efficiency	51.3%	56.7%
Savings Based on Heating Capacity (%)		5.4%
Savings from Run Time and Off Cycle (%)		6.5%
Average Savings		**5.9%**
Furnace Off Thermostat Temperature (F)	72.0	72.1
Fan Off Plenum Temperature (F)	143.9	97.9
Fan Off Supply Temperature (F)	116.9	97.3
Furnace On Thermostat Temperature before Cycle (F)	69.0	69.0

The rated furnace efficiency, EFC + HSF efficiency, and degraded temperature delay efficiency for an 81% AFUE gas furnace is shown in **Figure 5** and **Table 7**. For test 5 (baseline) and test 6 (EFC) the furnace is turned on when the thermostat temperature is below 68°F and turned off when the thermostat temperature is above 71°F. The low speed fan requires 8.0 minutes of

furnace operation to increase the thermostat temperature to above 71°F. The baseline degraded temperature delay provides 0.7 minutes of additional fan operation and the supply plenum fan-off temperature is 198.8°F. The EFC provides high speed fan operation 4 minutes after the furnace is turned on. This increases furnace efficiency by 7.1% and reduces furnace operation by 0.7 minutes or 8.8%. The EFC provides a 4-minute time delay with high-speed fan and the fan-off supply plenum temperature is 114.8°F. The EFC increases off cycle from 9.8 to 15.7 minutes or 60.2%. Test 6 EFC saves 24.5% of gas energy and -13.8% of heating fan ventilation energy. The high-speed fan power is 450W or 22.1% greater than low-speed fan power which is 368W.

For the test 7 (baseline) and test 8 (EFC) the furnace is turned on when the thermostat temperature is below 67°F and turned off when the thermostat temperature is above 73°F. The low speed fan requires 14.8 minutes of furnace operation to increase the thermostat temperature to above 73°F. The baseline degraded temperature delay provides 1 minute of additional fan operation and the supply plenum fan-off temperature is 206.4°F. The EFC provides high speed fan operation 4 minutes after the furnace is turned on. This increases furnace efficiency by 7.7% and reduces furnace operation by 1 minute or 6.8%. The EFC provides a 4-minute time delay with high-speed fan and the fan-off supply plenum temperature is 118.8°F. The EFC increases off cycle from 50.2 to 67.5 minutes or 34.6%. EFC test 8 saves 16.9% of gas energy and -30.5% of heating fan ventilation energy. The average savings from EFC (tests 6 and 8) versus degraded temperature delay (tests 5 and 7) are 20.7% of gas heating energy and -22.2% of heating fan ventilation energy. The high-speed fan power is 450W or 23.2% greater than low-speed fan power which is 365W.

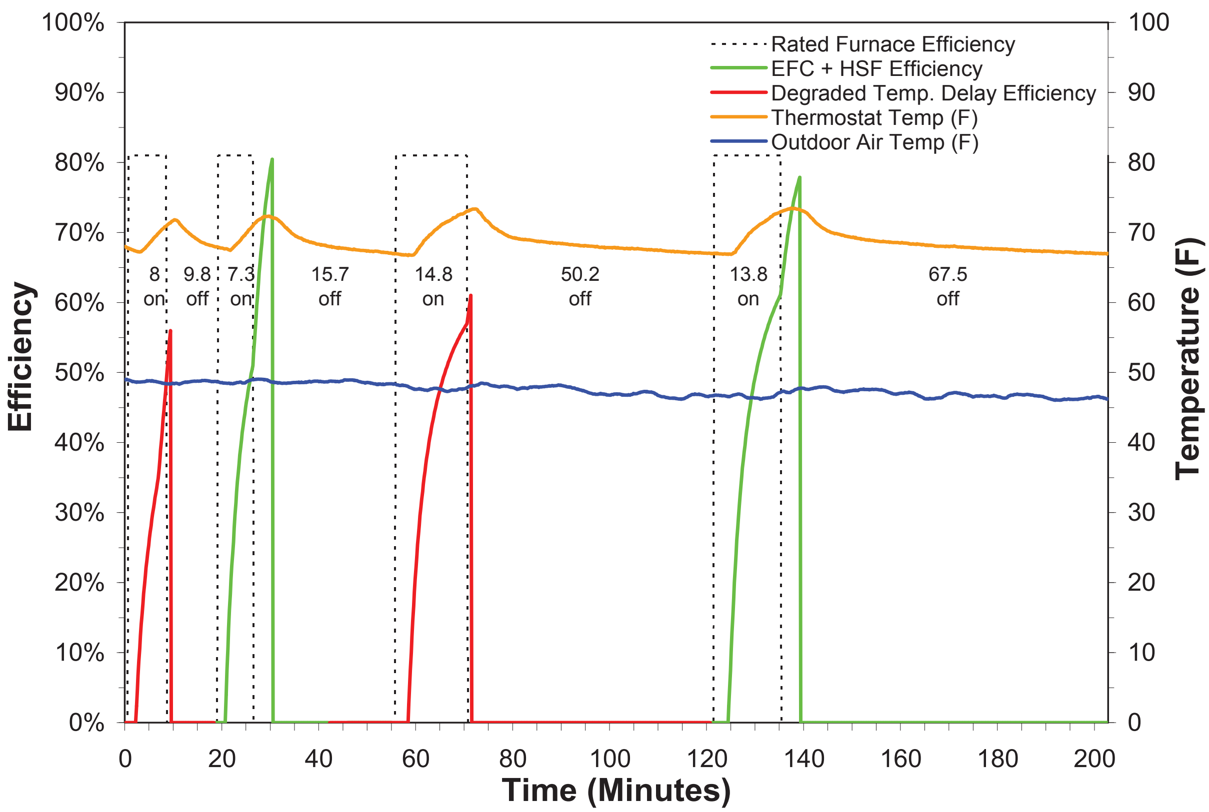

Figure 5. Heating Efficiency with EFC + HSF versus Degraded Temperature Delay

Table 7. Measured Heating Efficiency with EFC + HSF vs. Degraded Temp. Delay

Description	Test 5 Baseline	Test 6 EFC	Test 7 Baseline	Test 8 EFC	Average
Furnace On Time (minutes)	8.0	7.3	14.8	13.8	7.5%
Furnace Off Cycle Time (minutes)	9.8	15.7	50.2	67.5	46.9%
Fan Delay After Furnace Off (minutes)	0.8	4.0	1.0	4.0	
EFC Additional Fan Energy (kWh/cycle)		0.007		0.029	
EFC Additional Fan Energy		-13.8%		-30.5%	-22.2%
Furnace Energy Used (Btu)	-15,617	-14,315	-28,956	-27,004	
Heat Energy Delivered to Space (Btu)	-8,740	-11,519	-17,674	-21,033	
Delivered Efficiency	56.0%	80.5%	61.0%	77.9%	
Savings Based on Heating Capacity (%)		24.5%		16.9%	20.7%
Savings from Run Time and Off Cycle (%)		67.7%		41.3%	54.5%
Average Savings		**24.5%**		**16.9%**	**20.7%**
Furnace Off Thermostat Temperature (F)	71.1	71.2	73.1	73.0	
Fan Off Plenum Temperature (F)	198.8	114.8	206.4	118.8	
Fan Off Supply Temperature (F)	136.3	100.7	140.9	103.4	
Furnace On T-stat Temp. before Cycle (F)	68.0	68.0	67.0	67.0	

The ratio of additional electric power to operate the EFC fan compared to the standard fan is calculated using **Equation 5**.

Eq. 5 EFC Fan Energy = $$S_{vent} = \frac{\sum_{i=0}^{m}(t_i \times P_{std\ fan\ i}) - \sum_{j=0}^{n}(t_j \times P_{EFC\ fan\ j})}{\sum_{i=0}^{m}(t_i \times P_{std\ fan\ i})}$$

Where,

S_{vent} = electric residential air conditioner (RAC) or residential gas furnace (RGF) ventilation savings associated with the EFC based on field or laboratory tests (%),
t = time of measurement interval,
m = total time for EFC furnace fan operation,
n = total time for standard heating fan operation,
$P_{EFC\ fan}$ = power of heating fan with EFC (W),
$P_{std\ fan}$ = power of heating fan with standard control (W).

The test data presented in this report indicate 17.8 to 22.6% more fan energy is required for the permanent split-capacitance (PSC) motor (722W versus 613W and 450W versus 367W). A review of manufacturer product literature indicates that 20.5% more power is generally required to operate a PSC motor at high speed compared to medium speed (Lennox 1998a). In heating mode, the EFC requires 4.6% more electricity than furnace fans with standard temperature delay fan, 22.3% more electricity than furnace fans with degraded temperature delay, and 14.5% more electricity than furnace fans with 90-second time delay fan. In cooling mode, the EFC requires 37.5% more electricity than the fans with no delay and 19.3% more electricity than fans with 90-second time delay fan. The additional electricity required to operate the EFC fan is 13.8% in heating mode and 36.2% in cooling mode based on the weighted average of temperature and time delay market share (see **Table 12**).

Field measurements of the cooling sensible energy efficiency ratio (EER*) and total power (kW) for an air conditioner with a standard no time delay on the fan are shown in **Figure 6** and **Table 8**. The average cooling efficiency improvement from the EFC compared to the standard no TDR unit is 14.5% +/- 2% based on these measurements. The field tests were conducted with average air conditioner run times of 16.5 minutes and average EFC fan time delay times of 5 minutes. The EFC additional fan energy is 30.6% in cooling mode.

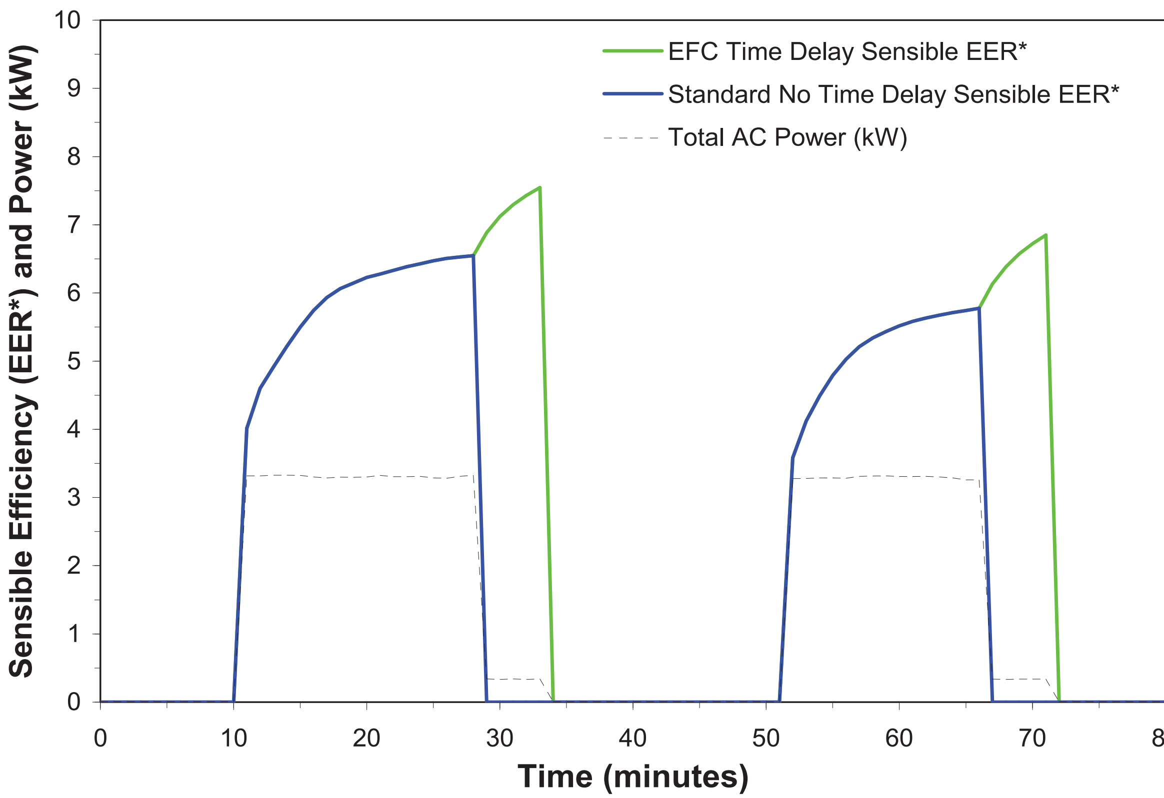

Figure 6. Field Tests Cooling Sensible EER and Power EFC versus no Time Delay

Table 8. Field Tests of Air Conditioner EFC versus No Time Delay

Description	Test 9	Test 10	Average
Compressor On Time (minutes)	18	15	16.5
EFC Delay After Compressor Off (minutes)	5	5	5
EFC Additional Fan Energy (kWh/cycle)	0.03	0.03	0.03
Std. Delay After Compressor Off (minutes)	0	0	0.00
EFC Additional Fan Cooling Energy	-27.8%	-33.3%	-30.6%
Std. AC Energy (kWh)	0.99	0.82	0.91
Standard Cooling Delivered (Btu)	6,497	4,752	5,625
Std. 90-Sec. Delay Cool Efficiency	6.55	5.77	6.16
EFC AC Energy (kWh)	1.02	0.85	0.94
EFC Cooling Delivered (Btu)	7,703	5,828	6,766
EFC Cooling Efficiency	7.55	6.85	7.20
Cooling Efficiency Improvement	**13.3%**	**15.7%**	**14.5%**

Field measurements of the cooling sensible energy efficiency ratio (EER*) and total power (kW) for an air conditioner with a 90-second time delay on the fan are shown in **Figure 7** and **Table 9**.

The average cooling efficiency improvement from the EFC compared to the 90-second TDR is 9.5% +/- 1.3% based on the field measurements. The field tests were conducted with average air conditioner run times of 16.5 minutes and average EFC fan time delay times of 5 minutes. The EFC additional fan energy is 19.6% in cooling mode.

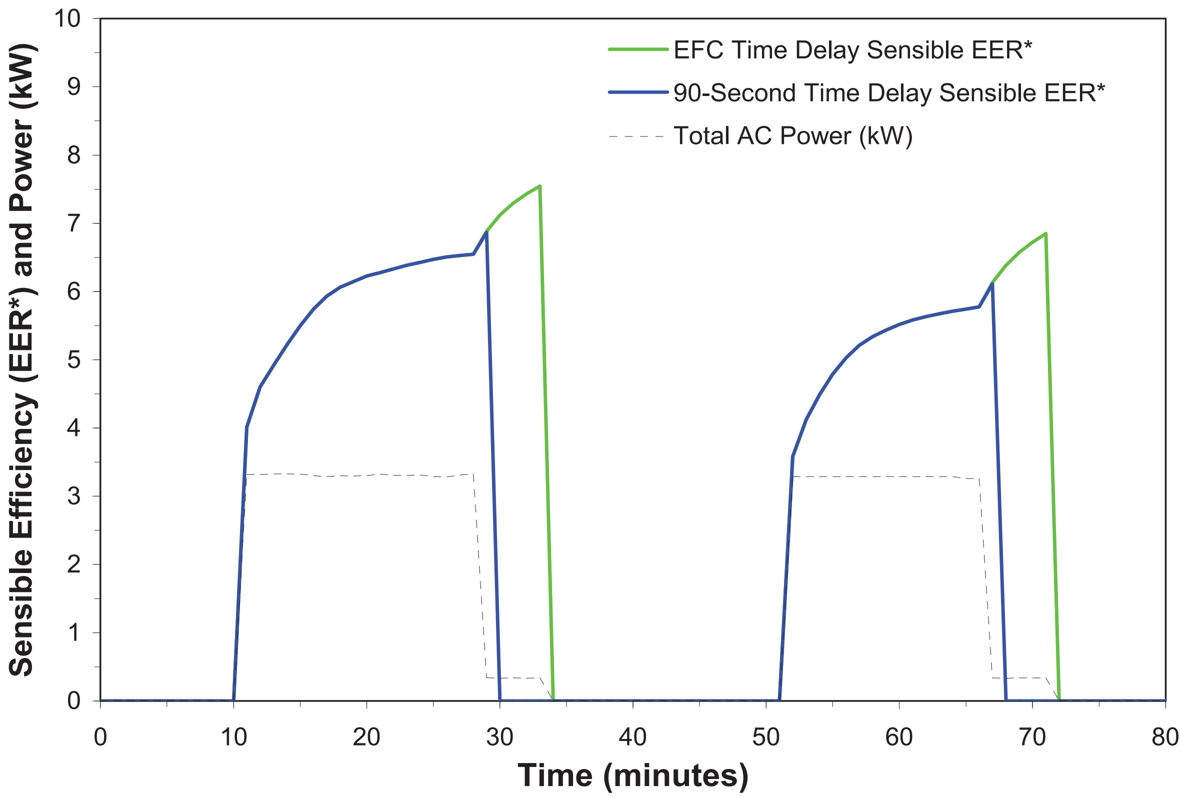

Figure 7. Field Tests Cooling Sensible EER and Power EFC versus 90-second TDR

Table 9. Field Tests of Air Conditioner EFC versus 90-Second TDR

Description	Test 11	Test 12	Average
Compressor On Time (minutes)	18	15	16.5
EFC Delay After Compressor Off (minutes)	5	5	5
EFC Additional Fan Energy (kWh/cycle)	0.02	0.02	0.02
Std. Delay After Compressor Off (minutes)	1.5	1.5	1.50
EFC Additional Fan Cooling Energy	-17.9%	-21.2%	-19.6%
Std. AC Energy (kWh)	1.00	0.83	0.91
Standard Cooling Delivered (Btu)	6,881	5,091	5,986
Std. 90-Sec. Delay Cool Efficiency	6.89	6.14	6.51
EFC AC Energy (kWh)	1.02	0.85	0.94
EFC Cooling Delivered (Btu)	7,703	5,828	6,766
EFC Cooling Efficiency	7.55	6.85	7.20
Cooling Efficiency Improvement	**8.7%**	**10.4%**	**9.5%**

1.4.4 Laboratory Test Data

The amount of moisture converted to sensible cooling is dependent on the airflow and the length of time the fan runs at the end of the compressor cycle. **Figure 8** and **Table 10** show laboratory

test data from Southern California Edison from the embedded Excel Workbook #2 in tab "SCE Data Fig7-8", Column O is the Cycle Sensible EER (see References Section). The sensible EER improvement decreases with increasing compressor run time from 22.2% for 5-minute run time to 6.2% for 30 minute compressor run time. The EFC adjusts the length of the time delay from 1.5 to 5 minutes based on the fan run time which is a proxy for the compressor run time. The average cooling efficiency improvement from the EFC compared to the standard unit is 15.3% +/- 5.7% based on these measurements. These savings are comparable to the average cooling efficiency improvement of 14.5% +/- 2% for the EFC compared to no time delay based on field measurements (see **Table 8**). **Figure 9** and **Table 11** show the same data set but with the baseline having a 90 second time delay. The average cooling efficiency improvement from the EFC compared to the 90-second delay is 8.1% +/- 2.4%. These savings are comparable to the average cooling efficiency improvement of 9.5% +/- 1.3% for the EFC compared to the 90-second delay based on field measurements (see **Table 9**).

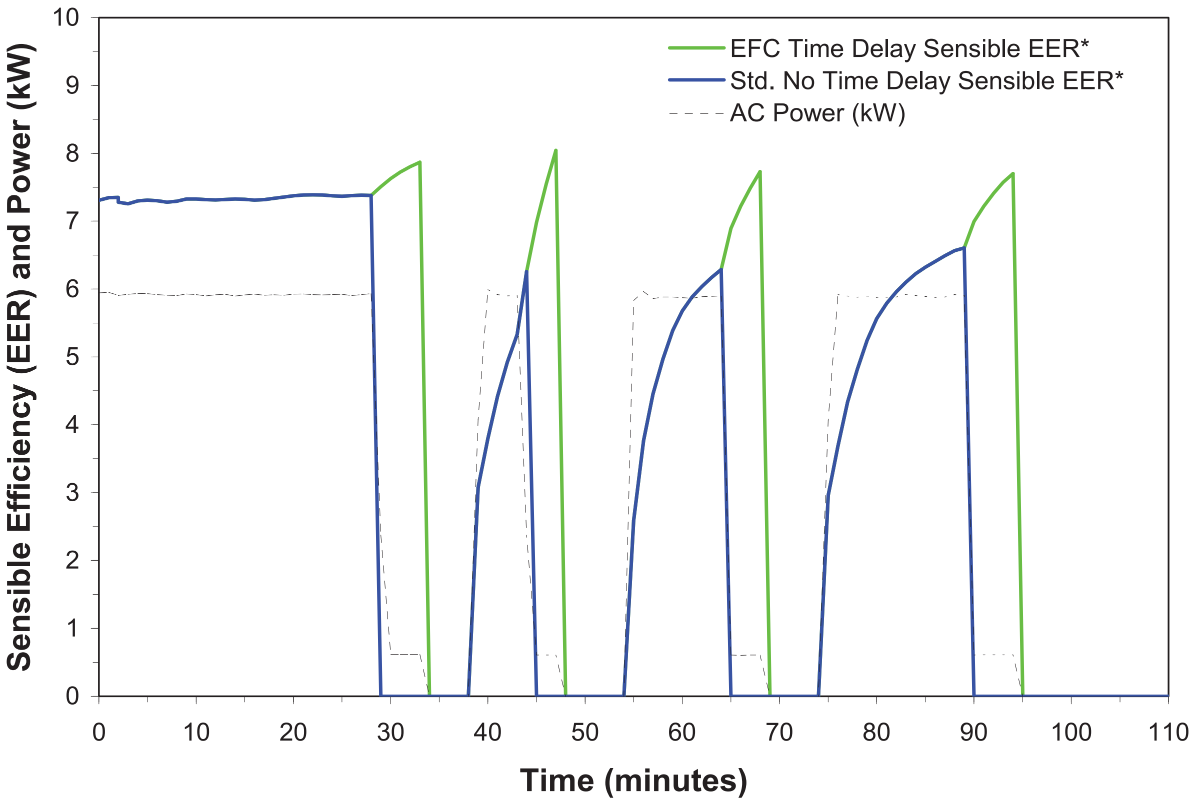

Figure 8. Laboratory Tests of Air Conditioner EFC versus No Time Delay

Table 10. Laboratory Tests of Air Conditioner with no Time Delay

Description	Test 13	Test 14	Test 15	Test 16	Average
Compressor On Time (minutes)	30	5	10	15	17.5
EFC Delay After Compressor Off (minutes)	5	3	4	5	4.25
EFC Additional Fan Energy (kWh/cycle)	0.05	0.03	0.04	0.05	0.04
Std. Delay After Compressor Off (minutes)	0	0	0	0	0.00
EFC Additional Fan Cooling Energy	-16.7%	-60.0%	-40.0%	-33.3%	-37.5%
No Time Delay AC Energy (kWh)	2.96	0.50	0.98	1.44	1.73
No Time Delay Cooling Delivered (Btu)	21,838	3,146	6,167	9,538	12,492
No Time Delay Application Sensible EER*	7.38	6.26	6.29	6.61	6.82
EFC AC Energy (kWh)	3.04	0.53	1.02	1.49	1.79
EFC Cooling Delivered (Btu)	23,917	4,288	7,893	11,507	11,901
EFC Application Sensible EER*	7.87	8.04	7.73	7.70	7.84
EFC Cooling Savings	**6.2%**	**22.2%**	**18.7%**	**14.2%**	**15.3%**

Source: Based on Southern California Edison data.

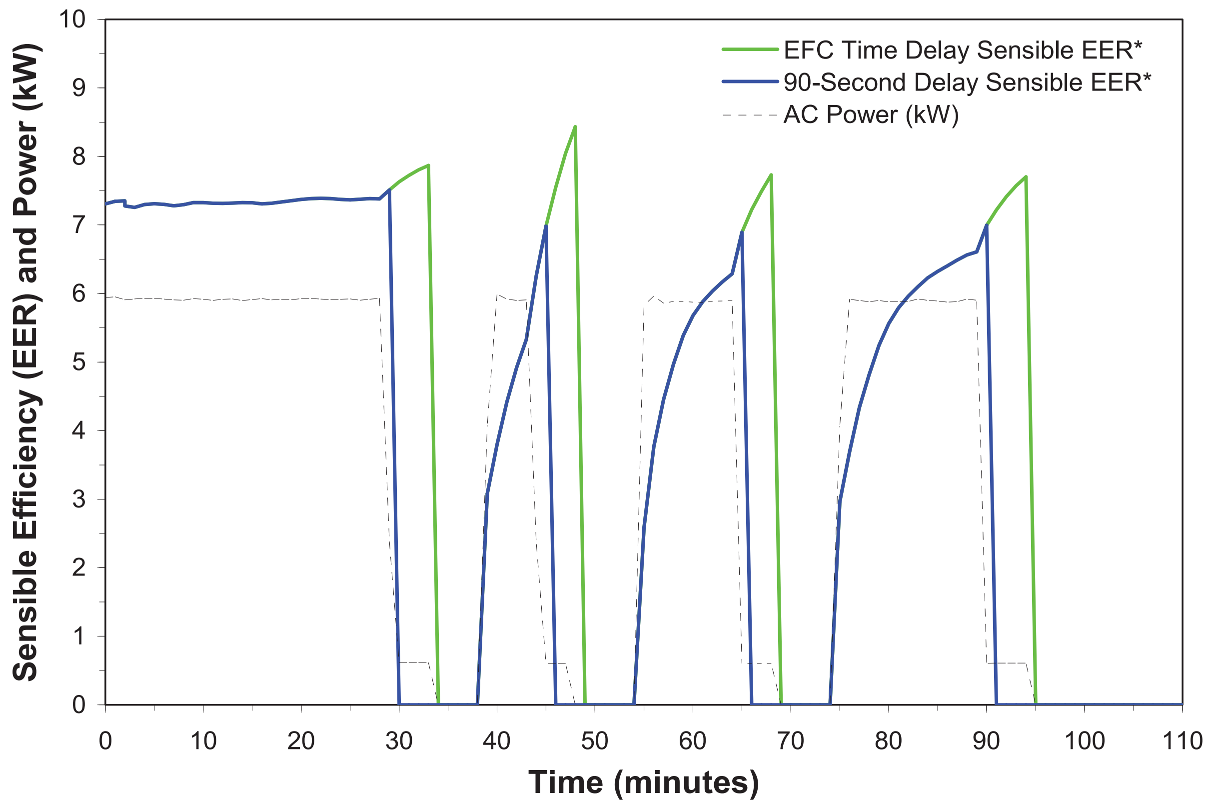

Figure 9. Laboratory Tests of Air Conditioner with EFC versus 90-Second Time Delay

Table 11. Laboratory Tests of Air Conditioner with EFC and 90-Second Time Delay

Description	Test 17	Test 18	Test 19	Test 20	Average
Compressor On Time (minutes)	30	5	10	15	17.5
EFC Delay After Compressor Off (minutes)	5	3	4	5	4.25
EFC Additional Fan Energy (kWh/cycle)	0.05	0.03	0.04	0.05	0.04
Std. Delay After Compressor Off (minutes)	1.5	1.5	1.5	1.5	1.50
EFC Additional Fan Cooling Energy	-11.1%	-23.1%	-21.7%	-21.2%	-19.3%
No Time Delay AC Energy (kWh)	3.00	0.52	1.00	1.46	1.76
No Time Delay Cooling Delivered (Btu)	22,738	3,765	7,029	10,365	13,251
No Time Delay Application Sensible EER*	7.57	7.27	7.06	7.11	7.42
EFC AC Energy (kWh)	3.04	0.53	1.02	1.49	1.79
EFC Cooling Delivered (Btu)	23,917	4,288	7,893	11,507	11,901
EFC Application Sensible EER*	7.87	8.04	7.73	7.70	7.84
EFC Cooling Savings	**3.9%**	**10.7%**	**9.5%**	**8.4%**	**8.1%**

Source: Based on Southern California Edison.

Equation 6 shows how the application sensible EER* is calculated.

Eq. 6 Sensible $EER_s^* = \sum_{i=0}^{n} \frac{Q_{cs\,i}}{P_i}$

Where,

EER_s^* = application sensible energy efficiency ratio (Btu/hr-W),

$Q_{cs\,i}$ = sensible cooling energy removed from the air by the air conditioner over the measurement interval (Btu/hr),

P_i = total power to operate the air conditioner compressor, fan, and controls over the measurement interval (W).

The cooling energy savings (S_{cool}) based on cooling Sensible EER improvements are calculated using **Equation 7**.

Eq. 7 $S_{cool} = \frac{EER_s^*\big|_{EFC}}{EER_s^*\big|_{Base}} - 1$

Where,

S_{cool} = cooling energy savings for the EFC (%),

$EER_s^*\big|_{EFC}$ = EFC sensible cooling efficiency with optimal time delay from 1.5 to 5 minutes, and

$EER_s^*\big|_{Base}$ = base sensible cooling efficiency with no delay or 90-second time delay.

1.4.5 Estimated Energy Savings

The estimated space cooling and heating energy savings for each market share for the EFC are shown in **Table 12**. The savings are based on field tests and laboratory tests of furnaces and air conditioners with and without the EFC. The estimated weighted average heating energy savings are 11.8% based on field tests (see tests 1 through 8 in **Tables 5**, **6**, and **7**). In heating mode, the EFC requires 4.6% more ventilation electricity than heating systems with standard temperature delay fan and 14.5% more electricity than ventilation systems with 90-second time delay. In

cooling mode, the EFC requires 37.5% more ventilation electricity than the standard cooling system with no time delay and 19.3% more ventilation electricity than the system with 90-second time delay. The EFC heating ventilation energy savings are -13.8% (i.e., negative) based on the weighted average of temperature and time delay. The EFC cooling ventilation energy savings are -36.2% (i.e., negative) based on the weighted average of temperature and time delay. The EFC cooling savings are 14.8% based on the weighted average savings from field and laboratory tests and estimated market share.

The test data presented in this report indicate 20.6% more fan power is required at high speed compared to low speed for the permanent split-capacitance (PSC) motor for a 3-ton unit (450W high speed versus 372W low speed) and 17.8% for a 4-ton unit (722W high speed versus 613W low speed). A review of manufacturer product literature indicates 20.5% more power is required to operate at high speed during the time delay (Lennox 1998a). The weighted average ventilation electricity savings are -13.8% instead of -20.6% due to running the fan in high speed during furnace operation which reduces both furnace and fan energy consumption.

The weighted average space heating savings are calculated using **Equation 8**.

Eq. 8 $$\overline{S_{heat}} = \sum_{k=0}^{p} S_{heat_k} \times M_k$$

Where,

$\overline{S_{heat}}$ = weighted average space heating energy savings for the EFC based field tests and market share (%),

S_{heat_k} = heating energy savings for the EFC for market segment “k” (%), and

M_k = market segment “k” for the following base thermostat control market segments: working temperature delay, degraded temperature delay, or 90-second time delay (%).

The weighted average space cooling savings are calculated using **Equation 9**.

Eq. 9 $$\overline{S_{cool}} = \sum_{k=1}^{p} S_{cool_k} \times M_k$$

Where,

$\overline{S_{cool}}$ = weighted average space cooling energy savings for the EFC based on field and laboratory tests and market share (%),

S_{cool_k} = cooling energy savings for the EFC for market segment “k” (%), and

M_k = market segment “k” for the following base thermostat control market segments: no time delay PSC motor, 90-second time delay PSC motor, no time delay EC motor, 90-second time delay EC motor (%).

The weighted average RGF ventilation savings are calculated using **Equation 10**.

Eq. 10 $\overline{S_{RGF\,vent}} = \sum_{k=1}^{p} S_{RGF\,vent_k} \times M_k$

Where,

$\overline{S_{RGF\,vent}}$ = weighted average RGF ventilation energy savings associated with the EFC based on field and laboratory tests and market share (%),

$S_{RGF\,vent_k}$ = RGF ventilation savings for the EFC for market segment "k" (%), and

M_k = market segment "k" for the following base thermostat control market segments: working temperature delay, degraded temperature delay, or 90-second time delay (%).

The weighted average RAC ventilation savings are calculated using **Equation 11**.

Eq. 11 $\overline{S_{RAC\,vent}} = \sum_{k=1}^{p} S_{RAC\,vent_k} \times M_k$

Where,

$\overline{S_{RAC\,vent}}$ = weighted average RAC ventilation energy savings associated with the EFC based on field and laboratory tests and market share (%),

$S_{RAC\,vent_k}$ = RAC ventilation savings for the EFC for market segment "k" (%), and

M_k = market segment "k" for the following base thermostat control market segments: no time delay PSC motor, 90-second time delay PSC motor, no time delay EC motor, 90-second time delay EC motor (%).

Table 12. Estimated Space Heating and Cooling Energy Savings for EFC

Pre-existing Description	Measure Description	EFC Heating Savings	EFC Fan Heating Savings	EFC Fan Cooling Savings	EFC Cooling Savings	Estimated Market Share
Heating Temperature Delay at 100 to 110°F, PSC motor	EFC High-Speed Fan plus Variable Time Delay (2 to 4 minutes)	7.9%	-4.6%			35%
Heating Temperature Degraded Delay at 130 to 200°F, PSC motor	EFC High-Speed Fan plus Variable Time Delay (2 to 4 minutes)	20.7%	-22.3%			35%
Heating 90 second Time Delay, PSC motor low speed	EFC Variable Time Delay (2 to 4 minutes)	5.9%	-14.5%			30%
Cooling No Time Delay, PSC Motor	EFC Variable Time Delay (1.5 to 5 minutes)			-37.5%	15.3%	90%
Cooling Standard 90 second Time Delay PSC motor	EFC Variable Time Delay (1.5 to 5 minutes)			-19.3%	8.1%	5%
Cooling No Time Delay, Efficient Fan Motor	EFC Variable Time Delay (1.5 to 5 minutes)			-37.5%	15.3%	3%
Cooling Standard 90 second Time Delay, Efficient Fan Motor	EFC Variable Time Delay (1.5 to 5 minutes)			-19.3%	8.1%	2%
Weighted Average		**11.8%**	**-13.8%**	**-36.2%**	**14.8%**	

1.4.5 Consumer Satisfaction Study

EFC units were installed at homes in California and Nevada to evaluate consumer satisfaction. Consumers provided the following feedback after using the EFC for two months during the winter heating season from January through March 2012. Additional consumer survey responses will be obtained after the summer cooling season. Consumer satisfaction survey data are provided in **Table 13**. The average number of occupants is 3.2 +/- 0.1 and the average conditioned floor area is 2800 ft^2. Survey respondents indicated that the EFC provides more comfortable heating with an overall rating of 7.5 ± 0.18 out of 10 points. One hundred percent of survey respondents indicated that the EFC saves energy. Survey respondents indicate high satisfaction with an overall rating of 10 out of 10 points.

Table 13. Consumer Satisfaction Survey Data

Description	Average	Respondents
1. Number of Occupants	3.2 +/- 0.1	20
2. Conditioned Floor Area (ft^2)	2,800 +/- 49	20
3. Air Conditioner Average Fan Off Delay (sec)	TBD	TBD
4. Pre-Existing Average Furnace Fan Off Delay (sec)	109.6 +/- 3.3	20
5. EFC Furnace Fan Off Delay (sec)	240 +/- 2	20
6. Does the EFC provide more comfortable heating on a scale of 1 to 10? (10=more, 5=same, 1=less).	7.5 +/- 0.18	20
7. Does the EFC provide more comfortable cooling on a scale of 1 to 10?	TBD	TBD
8. Does the EFC save energy compared to not using the EFC? (% Yes)	100%	20
9. How satisfied are you with the EFC on a scale of 1 to 10? (1=Low, 10=High).	10 +/- 0	20

1.5 Baseline Unit Energy Consumption (UEC) Values

The weighted baseline unit energy consumption (UEC) values for the Southern California service area for Single Family (SFM), Multifamily (MFM), and Double-wide Mobile (DMO) prototypical buildings and Residential Air Conditioner (RAC) with Gas Furnace (GF) HVAC system are shown in **Table 14** and Residential gas Furnace (RGF) HVAC system are shown in **Table 15**. The UEC values are from the DEER 2008.2.1 MISer (DEER 2008a). Section 2 provides engineering calculations used to develop estimates of the baseline annual cooling electric ventilation from the total baseline annual electric ventilation and the baseline annual heating electric ventilation. The baseline and energy savings should be defined in "Common energy units" rather than per household to allow for multiple EFC units to be installed at one home.

Table 14. Weighted Baseline UEC per Household –RAC with Gas Furnace (DEER 2008 MISer)

DEER2008 ImpactID	Weighted Building Vintage Climate Zone	Baseline Annual Gas Heating (therm/yr)	Baseline Annual Heating Elec Ventilation (kWh/yr)	Baseline Annual Cooling Elec Ventilation (kWh/yr)	Baseline Annual Elec Cooling (kWh/yr)	Baseline Annual Elec Cooling (kW)	Baseline Annual Elec Ventilation (kW)
SFM-w04-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	4	262.8	87.5	134.2	654.2	2.316	0.304
SFM-w05-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	5	329.7	129.0	54.3	147.6	1.303	0.181
SFM-w06-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	6	187.9	61.2	148.7	839.6	1.878	0.255
SFM-w07-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	7	133.1	47.3	118.1	721.8	1.864	0.258
SFM-w08-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	8	162.6	55.7	184.3	1,188.9	2.538	0.336
SFM-w09-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	9	194.8	66.5	230.1	1,551.2	3.123	0.390
SFM-w10-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	10	214.3	73.7	209.3	1,377.8	2.724	0.341
SFM-w13-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	13	269.9	96.5	280.7	1,900.2	3.016	0.378
SFM-w14-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	14	281.6	106.9	382.6	2,610.5	3.686	0.473
SFM-w15-vSCx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	15	111.4	0.0	0.0	3,662.0	3.963	0.466
SFM-w16-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	16	624.4	246.7	191.1	813.6	2.600	0.343
SFM-wSCG-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	SCG Weighted	207.4	67.6	225.3	1,456.9	2.810	0.357
MFM-w04-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	4	105.5	41.1	42.6	221.8	0.712	0.098
MFM-w05-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	5	136.3	41.2	34.5	64.7	0.332	0.064
MFM-w06-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	6	64.1	23.9	39.4	235.2	0.616	0.090
MFM-w07-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	7	51.0	18.9	33.7	199.9	0.616	0.085
MFM-w08-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	8	59.2	21.4	71.3	464.8	0.850	0.117
MFM-w09-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	9	84.8	25.9	136.9	903.9	1.246	0.169
MFM-w10-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	10	94.8	33.3	103.9	699.9	1.173	0.148
MFM-w13-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	13	115.7	45.4	148.7	1,061.1	1.302	0.163
MFM-w14-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	14	153.6	74.6	244.4	1,744.3	1.781	0.231
MFM-w15-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	15	55.9	15.8	366.5	2,868.6	2.112	0.252
MFM-w16-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	16	244.5	83.0	120.3	510.4	1.051	0.143
MFM-wSCG-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	SCG Weighted	80.0	24.6	124.3	825.0	1.130	0.152
DMO-w04-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	4	259.8	72.8	346.4	3,018.2	4.379	0.360
DMO-w05-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	5	337.8	101.6	194.8	1,101.9	2.887	0.232
DMO-w06-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	6	147.3	43.9	260.2	2,210.6	2.732	0.254
DMO-w07-vSCx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	7	123.8	41.2	206.6	1,932.1	3.164	0.277
DMO-w08-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	8	179.6	51.4	424.5	4,113.1	4.568	0.389
DMO-w09-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	9	170.1	71.4	317.8	3,281.1	4.703	0.381
DMO-w10-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	10	188.9	79.2	372.0	4,035.1	4.999	0.404
DMO-w13-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	13	257.5	104.2	372.4	4,028.7	5.218	0.417
DMO-w14-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	14	339.4	136.2	568.0	5,592.6	6.053	0.500
DMO-w15-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	15	158.2	137.5	573.7	7,451.6	6.332	0.500
DMO-w16-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	16	453.8	214.6	236.5	1,274.7	2.746	0.329
DMO-wSCG-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	SCG Weighted	195.0	218.0	240.2	4,011.2	4.917	0.401

Table 15. Weighted Baseline UEC per Household –RGF Only (DEER 2008 MISer)

DEER2008 ImpactID	Weighted Building Vintage Climate Zone	Baseline Annual Gas Heating (therm/yr)	Baseline Annual Heating Elec Ventilation (kWh/yr)	Baseline Annual Cooling Elec Ventilation (kWh/yr)	Baseline Annual Elec Cooling (kWh/yr)	Baseline Annual Elec Cooling (kW)	Baseline Annual Elec Ventilation (kW)
SFM-w04-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	4	229.4	87.5				
SFM-w05-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	5	341.1	129.0				
SFM-w06-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	6	169.9	61.2				
SFM-w07-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	7	125.9	47.3				
SFM-w08-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	8	150.6	55.7				
SFM-w09-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	9	183.6	66.5				
SFM-w10-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	10	200.7	73.7				
SFM-w13-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	13	256.6	96.5				
SFM-w14-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	14	286.3	106.9				
SFM-w15-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	15	124.2	43.3				
SFM-w16-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	16	607.7	246.7				
SFM-wSCG-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	SCG Weighted	183.8	67.6				
MFM-w04-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	4	107.4	41.1				
MFM-w05-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	5	108.2	41.2				
MFM-w06-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	6	66.0	23.9				
MFM-w07-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	7	51.4	18.9				
MFM-w08-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	8	56.9	21.4				
MFM-w09-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	9	69.9	25.9				
MFM-w10-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	10	87.9	33.3				
MFM-w13-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	13	117.4	45.4				
MFM-w14-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	14	155.9	74.6				
MFM-w15-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	15	42.2	15.8				
MFM-w16-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	16	207.8	83.0				
MFM-wSCG-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	SCG Weighted	66.5	24.6				
DMO-w04-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	4	199.7	72.8				
DMO-w05-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	5	277.7	101.6				
DMO-w06-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	6	126.3	43.9				
DMO-w07-vSCx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	7	118.0	41.2				
DMO-w08-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	8	142.7	51.4				
DMO-w09-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	9	197.3	71.4				
DMO-w10-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	10	212.4	79.2				
DMO-w13-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	13	272.1	104.2				
DMO-w14-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	14	347.9	136.2				
DMO-w15-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	15	162.1	137.5				
DMO-w16-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	16	547.6	214.6				
DMO-wSCG-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	SCG Weighted	235.3	218.0				

Energy common units for RAC and RGF are shown in **Tables 16** and **17**.

Table 16. Energy Common Units for RAC HVAC System (DEER 2008 MISer)

DEER2008 ImpactID	Weighted Building Vintage Climate Zone	HVAC System	Energy Common Units 1 description	Number Energy Common Units 1
SFM-w04-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	4	RAC	tons cool cap	3.01
SFM-w05-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	5	RAC	tons cool cap	3.19
SFM-w06-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	6	RAC	tons cool cap	3.51
SFM-w07-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	7	RAC	tons cool cap	2.51
SFM-w08-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	8	RAC	tons cool cap	3.14
SFM-w09-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	9	RAC	tons cool cap	3.48
SFM-w10-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	10	RAC	tons cool cap	3.63
SFM-w13-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	13	RAC	tons cool cap	3.32
SFM-w14-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	14	RAC	tons cool cap	3.99
SFM-w15-vSCx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	15	RAC	tons cool cap	4.63
SFM-w16-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	16	RAC	tons cool cap	3.43
SFM-wSCG-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	SCG Weighted	RAC	tons cool cap	3.51
MFM-w04-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	4	RAC	tons cool cap	1.33
MFM-w05-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	5	RAC	tons cool cap	1.57
MFM-w06-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	6	RAC	tons cool cap	1.52
MFM-w07-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	7	RAC	tons cool cap	1.38
MFM-w08-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	8	RAC	tons cool cap	1.41
MFM-w09-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	9	RAC	tons cool cap	1.84
MFM-w10-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	10	RAC	tons cool cap	2.01
MFM-w13-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	13	RAC	tons cool cap	1.71
MFM-w14-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	14	RAC	tons cool cap	2.32
MFM-w15-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	15	RAC	tons cool cap	2.50
MFM-w16-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	16	RAC	tons cool cap	1.52
MFM-wSCG-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	SCG Weighted	RAC	tons cool cap	1.76
DMO-w04-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	4	RAC	tons cool cap	3.50
DMO-w05-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	5	RAC	tons cool cap	3.50
DMO-w06-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	6	RAC	tons cool cap	3.50
DMO-w07-vSCx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	7	RAC	tons cool cap	3.50
DMO-w08-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	8	RAC	tons cool cap	3.50
DMO-w09-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	9	RAC	tons cool cap	3.50
DMO-w10-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	10	RAC	tons cool cap	3.50
DMO-w13-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	13	RAC	tons cool cap	3.50
DMO-w14-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	14	RAC	tons cool cap	3.50
DMO-w15-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	15	RAC	tons cool cap	3.50
DMO-w16-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	16	RAC	tons cool cap	3.50
DMO-wSCG-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	SCG Weighted	RAC	tons cool cap	3.50

Table 17. Energy Common Units for RGF HVAC System (DEER 2008 MISer)

DEER2008 ImpactID	Weighted Building Vintage Climate Zone	HVAC System	Energy Common Units 1 description	Number Energy Common Units 1
SFM-w04-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	4	RGF	kBtuh furnace	53.57
SFM-w05-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	5	RGF	kBtuh furnace	60.23
SFM-w06-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	6	RGF	kBtuh furnace	63.15
SFM-w07-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	7	RGF	kBtuh furnace	47.49
SFM-w08-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	8	RGF	kBtuh furnace	57.18
SFM-w09-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	9	RGF	kBtuh furnace	65.20
SFM-w10-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	10	RGF	kBtuh furnace	71.93
SFM-w13-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	13	RGF	kBtuh furnace	67.61
SFM-w14-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	14	RGF	kBtuh furnace	80.03
SFM-w15-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	15	RGF	kBtuh furnace	89.88
SFM-w16-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	16	RGF	kBtuh furnace	55.63
SFM-wSCG-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	SCG Weighted	RGF	kBtuh furnace	61.41
MFM-w04-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	4	RGF	kBtuh furnace	28.37
MFM-w05-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	5	RGF	kBtuh furnace	24.99
MFM-w06-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	6	RGF	kBtuh furnace	29.94
MFM-w07-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	7	RGF	kBtuh furnace	25.63
MFM-w08-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	8	RGF	kBtuh furnace	27.85
MFM-w09-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	9	RGF	kBtuh furnace	35.13
MFM-w10-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	10	RGF	kBtuh furnace	37.66
MFM-w13-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	13	RGF	kBtuh furnace	33.45
MFM-w14-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	14	RGF	kBtuh furnace	45.38
MFM-w15-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	15	RGF	kBtuh furnace	48.66
MFM-w16-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	16	RGF	kBtuh furnace	25.99
MFM-wSCG-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	SCG Weighted	RGF	kBtuh furnace	31.19
DMO-w04-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	4	RGF	kBtuh furnace	55.06
DMO-w05-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	5	RGF	kBtuh furnace	55.04
DMO-w06-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	6	RGF	kBtuh furnace	55.01
DMO-w07-vSCx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	7	RGF	kBtuh furnace	55.06
DMO-w08-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	8	RGF	kBtuh furnace	55.02
DMO-w09-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	9	RGF	kBtuh furnace	54.96
DMO-w10-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	10	RGF	kBtuh furnace	54.96
DMO-w13-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	13	RGF	kBtuh furnace	55.00
DMO-w14-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	14	RGF	kBtuh furnace	54.96
DMO-w15-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	15	RGF	kBtuh furnace	54.96
DMO-w16-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	16	RGF	kBtuh furnace	55.00
DMO-wSCG-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	SCG Weighted	RGF	kBtuh furnace	54.98

Tables 18 and **19** provide baseline UEC data normalized per "Energy Common Units" (ECU), i.e., tons cooling capacity or kBtuh furnace capacity.

Table 18. Weighted Baseline UEC per ECU – RAC with Gas Furnace (DEER 2008 MISer)

DEER2008 ImpactID	Weighted Building Vintage Climate Zone	Baseline Annual Gas Heating (therm/yr-ECU)	Baseline Annual Heating Elec Ventilation (kWh/yr-ECU)	Baseline Annual Cooling Elec Ventilation (kWh/yr-ECU)	Baseline Annual Elec Cooling (kWh/yr-ECU)	Baseline Annual Elec Cooling (kW/ECU)	Baseline Annual Elec Ventilation (kW/ECU)
SFM-w04-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	4	87.41	29.10	44.65	217.63	0.771	0.101
SFM-w05-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	5	103.31	40.43	17.01	46.26	0.408	0.057
SFM-w06-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	6	53.48	17.42	42.31	238.91	0.534	0.073
SFM-w07-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	7	52.96	18.83	46.99	287.25	0.742	0.103
SFM-w08-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	8	51.74	17.73	58.65	378.38	0.808	0.107
SFM-w09-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	9	55.91	19.09	66.07	445.29	0.897	0.112
SFM-w10-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	10	59.03	20.29	57.64	379.52	0.750	0.094
SFM-w13-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	13	81.31	29.08	84.56	572.50	0.909	0.114
SFM-w14-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	14	70.65	26.82	96.00	655.05	0.925	0.119
SFM-w15-vSCx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	15	24.04	0.00	0.00	790.59	0.856	0.101
SFM-w16-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	16	182.20	71.98	55.78	237.40	0.759	0.100
SFM-wSCG-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	SCG Weighted	59.02	19.25	64.11	414.63	0.800	0.102
MFM-w04-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	4	79.42	30.97	32.10	167.04	0.536	0.074
MFM-w05-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	5	86.92	26.24	21.98	41.26	0.211	0.041
MFM-w06-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	6	42.16	15.72	25.89	154.62	0.405	0.059
MFM-w07-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	7	36.96	13.72	24.41	144.76	0.446	0.061
MFM-w08-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	8	41.92	15.14	50.51	329.19	0.602	0.083
MFM-w09-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	9	46.14	14.06	74.50	491.75	0.678	0.092
MFM-w10-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	10	47.19	16.60	51.72	348.31	0.584	0.073
MFM-w13-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	13	67.69	26.56	87.00	621.02	0.762	0.096
MFM-w14-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	14	66.29	32.18	105.43	752.55	0.768	0.100
MFM-w15-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	15	22.39	6.34	146.68	1148.01	0.845	0.101
MFM-w16-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	16	161.37	54.76	79.42	336.89	0.694	0.095
MFM-wSCG-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	SCG Weighted	45.35	13.93	70.40	467.47	0.640	0.086
DMO-w04-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	4	74.26	20.81	99.00	862.68	1.252	0.103
DMO-w05-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	5	96.55	29.05	55.67	314.95	0.825	0.066
DMO-w06-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	6	42.10	12.54	74.40	631.98	0.781	0.073
DMO-w07-vSCx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	7	35.39	11.78	59.07	552.41	0.905	0.079
DMO-w08-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	8	51.36	14.68	121.36	1175.92	1.306	0.111
DMO-w09-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	9	48.63	20.41	90.87	938.12	1.345	0.109
DMO-w10-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	10	54.01	22.65	106.36	1153.59	1.429	0.115
DMO-w13-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	13	73.62	29.80	106.49	1151.89	1.492	0.119
DMO-w14-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	14	97.02	38.93	162.36	1598.71	1.730	0.143
DMO-w15-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	15	45.21	39.32	163.99	2130.13	1.810	0.143
DMO-w16-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	16	129.72	61.34	67.59	364.35	0.785	0.094
DMO-wSCG-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	SCG Weighted	55.75	62.33	68.68	1146.78	1.406	0.115

Table 19. Weighted Baseline UEC per ECU – RGF Only (DEER 2008 MISer)

DEER2008 ImpactID	Weighted Building Vintage Climate Zone	Baseline Annual Gas Heating (therm/yr-ECU)	Baseline Annual Heating Elec Ventilation (kWh/yr-ECU)	Baseline Annual Cooling Elec Ventilation (kWh/yr-ECU)	Baseline Annual Elec Cooling (kWh/yr-ECU)	Baseline Annual Elec Cooling (kW/ECU)	Baseline Annual Elec Ventilation (kW/ECU)
SFM-w04-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	4	4.28	1.63				
SFM-w05-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	5	5.66	2.14				
SFM-w06-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	6	2.69	0.97				
SFM-w07-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	7	2.65	1.00				
SFM-w08-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	8	2.63	0.97				
SFM-w09-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	9	2.82	1.02				
SFM-w10-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	10	2.79	1.02				
SFM-w13-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	13	3.80	1.43				
SFM-w14-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	14	3.58	1.34				
SFM-w15-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	15	1.38	0.48				
SFM-w16-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	16	10.92	4.43				
SFM-wSCG-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	SCG Weighted	2.99	1.10				
MFM-w04-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	4	3.79	1.45				
MFM-w05-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	5	4.33	1.65				
MFM-w06-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	6	2.21	0.80				
MFM-w07-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	7	2.00	0.74				
MFM-w08-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	8	2.04	0.77				
MFM-w09-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	9	1.99	0.74				
MFM-w10-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	10	2.33	0.89				
MFM-w13-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	13	3.51	1.36				
MFM-w14-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	14	3.44	1.64				
MFM-w15-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	15	0.87	0.33				
MFM-w16-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	16	7.99	3.19				
MFM-wSCG-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	SCG Weighted	2.13	0.79				
DMO-w04-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	4	3.63	1.32				
DMO-w05-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	5	5.05	1.85				
DMO-w06-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	6	2.30	0.80				
DMO-w07-vSCx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	7	2.14	0.75				
DMO-w08-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	8	2.59	0.93				
DMO-w09-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	9	3.59	1.30				
DMO-w10-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	10	3.86	1.44				
DMO-w13-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	13	4.95	1.90				
DMO-w14-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	14	6.33	2.48				
DMO-w15-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	15	2.95	2.50				
DMO-w16-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	16	9.96	3.90				
DMO-wSCG-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	SCG Weighted	4.28	3.97				

1.6 Pre-Existing Baseline and Measure Effective Useful Lives

The pre-existing baseline measure characteristics are provided in **Table 3**. For heating the baseline is either temperature controlled or time controlled delay on the furnace fan. For cooling the baseline is either no time delay or time delay of 90 seconds. The baseline measure is installed inside the HVAC equipment and is dependent on the life of the equipment. The EFC measure is not installed inside the air conditioner, furnace, forced-air unit, or thermostat. Therefore, the EFC EUL is not dependent on the life of the air conditioner, furnace, FAU, or thermostat. The EFC is a small microchip approximately the size of a US penny which is installed in the wall behind the thermostat on the low-voltage wires coming from the HVAC equipment. The effective useful lifetime of the EFC is assumed to be 10 years based on the EUL of programmable thermostats (DEER 2008). However, since the EFC is solid-state its lifetime could be longer (i.e., 15 to 25 years) since there are no moving parts or parts to wear out since the product operates on low voltage without the need for a battery,

1.7 Net-to-Gross Ratios

A net to gross ratio of the EFC is 1.0 based on the EUL for comprehensive air conditioning measures.

Section 2. Engineering Calculations

The engineering calculations for annual natural gas and electricity savings and peak demand reduction are provided in the embedded Excel workbook using the following equations. The baseline annual gas heating (therm/yr) values shown in **Table 14**, column 3, and the baseline annual electric cooling (kWh/yr) values shown in **Table 14**, column 5, are taken directly from the 2008 DEER Update (DEER 2008a) for the Southern California weighted vintage for each climate zone and residential air conditioner (RAC) HVAC system (includes gas furnace and air conditioner). The baseline annual heating electric ventilation (kWh/yr) values shown in **Table 15**, column 4, are taken directly from the 2008 DEER Update (DEER 2008a) for the SCG weighted vintage for each climate zone and residential gas furnace (RGF) HVAC system (excludes air conditioning). The baseline annual cooling electric ventilation values shown in **Table 14**, column 5, are calculated using **Equation 12**.

Eq. 12 $UEC_{cool\ vent} = UEC_{RAC\ vent} - UEC_{RGF\ vent}$

Where,

$UEC_{cool\ vent}$ = baseline cooling electric ventilation exclusive of heating (kWh/year),
$UEC_{RAC\ vent}$ = baseline electric ventilation for residential air conditioning including cooling and heating (i.e., furnace) from DEER 2008a (kWh/year), and
$UEC_{RGF\ vent}$ = baseline heating-only electric ventilation for residential gas furnace (RGF) excluding cooling from DEER 2008a (kWh/year).

The annual heating energy savings shown in **Table 1** for RAC are calculated using **Equation 13** and the baseline UEC values shown in **Table 14**.

Eq. 13 $ES_{EFC\ heat} = UEC_{RAC\ heat} \times \overline{S_{heat}}$

Where,

$ES_{EFC\ heat}$ = energy savings for the EFC measure for space heating (therm/year),
$UEC_{RAC\ heat}$ = baseline space heating from DEER 2008a (therm/year), and
$\overline{S_{heat}}$ = weighted average space heating energy savings associated with the EFC based on field and laboratory tests (%).

The annual net electric energy savings shown in **Table 1** are calculated using **Equation 14** and the baseline UEC values shown in **Table 14** for RAC and **Table 15** for RGF.

Eq. 14 $ES_{EFC\ cool} = [UEC_{RAC\ cool} \times \overline{S_{cool}}\ ] + [UEC_{RAC\ vent} \times (\overline{S_{cool}} + \overline{S_{RAC vent}}\ )] + [UEC_{RGF\ vent} \times \overline{S_{RGF vent}}\ ]$

Where,

$ES_{EFC\ cool}$ = energy savings for the EFC measure for space cooling (kWh/year),
$UEC_{RAC\ cool}$ = baseline space cooling from DEER 2008a (kWh/year),
$\overline{S_{cool}}$ = weighted average space cooling electric energy savings associated with the EFC based on field and laboratory tests (%),
$\overline{S_{RAC vent}}$ = weighted average RAC ventilation savings associated with the EFC based on field and laboratory tests (%), and
$\overline{S_{RGF vent}}$ = weighted average RGF ventilation savings associated with the EFC based on field and laboratory tests (%).

The annual peak demand savings (PDS) shown in **Table 1** are calculated using **Equation 15** and the baseline Unit Peak Demand (UPD) values shown in **Table 14**.

Eq. 15 $PDS_{EFC} = DF \times \{[UPD_{RAC\ cool} \times \overline{S_{cool}}\ ] + [UPD_{RAC\ vent} \times (\overline{S_{cool}} + \overline{S_{RAC vent}}\ )]\}$

Where,

PDS_{EFC} = peak demand savings for the EFC measure (kW),
DF = diversity factor of 0.33 for space cooling assuming one-third of air conditioners are on at any given time during the peak period (dimensionless),
$UPD_{RAC\ cool}$ = baseline space cooling peak demand from DEER 2008a (kW), and
$UPD_{RAC\ vent}$ = baseline ventilation peak demand from DEER 2008a (kW).

Tables 18 and **19** provide baseline UEC data normalized per "Energy Common Units" (ECU), i.e., tons cooling capacity or kBtuh furnace capacity. ECU data are provided in **Tables 16** and **17**. These data can be used with **Equation 16** to calculate annual heating energy savings.

Eq. 16 $ES_{EFC\ heat} = UEC_{heat} \times \overline{S_{heat}} \times ECU$

Where,

ECU = Energy Common Unit per **Table 16** for RAC and **Table 17** for RGF.

The annual net electric energy savings are calculated using **Equation 17**, baseline UEC data per ECU in **Tables 18** and **19**, and ECU data in **Tables 16** and **17**.

Eq. 17 $$ES_{\text{EFC cool}} = \Big\{[UEC_{\text{cool}} \times \overline{S_{cool}}\,] + [UEC_{\text{vent}} \times (\overline{S_{cool}} + \overline{S_{RAC\,vent}}\,)] + [UEC_{\text{vent}} \times \overline{S_{RGF\,vent}}\,]\Big\} \times ECU$$

The annual peak demand savings (PDS) are calculated using **Equation 18** and the baseline UEC data per ECU in **Tables 18** and **19**, and ECU data in **Tables 16** and **17**.

Eq. 18 $$PDS_{\text{EFC}} = \Big\{DF \times \big\{[UPD_{\text{RAC cool}} \times \overline{S_{cool}}\,] + [UPD_{\text{RAC vent}} \times (\overline{S_{cool}} + \overline{S_{RAC\,vent}}\,)]\big\}\Big\} \times ECU$$

References

ARI Standard 210/240 2003. Air Conditioning and Refrigeration Institute, Table 3, page 6. (pdf Document: Pages from ARISEER.pdf)

Carrier 1973. Installation, Start-up, and Service Instructions, 58GA, GC 3SI. Upflow Gas Furnaces. Carrier Air Conditioning Company, Syracuse, NY.

Carrier 2006. 58STA/STX Single---Stage Deluxe Induced---Combustion 4---Way Multipoise Furnace. The blower motor BLWM and air cleaner terminal EAC--1 will remain energized for 90, 120, 150, or 180 seconds (depending on the blower-- OFF delay selection). The furnace control CPU is factory-- set for a 120--second blower--OFF delay.

Carrier 2006a. Time-Delay Relay Kit Installation Instructions. Part Number KAATD0101TDR. 90 second cooling time delay – “once the thermostat is satisfied, the indoor fan will continue to run approximately 90 seconds, then shut off.” CAC (Carrier Air Conditioning Company) / BDP (Bryant / Day & Night / Payne). S 7310 W. Morris St. S Indianapolis, IN 46231.

DEER 2008. Database for Energy Efficiency Resources. Summary of the EUL-RUL Analysis for the April 2008 Update to DEER EUL/RUL (Effective/Remaining Useful Life) Values (Updated 10 October 2008) and EUL/RUL Summary Documentation (Posted April 2008). Prepared by KEMA, Inc. http://www.deeresources.com/deer2008exante/downloads/EUL_Summary_10-1-08.xls.

DEER 2008a. DEER2008 unit energy consumption values are from the Measure Inspection and Summary viewer tool (MISer Version 1.10.25) and DEER (Version: DEER2008.2.2). See http://www.deeresources.com/.

Excel Workbook #1 with DEER2008 Data, E3 Inputs, and Energy Savings Calculations (embedded “Workpaper_Verified_EFC_DEER2008-BaseResEnergyUse_v0.xls”).

Workpaper_Verified_
EFC_DEER2008-Base

Excel Workbook #2 including field measurements from R. Mowris and E. Jones, Verified, Inc., and laboratory data from Faramazi, R. and S. Mitchell. 2006. Hot and Dry Air Conditioner 5-ton Proof of Concept Test Summary and Data Analysis Report. Irvine, CA. Southern California Edison. (embedded “Workpaper_Verified_SC0007_EFC_Rev_v0.xls”).

Workpaper_Verified_
SC0077_EFC_Rev_v(

Lennox 1998. Unit Service Information. G20 Series Units. Figure 5. Furnace Fan Off Time Adjustment (90 to 330 seconds). "Unit is shipped with a factory setting of 90 seconds. Fan 'off' time will affect comfort and efficiency and is adjustable to satisfy individual applications." P. 5. Lennox Industries, Inc. Publication 9418-L9 Revised 07-98.

Lennox 1998a. Unit Service Information. G23 Series Units. Figure 5. Furnace Fan Off Time Adjustment (90 to 330 seconds). "Unit is shipped with a factory setting of 90 seconds. Fan "off" time will affect comfort and efficiency and is adjustable to satisfy individual applications." P. 10. Lennox Industries, Inc. Publication 9418-L8. Furnace fan airflow at high speed is 1030 cfm with is 25.6% greater than medium speed airflow of 820 cfm. Fan power use is 16.6% greater at 0.5 inches of water gage static pressure (440W at high speed versus 385W at medium speed).

REFPROP 2010. Reference Fluid Thermodynamic and Transport Properties Database (REFPROP) 2010. Developed and supported by the National Institute of Standards and Technology (NIST), Scientific and Technical Databases, Boulder, CO, 80305 (see http://www.nist.gov/srd/nist23.htm).

Rheem 2005. Installation Instructions Upflow, Upflow/Horizontal, and Downflow Induced Draft Gas Furnaces, 80PJ and 80LJ Series. Page 28, Figures 18, 19, and 20. Furnace fan "off" time 90 seconds factory setting (adjustable up to 180 seconds based on switch settings or jumpers. Pub. No. 22-1677-05.

Trane 2009. Downflow/Horizontal Right Induced Draft Gas Furnace. XB80 Single-Stage Fan Assisted Combustion System. Page 9, Wiring Diagram for TDE1 Furnaces. Cooling fan "off" delay 0 seconds and heating fan "off" time delay fixed at 100 seconds factory setting. Pub. No. 22-1677-05.

WPSDGEREHC0024
Revision #0

San Diego Gas & Electric
Energy Efficiency Engineering

California HVAC Upgrade: Efficient Fan Controller (EFC) – Residential

1.4.5 Estimated Energy Savings

The estimated space cooling and heating energy savings for each market share for the EFC are shown in **Table 12**. The savings are based on field tests and laboratory tests of furnaces and air conditioners with and without the EFC. The estimated weighted average heating energy savings are 11.8% based on field tests. The EFC cooling savings are 14.8% based on the weighted average savings from field and laboratory tests and estimated market share.

October 25, 2012

At a Glance Summary

Measure Name:	Efficient Fan Controller (EFC) - Residential
Savings Impacts Energy Common Units (ECU):	Household or tons for Residential Air Conditioner (RAC) or kBtuh for Residential Gas Furnace (RGF) space heating only
Customer Base Case Description:	The customer base case heating, ventilating, and air conditioning (HVAC) system has low-speed fan operation in heating mode. After the furnace turns off the fan continues to operate for a fixed time delay of 90 seconds or the fan continues to operate based on a temperature delay which turns off the fan when the plenum temperature falls below a control threshold of 100 to 200°F depending on whether or not the temperature delay sensor is operating or set properly. In cooling mode the fan turns off when the compressor turns off (i.e., no time delay). Some customer base case systems (less than 8%) continue to operate the fan for a fixed time delay of 90 seconds after the compressor turns off.
Code Base Case Description:	The code base case description is the same as the customer base case description (above).
Costs Common Units:	Household or tons for RAC, or kBtuh for RGF
Measure Equipment Cost ($/unit):	25
Measure Incremental Cost ($/unit):	75 (SFM, MFM, and DMO)
Measure Installed Cost ($/unit):	75 (SFM, MFM, and DMO)
Measure Load Shape:	26 = Res. Central Air Conditioning
Effective Useful Life (years):	10
Program Type:	Retrofit
TOU AC Adjustment:	100%
Net-to-Gross Ratios:	1.00
Important Comments:	DEER Vintage Weighting

E3 Calculator Data – EFC for Residential Air Conditioner (RAC) Cooling and Heating

DEER 2008 ImpactID	Measure Description	Building Type	Building Vintage	Climate Zone	Above Code Annual Electric Savings (kWh/unit)	Above Code Peak Electric Demand Reduction (kW/unit)	Above Code Annual Savings (Therms /unit)	Incremental Measure Cost ($/unit)	Effective Useful Life (years)	Net to Gross Ratio	Total Resource Cost (TRC) Test
SFM-w06-vSDGx-hAC-tWt-bCAv-eMsr	EFC	SFM	SDG Weighted	6	84.13	0.1	22.13	75	10	1	4.15
SFM-w07-vSDGx-hAC-tWt-bCAv-eMsr	EFC	SFM	SDG Weighted	7	75.14	0.11	15.67	75	10	1	3.4
SFM-w08-vSDGx-hAC-tWt-bCAv-eMsr	EFC	SFM	SDG Weighted	8	129.02	0.14	19.15	75	10	1	4.78
SFM-w10-vSDGx-hAC-tWt-bCAv-eMsr	EFC	SFM	SDG Weighted	10	149.18	0.15	25.24	75	10	1	5.79
SFM-w14-vSDGx-hAC-tWt-bCAv-eMsr	EFC	SFM	SDG Weighted	14	290.13	0.2	33.16	75	10	1	9.16
SFM-w15-vSDGx-hAC-tWt-bCAv-eMsr	EFC	SFM	SDG Weighted	15	542.52	0.2	13.12	75	10	1	11.16
SFM-wSDG-vEx-hAC-tWt-bCAv-eMsr	EFC	SFM	SDG Weighted	SDG Weighted	211.69	0.15	21.41	75.00	10.00	1.00	6.41
MFM-w06-vSDGx-hAC-tWt-bCAv-eMsr	EFC	MFM	SDG Weighted	6	23.13	0.06	7.55	75	10	1	1.48
MFM-w07-vSDGx-hAC-tWt-bCAv-eMsr	EFC	MFM	SDG Weighted	7	19.79	0.06	6.01	75	10	1	1.26
MFM-w08-vSDGx-hAC-tWt-bCAv-eMsr	EFC	MFM	SDG Weighted	8	50.65	0.07	6.97	75	10	1	1.93
MFM-w10-vSDGx-hAC-tWt-bCAv-eMsr	EFC	MFM	SDG Weighted	10	76.85	0.09	11.17	75	10	1	2.87
MFM-w14-vSGx-hAC-tWt-bCAv-eMsr	EFC	MFM	SDG Weighted	14	195.83	0.13	18.09	75	10	1	5.71
MFM-w15-vSDGx-hAC-tWt-bCAv-eMsr	EFC	MFM	SDG Weighted	15	344.33	0.14	6.59	75	10	1	6.99
MFM-wSDG-vEx-hAC-tWt-bCAv-eMsr	EFC	MFM	SDG Weighted	SDG Weighted	118.43	0.09	9.40	75.00	10.00	1.00	3.37
DMO-w06-vSDGx-hAC-tWt-bCAv-eMsr	EFC	DMO	SDG Weighted	6	265.75	0.13	17.34	75	10	1	6.76
DMO-w07-vSDGx-hAC-tWt-bCAv-eMsr	EFC	DMO	SDG Weighted	7	236.33	0.16	14.58	75	10	1	6.13
DMO-w08-vSDGx-hAC-tWt-bCAv-eMsr	EFC	DMO	SDG Weighted	8	511.41	0.23	21.16	75	10	1	11.64
DMO-w10-vSDGx-hAC-tWt-bCAv-eMsr	EFC	DMO	SDG Weighted	10	507.25	0.25	22.25	75	10	1	11.83
DMO-w14-vSDGx-hAC-tWt-bCAv-eMsr	EFC	DMO	SDG Weighted	14	688.2	0.32	39.97	75	10	1	16.9
DMO-w15-vSGDx-hAC-tWt-bCAv-eMsr	EFC	DMO	SDG Weighted	15	962.2	0.33	18.63	75	10	1	19.16
DMO-wSDG-vEx-hAC-tWt-bCAv-eMsr-	EFC	DMO	SDG Weighted	SDG Weighted	528.52	0.24	22.32	75.00	10.00	1.00	12.07

See **Section 1.5** for baseline unit energy consumption (UEC) values.

E3 Calculator Data – EFC for Residential Gas Furnace (RGF) Space Heating Only

DEER 2008 ImpactID	Measure Description	Building Type	Building Vintage	Climate Zone	Above Code Annual Electric Savings (kWh/unit)	Above Code Peak Electric Demand Reduction (kW/unit)	Above Code Annual Savings (Therms /unit)	Incremental Measure Cost ($/unit)	Effective Useful Life (years)	Net to Gross Ratio	Total Resource Cost (TRC) Test
SFM-w06-vSDGx-hGF-tWt-bCAv-eMsr	EFC	SFM	SDG Weighted	6	-8.42	0	20.01	75	10	1	1.91
SFM-w07-vSDGx-hGF-tWt-bCAv-eMsr	EFC	SFM	SDG Weighted	7	-6.51	0	14.83	75	10	1	1.41
SFM-w08-vSDGx-hGF-tWt-bCAv-eMsr	EFC	SFM	SDG Weighted	8	-7.67	0	17.73	75	10	1	1.69
SFM-w10-vSDGx-hGF-tWt-bCAv-eMsr	EFC	SFM	SDG Weighted	10	-10.14	0	23.64	75	10	1	2.25
SFM-w14-vSDGx-hGF-tWt-bCAv-eMsr	EFC	SFM	SDG Weighted	14	-14.71	0	33.72	75	10	1	3.21
SFM-w15-vSDGx-hGF-tWt-bCAv-eMsr	EFC	SFM	SDG Weighted	15	-5.96	0	14.63	75	10	1	1.4
SFM-wSDG-vEx-hGF-tWt-bCAv-eMsr	EFC	SFM	SDG Weighted	SDG Weighted	-8.90	0.00	20.76	75.00	10.00	1.00	1.98
MFM-w06-vSDGx-hGF-tWt-bCAv-eMsr	EFC	MFM	SDG Weighted	6	-3.29	0	7.78	75	10	1	0.74
MFM-w07-vSDGx-hGF-tWt-bCAv-eMsr	EFC	MFM	SDG Weighted	7	-2.61	0	6.05	75	10	1	0.58
MFM-w08-vSDGx-hGF-tWt-bCAv-eMsr	EFC	MFM	SDG Weighted	8	-2.94	0	6.7	75	10	1	0.64
MFM-w10-vSDGx-hGF-tWt-bCAv-eMsr	EFC	MFM	SDG Weighted	10	-4.59	0	10.35	75	10	1	0.98
MFM-w14-vSDGx-hGF-tWt-bCAv-eMsr	EFC	MFM	SDG Weighted	14	-10.26	0	18.37	75	10	1	1.71
MFM-w15-vSDGx-hGF-tWt-bCAv-eMsr	EFC	MFM	SDG Weighted	15	-2.18	0	4.97	75	10	1	0.47
MFM-wSDG-vEx-hGF-tWt-bCAv-eMsr	EFC	MFM	SDG Weighted	SDG Weighted	-4.31	0.00	9.04	75.00	10.00	1.00	0.85
DMO-w06-vSDx-hGF-tWt-bCAv-eMsr	EFC	DMO	SDG Weighted	6	-6.04	0	14.87	75	10	1	1.42
DMO-w07-vSDGx-hGF-tWt-bCAv-eMsr	EFC	DMO	SDG Weighted	7	-5.67	0	13.89	75	10	1	1.33
DMO-w08-vSDGx-hGF-tWt-bCAv-eMsr	EFC	DMO	SDG Weighted	8	-7.07	0	16.8	75	10	1	1.6
DMO-w10-vSDGx-hGF-tWt-bCAv-eMsr	EFC	DMO	SDG Weighted	10	-10.9	0	25.01	75	10	1	2.38
DMO-w14-vSDGx-hGF-tWt-bCAv-eMsr	EFC	DMO	SDG Weighted	14	-18.74	0	40.97	75	10	1	3.88
DMO-w15-vSDGx-hGF-tWt-bCAv-eMsr	EFC	DMO	SDG Weighted	15	-18.93	0	19.09	75	10	1	1.65
DMO-wSDG-vEx-hGF-tWt-bCAv-eMsr	EFC	DMO	SDG Weighted	SDG Weighted	-11.23	0.00	21.77	75.00	10.00	1.00	2.04

Work Paper Approvals

Pete Ford
Manager, Customer Programs Engineering

Date

Document Revision History

Revision 0	October 25, 2010	Adapted from SoCalGas Workpaper SCG0077 Revision #0 dated April 4, 2010, developed by Verified, Inc. Revised weighting in multiple tables for SDGE Climate zones. Added SDGE Work paper number.

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Section 1. General Measure & Baseline Data

1.1 Measure Description & Background

This work paper provides engineering estimates of savings for upgrading Heating, Ventilating, and Air Conditioning (HVAC) equipment with an Efficient Fan Controller (EFC) to recover additional heating and cooling capacity and operate HVAC equipment at higher efficiency. The savings documented here are for the installation of a patent pending EFC that adjusts fan operation for heating based on gas valve activation time (which is a proxy for furnace operation), and fan operation for cooling based on fan run time (which is a proxy for compressor operation). The amount of time the fan operates after the furnace is off or after the compressor is off varies with the amount of time the furnace or compressor are on. The furnace run time indicates how much heat is stored in the heat exchanger. The air conditioner fan run time indicates how much cold water is condensed on the evaporator coil. Most furnaces fans operate at low speed and this reduces airflow and heating efficiency. The EFC provides high speed fan operation in heating mode to increase heating efficiency and reduce furnace run time.[1] This measure applies to HVAC systems that have a fan off time delay of less than 2 minutes in heating or cooling operation. The measure applies to standard and high efficiency furnaces and heat pumps in heating mode and air conditioners with furnaces in cooling and heating mode. The savings estimates assume a baseline temperature delay or 90 second fan time delay on heating and no time delay on cooling. Some units have a 60 to 90 second time delay on cooling. With these units the savings will be slightly lower compared to units with no existing time delay. If an HVAC unit includes a high efficiency fan motor, the savings will be higher due to lower power consumption of the fan motor. Savings for combined measures are discussed in **Table 10**.

Conventional fan controllers typically operate the ventilation fan for 0 to 90 seconds after the furnace or compressor turn off and this wastes heating and cooling energy that is not delivered to the conditioned space. The EFC recovers and delivers more heating and cooling energy to the conditioned space than is possible with conventional fan controllers. The EFC improves the efficiency of HVAC equipment by delivering additional heating or cooling capacity for a small amount of additional electric energy (kWh).

Air conditioners cool conditioned spaces by removing sensible and latent heat from the return air which reduces the supply air temperature and humidity. Latent heat is removed as water vapor is condensed out of the air due to the temperature of the evaporator coil being less than the return air dew point temperature.[2] Most evaporators are cold and wet (below 40 to 50°F) after the compressor turns off. Cooling energy left on the evaporator coil after the compressor turns off is generally wasted. The evaporator absorbs heat from the attic and cold water on the coil flows

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[1] Some newer heating systems with standard 90-second time delay do not allow high speed fan operation without switching the fan control jumper.

[2] Latent heat is the quantity of heat absorbed or released by air undergoing a change of state, such as water vapor condensing out of the air as water onto a cold evaporator coil or cold water evaporating to water vapor which will cool the air.

down the condensate drain. The EFC recovers the remaining cooling energy from evaporator coil by operating the fan after the compressor turns off to cool the conditioned space.

Most furnaces fans operate at low speed and this reduces airflow and heating efficiency. The EFC provides high speed fan operation in heating mode to increase heating efficiency and reduce furnace run time. Most furnace heat exchangers are still hot (above 135 to 210°F) after the furnace fan turns off. The EFC recovers the remaining heat energy from the hot furnace heat exchanger after the furnace turns off and delivers this heat to the conditioned space.

The EFC is a small low-voltage microprocessor controller approximately the size of a US penny. The EFC connects to the existing thermostat wires and is mounted in one of three positions: 1) behind the thermostat mounting plate, 2) between the thermostat and the thermostat mounting plate (with sufficient clearance), or 3) in a hole behind thermostat mounting plate where thermostat wires attach to thermostat.

This measure is cross cutting for use the residential market sector and available for use in the commercial sector.

The values used to forecast the measure's impacts are as follows:

- Incremental Measure Cost: $75 per air conditioner,
- Annual Energy Savings: See **Table 1** and **Table 2**,
- Demand Reduction: See **Table 1** and **Table 2**,
- Effective Useful Life: 10 years, and
- Net to Gross Ratio: 1.0 (Comprehensive Space Conditioning).

1.2 DEER Differences Analysis

The Database for Energy Efficiency Resources (DEER 2008) does not provide energy savings for the Efficient Fan Controller (EFC) measure. The cooling, heating, and ventilation Unit Energy Consumption (UEC) values for residential air conditioners (RAC) and residential gas furnaces (RGF) are based on the DEER2008 UEC values from the Measure Inspection and Summary viewer tool (MISer Version 1.10.25) and DEER (Version: DEER2008.2.2). See http://www.deeresources.com/. UEC values and DEER 2008 ImpactIDs listed in **Section 1.5** are in the embedded Excel Workbook #1 (see References Section). The DEER annual cooling and heating energy consumption are average values assuming no degradation due to excessive duct leakage, improper refrigerant charge and airflow, restrictions, non condensables, or blocked condenser coils. If the unit efficiency is degraded, the UEC will increase and this will increase the energy savings (therms, kWh and kW) beyond the estimates provided in this work paper. The annual natural gas savings (therm/yr) are based on weighted average savings of 11% (see **Table 12**). The annual electricity energy savings (kWh/yr) are based on 14.8% weighted average cooling savings and include the impact of increased ventilation energy use of 13.8% for space heating ventilation and -36.2% for space cooling ventilation.

EFC Energy and demand savings for residential air conditioning (RAC - space cooling and heating) are shown in **Table 1**. Data are based on analysis in **Section 1.4** provided in the embedded Excel workbooks #1 and #2 in the References Section.

Table 1. EFC Energy and Demand Savings Impacts by Building Type – RAC

Building Type	Climate Zone	Vintage	Net Elec Savings (kWh/yr)	Elec Demand Savings (kW)	Annual Gas Savings (therm/yr)
Single Family	6	SDG Weighted	84.13	0.1	22.13
Single Family	7	SDG Weighted	75.14	0.11	15.67
Single Family	8	SDG Weighted	129.02	0.14	19.15
Single Family	10	SDG Weighted	149.18	0.15	25.24
Single Family	14	SDG Weighted	290.13	0.2	33.16
Single Family	15	SDG Weighted	542.52	0.2	13.12
Single Family	SDG Weighted	SDG Weighted	211.69	0.15	21.41
Multi Family	6	SDG Weighted	23.13	0.06	7.55
Multi Family	7	SDG Weighted	19.79	0.06	6.01
Multi Family	8	SDG Weighted	50.65	0.07	6.97
Multi Family	10	SDG Weighted	76.85	0.09	11.17
Multi Family	14	SDG Weighted	195.83	0.13	18.09
Multi Family	15	SDG Weighted	344.33	0.14	6.59
Multi Family	SDG Weighted	SDG Weighted	118.43	0.09	9.40
Mobile Home	6	SDG Weighted	265.75	0.13	17.34
Mobile Home	7	SDG Weighted	236.33	0.16	14.58
Mobile Home	8	SDG Weighted	511.41	0.23	21.16
Mobile Home	10	SDG Weighted	507.25	0.25	22.25
Mobile Home	14	SDG Weighted	688.2	0.32	39.97
Mobile Home	15	SDG Weighted	962.2	0.33	18.63
Mobile Home	SDG Weighted	SDG Weighted	528.52	0.24	22.32

EFC Energy and demand savings for residential gas furnace (RGF - space heating only) are shown in **Table 2**. Data are based on analysis in **Section 1.4** provided in the embedded Excel workbooks #1 and #2 in the References Section.

Table 2. EFC Energy and Demand Savings Impacts by Building Type – RGF

Building Type	Climate Zone	Vintage	Net Elec Savings (kWh/yr)	Elec Demand Savings (kW)	Annual Gas Savings (therm/yr)
Single Family	6	SDG Weighted	-8.42	0	20.01
Single Family	7	SDG Weighted	-6.51	0	14.83
Single Family	8	SDG Weighted	-7.67	0	17.73
Single Family	10	SDG Weighted	-10.14	0	23.64
Single Family	14	SDG Weighted	-14.71	0	33.72
Single Family	15	SDG Weighted	-5.96	0	14.63
Single Family	SDG Weighted	SDG Weighted	-8.90	0.00	20.76
Multi Family	6	SDG Weighted	-3.29	0	7.78
Multi Family	7	SDG Weighted	-2.61	0	6.05
Multi Family	8	SDG Weighted	-2.94	0	6.7
Multi Family	10	SDG Weighted	-4.59	0	10.35
Multi Family	14	SDG Weighted	-10.26	0	18.37
Multi Family	15	SDG Weighted	-2.18	0	4.97
Multi Family	SDG Weighted	SDG Weighted	-4.31	0.00	9.04
Mobile Home	6	SDG Weighted	-6.04	0	14.87
Mobile Home	7	SDG Weighted	-5.67	0	13.89
Mobile Home	8	SDG Weighted	-7.07	0	16.8
Mobile Home	10	SDG Weighted	-10.9	0	25.01
Mobile Home	14	SDG Weighted	-18.74	0	40.97
Mobile Home	15	SDG Weighted	-18.93	0	19.09
Mobile Home	SDG Weighted	SDG Weighted	-11.23	0.00	21.77

1.3 Codes & Standards Requirements Analysis

There is no code or standard addressing the EFC. The measure can be retrofit to any RAC with gas furnace or heat pump having a thermostat with less than 2-minute time delay for cooling or heating or standard temperature delay for heating. The measure can also be retrofit to any RGF thermostat with less than 2-minute time delay or standard temperature delay for heating.

1.4 EM&V, Market Potential, and Other Studies

The forecast values were derived from these sources:

- Incremental (Full) Measure Cost is based on what HVAC Contractors charge for the materials, labor, and overhead to install the Efficient Fan Controller.
- Annual Energy Savings is based on the Percentage Energy Savings times the Baseline Electrical Usage as described in **Section 1.4.5** (Estimated Energy Savings).

- Percentage Energy Savings are based on Field and Laboratory Tests as described in **Section 1.4.3** (Field Test Data) and **Section 1.4.4** (Laboratory Test Data).

1.4.1 Abstract

The EFC improves on the conventional temperature or time delay relay (TDR) which will continue to operate the fan after the furnace or compressor turns off. In heating mode, the EFC micro-computer monitors gas valve activation time and determines whether or not to continue operating the fan after the furnace turns on and how long the fan should continue operating to maximize heat recovery from the heat exchanger. In cooling mode the EFC monitors fan operation and determines whether or not to continue operating the fan after the compressor turns off to transfer heat to the cold evaporator coil and recover energy stored in the form of condensed cold water on the evaporator coil to further cool the building. In cooling mode the EFC uses the evaporator coil as an evaporative cooler. The fan uses 8 to 15 times less power than the compressor and is adaptively controlled to operate based on fan run time (which is a proxy for compressor operation). Air conditioning equipment manufacturers provide an optional 1.5 minute TDR kit to improve SEER by 2 to 3%. Furnace manufacturers provide either a 1.5 minute fan time delay or a temperature delay that extends fan operation from 1 to 4 minutes by shutting off the fan when the supply air is less than 110°F. The standard furnace TDR improves AFUE by 2 to 3%. The delivered furnace efficiency improvements from EFC are shown in **Figure 1**. The EFC maximizes heating efficiency by increasing fan speed from low to high four minutes after the furnace is turned on. Standard furnace fans operate at low speed delivering less heating capacity to the conditioned space at lower efficiency compared to operating the fan at high speed. The EFC maximizes heat recovery from the heat exchanger after the furnace is turned off with an extended fan delay of 2 to 4 minutes depending on how long the furnace gas valve signal is on during the heating cycle. The EFC improves heating efficiency by 7 to 10% above standard temperature delay and 6 to 8% above standard 90-second delay. For systems with degraded temperature sensors the EFC saves 7 to 23% depending on furnace run time and ambient conditions. Savings will be greater for furnaces with degraded temperature delay. The delivered air conditioner sensible energy efficiency ratio (EER*) improvements from EFC are shown in **Figure 2**. Standard air conditioners have a 0 to 1.5 minute fan time delay. The EFC maximizes recovery of latent cooling from the evaporator after the compressor is turned off with an extended fan delay of 1.5 to 5 minutes depending on how long the air conditioner compressor is on during the cooling cycle.

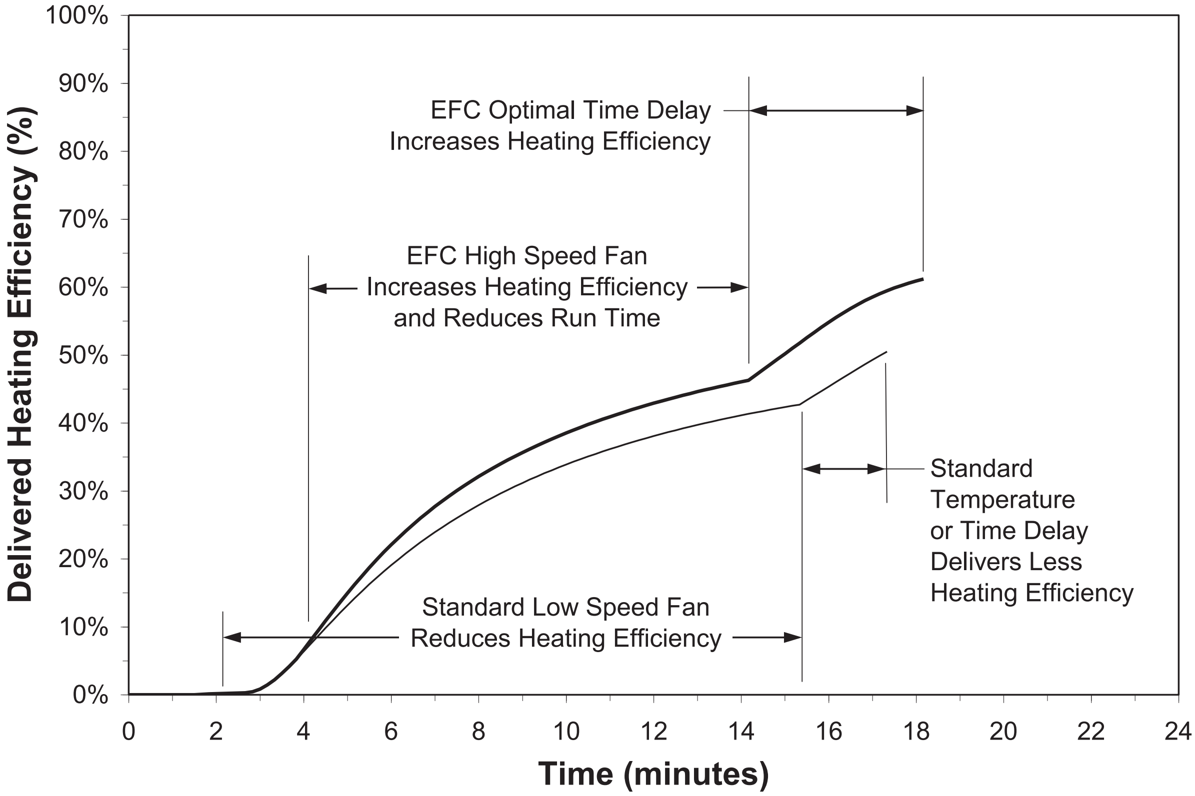

Figure 1. Heating Efficiency Improvement from EFC

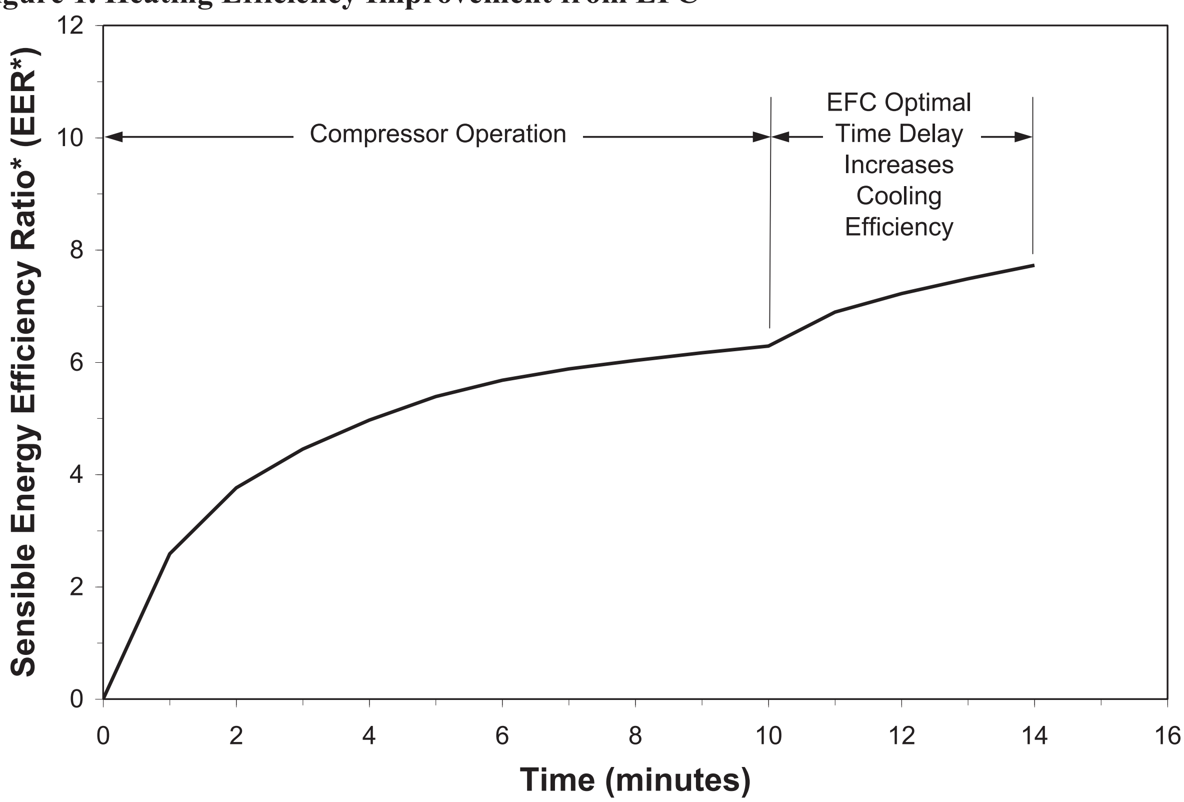

Figure 2. Air Conditioner Sensible EER* Improvement from EFC

The SEER cycling test is performed with a dry evaporator coil. In California the air conditioner condenses moisture from the air onto the cold evaporator coil. The EFC intelligently optimizes the fan operation after the compressor turns off to improve the EER and SEER. Many new air conditioning systems are installed without the standard manufacturer TDR due to market barriers (i.e., information, availability, or organizational practices) or the evaporator and condenser are replaced without replacing the furnace forced air unit (FAU).

Most furnaces operate at low fan speed with a time or temperature delay relay that stops the fan with heat left in the heat exchanger at temperatures between 100°F and 200°F. Most air conditioners do not have a fan time delay. Therefore, the EFC is applicable to all existing and new HVAC systems.

EFC units were installed at homes in California and Nevada to evaluate consumer satisfaction. Survey respondents indicated that the EFC provides more comfortable heating with an overall rating of 7.5 ± 0.18 out of 10 points. One hundred percent of survey respondents indicated that the EFC saves energy. Survey respondents indicate high satisfaction with an overall rating of 10 out of 10 points.

1.4.2 Baseline

The baseline furnace and air conditioner characteristics are provided in **Table 3**. For heating the baseline is either temperature controlled, degraded temperature controlled, or time controlled delay on the furnace fan. The estimated market share for heating system controls is as follows: 35% for properly working temperature delay, 35% for degraded temperature delay, and 30% for time delay.[3] For cooling the baseline is either no time delay or time delay of 90 seconds. The estimated market share for cooling systems with no time delay is 90% and the estimated market share for cooling systems with 90-second time delay is 10%. Furnaces having temperature delay controllers typically turn on the furnace fan at supply plenum temperatures ranging from 135 to 160°F and turn off the furnace fan at supply plenum temperatures ranging from 100 to 110°F (Carrier 1973). Over time the bi-metal temperature sensor accuracy and performance degrades and the sensors will drift up by approximately 30 to 60°F. This causes the standard temperature delay controller to not turn on the furnace fan until the plenum temperature is 140 to 160°F which can take more than 4 minutes. When the furnace turns off the degraded sensor will cause the controller to turn off the furnace fan with supply plenum temperatures still at or above 120 to 210°F. This will typically occur within 40 to 90 seconds instead of 180 to 240 seconds. Degraded bi-metal temperature sensors leave a significant amount of heat stranded in the heat exchanger (i.e., 15 to 25%). For systems with degraded bi-metal sensors the EFC can save 15 to 65% depending on furnace run time and ambient conditions. Newer heating systems are sold with adjustable time delay controllers with factory settings of 90 to 120 seconds (Carrier 2006, Lennox 1998, Lennox 1998a, Trane 2009, Rheem 2005). The 90 second time delay will turn off

[3] Most HVAC manufacturers introduced heating time delay controls with 90-second factory settings in the early 1980s. New furnaces currently sold are manufactured with 90-second time delays. Furnaces systems more than 20 years old typically have temperature delays. Approximately 50% of the older systems have degraded temperature delays due to dirt build-up or excessive supply plenum temperatures which cause the delays to drift upward by approximately 30°F to 40°F.

the furnace with supply plenum temperatures still at or above 110 to 120°F. Some newer air conditioners can have an optional time delay relay kit installed with factory settings of 90 seconds (Carrier 2006a, Carrier 2010). Most existing and new air conditioners do not have a cooling fan time delay. Therefore, the EFC is applicable to all existing and new HVAC systems. For heating, the EFC will correct for improperly operating temperature delays with degraded bi-metal temperature sensors with less material and labor cost than would be required to replace degraded temperature sensors and controllers. Increasing the heating fan speed from low and high will increase power use by approximately 18 to 21% (60 to 150W) for permanent split capacitance (PSC) motors depending on the size of the fan motor and total system static pressure. PSC blower motors that are worn out will use more power in high speed due to increased bearing friction. Worn out PSC blower motors should be replaced.

Table 3. Pre-Existing Baseline and Measure Characteristics

Pre-Existing Description	Measure Description	Estimated Market Share
Heating properly working Temperature Delay at 100 to 110°F, PSC motor	EFC High Speed Fan plus Variable Time Delay (2 to 4 minutes)	35%
Heating degraded Temperature Delay at 130 to 200°F, PSC motor	EFC High Speed Fan plus Variable Time Delay (2 to 4 minutes)	35%
Heating 90 second Time Delay, PSC motor	Variable Time Delay (2 to 4 minutes)	30%
Cooling No Time Delay, PSC Motor	Variable Time Delay (1.5 to 5 minutes)	90%
Cooling 90 second Time Delay, PSC Motor	Variable Time Delay (1.5 to 5 minutes)	5%
Cooling No Time Delay, Efficient Motor	Variable Time Delay (1.5 to 5 minutes)	3%
Cooling 90 second Time Delay, Efficient Motor	Variable Time Delay (1.5 to 5 minutes)	2%

1.4.3 Field Test Data

Field measurements and equipment accuracy are provided in **Table 4**.

Table 4. Field Measurements, Measurement Equipment, and Accuracy

Field Measurement	Measurement Equipment	Measurement Accuracy
Relative humidity (%) and temperature in degrees Fahrenheit (°F) of return and supply, thermostat, and outdoor condenser entering air	Platinum Resistance Pt100 1/3 Class B 6-channel humidity and temperature data loggers.	Temperature: 0.1°C or 0.18°F RH: ± 0.5 RH at 23°C and 10, 20, 30, 40, 50, 60, 70, 80, 90 % RH
Airflow in cubic feet per minute (cfm) across air conditioner evaporator coil	Digital pressure gauge and fan-powered flow hood, flow meter pitot tube array, and electronic balometer	Fan-powered flowhood: ± 3% Flow meter pitot tube array: ± 7% Electronic balometer: ± 4%
Total power in kilowatts (kW) of air conditioner compressor and fans	True RMS 4-channel power data loggers and 4-channel power analyzer	Data loggers, CTs, PTs: ± 1% Power analyzer: ± 1%
Total gas energy use (Btu) of furnace	Natural gas utility diaphragm flow meter	± 1% of reading
Combustion efficiency, CO	Digital combustion analyzer	Combustion efficiency: ±0.1% CO: ± 5%, O2: ±0.3%

Return and supply temperatures were measured inside the return and supply ducts either in the plenums or near the plenums. Temperature and power were measured at intervals of 10 to 60 seconds. Airflow was measured before and after making any changes to the supply/return ducts, opening vents, or installing new air filters that would affect airflow. Return and supply enthalpies were derived from the temperature measurements using standard psychrometric algorithms (REFPROP 2010). The "application" EER* is calculated from the combination of enthalpy, airflow, and power measurements. Measurements of air conditioner performance were made continuously.

The heating or cooling capacity of the HVAC system is measured as the rate of delivered heating or cooling energy per measurement interval (i.e., English units of British thermal units per hour).[4] Heating of air occurs in the heat exchanger of the furnace or heat pump. Cooling occurs in the evaporator coil of the air conditioner. The heating capacity or energy is based on the measured airflow rate, specific volume, and sensible temperature difference across the return and supply plenums. **Equation 1** provides the calculation of sensible heating energy delivered to the conditioned space by the HVAC system.

Eq. 1 $$Q_{hs} = \frac{cfm \times 60}{v} \times c_v \times (T_r - T_s)$$

Where,

Q_{hs} = sensible heating energy delivered to the conditioned space over the measurement interval (i.e., Btu/hr),

cfm= airflow rate in cubic feet per minute (cfm),

v = specific volume per pound of dry air (ft^3/lbm),

c_v = specific heat of dry air = 0.24 Btu/lbm-°F,

T_r = dry bulb temperature of return air in plenum entering the heat exchanger (°F), and

T_s = dry bulb temperature of supply air in plenum leaving the heat exchanger (°F).

The cooling capacity is based on the measured airflow rate, specific volume, and enthalpy difference across the return and supply plenums. **Equation 2** provides the calculation of total cooling energy removed from the air by the HVAC system.

Eq. 2 $$Q_c = \frac{cfm \times 60}{v} \times (h_r - h_s)$$

Where,

Q_c = cooling energy removed from the air by the HVAC system over the measurement interval (Btu/hr),

h_r = enthalpy of return air entering the evaporator coil (i.e., Btu/lbm), and

h_s = enthalpy of supply air leaving the evaporator coil (i.e., Btu/lbm).

[4] The British Thermal Unit (Btu) is the unit of heat required to raise the temperature of one pound of water one degree Fahrenheit (°F). The Btu is equivalent to 1055.06 joules or 251.997 calories.

Laboratory and field test data show that standard fan delays are insufficient to harvest available cooling stored in the evaporator and that medium fan speed and standard fan delays are insufficient to harvest available heating stored in the heat exchanger. The combustion efficiency, EFC efficiency, and standard temperature delay efficiency are illustrated in **Figure 3** and **Table 5** for an 80 AFUE gas furnace. **Equation 3** shows how the heating efficiency is calculated.

Eq. 3 $\eta = \sum_{i=0}^{t} \frac{Q_{hs\,i}}{Q_{hf\,i}}$

Where,

η = heating efficiency (ratio or %),
i = measurement interval for which data is collected ranging from 10 to 60 seconds,
t = total number of measurement intervals for the test,
$Q_{hs\,i}$ = sensible heating energy delivered to the conditioned space per measurement interval (Btu/hr), and
$Q_{hf\,i}$ = heating energy fuel input per measurement interval (Btu/hr).

The heating energy savings (S_{heat}) based on the heating efficiency improvement are calculated using **Equation 4**.

Eq. 4 $S_{heat} = \eta_{EFC} - \eta_{Base}$

Where,

S_{heat} = heating energy savings for the EFC (ratio or %),
η_{EFC} = delivered heating efficiency of the EFC with high speed fan and/or optimal time delay from 2 to 4 minutes (ratio or %), and
η_{Base} = delivered heating efficiency of the base case thermostat with temperature delay, 90-second time delay, or degraded temperature delay (ratio or %).

The rated furnace efficiency, EFC plus high speed fan (HSF) efficiency, and standard temperature delay efficiency for an 80% AFUE gas furnace is shown in **Figure 3** and **Table 5**. The furnace is turned on when the thermostat temperature is below 65°F and turned off when the thermostat temperature is above 68°F. The low speed fan requires 14.8 minutes of furnace operation to increase the thermostat temperature to above 68°F, and the baseline working temperature delay provides 4.2 minutes of additional fan operation and supply plenum fan off temperature of 99.4°F. The EFC provides high speed fan operation 4 minutes after the furnace is turned on and this increases furnace efficiency by 5.9% and reduces furnace operation by 1.1 minutes or 7.9%. The EFC provides a 4 minute time delay with high speed fan recovering slightly more energy than the standard temperature delay with fan off supply plenum temperature of 98.3°F and increased off cycle of 1%. The EFC saves 7.9% of gas heating energy and -4.6% of heating fan ventilation energy. High speed fan power is 722W or 17.8% greater than low speed fan power which is 613W.

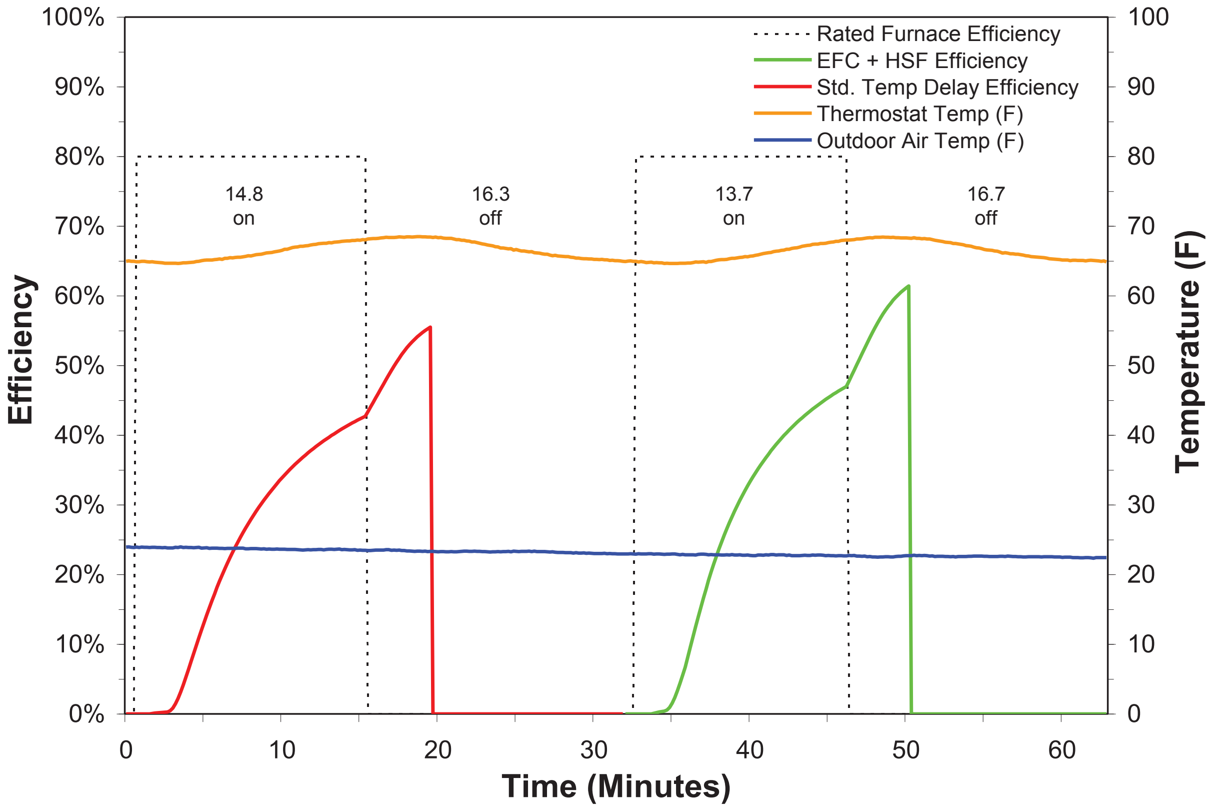

Figure 3. Heating Efficiency with EFC + HSF versus Standard Temperature Delay

Table 5. Measured Heating Efficiency from EFC + HSF vs. Standard Temp. Delay

Description	Test 1 Baseline	Test 2 EFC
Furnace On Time (minutes)	14.8	13.7
Furnace Off Cycle Time (minutes)	16.3	16.7
Fan Delay After Furnace Off (minutes)	4.2	4
EFC Additional Fan Energy (kWh/cycle)		0.009
EFC Additional Fan Energy		-4.6%
Furnace Energy Used (Btu)	-32,689	-30,118
Heat Energy Delivered to Space (Btu)	-18,147	-18,493
Delivered Efficiency	55.5%	61.4%
Savings Based on Heating Capacity (%)		5.9%
Savings from Run Time and Off Cycle (%)		9.9%
Average Savings		**7.9%**
Furnace Off Thermostat Temperature (F)	68.1	68.0
Fan Off Plenum Temperature (F)	99.4	98.3
Fan Off Supply Temperature (F)	95.7	94.0
Furnace On Thermostat Temperature before Cycle (F)	64.9	64.9

The rated furnace efficiency, EFC efficiency, and 90-second time delay efficiency for an 80% AFUE gas furnace is shown in **Figure 4** and **Table 6**. The furnace is turned on when the thermostat temperature is below 69°F and turned off when the thermostat temperature is above 72°F. The baseline time delay provides 1.5 minutes of additional fan operation and supply plenum fan off temperature of 143.9°F. The EFC provides a 4 minute time delay with fan off

supply plenum temperature of 97.9°F and increased off cycle by 1.2 minutes or 6.5%. The EFC saves 5.9% of gas heating energy and -14.5% of heating fan ventilation energy.

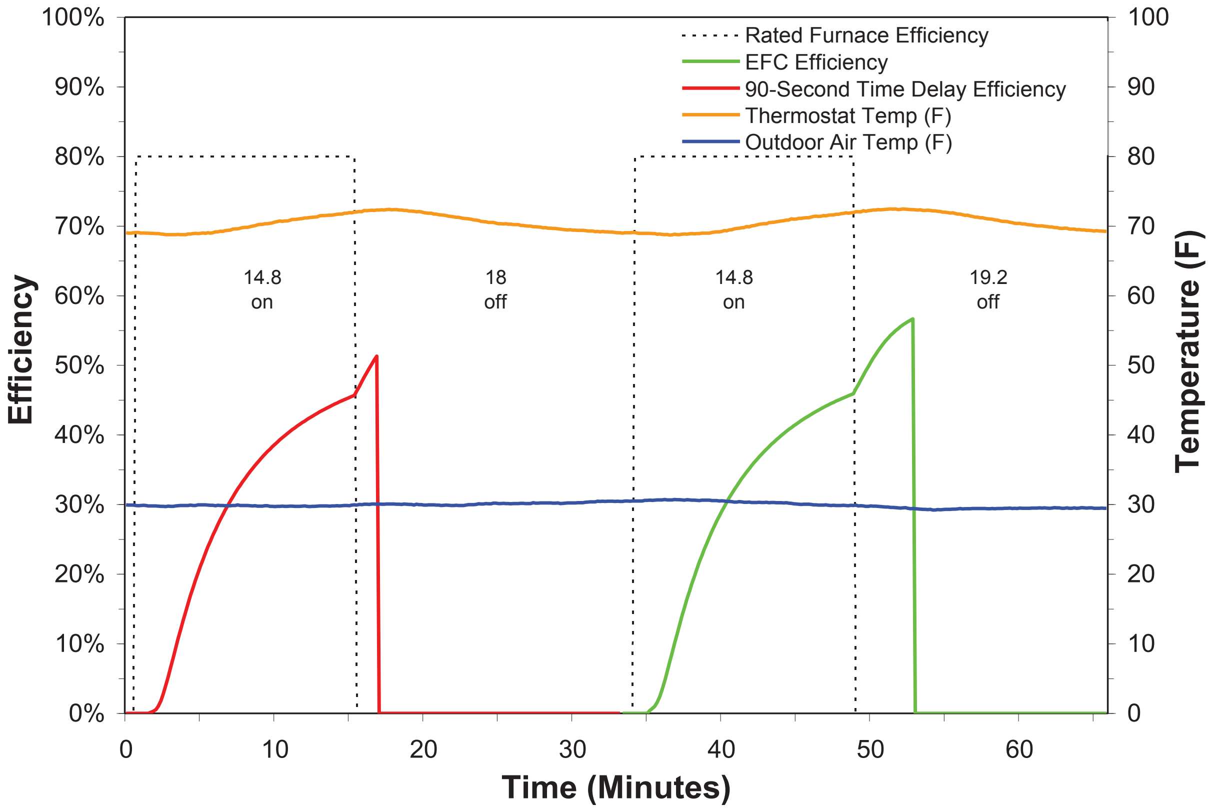

Figure 4. Heating Efficiency with EFC versus 90-Second Time Delay (Low Speed Fan)

Table 6. Measured Heating Efficiency with EFC vs. 90-Sec. Time Delay (Low Speed Fan)

Description	**Test 3 Baseline**	**Test 4 EFC**
Furnace On Time (minutes)	14.8	14.8
Furnace Off Cycle Time (minutes)	18.0	19.2
Fan Delay After Furnace Off (minutes)	1.5	4
EFC Additional Fan Energy (kWh/cycle)		0.025
EFC Additional Fan Energy		-14.5%
Furnace Energy Used (Btu)	-32,689	-32,689
Heat Energy Delivered to Space (Btu)	-16,769	-18,523
Delivered Efficiency	51.3%	56.7%
Savings Based on Heating Capacity (%)		5.4%
Savings from Run Time and Off Cycle (%)		6.5%
Average Savings		**5.9%**
Furnace Off Thermostat Temperature (F)	72.0	72.1
Fan Off Plenum Temperature (F)	143.9	97.9
Fan Off Supply Temperature (F)	116.9	97.3
Furnace On Thermostat Temperature before Cycle (F)	69.0	69.0

The rated furnace efficiency, EFC + HSF efficiency, and degraded temperature delay efficiency for an 81% AFUE gas furnace is shown in **Figure 5** and **Table 7**. For test 5 (baseline) and test 6 (EFC) the furnace is turned on when the thermostat temperature is below 68°F and turned off when the thermostat temperature is above 71°F. The low speed fan requires 8.0 minutes of

furnace operation to increase the thermostat temperature to above 71°F. The baseline degraded temperature delay provides 0.7 minutes of additional fan operation and the supply plenum fan-off temperature is 198.8°F. The EFC provides high speed fan operation 4 minutes after the furnace is turned on. This increases furnace efficiency by 7.1% and reduces furnace operation by 0.7 minutes or 8.8%. The EFC provides a 4-minute time delay with high-speed fan and the fan-off supply plenum temperature is 114.8°F. The EFC increases off cycle from 9.8 to 15.7 minutes or 60.2%. Test 6 EFC saves 24.5% of gas energy and -13.8% of heating fan ventilation energy. The high-speed fan power is 450W or 22.1% greater than low-speed fan power which is 368W.

For the test 7 (baseline) and test 8 (EFC) the furnace is turned on when the thermostat temperature is below 67°F and turned off when the thermostat temperature is above 73°F. The low speed fan requires 14.8 minutes of furnace operation to increase the thermostat temperature to above 73°F. The baseline degraded temperature delay provides 1 minute of additional fan operation and the supply plenum fan-off temperature is 206.4°F. The EFC provides high speed fan operation 4 minutes after the furnace is turned on. This increases furnace efficiency by 7.7% and reduces furnace operation by 1 minute or 6.8%. The EFC provides a 4-minute time delay with high-speed fan and the fan-off supply plenum temperature is 118.8°F. The EFC increases off cycle from 50.2 to 67.5 minutes or 34.6%. EFC test 8 saves 16.9% of gas energy and -30.5% of heating fan ventilation energy. The average savings from EFC (tests 6 and 8) versus degraded temperature delay (tests 5 and 7) are 20.7% of gas heating energy and -22.2% of heating fan ventilation energy. The high-speed fan power is 450W or 23.2% greater than low-speed fan power which is 365W.

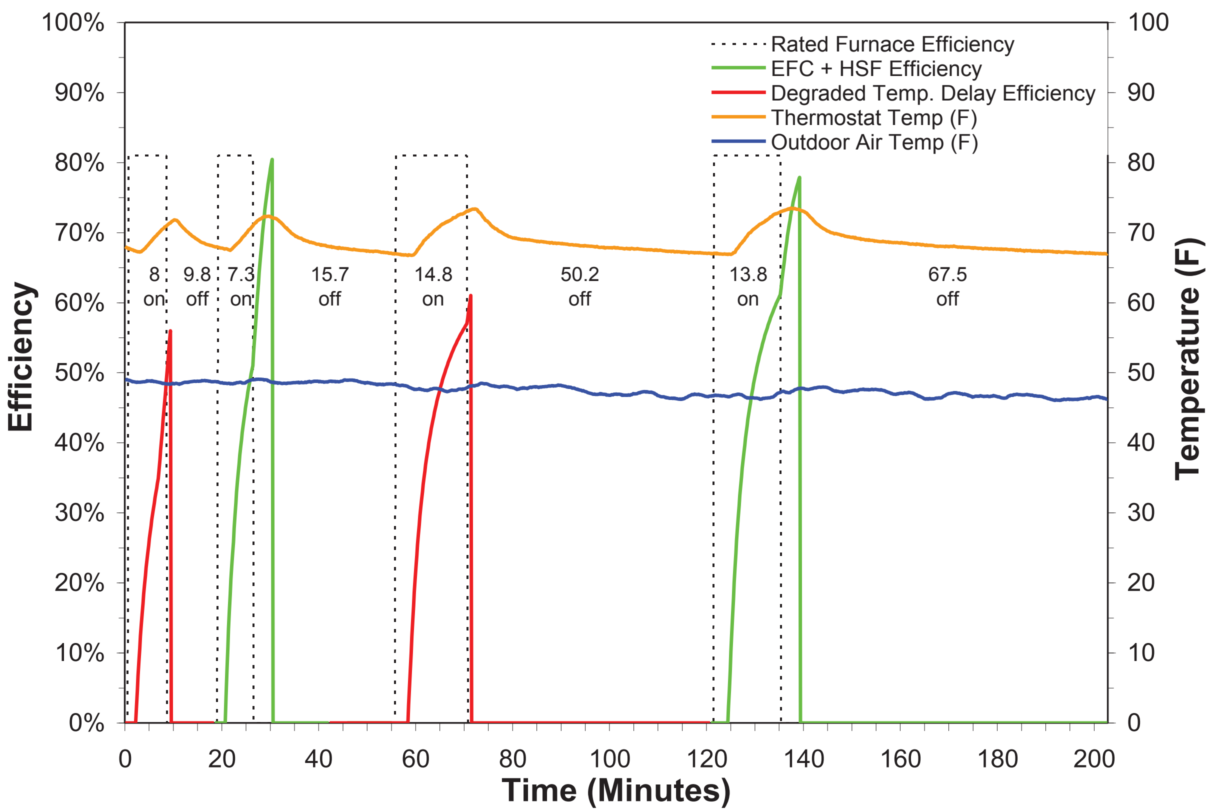

Figure 5. Heating Efficiency with EFC + HSF versus Degraded Temperature Delay

Table 7. Measured Heating Efficiency with EFC + HSF vs. Degraded Temp. Delay

Description	Test 5 Baseline	Test 6 EFC	Test 7 Baseline	Test 8 EFC	Average
Furnace On Time (minutes)	8.0	7.3	14.8	13.8	7.5%
Furnace Off Cycle Time (minutes)	9.8	15.7	50.2	67.5	46.9%
Fan Delay After Furnace Off (minutes)	0.8	4.0	1.0	4.0	
EFC Additional Fan Energy (kWh/cycle)		0.007		0.029	
EFC Additional Fan Energy		-13.8%		-30.5%	-22.2%
Furnace Energy Used (Btu)	-15,617	-14,315	-28,956	-27,004	
Heat Energy Delivered to Space (Btu)	-8,740	-11,519	-17,674	-21,033	
Delivered Efficiency	56.0%	80.5%	61.0%	77.9%	
Savings Based on Heating Capacity (%)		24.5%		16.9%	20.7%
Savings from Run Time and Off Cycle (%)		67.7%		41.3%	54.5%
Average Savings		**24.5%**		**16.9%**	**20.7%**
Furnace Off Thermostat Temperature (F)	71.1	71.2	73.1	73.0	
Fan Off Plenum Temperature (F)	198.8	114.8	206.4	118.8	
Fan Off Supply Temperature (F)	136.3	100.7	140.9	103.4	
Furnace On T-stat Temp. before Cycle (F)	68.0	68.0	67.0	67.0	

The ratio of additional electric power to operate the EFC fan compared to the standard fan is calculated using **Equation 5**.

Eq. 5 EFC Fan Energy = $S_{vent} = \dfrac{\sum_{i=0}^{m}(t_i \times P_{std\ fan\ i}) - \sum_{j=0}^{n}(t_j \times P_{EFC\ fan\ j})}{\sum_{i=0}^{m}(t_i \times P_{std\ fan\ i})}$

Where,

S_{vent} = electric residential air conditioner (RAC) or residential gas furnace (RGF) ventilation savings associated with the EFC based on field or laboratory tests (%),
t = time of measurement interval,
m = total time for EFC furnace fan operation,
n = total time for standard heating fan operation,
$P_{EFC\ fan}$ = power of heating fan with EFC (W),
$P_{std\ fan}$ = power of heating fan with standard control (W).

The test data presented in this report indicate 17.8 to 22.6% more fan energy is required for the permanent split-capacitance (PSC) motor (722W versus 613W and 450W versus 367W). A review of manufacturer product literature indicates that 20.5% more power is generally required to operate a PSC motor at high speed compared to medium speed (Lennox 1998a). In heating mode, the EFC requires 4.6% more electricity than furnace fans with standard temperature delay fan, 22.3% more electricity than furnace fans with degraded temperature delay, and 14.5% more electricity than furnace fans with 90-second time delay fan. In cooling mode, the EFC requires 37.5% more electricity than the fans with no delay and 19.3% more electricity than fans with 90-second time delay fan. The additional electricity required to operate the EFC fan is 13.8% in heating mode and 36.2% in cooling mode based on the weighted average of temperature and time delay market share (see **Table 12**).

Field measurements of the cooling sensible energy efficiency ratio (EER*) and total power (kW) for an air conditioner with a standard no time delay on the fan are shown in **Figure 6** and **Table 8**. The average cooling efficiency improvement from the EFC compared to the standard no TDR unit is 14.5% +/- 2% based on these measurements. The field tests were conducted with average air conditioner run times of 16.5 minutes and average EFC fan time delay times of 5 minutes. The EFC additional fan energy is 30.6% in cooling mode.

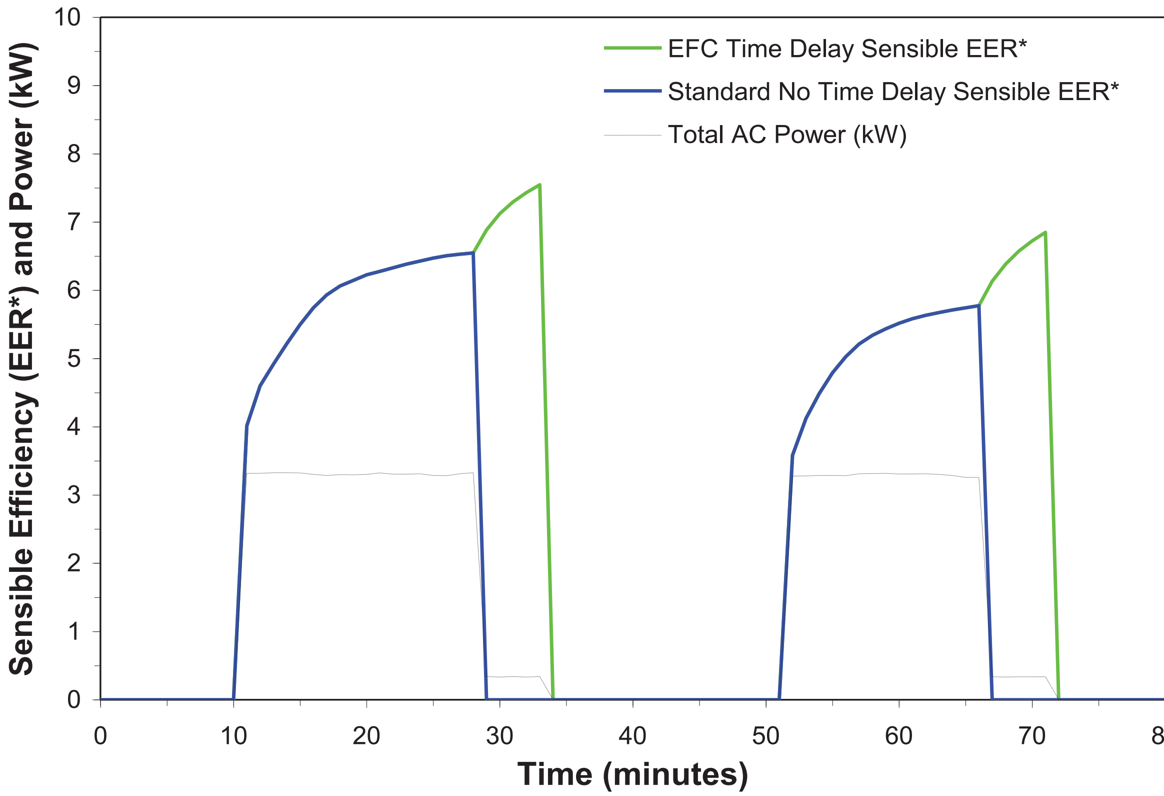

Figure 6. Field Tests Cooling Sensible EER and Power EFC versus no Time Delay

Table 8. Field Tests of Air Conditioner EFC versus No Time Delay

Description	Test 9	Test 10	Average
Compressor On Time (minutes)	18	15	16.5
EFC Delay After Compressor Off (minutes)	5	5	5
EFC Additional Fan Energy (kWh/cycle)	0.03	0.03	0.03
Std. Delay After Compressor Off (minutes)	0	0	0.00
EFC Additional Fan Cooling Energy	-27.8%	-33.3%	-30.6%
Std. AC Energy (kWh)	0.99	0.82	0.91
Standard Cooling Delivered (Btu)	6,497	4,752	5,625
Std. 90-Sec. Delay Cool Efficiency	6.55	5.77	6.16
EFC AC Energy (kWh)	1.02	0.85	0.94
EFC Cooling Delivered (Btu)	7,703	5,828	6,766
EFC Cooling Efficiency	7.55	6.85	7.20
Cooling Efficiency Improvement	**13.3%**	**15.7%**	**14.5%**

Field measurements of the cooling sensible energy efficiency ratio (EER*) and total power (kW) for an air conditioner with a 90-second time delay on the fan are shown in **Figure 7** and **Table 9**.

The average cooling efficiency improvement from the EFC compared to the 90-second TDR is 9.5% +/- 1.3% based on the field measurements. The field tests were conducted with average air conditioner run times of 16.5 minutes and average EFC fan time delay times of 5 minutes. The EFC additional fan energy is 19.6% in cooling mode.

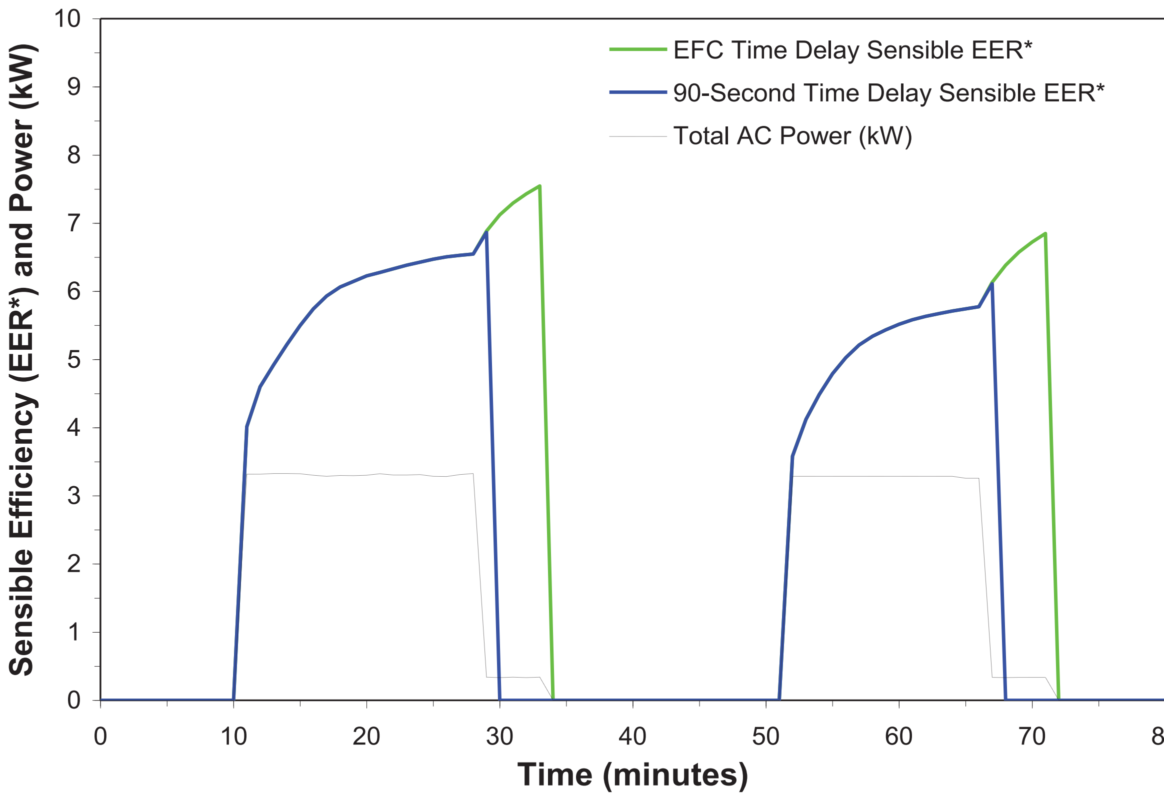

Figure 7. Field Tests Cooling Sensible EER and Power EFC versus 90-second TDR

Table 9. Field Tests of Air Conditioner EFC versus 90-Second TDR

Description	Test 11	Test 12	Average
Compressor On Time (minutes)	18	15	16.5
EFC Delay After Compressor Off (minutes)	5	5	5
EFC Additional Fan Energy (kWh/cycle)	0.02	0.02	0.02
Std. Delay After Compressor Off (minutes)	1.5	1.5	1.50
EFC Additional Fan Cooling Energy	-17.9%	-21.2%	-19.6%
Std. AC Energy (kWh)	1.00	0.83	0.91
Standard Cooling Delivered (Btu)	6,881	5,091	5,986
Std. 90-Sec. Delay Cool Efficiency	6.89	6.14	6.51
EFC AC Energy (kWh)	1.02	0.85	0.94
EFC Cooling Delivered (Btu)	7,703	5,828	6,766
EFC Cooling Efficiency	7.55	6.85	7.20
Cooling Efficiency Improvement	**8.7%**	**10.4%**	**9.5%**

1.4.4 Laboratory Test Data

The amount of moisture converted to sensible cooling is dependent on the airflow and the length of time the fan runs at the end of the compressor cycle. **Figure 8** and **Table 10** show laboratory

test data from Southern California Edison from the embedded Excel Workbook #2 in tab "SCE Data Fig7-8", Column O is the Cycle Sensible EER (see References Section). The sensible EER improvement decreases with increasing compressor run time from 22.2% for 5-minute run time to 6.2% for 30 minute compressor run time. The EFC adjusts the length of the time delay from 1.5 to 5 minutes based on the fan run time which is a proxy for the compressor run time. The average cooling efficiency improvement from the EFC compared to the standard unit is 15.3% +/- 5.7% based on these measurements. These savings are comparable to the average cooling efficiency improvement of 14.5% +/- 2% for the EFC compared to no time delay based on field measurements (see **Table 8**). **Figure 9** and **Table 11** show the same data set but with the baseline having a 90 second time delay. The average cooling efficiency improvement from the EFC compared to the 90-second delay is 8.1% +/- 2.4%. These savings are comparable to the average cooling efficiency improvement of 9.5% +/- 1.3% for the EFC compared to the 90-second delay based on field measurements (see **Table 9**).

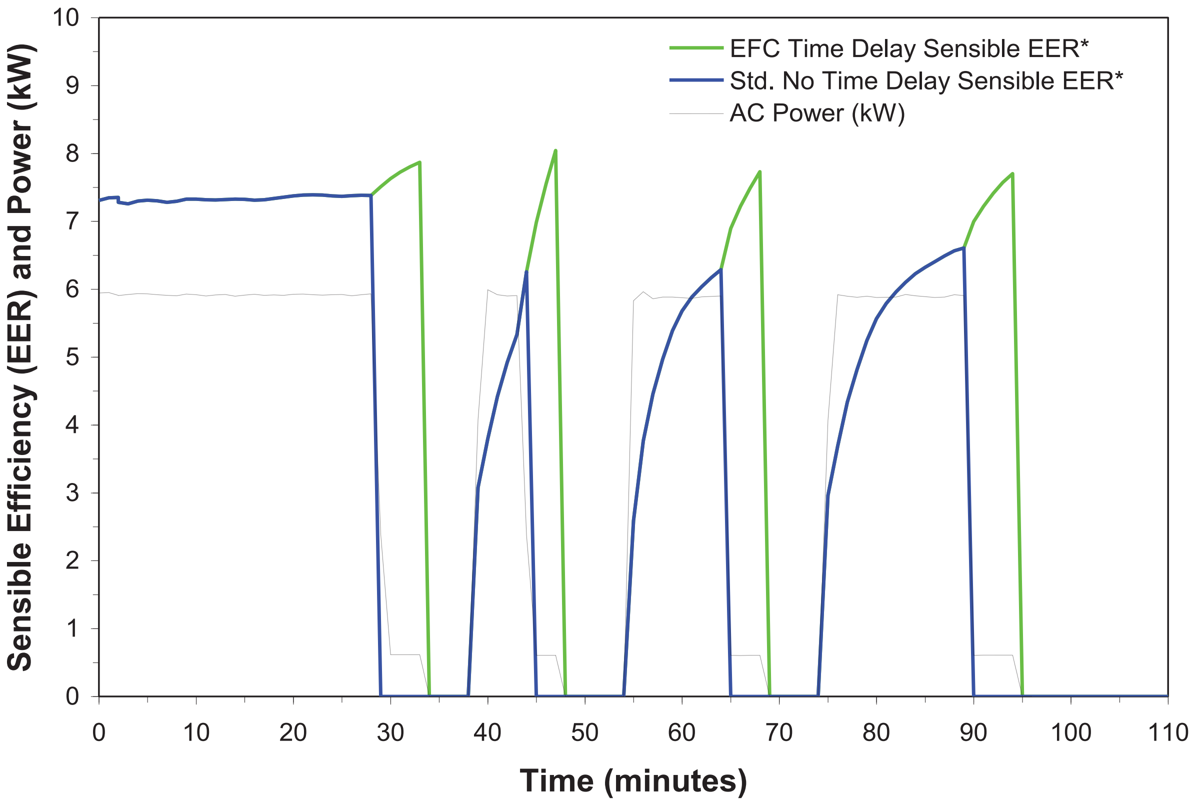

Figure 8. Laboratory Tests of Air Conditioner EFC versus No Time Delay

Table 10. Laboratory Tests of Air Conditioner with no Time Delay

Description	Test 13	Test 14	Test 15	Test 16	Average
Compressor On Time (minutes)	30	5	10	15	17.5
EFC Delay After Compressor Off (minutes)	5	3	4	5	4.25
EFC Additional Fan Energy (kWh/cycle)	0.05	0.03	0.04	0.05	0.04
Std. Delay After Compressor Off (minutes)	0	0	0	0	0.00
EFC Additional Fan Cooling Energy	-16.7%	-60.0%	-40.0%	-33.3%	-37.5%
No Time Delay AC Energy (kWh)	2.96	0.50	0.98	1.44	1.73
No Time Delay Cooling Delivered (Btu)	21,838	3,146	6,167	9,538	12,492
No Time Delay Application Sensible EER*	7.38	6.26	6.29	6.61	6.82
EFC AC Energy (kWh)	3.04	0.53	1.02	1.49	1.79
EFC Cooling Delivered (Btu)	23,917	4,288	7,893	11,507	11,901
EFC Application Sensible EER*	7.87	8.04	7.73	7.70	7.84
EFC Cooling Savings	**6.2%**	**22.2%**	**18.7%**	**14.2%**	**15.3%**

Source: Based on Southern California Edison data.

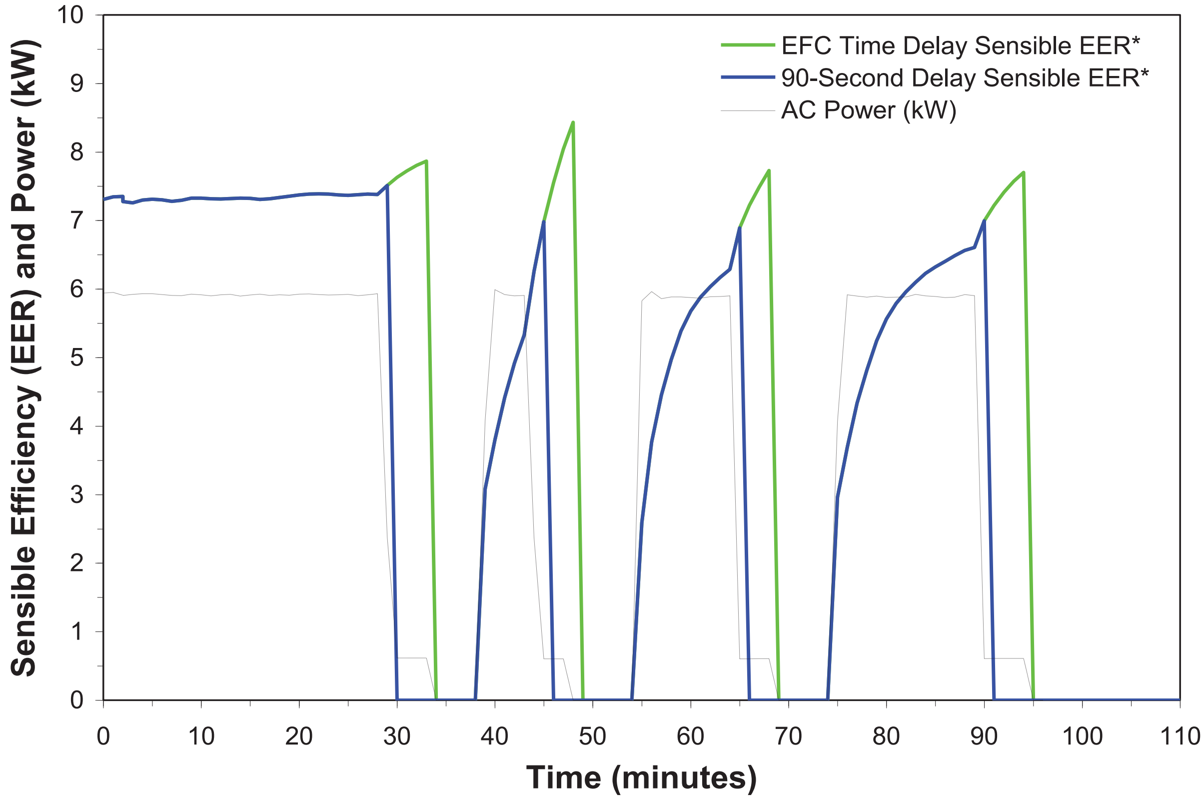

Figure 9. Laboratory Tests of Air Conditioner with EFC versus 90-Second Time Delay

Table 11. Laboratory Tests of Air Conditioner with EFC and 90-Second Time Delay

Description	Test 17	Test 18	Test 19	Test 20	Average
Compressor On Time (minutes)	30	5	10	15	17.5
EFC Delay After Compressor Off (minutes)	5	3	4	5	4.25
EFC Additional Fan Energy (kWh/cycle)	0.05	0.03	0.04	0.05	0.04
Std. Delay After Compressor Off (minutes)	1.5	1.5	1.5	1.5	1.50
EFC Additional Fan Cooling Energy	-11.1%	-23.1%	-21.7%	-21.2%	-19.3%
No Time Delay AC Energy (kWh)	3.00	0.52	1.00	1.46	1.76
No Time Delay Cooling Delivered (Btu)	22,738	3,765	7,029	10,365	13,251
No Time Delay Application Sensible EER*	7.57	7.27	7.06	7.11	7.42
EFC AC Energy (kWh)	3.04	0.53	1.02	1.49	1.79
EFC Cooling Delivered (Btu)	23,917	4,288	7,893	11,507	11,901
EFC Application Sensible EER*	7.87	8.04	7.73	7.70	7.84
EFC Cooling Savings	**3.9%**	**10.7%**	**9.5%**	**8.4%**	**8.1%**

Source: Based on Southern California Edison.

Equation 6 shows how the application sensible EER* is calculated.

Eq. 6 Sensible $EER_s^* = \sum_{i=0}^{n} \frac{Q_{cs_i}}{P_i}$

Where,

EER_s^* = application sensible energy efficiency ratio (Btu/hr-W),

Q_{cs_i} = sensible cooling energy removed from the air by the air conditioner over the measurement interval (Btu/hr),

P_i = total power to operate the air conditioner compressor, fan, and controls over the measurement interval (W).

The cooling energy savings (S_{cool}) based on cooling Sensible EER improvements are calculated using **Equation 7**.

Eq. 7 $S_{cool} = \frac{EER_s^*\big|_{EFC}}{EER_s^*\big|_{Base}} - 1$

Where,

S_{cool} = cooling energy savings for the EFC (%),

$EER_s^*\big|_{EFC}$ = EFC sensible cooling efficiency with optimal time delay from 1.5 to 5 minutes, and

$EER_s^*\big|_{Base}$ = base sensible cooling efficiency with no delay or 90-second time delay.

1.4.5 Estimated Energy Savings

The estimated space cooling and heating energy savings for each market share for the EFC are shown in **Table 12**. The savings are based on field tests and laboratory tests of furnaces and air conditioners with and without the EFC. The estimated weighted average heating energy savings are 11.8% based on field tests (see tests 1 through 8 in **Tables 5**, **6**, and **7**). In heating mode, the EFC requires 4.6% more ventilation electricity than heating systems with standard temperature delay fan and 14.5% more electricity than ventilation systems with 90-second time delay. In

cooling mode, the EFC requires 37.5% more ventilation electricity than the standard cooling system with no time delay and 19.3% more ventilation electricity than the system with 90-second time delay. The EFC heating ventilation energy savings are -13.8% (i.e., negative) based on the weighted average of temperature and time delay. The EFC cooling ventilation energy savings are -36.2% (i.e., negative) based on the weighted average of temperature and time delay. The EFC cooling savings are 14.8% based on the weighted average savings from field and laboratory tests and estimated market share.

The test data presented in this report indicate 20.6% more fan power is required at high speed compared to low speed for the permanent split-capacitance (PSC) motor for a 3-ton unit (450W high speed versus 372W low speed) and 17.8% for a 4-ton unit (722W high speed versus 613W low speed). A review of manufacturer product literature indicates 20.5% more power is required to operate at high speed during the time delay (Lennox 1998a). The weighted average ventilation electricity savings are -13.8% instead of -20.6% due to running the fan in high speed during furnace operation which reduces both furnace and fan energy consumption.

The weighted average space heating savings are calculated using **Equation 8**.

Eq. 8 $$\overline{S_{heat}} = \sum_{k=0}^{p} S_{heat_k} \times M_k$$

Where,

$\overline{S_{heat}}$ = weighted average space heating energy savings for the EFC based field tests and market share (%),

S_{heat_k} = heating energy savings for the EFC for market segment “k” (%), and

M_k = market segment “k” for the following base thermostat control market segments: working temperature delay, degraded temperature delay, or 90-second time delay (%).

The weighted average space cooling savings are calculated using **Equation 9**.

Eq. 9 $$\overline{S_{cool}} = \sum_{k=1}^{p} S_{cool_k} \times M_k$$

Where,

$\overline{S_{cool}}$ = weighted average space cooling energy savings for the EFC based on field and laboratory tests and market share (%),

S_{cool_k} = cooling energy savings for the EFC for market segment “k” (%), and

M_k = market segment “k” for the following base thermostat control market segments: no time delay PSC motor, 90-second time delay PSC motor, no time delay EC motor, 90-second time delay EC motor (%).

The weighted average RGF ventilation savings are calculated using **Equation 10**.

Eq. 10 $\overline{S_{RGF\,vent}} = \sum_{k=1}^{p} S_{RGF\,vent_k} \times M_k$

Where,

$\overline{S_{RGF\,vent}}$ = weighted average RGF ventilation energy savings associated with the EFC based on field and laboratory tests and market share (%),

$S_{RGF\,vent_k}$ = RGF ventilation savings for the EFC for market segment "k" (%), and

M_k = market segment "k" for the following base thermostat control market segments: working temperature delay, degraded temperature delay, or 90-second time delay (%).

The weighted average RAC ventilation savings are calculated using **Equation 11**.

Eq. 11 $\overline{S_{RAC\,vent}} = \sum_{k=1}^{p} S_{RAC\,vent_k} \times M_k$

Where,

$\overline{S_{RAC\,vent}}$ = weighted average RAC ventilation energy savings associated with the EFC based on field and laboratory tests and market share (%),

$S_{RAC\,vent_k}$ = RAC ventilation savings for the EFC for market segment "k" (%), and

M_k = market segment "k" for the following base thermostat control market segments: no time delay PSC motor, 90-second time delay PSC motor, no time delay EC motor, 90-second time delay EC motor (%).

Table 12. Estimated Space Heating and Cooling Energy Savings for EFC

Pre-existing Description	Measure Description	EFC Heating Savings	EFC Fan Heating Savings	EFC Fan Cooling Savings	EFC Cooling Savings	Estimated Market Share
Heating Temperature Delay at 100 to 110°F, PSC motor	EFC High-Speed Fan plus Variable Time Delay (2 to 4 minutes)	7.9%	-4.6%			35%
Heating Temperature Degraded Delay at 130 to 200°F, PSC motor	EFC High-Speed Fan plus Variable Time Delay (2 to 4 minutes)	20.7%	-22.3%			35%
Heating 90 second Time Delay, PSC motor low speed	EFC Variable Time Delay (2 to 4 minutes)	5.9%	-14.5%			30%
Cooling No Time Delay, PSC Motor	EFC Variable Time Delay (1.5 to 5 minutes)			-37.5%	15.3%	90%
Cooling Standard 90 second Time Delay PSC motor	EFC Variable Time Delay (1.5 to 5 minutes)			-19.3%	8.1%	5%
Cooling No Time Delay, Efficient Fan Motor	EFC Variable Time Delay (1.5 to 5 minutes)			-37.5%	15.3%	3%
Cooling Standard 90 second Time Delay, Efficient Fan Motor	EFC Variable Time Delay (1.5 to 5 minutes)			-19.3%	8.1%	2%
Weighted Average		**11.8%**	**-13.8%**	**-36.2%**	**14.8%**	

1.4.5 Consumer Satisfaction Study

EFC units were installed at homes in California and Nevada to evaluate consumer satisfaction. Consumers provided the following feedback after using the EFC for two months during the winter heating season from January through March 2012. Additional consumer survey responses will be obtained after the summer cooling season. Consumer satisfaction survey data are provided in **Table 13**. The average number of occupants is 3.2 +/- 0.1 and the average conditioned floor area is 2800 ft^2. Survey respondents indicated that the EFC provides more comfortable heating with an overall rating of 7.5 ± 0.18 out of 10 points. One hundred percent of survey respondents indicated that the EFC saves energy. Survey respondents indicate high satisfaction with an overall rating of 10 out of 10 points.

Table 13. Consumer Satisfaction Survey Data

Description	Average	Respondents
1. Number of Occupants	3.2 +/- 0.1	20
2. Conditioned Floor Area (ft^2)	2,800 +/- 49	20
3. Air Conditioner Average Fan Off Delay (sec)	TBD	TBD
4. Pre-Existing Average Furnace Fan Off Delay (sec)	109.6 +/- 3.3	20
5. EFC Furnace Fan Off Delay (sec)	240 +/- 2	20
6. Does the EFC provide more comfortable heating on a scale of 1 to 10? (10=more, 5=same, 1=less).	7.5 +/- 0.18	20
7. Does the EFC provide more comfortable cooling on a scale of 1 to 10?	TBD	TBD
8. Does the EFC save energy compared to not using the EFC? (% Yes)	100%	20
9. How satisfied are you with the EFC on a scale of 1 to 10? (1=Low, 10=High).	10 +/- 0	20

1.5 Baseline Unit Energy Consumption (UEC) Values

The weighted baseline unit energy consumption (UEC) values for the Southern California service area for Single Family (SFM), Multifamily (MFM), and Double-wide Mobile (DMO) prototypical buildings and Residential Air Conditioner (RAC) with Gas Furnace (GF) HVAC system are shown in **Table 14** and Residential gas Furnace (RGF) HVAC system are shown in **Table 15**. The UEC values are from the DEER 2008.2.1 MISer (DEER 2008a). Section 2 provides engineering calculations used to develop estimates of the baseline annual cooling electric ventilation from the total baseline annual electric ventilation and the baseline annual heating electric ventilation. The baseline and energy savings should be defined in "Common energy units" rather than per household to allow for multiple EFC units to be installed at one home.

Table 14. Weighted Baseline UEC per Household –RAC with Gas Furnace (DEER 2008 MISer)

DEER2008 ImpactID	Weighted Building Vintage Climate Zone	Baseline Annual Gas Heating (therm/yr)	Baseline Annual Heating Elec Ventilation (kWh/yr)	Baseline Annual Cooling Elec Ventilation (kWh/yr)	Baseline Annual Elec Cooling (kWh/yr)	Baseline Annual Elec Cooling (kW)	Baseline Annual Elec Ventilation (kW)
SFM-w06-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	6	187.9	61.2	148.7	839.6	1.878	0.255
SFM-w07-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	7	133.1	47.3	118.1	721.8	1.864	0.258
SFM-w08-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	8	162.6	55.7	184.3	1,188.90	2.538	0.336
SFM-w10-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	10	214.3	73.7	209.3	1,377.80	2.724	0.341
SFM-w14-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	14	281.6	106.9	382.6	2,610.50	3.686	0.473
SFM-w15-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	15	111.4	0	0	3,662.00	3.963	0.466
SFM-wSDG-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	SDG Weighted	181.82	57.47	173.83	1733.43	2.78	0.35
MFM-w06-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	6	64.1	23.9	39.4	235.2	0.616	0.09
MFM-w07-vDSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	7	51	18.9	33.7	199.9	0.616	0.085
MFM-w08-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	8	59.2	21.4	71.3	464.8	0.85	0.117
MFM-w10-vDSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	10	94.8	33.3	103.9	699.9	1.173	0.148
MFM-w14-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	14	153.6	74.6	244.4	1,744.30	1.781	0.231
MFM-w15-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	15	55.9	15.8	366.5	2,868.60	2.112	0.252
MFM-wSDG-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	SDG Weighted	79.77	31.32	143.20	1035.45	1.19	0.15
DMO-w06-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	6	147.3	43.9	260.2	2,210.60	2.732	0.254
DMO-w07-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	7	123.8	41.2	206.6	1,932.10	3.164	0.277
DMO-w08-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	8	179.6	51.4	424.5	4,113.10	4.568	0.389
DMO-w10-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	10	188.9	79.2	372	4,035.10	4.999	0.404
DMO-w14-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	14	339.4	136.2	568	5,592.60	6.053	0.5
DMO-w15-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	15	158.2	137.5	573.7	7,451.60	6.332	0.5
DMO-wSDG-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	SDG Weighted	189.53	81.57	400.83	4222.52	4.64	0.39

Table 15. Weighted Baseline UEC per Household –RGF Only (DEER 2008 MISer)

DEER2008 ImpactID	Weighted Building Vintage Climate Zone	Baseline Annual Gas Heating (therm/yr)	Baseline Annual Heating Elec Ventilation (kWh/yr)	Baseline Annual Cooling Elec Ventilation (kWh/yr)	Baseline Annual Elec Cooling (kWh/yr)	Baseline Annual Elec Cooling (kW)	Baseline Annual Elec Ventilation (kW)
SFM-w06-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	6	169.9	61.2				
SFM-w07-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	7	125.9	47.3				
SFM-w08-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	8	150.6	55.7				
SFM-w10-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	10	200.7	73.7				
SFM-w14-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	14	286.3	106.9				
SFM-w15-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	15	124.2	43.3				
SFM-wSDG-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	SDG Weighted	176.27	64.68				
MFM-w06-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	6	66	23.9				
MFM-w07-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	7	51.4	18.9				
MFM-w08-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	8	56.9	21.4				
MFM-w10-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	10	87.9	33.3				
MFM-w14-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	14	155.9	74.6				
MFM-w15-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	15	42.2	15.8				
MFM-wSDG-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	SCG Weighted	66.5	24.6				
DMO-w06-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	6	126.3	43.9				
DMO-w07-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	7	118	41.2				
DMO-w08-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	8	142.7	51.4				
DMO-w10-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	10	212.4	79.2				
DMO-w14-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	14	347.9	136.2				
DMO-w15-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	15	162.1	137.5				
DMO-wSDG-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	SCG Weighted	235.3	218				

Energy common units for RAC and RGF are shown in **Tables 16** and **17**.

Table 16. Energy Common Units for RAC HVAC System (DEER 2008 MISer)

DEER2008 ImpactID	Weighted Building Vintage Climate Zone	HVAC System	Energy Common Units 1 description	Number Energy Common Units 1
SFM-w06-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	6	RAC	tons cool cap	3.51
SFM-w07-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	7	RAC	tons cool cap	2.51
SFM-w08-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	8	RAC	tons cool cap	3.14
SFM-w10-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	10	RAC	tons cool cap	3.63
SFM-w14-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	14	RAC	tons cool cap	3.99
SFM-w15-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	15	RAC	tons cool cap	4.63
SFM-wSDG-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	SDG Weighted	RAC	tons cool cap	3.57
MFM-w06-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	6	RAC	tons cool cap	1.52
MFM-w07-vDSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	7	RAC	tons cool cap	1.38
MFM-w08-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	8	RAC	tons cool cap	1.41
MFM-w10-vDSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	10	RAC	tons cool cap	2.01
MFM-w14-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	14	RAC	tons cool cap	2.32
MFM-w15-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	15	RAC	tons cool cap	2.5
MFM-wSDG-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	SCG Weighted	RAC	tons cool cap	1.76
DMO-w06-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	6	RAC	tons cool cap	3.5
DMO-w07-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	7	RAC	tons cool cap	3.5
DMO-w08-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	8	RAC	tons cool cap	3.5
DMO-w10-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	10	RAC	tons cool cap	3.5
DMO-w14-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	14	RAC	tons cool cap	3.5
DMO-w15-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	15	RAC	tons cool cap	3.5
DMO-wSDG-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	SCG Weighted	RAC	tons cool cap	3.5

Table 17. Energy Common Units for RGF HVAC System (DEER 2008 MISer)

DEER2008 ImpactID	Weighted Building Vintage Climate Zone	HVAC System	Energy Common Units 1 description	Number Energy Common Units
SFM-w06-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	6	RGF	kBtuh furnace	63.15
SFM-w07-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	7	RGF	kBtuh furnace	47.49
SFM-w08-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	8	RGF	kBtuh furnace	57.18
SFM-w10-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	10	RGF	kBtuh furnace	71.93
SFM-w14-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	14	RGF	kBtuh furnace	80.03
SFM-w15-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	15	RGF	kBtuh furnace	89.88
SFM-wSDG-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	SDG Weighted	RGF	kBtuh furnace	68.28
MFM-w06-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	6	RGF	kBtuh furnace	29.94
MFM-w07-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	7	RGF	kBtuh furnace	25.63
MFM-w08-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	8	RGF	kBtuh furnace	27.85
MFM-w10-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	10	RGF	kBtuh furnace	37.66
MFM-w14-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	14	RGF	kBtuh furnace	45.38
MFM-w15-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	15	RGF	kBtuh furnace	48.66
MFM-wSDG-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	SDG Weighted	RGF	kBtuh furnace	31.19
DMO-w06-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	6	RGF	kBtuh furnace	55.01
DMO-w07-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	7	RGF	kBtuh furnace	55.06
DMO-w08-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	8	RGF	kBtuh furnace	55.02
DMO-w10-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	10	RGF	kBtuh furnace	54.96
DMO-w14-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	14	RGF	kBtuh furnace	54.96
DMO-w15-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	15	RGF	kBtuh furnace	54.96
DMO-wSDG-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	SDG Weighted	RGF	kBtuh furnace	54.98

Tables 18 and **19** provide baseline UEC data normalized per "Energy Common Units" (ECU), i.e., tons cooling capacity or kBtuh furnace capacity.

Table 18. Weighted Baseline UEC per ECU – RAC with Gas Furnace (DEER 2008 MISer)

DEER2008 ImpactID	Weighted Building Vintage Climate Zone	Baseline Annual Gas Heating (therm/yr-ECU)	Baseline Annual Heating Elec Ventilation (kWh/yr-ECU)	Baseline Annual Cooling Elec Ventilation (kWh/yr-ECU)	Baseline Annual Elec Cooling (kWh/yr-ECU)	Baseline Annual Elec Cooling (kW/ECU)	Baseline Annual Elec Ventilation (kW/ECU)
SFM-w06-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	6	53.48	17.42	42.31	238.91	0.534	0.073
SFM-w07-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	7	52.96	18.83	46.99	287.25	0.742	0.103
SFM-w08-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	8	51.74	17.73	58.65	378.38	0.808	0.107
SFM-w10-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	10	59.03	20.29	57.64	379.52	0.75	0.094
SFM-w14-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	14	70.65	26.82	96	655.05	0.925	0.119
SFM-w15-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	15	24.04	0	0	790.59	0.856	0.101
SFM-wSDG-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	SDG Weighted	51.98	16.85	50.27	454.95	0.77	0.10
MFM-w06-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	6	42.16	15.72	25.89	154.62	0.405	0.059
MFM-w07-vDSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	7	36.96	13.72	24.41	144.76	0.446	0.061
MFM-w08-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	8	41.92	15.14	50.51	329.19	0.602	0.083
MFM-w10-vDSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	10	47.19	16.6	51.72	348.31	0.584	0.073
MFM-w14-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	14	66.29	32.18	105.43	752.55	0.768	0.1
MFM-w15-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	15	22.39	6.34	146.68	1148.01	0.845	0.101
MFM-wSDG-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	SDG Weighted	42.82	16.62	67.44	479.57	0.61	0.08
DMO-w06-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	6	42.1	12.54	74.4	631.98	0.781	0.073
DMO-w07-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	7	35.39	11.78	59.07	552.41	0.905	0.079
DMO-w08-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	8	51.36	14.68	121.36	1175.92	1.306	0.111
DMO-w10-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	10	54.01	22.65	106.36	1153.59	1.429	0.115
DMO-w14-vSGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	14	97.02	38.93	162.36	1598.71	1.73	0.143
DMO-w15-vSDGx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	15	45.21	39.32	163.99	2130.13	1.81	0.143
DMO-wSDG-vEx-hAC-tWt-bCAv-eMsr-mRE-HV-ResAC-14S	SDG Weighted	54.18	23.32	114.59	1207.12	1.33	0.11

Table 19. Weighted Baseline UEC per ECU – RGF Only (DEER 2008 MISer)

DEER2008 ImpactID	Weighted Building Vintage Climate Zone	Baseline Annual Gas Heating (therm/yr-ECU)	Baseline Annual Heating Elec Ventilation (kWh/yr-ECU)	Baseline Annual Cooling Elec Ventilation (kWh/yr-ECU)	Baseline Annual Elec Cooling (kWh/yr-ECU)	Baseline Annual Elec Cooling (kW/ECU)	Baseline Annual Elec Ventilation (kW/ECU)
SFM-w06-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	6	2.69	0.97				
SFM-w07-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	7	2.65	1				
SFM-w08-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	8	2.63	0.97				
SFM-w10-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	10	2.79	1.02				
SFM-w14-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	14	3.58	1.34				
SFM-w15-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	15	1.38	0.48				
SFM-wSDG-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	SDG Weighted	2.62	0.96				
MFM-w06-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	6	2.21	0.8				
MFM-w07-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	7	2	0.74				
MFM-w08-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	8	2.04	0.77				
MFM-w10-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	10	2.33	0.89				
MFM-w14-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	14	3.44	1.64				
MFM-w15-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	15	0.87	0.33				
MFM-wSDG-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	SDG Weighted	2.13	0.79				
DMO-w06-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	6	2.3	0.8				
DMO-w07-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	7	2.14	0.75				
DMO-w08-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	8	2.59	0.93				
DMO-w10-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	10	3.86	1.44				
DMO-w14-vSGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	14	6.33	2.48				
DMO-w15-vSDGx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	15	2.95	2.5				
DMO-wSDG-vEx-hGF-tWt-bCAv-eMsr-mRG-HV-EffFurn-90AFUE	SDG Weighted	4.28	3.97				

1.6 Pre-Existing Baseline and Measure Effective Useful Lives

The pre-existing baseline measure characteristics are provided in **Table 3**. For heating the baseline is either temperature controlled or time controlled delay on the furnace fan. For cooling the baseline is either no time delay or time delay of 90 seconds. The baseline measure is installed inside the HVAC equipment and is dependent on the life of the equipment. The EFC measure is not installed inside the air conditioner, furnace, forced-air unit, or thermostat. Therefore, the EFC EUL is not dependent on the life of the air conditioner, furnace, FAU, or thermostat. The EFC is a small microchip approximately the size of a US penny which is installed in the wall behind the thermostat on the low-voltage wires coming from the HVAC equipment. The effective useful lifetime of the EFC is assumed to be 10 years based on the EUL of programmable thermostats (DEER 2008). However, since the EFC is solid-state its lifetime could be longer (i.e., 15 to 25 years) since there are no moving parts or parts to wear out since the product operates on low voltage without the need for a battery,

1.7 Net-to-Gross Ratios

A net to gross ratio of the EFC is 1.0 based on the EUL for comprehensive air conditioning measures.

Section 2. Engineering Calculations

The engineering calculations for annual natural gas and electricity savings and peak demand reduction are provided in the embedded Excel workbook using the following equations. The baseline annual gas heating (therm/yr) values shown in **Table 14**, column 3, and the baseline annual electric cooling (kWh/yr) values shown in **Table 14**, column 5, are taken directly from the 2008 DEER Update (DEER 2008a) for the Southern California weighted vintage for each climate zone and residential air conditioner (RAC) HVAC system (includes gas furnace and air conditioner). The baseline annual heating electric ventilation (kWh/yr) values shown in **Table 15**, column 4, are taken directly from the 2008 DEER Update (DEER 2008a) for the SCG weighted vintage for each climate zone and residential gas furnace (RGF) HVAC system (excludes air conditioning). The baseline annual cooling electric ventilation values shown in **Table 14**, column 5, are calculated using **Equation 12**.

Eq. 12 $UEC_{cool\ vent} = UEC_{RAC\ vent} - UEC_{RGF\ vent}$

Where,

$UEC_{cool\ vent}$ = baseline cooling electric ventilation exclusive of heating (kWh/year),
$UEC_{RAC\ vent}$ = baseline electric ventilation for residential air conditioning including cooling and heating (i.e., furnace) from DEER 2008a (kWh/year), and
$UEC_{RGF\ vent}$ = baseline heating-only electric ventilation for residential gas furnace (RGF) excluding cooling from DEER 2008a (kWh/year).

The annual heating energy savings shown in **Table 1** for RAC are calculated using **Equation 13** and the baseline UEC values shown in **Table 14**.

Eq. 13 $ES_{EFC\ heat} = UEC_{RAC\ heat} \times \overline{S_{heat}}$

Where,

$ES_{EFC\ heat}$ = energy savings for the EFC measure for space heating (therm/year),
$UEC_{RAC\ heat}$ = baseline space heating from DEER 2008a (therm/year), and
$\overline{S_{heat}}$ = weighted average space heating energy savings associated with the EFC based on field and laboratory tests (%).

The annual net electric energy savings shown in **Table 1** are calculated using **Equation 14** and the baseline UEC values shown in **Table 14** for RAC and **Table 15** for RGF.

Eq. 14 $ES_{EFC\ cool} = [UEC_{RAC\ cool} \times \overline{S_{cool}}] + [UEC_{RAC\ vent} \times (\overline{S_{cool}} + \overline{S_{RAC\ vent}})] + [UEC_{RGF\ vent} \times \overline{S_{RGF\ vent}}]$

Where,

$ES_{EFC\ cool}$ = energy savings for the EFC measure for space cooling (kWh/year),
$UEC_{RAC\ cool}$ = baseline space cooling from DEER 2008a (kWh/year),
$\overline{S_{cool}}$ = weighted average space cooling electric energy savings associated with the EFC based on field and laboratory tests (%),
$\overline{S_{RAC\ vent}}$ = weighted average RAC ventilation savings associated with the EFC based on field and laboratory tests (%), and
$\overline{S_{RGF\ vent}}$ = weighted average RGF ventilation savings associated with the EFC based on field and laboratory tests (%).

The annual peak demand savings (PDS) shown in **Table 1** are calculated using **Equation 15** and the baseline Unit Peak Demand (UPD) values shown in **Table 14**.

Eq. 15 $PDS_{EFC} = DF \times \left\{[UPD_{RAC\ cool} \times \overline{S_{cool}}] + [UPD_{RAC\ vent} \times (\overline{S_{cool}} + \overline{S_{RAC\ vent}})]\right\}$

Where,

PDS_{EFC} = peak demand savings for the EFC measure (kW),
DF = diversity factor of 0.33 for space cooling assuming one-third of air conditioners are on at any given time during the peak period (dimensionless),
$UPD_{RAC\ cool}$ = baseline space cooling peak demand from DEER 2008a (kW), and
$UPD_{RAC\ vent}$ = baseline ventilation peak demand from DEER 2008a (kW).

Tables 18 and **19** provide baseline UEC data normalized per "Energy Common Units" (ECU), i.e., tons cooling capacity or kBtuh furnace capacity. ECU data are provided in **Tables 16** and **17**. These data can be used with **Equation 16** to calculate annual heating energy savings.

Eq. 16 $ES_{EFC\ heat} = UEC_{heat} \times \overline{S_{heat}} \times ECU$

Where,

ECU = Energy Common Unit per **Table 16** for RAC and **Table 17** for RGF.

The annual net electric energy savings are calculated using **Equation 17**, baseline UEC data per ECU in **Tables 18** and **19**, and ECU data in **Tables 16** and **17**.

Eq. 17 $ES_{EFC\ cool} = \{[UEC_{cool} \times \overline{S_{cool}}] + [UEC_{vent} \times (\overline{S_{cool}} + \overline{S_{RAC\ vent}})]$

$+ [UEC_{vent} \times \overline{S_{RGF\ vent}}]\} \times ECU$

The annual peak demand savings (PDS) are calculated using **Equation 18** and the baseline UEC data per ECU in **Tables 18** and **19**, and ECU data in **Tables 16** and **17**.

Eq. 18 $PDS_{EFC} = \{DF \times \{[UPD_{RAC\ cool} \times \overline{S_{cool}}] + [UPD_{RAC\ vent} \times (\overline{S_{cool}} + \overline{S_{RAC\ vent}})]\}\} \times$ ECU

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Workpaper_Verified_
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Lennox 1998a. Unit Service Information. G23 Series Units. Figure 5. Furnace Fan Off Time Adjustment (90 to 330 seconds). "Unit is shipped with a factory setting of 90 seconds. Fan "off" time will affect comfort and efficiency and is adjustable to satisfy individual applications." P. 10. Lennox Industries, Inc. Publication 9418-L8. Furnace fan airflow at high speed is 1030 cfm with is 25.6% greater than medium speed airflow of 820 cfm. Fan power use is 16.6% greater at 0.5 inches of water gage static pressure (440W at high speed versus 385W at medium speed).

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Trane 2009. Downflow/Horizontal Right Induced Draft Gas Furnace. XB80 Single-Stage Fan Assisted Combustion System. Page 9, Wiring Diagram for TDE1 Furnaces. Cooling fan "off" delay 0 seconds and heating fan "off" time delay fixed at 100 seconds factory setting. Pub. No. 22-1677-05.

Attachment

Workpaper Tables in Excel format

FAN CONTROLLER.xlsx

Short Form Work Paper WPSDGEREHC0024
Revision 2

San Diego Gas & Electric

Energy Efficiency Engineering

Efficient Fan Controller for Residential Air Conditioners

December 15, 2016

Efficient Fan Controller for Residential Conditioners Short Form WP

Introduction

This short form workpaper (WP) documents the values adopted from SCE's workpaper entitled "Efficient Fan Controller for Residential Air Conditioners and Furnaces" (SCE13HC052 Rev 2). SDG&E adopts all of the values associated with our climate zone as stated in SCE13HC052 Rev 2 workpaper with the following exceptions:

1. SDG&E intends to use the "SDG:DEER:Res:HVAC_Eff_AC" E3 load shape.
2. SDG&E intends to offer Energy Impacts Common Units per controller or each. For SDG&E, the savings are normalized to a "per controller" value using tonnages for each building type extracted from the MASControl tool. These tonnages are 3.184, 2.123, and 1.122 for single family, double wide mobile home, and multi-family, respectively;
3. SDG&E intends to provide Measure Cost per unit ($/unit). The controller cost is also normalized on a per-ton basis using the average rated capacities of the HVAC systems in the DEER eQuest models for DMO, MFM, and SFM. The average rated capacities for DMO, MFM, and SFM are 2.123, 1.122, and 3.184 tons, respectively;
4. SDG&E intends to use a Net-to-Gross Ratio "Res-Default>2" with 0.55 value.
5. SDG&E intends to use EUL_ID of "HV-ResAC";

Document Revision History

Rev	Date	Author	Summary of Changes
0	10/25/10		Adapted from SoCalGas Workpaper SCG0077 Revision #0 dated April 4, 2010, developed by Verified, Inc. Revised weighting in multiple tables for SDGE Climate zones. Added SDGE Work paper number.
1	08/25/14	Phillip Hasley (Hasley Consulting)	- Adopted SCE Work Paper SCE13HC052.1 - Updated Workpaper name - Removed calculation template - Removed Table of Contents - Replaced summary tables with At-A-Glance Summary - Updated EUL_ID - Updated NTG - Added GSIA - Updated load shapes - Updated building types
2	12/15/16	Eduardo Reynoso (SDG&E)	Adopted Short Form Workpaper based on referencing IOU lead workpaper by SCE, SCE13HC052 Rev2.

Table 1: Measure Summary Table

Section	Value
1.1 Measure & Baseline Data	The retrofit add-on of an efficient fan controller (EFC) device onto a residential single-family, multi-family or double-wide mobile home split-system air conditioner. The base case is a 14 SEER AC unit without an EFC and without a built in fan delay.
1.2 Technical Description	EFC devices delay the evaporator fan cycle off time to take advantage of the residual liquid refrigerant remaining in the evaporator after the compressor cycles off. The controller can delay the fan cycle off time either by allowing the user to set the time delay period, or by using built-in logic to delay the fan cycle off time based on the compressor run time. This work paper only allows the installation of a fan controller with built-in logic, heretofore after referred to as "automated fan controller," unless the manually set time delay is set and commissioned by a trained contractor.
Measure 1 (placeholder) Measure 2 (placeholder) Measure 3 (placeholder) Measure 4	Measures 1, 2 and 3 are legacy placeholders and are necessary for SDG&E Ex-ante database alignment. Measure 4 (462282, 420156): Fan controller device using built-in logic to delay the evaporator fan cycle off time.
Code for Measure **(Cited per SCE Workpaper as stated in Document Revision History)**	There is no code or other jurisdictional requirements related to these measures. However, starting in 2015 federal code requires a packaged residential AC unit installed in California to have a SEER (Seasonal Energy Efficiency Ratio) rating of at least 14. This efficiency rating was used to establish the baseline AC unit for this measure.
Requirements	• This measure only applies to residential split-system air conditioning units with an indoor evaporator coil. The baseline air conditioning system cannot have built-in delay. • This work paper only allows the installation of an automated fan controller, unless the manually-set time-delay fan controller is set and commissioned by a trained contractor. This measure can be installed in single family, multi-family, and double-wide mobile homes in all SDG&E climate zones.
1.3 Installation Type and Delivery Mechanisms	
Installation Type	Retrofit Add-On (REA)
Delivery Mechanisms	• Financial Support – Downstream Prescriptive Rebate -"PreRebDown" • Deemed and Financial Support/Direct Install
1.4.1 DEER Data	
DEER Measure ID	DEER does not contain this type of measure.
Net-to-Gross Ratio	Com-Default>2yrs
Effective and Remaining Useful Life **(Cited per SCE Workpaper as stated in Document Revision History)**	EUL_ID / RUL_ID : HV-ResAC = 15 / 5 years The EUL of the measure is capped at the remaining useful life of split and package equipment, as it is assumed that the controller would be removed with the equipment once it reaches its remaining useful life. Refer to the Ex-

	Ante Database for the EUL and RUL values.
Section 2. Calculation Methodology **(Cited per SCE Workpaper as stated in Document Revision History)**	Energy savings was calculated using eQuest v3.64 to establish the baseline energy consumption then applying the part load ratio curve fit equation from the ET report. The eQuest simulations used a minimally above-code SEER 14 split-AC system to be slightly conservative. The cooling capacity varied by building type and climate zone based on the DEER building prototypes for double-wide mobile home, multi-family, and single family residential buildings. For SDG&E, the savings are normalized to a "per controller" value using tonnages for each building type extracted from the MASControl tool. These tonnages are 3.184, 2.123, and 1.122 for single family, double wide mobile home, and multi-family, respectively.

		Impacts			
BldgType	Climate Zn	KWh/ton	KW/ton	KWh/each	KW/each
DMo	6	7.415	0.001	15.742	0.003
DMo	7	15.843	0.000	33.635	0.000
DMo	8	43.093	0.020	91.487	0.043
DMo	10	90.611	0.057	192.368	0.122
DMo	14	105.550	0.066	224.082	0.140
DMo	15	215.529	0.047	457.567	0.100
MFm	6	6.710	0.001	7.528	0.001
MFm	7	10.397	0.005	11.666	0.006
MFm	8	24.850	0.007	27.881	0.007
MFm	10	55.120	0.055	61.845	0.062
MFm	14	70.317	0.059	78.896	0.066
MFm	15	174.247	0.059	195.505	0.066
SFm	6	13.457	0.001	42.846	0.002
SFm	7	23.650	0.006	75.303	0.020
SFm	8	52.753	0.025	167.966	0.080
SFm	10	98.394	0.051	313.288	0.163
SFm	14	109.927	0.061	350.006	0.196
SFm	15	217.884	0.046	693.743	0.146

Units	Per Controller (each)
Section 3. Load Shapes	SDG:DEER:Res:HVAC_Eff_AC
Section 4. Costs	
Units	Per Controller (each)
	Downstream Prescriptive Rebate (All Cost References per SCE Workpaper-Lead IOU)
Base Cost – Measure 4	= $0.00
Measure Cost – Measure 4	= Equipment Cost +Labor Cost = $28.50 +135.76 = $164.26/controller (each)
Incremental Cost – Measure 4	= $ 164.26/Controller (each)
	Direct Install
DI Cost Measure 4	= DI Material Cost + DI Material Cost = $64.60 +78.95

	= $143.55/controller (each)

Work Paper SCE15HC052
Revision 2

Southern California Edison

Efficient Fan Controller for Residential Air Conditioners and Furnaces

For Work Paper Reviewer Use Only

List all major comments that occurred during the review. This table may only be removed during management review.

Major Comment	Reviewer Name	Date	Outcome/Resolution
E.g. Please remove measure LT-12345 (LD123) from this work paper because it is no longer eligible for incentives.	Reviewer 1	6/1/15	E.g. Comment incorporated. LT-12345 was removed.

March 16, 2016

AT-A-GLANCE SUMMARY

Measure Codes	AC-48754 – Air Conditioner – Efficient Fan Control
Measure Description	Fan controller device using built-in logic to delay the evaporator fan cycle off time.
Base Case Description	Split-system air-conditioner with fan cycling off at the same time as the compressor.
Units	Per unit (PG&E) Per ton (SCE)
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 (HVAC-FlowCtrl-AirFiltCtrls)
Measure Installation Type	REA
Net-to-Gross Ratio	0.85; ET-Default
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	08/24/12	Brian James/SCE	Original work paper
1	04/01/14	Ray Phillips/PECI	Update using the latest DEER eQUEST prototypes (via MASControl). • Update to include all 16 CA climate zones • Update kW and kWh savings
2	01/04/2016	Andres Fergadiotti/SCE	-New template update for 2016 program year -WP effective from 1/1/2016 thru 12/31/2016 -No value modifications -Added solution Code for Fan Controller – Smart (Programmable) T-Stat -Workpaper converted over to SCE template

COMMISSION STAFF AND CAL TF COMMENTS

Rev	Party	Submittal	Comment	Comments	WP Developer Response

		Date	Date		
				•	•
				•	•

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

SECTION 1. GENERAL MEASURE & BASELINE DATA

1.1 MEASURE DESCRIPTION & BACKGROUND

This work paper outlines the retrofit add-on of an efficient fan controller (EFC) device onto a residential single-family, multi-family or double-wide mobile home split-system air conditioner or gas furnace. The base case is a 14 SEER AC unit without an EFC.

Base, Standard, and Measure Cases

Case	Description of Typical Scenario
Measure	Installation of efficient fan controller or thermostat with an efficient fan controller to control fan after standard cooling or heating cycles
Existing Condition	Split-system air conditioning unit with indoor evaporator coil or ducted natural gas furnace without a built-in fan delay.
Code/Standard	N/A
Industry Standard Practice	N/A

Measures and Codes

Measure Codes				Measure Name
SCG	SDG&E	SCE	PG&E	
		AC-48754		Air Conditioner - Efficient Fan Control

Eligibility Requirements:

This measure only applies to residential split-system air conditioning units with an indoor evaporator coil. The baseline air conditioning system cannot have built-in delay.

Implementation Requirements:

This work paper only allows the installation of an automated fan controller, unless the manually-set time-delay fan controller is set and commissioned by a trained contractor. This measure can be installed in single family, multi-family, and double-wide mobile homes in all SCE climate zones.

Documentation Requirements

There are no documentation requirements at this time.

1.2 TECHNICAL DESCRIPTION

EFC devices delay the evaporator fan cycle off time to take advantage of the residual liquid refrigerant remaining in the evaporator after the compressor cycles off. The controller can delay the fan cycle off time either by allowing the user to set the time delay period, or by using built-in logic to delay the fan cycle off time based on the compressor run time. This work paper only allows the installation of a fan controller with built-in logic, heretofore after referred to as "automated fan controller," unless the manually set time delay is set and commissioned by a trained contractor.

1.3 INSTALLATION TYPES AND DELIVERY MECHANISMS

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.

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.
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

DEER Difference Summary

DEER Item	Used for Workpaper?
Modified DEER methodology	Yes
Scaled DEER measure	No
DEER Base Case	Yes
DEER Measure Case	No
DEER Building Types	Yes
DEER Operating Hours	Yes
DEER eQUEST Prototypes	Yes, with modifications; see below
DEER Version	DEER, 2014, DEER 2015, READI v2.3.0
Reason for Deviation from DEER	Packaged Variable Volume Variable Temperature HVAC system was changed to Package Single Zone to reflect a typical residential building with a single zone
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
ET-Default	Emerging Technologies approved by ED through work paper review	All	Any	Any	0.85

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. 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 split and package equipment, or a third of 15 years, as it is assumed that the controller would be removed with the equipment once it reaches its remaining useful life.

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 currently no federal, state, or regional codes that impact efficient fan controllers for residential AC. However, starting in 2015 federal code requires a residential AC unit installed in California to have a SEER (Seasonal Energy Efficiency Ratio) rating of at least 1 [B]. This efficiency rating was used to establish the baseline AC unit for this measure. For application in 2014 programs the savings are slightly conservative as the 2014 code requires SEER 13.

Code Summary

Code	Reference	Effective Dates
Title 24 (2013)	N/A	N/A
Title 20 (2014)	N/A	N/A

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

1.5.1 Non-DEER Study Review

ET11SCE1130 tested a nominal 3-ton split air-conditioning unit in a laboratory setting where the 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 delay controllers. The two fan 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 projects findings were used for subsequent analysis using eQuest to perform multiple simulations across

California climate zones. The full report can be viewed in the attached file "ET11SCE1130_Evap Fan Delay_Final.pdf" found below.

1.6 Data Quality and Future Data Needs

N/A

SECTION 2. CALCULATION METHODOLOGY

Energy savings was calculated using eQuest v3.64 to establish the baseline energy consumption then applying the part load ratio curve fit equation from the ET report [A]. The eQuest simulations used a minimally above-code SEER 14 split-AC system to be slightly conservative. The cooling capacity varied by building type and climate zone based on the DEER building prototypes for double-wide mobile home, multi-family, and single family residential buildings. The DEER building prototypes are the most recent updates to include the Title 24 2008 [208] and Title 24 2013 [355] code based vintages. These new prototypes were the models that were used in conjunction with revised weather data files to provide the energy savings for the measure. Four hourly variables were captured from the eQuest simulations for a year: total cooling load (Btu/hr), condensing unit energy (kWh), supply (indoor) fan energy (kWh), and AC total cooling capacity (Btu/hr). The total AC energy usage was calculated by equation 1:

Equation 1

$$Total\ Baseline\ AC\ Energy\ Usage\ (kWh) = Condensing\ Unit\ Energy (kWh) + Supply\ Fan\ Energy\ (kWh)$$

The part load ratio was determined by equation 2:

Equation 2

$$Part\ Load\ Ratio = \frac{Total\ Cooling\ Load\ \left(\frac{Btu}{hr}\right)}{AC\ Total\ Cooling\ Capacity\ \left(\frac{Btu}{hr}\right)}$$

Once the Part Load Ratio (PLR) is obtained, equation 3 applies the logarithmic curve fit of percentage of energy savings versus part load ratio determined from laboratory testing. See Figure 11 on page 15 of the attached report [A].

Equation 3

$$AC\ Energy\ Savings\ (kWh) = Total\ Baseline\ Energy\ Usage\ (kWh) \times (-0.2\ln(PLR) + 0.0006)$$

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. Results were obtained for each zone (each with a separate split-AC system) as specified in the DEER building prototypes. There were 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 24 systems in multi-family homes (two-story buildings with 12 units, two orientations). The results obtained for each of the building prototypes were averaged to obtain one representative savings number per building type.

For a sample calculation, consider a double-wide mobile home in climate zone 6 with a N-S orientation at 5:00 PM on July 9 per the example cooling calculation spreadsheets in Attachments 7 and 8. First solve equation 1:

$$0.972\ Total\ Baseline\ AC\ Energy\ Usage\ (kWh) = 0.863\ Condensing\ Unit\ Energy (kWh) + 0.109\ Supply\ Fan\ En$$

Next, solve for the PLR with equation 2:

$$0.476\ Part\ Load\ Ratio = \frac{12{,}078\ Total\ Cooling\ Load\ \left(\frac{Btu}{hr}\right)}{25{,}356\ AC\ Total\ Cooling\ Capacity\ \left(\frac{Btu}{hr}\right)}$$

Lastly, solve for the AC energy savings for that hour with equation 3:

$$0.145\ AC\ Energy\ Savings\ (kWh) = 0.972\ Total\ Baseline\ Energy\ Usage\ (kWh) \times (-0.2\ln(0.476) + 0.0006)$$

This process is repeated for all 8,760 hours in the year and summed to obtain the total annual energy savings for the EFC controller of each DEER building prototype. The annual energy savings were then normalized by cooling capacity using actual tonnage for each unit examined within each prototype for SCE. For PG&E, the savings are normalized to a “per unit” value using tonnages for each building type extracted from the MASControl tool. These tonnages are 3.184, 2.123, and 1.122 for single family, double wide mobile home, and multi-family, respectively. Results for all zones or systems were simple averages for each building type and orientation. As an example of the energy savings, for a double-wide mobile home in CZ 13, the calculated energy savings were 113.63 kWh/ton annually. (The mobile home energy savings is currently being represented by the single family home savings until DEER mobile family prototypes are available with post 2008-2013 Title 24 Code updates.) The savings are converted to a per unit basis as follows for PG&E:

$$241.24\ AC\ Energy\ Savings\ \left(\frac{kWh}{unit}\right) = 113.63\ AC\ Energy\ Savings\ \left(\frac{kWh}{ton}\right) \times \left(2.123\frac{tons}{unit}\right)$$

Demand Reduction Calculations

Since hourly values of AC energy savings were available for one full year, demand reduction was calculated by summing the total energy consumed during the peak demand period for the specific summer weekday periods delineated by climate zone, 2:00 PM to 5:00 PM as set forth in CPUC Decision D06-06-063. The total energy consumption during this period was then divided by nine, the number of peak hours, as shown in equation 4. The AC Energy Savings During Peak Period was normalized by cooling capacity using actual tonnage from the DEER prototypes:

Equation 4

$$\text{Demand Reduction (kW)} = \frac{\Sigma \text{AC Energy Savings During Peak Period(kWh)}}{\text{Total Hours in Peak Period (hr)}}$$

Using the previous example of a double-wide mobile home in CZ 13, whose peak period falls between 2:00 PM and 5:00 PM, July 8-10 we obtain the following results after applying equation 4:

$$0.0687\ \text{Demand Reduction (kW)} = \frac{\Sigma \text{AC Energy Savings During Peak Period(kWh)} = 0.618}{9\ \text{Total Hours in Peak Period (hr)}}$$

This value is averaged with the E-W orientation to obtain a final peak demand reduction of 0.0687 kW.

See attachments 2, 3, and 4 for detailed energy savings and demand reduction calculations [D, E, F].

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 equipment.

4.2 MEASURE CASE COST

The measure equipment material cost was determined by reviewing the purchased price for two fan delay controllers tested in the ET laboratory report [A]. The price paid was $25 per controller, plus $3.50 for shipping and handling. The price was cross-referenced with Southern California Gas Company's work paper SCG0077.0 California HVAC Upgrade: Efficient Fan Controller (EFC) – Residential, which listed the material equipment cost at $25. The controller cost is also normalized on a per-ton basis using the average rated capacities of the HVAC systems in the DEER eQuest models for DMO, MFM, and SFM. The average rated capacities for DMO, MFM, and SFM are 2.123, 1.122, and 3.184 tons, respectively. The combined average rated capacity used to calculate the average cost per ton is 2.14 tons. This results in an average equipment cost of $13.32 per ton.

The measure labor cost was determined from "Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008).xls." The base labor rate is $67.88 per hour for the residential sector for downstream prescriptive rebates/incentives. Installation of the fan controller takes 1-2 hours, so the labor cost is estimated at $135.76. Normalized per ton, the measure labor cost is $63.44. Refer to Attachment 5 for the cost calculation [G].

Measure Case Cost= Measure Equipment Cost + Measure Labor Cost
= $28.50+ $135.76
= $164.26/unit

Measure Case Cost= Measure Equipment Cost + Measure Labor Cost
= $13.32+ $63.44
= $76.76/ton

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-48754	REA	$76.76	$76.76	N/A

ATTACHMENTS

1. SCE13HC052_2_Calcul
ation Template v6.1 1.

2. Efficient_Fan_Controller_for_Residential_Air_Conditioners_SFM_Results_v4.xlsb (**available upon request due to size**)

3. Efficient_Fan_Controller_for_Residential_Air_Conditioners_MFM_Results_v4.xlsb (**available upon request due to size**)

4. Efficient_Fan_Controller_for_Residential_Air_Conditioners_DMO_Results_v4.xlsb (**available upon request due to size**)

5. Cost Calcs.xlsx

6. ET11SCE1130_Evap
Fan Delay_Final.pdf

REFERENCES

References_01212016
_132713.xlsx

[208]
[355]

[A] Effects of Delaying Evaporator Fan Cycle Off Time for Residential Air-Conditioning Units. Design and Engineering Services, Emerging Technologies Program. March 20, 2012. - Attachment

[B] Energy Conservation Standards for Residential Central Air Conditioners and Heat Pumps http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_cac_hp.html

[C] Attachment 1. Calculation Template 2015 v4.xlsm

[D] Attachment 2. Efficient_Fan_Controller_for_Residential_Air_Conditioners_SFM_Results_v4.xlsb

[E] Attachment 3. Efficient_Fan_Controller_for_Residential_Air_Conditioners_MFM_Results_v4.xlsb

[F] Attachment 4. Efficient_Fan_Controller_for_Residential_Air_Conditioners_DMO_Results_v4.xlsb

[G] Attachment 5. Cost Calcs.xlsx

Work Paper PGE3PHVC150
Enhanced Time Delay Relay
Revision 2

Pacific Gas & Electric Company

Customer Energy Solutions

Enhanced Time Delay

Measure Code H796

At-a-Glance Summary

Applicable Measure Codes:	**H796**
Measure Description:	Enhanced Fan Time Delay – Residential
Energy Impact Common Units:	Per ton
Base Case Description:	Air-conditioner with fan cycling off at the same time as the compressor.
Base Case Energy Consumption:	HVAC end use for appropriate climate zone and building type, PG&E existing vintage weighted
Measure Energy Consumption:	Building type, climate zone, fan usage dependent
Energy Savings (Base Case – Measure):	Building type and climate zone dependent
Costs Common Units:	Per ton
Base Case Equipment Cost ($/unit):	$0
Measure Equipment Cost ($/unit):	Source: SCE ET Report $13.32 Material Cost
Gross Measure Cost ($/unit)	Source: SCE ET Report $13.32 Material per ton $63.44 Labor per ton $76.76 Total per ton
Measure Incremental Cost ($/unit):	$76.76 Total per ton
Effective Useful Life (years):	5 years (1/3 EUL for HV-ResAC)
Measure Application Type:	REA
Net-to-Gross Ratios:	0.85; SCE ET-Default
Important Comments:	

PGE3PHVC150 Enhanced Time Delay Relay R2

PG&E is using the SCE work paper Work Paper SCE13HC0521 ex-ante values for PG&E measure code H79. The ex-ante values are located in file name: *SCE data for PGE3PHVC150 Enhanced Time Delay Relay R1.xlsm*

The measure mapping is as follows:

PG&E Measure code H796 = SCE code AC-48754

DOCUMENT REVISION HISTORY

Revision #	Date	Section-by-Section Description of Revisions	Author (Company)
Revision 1	Aug. 29, 2014	SCE WP used 2.123 Tons/System for building type DMO. New DEER number is 3.4977 Tons/System for DMO. DMO energy savings (kW & kWh) are revised with the new number 3.4977 Tons/System.	Tai Voong (PG&E)
Revision 2	December 1, 2014	Impacts are now reported as per tonnage.	Jia Huang (PG&E)

Work Paper Approvals

The following Manager(s) approved this workpaper through the PG&E Electronic Data Routing System under Routing Requisition # ________________

Grant Brohard
Manager, Technical Product Support

Carolyn Weiner
Manager, CES Products and Programs

AT-A-GLANCE SUMMARY

Applicable Measure Codes:	**AC-48754 – Air Conditioner – Efficient Fan Control**
Measure Description:	Fan controller device using built-in logic to delay the evaporator fan cycle off time.
Base Case Description:	Split-system air-conditioner with fan cycling off at the same time as the compressor.
Energy Impact Common Units:	Per unit (PG&E) Per ton (SCE)
Energy Savings :	Refer to Excel Calculation Attachment.
Gross Measure Cost ($/unit)	Refer to Excel Calculation Attachment.
Measure Incremental Cost ($/unit):	Refer to Excel Calculation Attachment.
Effective Useful Life (years):	5 years (1/3 EUL for HV-ResAC)
Measure Application Type:	REA
Net-to-Gross Ratios:	0.85; ET-Default
Important Comments:	**This work paper document does not contain a data set in conformance with the 4/1/14 CPUC Ex Ante Database Specification; SCE will provide that data set separately.**

DOCUMENT REVISION HISTORY

Workpaper and Revision #	Tech. Revision	MM/DD/YY	Author/Affiliation	Summary of Changes
SCE13HC052.0	Yes	08/24/12	Brian James/SCE	Original work paper
SCE13HC052.1	Yes	04/01/14	Ray Phillips/PECI	-Update using the latest DEER eQUEST prototypes (via MASControl). • Update to include all 16 CA climate zones • Update kW and kWh savings -Work paper updated for the reporting period, effective 7/1/14 – 12/31/14.

SECTION 1. GENERAL MEASURE & BASELINE DATA

1.1 MEASURE DESCRIPTION & BACKGROUND

This work paper outlines the retrofit add-on of an efficient fan controller (EFC) device onto a residential single-family, multi-family or double-wide mobile home split-system air conditioner. The base case is a 14 SEER AC unit without an EFC.

Table 1 Measure Names

Solution Code	Measure name
AC-48754	Air Conditioner - Efficient Fan Control

Measure Requirements

Eligibility Requirements

This measure only applies to residential split-system air conditioning units with an indoor evaporator coil. The baseline air conditioning system cannot have built-in delay.

Implementation Requirements

This work paper only allows the installation of an automated fan controller, unless the manually-set time-delay fan controller is set and commissioned by a trained contractor. This measure can be installed in single family, multi-family, and double-wide mobile homes in all SCE climate zones.

Documentation Requirements

There are no documentation requirements at this time.

1.2 TECHNICAL DESCRIPTION

EFC devices delay the evaporator fan cycle off time to take advantage of the residual liquid refrigerant remaining in the evaporator after the compressor cycles off. The controller can delay the fan cycle off time either by allowing the user to set the time delay period, or by using built-in logic to delay the fan cycle off time based on the compressor run time. This work paper only allows the installation of a fan controller with built-in logic, heretofore after referred to as “automated fan controller,” unless the manually set time delay is set and commissioned by a trained contractor.

1.3 MEASURE APPLICATION TYPE

Note: See Appendix A for a comparison of the application types used by and incorporated into SCE systems versus the application types available in the newest revision of DEER 2014. Appendix A will serve as a translation between the outputs of this workpaper and application types used by READi.

Delivery Mechanism for this measure is Financial Support / Down-Stream Incentive – Deemed and Financial Support / Direct Install.

Program Type/Install Type of this measure is RET – Add-on (REA).

1.4 MEASURE AND BASE CASE COST EFFECTIVENESS DATA

1.4.1 DEER Measure and Base Case Analysis

DEER building prototypes for all vintages were used to establish the baseline energy consumption of the single family, multi-family, and double-wide mobile home of a SEER 14 split-system AC. The 03 vintage was selected as an un-weighted representative for the average residence. DEER prototypes assume the system type to be Packaged Variable Volume Variable Temperature (PVVT) systems. This was changed to Packaged Single Zone to reflect a typical residential building with a single zone because there is no built-in system for Split Single Zone units in eQuest. It is assumed variances in simulation results between split and packaged systems would be insignificant.

At the time the analysis was performed the current version of MASControl (version 3.00.019 and 3.00.20) were not able to generate a prototype for the double-wide mobile home type of residential building. The SFM prototype was substituted for the DMO for this workpaper to provide savings for the DMO type of building.

Table 2 DEER Difference Summary

DEER Difference Summary Table	
Modified DEER Methodology	Yes
Scaled DEER Measure	No
DEER Building Prototypes Used	Yes
Deviation from DEER	DEER assumed different baseline systems of packaged variable-volume units. Changed to packaged single zone.
DEER Version	DEER 14
DEER Run ID and Measure Name (Sample)	RSFm1405RSA14

Net to Gross

The NTG value was obtained from the "DEER2011_NTGR_2012-05-16.xls" on the DEER website as required by Version 5 of the California Public Utilities Commission (CPUC) Energy Efficiency Policy Manual [351]. The relevant NTGR for this measure is shown in **Error! Reference source not found.**Table 3 below.

Table 3 Net-to-Gross Ratio

NTGR_ID*	Description*	Sector*	BldgType*	ProgDelivID	NTG*
ET-Default	Emerging Technologies approved by ED through work paper review	All	Any	Any	0.85

*Denotes that the column is taken from the DEER NTG Table.

Installation Rate

The installation rate (IR) is identified in the calculation attachment. This value is obtained from the support table available in READi. Currently there is no versioning on the installation rate table. To address appropriate selection of the installation rate the date of the workpaper will serve as the last date checked for updated IR values. The installation rate varies by end use, sector, technology, application, and delivery method. The relevant IR values for this measure are shown in Table 4**Error! Reference source not found.** below.

Table 4 Installation Rate

GSIA_ID*	Description*	Sector*	BldgType*	ProgDelivID	GSIAValue*
Def-GSIA	Default GSIA values	Any	Any	Any	1.0

Spillage Rate

Spillage rate will also be applied to measures however the values will not be tracked in the workpapers. The spillage rate will be tracked in an external table to be supplied to the Energy Division.

READi Technology Fields

To support the development of the ED ex-ante tables, select fields from the ex-ante database will be identified in the workpaper. For a full set of values associated with the measures in the workpaper refer the Excel calculation template.

Table 5 READi Tech IDs

READi Field Name	Values included in this workpaper
Measure Case UseCategory	HVAC
Measure Case UseSubCats	Space Cooling (SpaceCool)
Measure Case TechGroups	dX AC Equipment (dxAC_equip)
Measure Case TechTypes	Non-DEER (NonDEER)
Base Case TechGroups	dX AC Equipment (dxAC_equip)
Base Case TechTypes	SEER Rated Split System AC (spltSEER)

1.4.2 Codes and Standards Analysis

There are currently no federal, state, or regional codes that impact efficient fan controllers for residential AC. However, starting in 2015 federal code requires a residential AC unit installed in California to have a SEER (Seasonal Energy Efficiency Ratio) rating of at least 1 [B]. This efficiency rating was used to establish the baseline AC unit for this measure. For application in 2014 programs the savings are slightly conservative as the 2014 code requires SEER 13.

Table 6 Code Summary

Code	Applicable Code Reference	Effective Dates
Title 24 (2013)	N/A	N/A
Title 20 (2014)	N/A	N/A
N/A	N/A	N/A

1.4.3 Non-DEER Study Review

ET11SCE1130 tested a nominal 3-ton split air-conditioning unit in a laboratory setting where the 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 delay controllers. The two fan 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 projects findings were used for subsequent analysis using eQuest to perform multiple simulations across California climate zones. The full report can be viewed in the attached file "ET11SCE1130_Evap Fan Delay_Final.pdf" found below.

1.4.4 Measure and Base Case Effective Useful Life

DEER14 update documentation provides EUL and RUL information to be used for the 2013-14 program cycle on www.deeresources.com. The DEER documentation "DEER2014-EUL-table-update_2014-02-05.xlsx" provides the RUL value as a flat 1/3 of the EUL value. The RUL value will only be applied to the first baseline period for retrofit measures that have applicable code that will affect the energy savings. In all other installation types and retrofit with no applicable code that affects the energy savings, the RUL is not applicable to either the first or second baseline period.

To obtain the EUL value the DEER14 update documentation, "DEER2014-EUL-table-update_2014-02-05.xlsx" [436], was consulted. Table 7 below identifies the value/methodology used for the measures in this work paper. The EUL of the measure is capped at the remaining useful life of split and package equipment, or a third of 15 years, as it is assumed that the controller would be removed with the equipment once it reaches its remaining useful life.

Table 7 DEER14 EUL Value/Methodology

READi EUL ID	Market	Enduse	Measure	EUL (Years)	RUL (Years)
HV-ResAC	Residential	HVAC - Miscellaneous	High Efficiency Air Conditioner (package and split systems)	5	N/A

SECTION 2. ENERGY SAVINGS & DEMAND REDUCTION CALCULATIONS

Energy savings was calculated using eQuest v3.64 to establish the baseline energy consumption then applying the part load ratio curve fit equation from the ET report [A]. The eQuest simulations used a minimally above-code SEER 14 split-AC system to be slightly conservative. The cooling capacity varied by building type and climate zone based on the DEER building prototypes for double-wide mobile home, multi-family, and single family residential buildings. The DEER building prototypes are the most recent updates to include the Title 24 2008 [208] and Title 24 2013 [355] code based vintages. These new prototypes were the models that were used in conjunction with revised weather data files to provide the energy savings for the measure. Four hourly variables were captured from the eQuest simulations for a year: total cooling load (Btu/hr), condensing unit energy (kWh), supply (indoor) fan energy (kWh), and AC total cooling capacity (Btu/hr). The total AC energy usage was calculated by equation 1:

Equation 1

$$\mathit{Total\ Baseline\ AC\ Energy\ Usage}\ (kWh) = \mathit{Condensing\ Unit\ Energy}(kWh) + \mathit{Supply\ Fan\ Energy}\ (kWh)$$

The part load ratio was determined by equation 2:

Equation 2

$$\mathit{Part\ Load\ Ratio} = \frac{\mathit{Total\ Cooling\ Load}\left(\frac{Btu}{hr}\right)}{\mathit{AC\ Total\ Cooling\ Capacity}\left(\frac{Btu}{hr}\right)}$$

Once the Part Load Ratio (PLR) is obtained, equation 3 applies the logarithmic curve fit of percentage of energy savings versus part load ratio determined from laboratory testing. See Figure 11 on page 15 of the attached report [A].

Equation 3

$$\mathit{AC\ Energy\ Savings}\ (kWh) = \mathit{Total\ Baseline\ Energy\ Usage}\ (kWh) \times (-0.2\ln(PLR) + 0.0006)$$

The result from equation 3 is AC energy savings per hour. This number is summed for all hours of the year to obtain the total energy savings. Results were obtained for each zone (each with a separate split-AC system) as specified in the DEER building prototypes. There were 2 systems (N-S, E-W orientations) in double-wide mobile homes (however this was represented by the SFM), 4 systems in single-family homes (single-story, two-story, two orientations), and 24 systems in multi-family homes (two-story buildings with 12 units, two orientations). The results obtained for each of the building prototypes were averaged to obtain one representative savings number per building type.

For a sample calculation, consider a double-wide mobile home in climate zone 13 with a N-S orientation at 5:00 PM on July 8th per the calculation spreadsheet in Attachment 2 [F]. First solve equation 1:

$$0.972\ \mathit{Total\ Baseline\ AC\ Energy\ Usage}\ (kWh) = 0.863\ \mathit{Condensing\ Unit\ Energy}(kWh) + 0.109\ \mathit{Supply\ Fan\ En}$$

Next, solve for the PLR with equation 2:

$$0.476\ \mathit{Part\ Load\ Ratio} = \frac{12{,}070\ \mathit{Total\ Cooling\ Load}\left(\frac{Btu}{hr}\right)}{25{,}358\ \mathit{AC\ Total\ Cooling\ Capacity}\left(\frac{Btu}{hr}\right)}$$

Lastly, solve for the AC energy savings for that hour with equation 3:

$$0.145\ \mathit{AC\ Energy\ Savings}\ (kWh) = 0.972\ \mathit{Total\ Baseline\ Energy\ Usage}\ (kWh) \times (-0.2\ln(0.476) + 0.0006)$$

This process is repeated for all 8,760 hours in the year and summed to obtain the total annual energy savings for the EFC controller of each DEER building prototype. The annual energy savings were then normalized by cooling capacity using actual tonnage for each unit examined within each prototype for SCE. For PG&E, the savings are normalized to a "per unit" value using tonnages for each building type extracted from the MASControl tool. These tonnages are 3.184, 2.123, and 1.122 for single family, double wide mobile home, and multi-family, respectively. Results for all zones or systems were simple averages for each building type and orientation. As an example of the energy savings, for a double-wide mobile home in CZ 13, the calculated energy savings were 113.63 kWh/ton annually. (The mobile home energy savings is currently being represented by the single family home savings until DEER mobile family prototypes are available with post 2008-2013 Title 24 Code updates.) The savings are converted to a per unit basis as follows for PG&E:

$$241.24\ AC\ Energy\ Savings\ \left(\frac{kWh}{unit}\right) = 113.63\ AC\ Energy\ Savings\ \left(\frac{kWh}{ton}\right) \times \left(2.123\frac{tons}{unit}\right)$$

Demand Reduction Calculations

Since hourly values of AC energy savings were available for one full year, demand reduction was calculated by summing the total energy consumed during the peak demand period for the specific summer weekday periods delineated by climate zone, 2:00 PM to 5:00 PM as set forth in CPUC Decision D06-06-063. The total energy consumption during this period was then divided by nine, the number of peak hours, as shown in equation 4. The AC Energy Savings During Peak Period was normalized by cooling capacity using actual tonnage from the DEER prototypes:

Equation 4

$$Demand\ Reduction\ (kW) = \frac{\Sigma AC\ Energy\ Savings\ During\ Peak\ Period (kWh)}{Total\ Hours\ in\ Peak\ Period\ (hr)}$$

Using the previous example of a double-wide mobile home in CZ 13, whose peak period falls between 2:00 PM and 5:00 PM, July 8-10 we obtain the following results after applying equation 4:

$$0.0687\ Demand\ Reduction\ (kW) = \frac{\Sigma AC\ Energy\ Savings\ During\ Peak\ Period (kWh) = 0.618}{9\ Total\ Hours\ in\ Peak\ Period\ (hr)}$$

This value is averaged with the E-W orientation to obtain a final peak demand reduction of 0.0687 kW.

See attachments 2, 3, and 4 for detailed energy savings and demand reduction calculations [D, E, F].

SECTION 3. LOAD SHAPES

The difference between the base case load shape and the measure load shape would be the most appropriate load shape; however, only end-use profiles are available. Therefore, the closest load shape chosen for this measure is the DEER:HVAC_EFF_AC load shape. See Table 9 for a list of all Building Types and Load Shapes. See the KEMA report [31] for a more thorough discussion regarding the load shapes for this measure.

Table 8 Building Types and Load Shapes

Building Type	E3 Alt. Building Type	Load Shape
Residential – Double-Wide Mobile Home	RES	DEER:HVAC_EFF_AC
Residential – Multi-Family	RES	DEER:HVAC_EFF_AC
Residential – Single Family	RES	DEER:HVAC_EFF_AC

SECTION 4. BASE CASE & MEASURE COSTS

4.1 BASE CASE COST

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

4.2 MEASURE CASE COST

The measure equipment material cost was determined by reviewing the purchased price for two fan delay controllers tested in the ET laboratory report [A]. The price paid was $25 per controller, plus $3.50 for shipping and handling. The price was cross-referenced with Southern California Gas Company's work paper SCG0077.0 California HVAC Upgrade: Efficient Fan Controller (EFC) – Residential, which listed the material equipment cost at $25. The controller cost is also normalized on a per-ton basis using the average rated capacities of the HVAC systems in the DEER eQuest models for DMO, MFM, and SFM. The average rated capacities for DMO, MFM, and SFM are 2.123, 1.122, and 3.184 tons, respectively. The combined average rated capacity used to calculate the average cost per ton is 2.14 tons. This results in an average equipment cost of $13.32 per ton.

The measure labor cost was determined from "Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008).xls." The base labor rate is $67.88 per hour for the residential sector for downstream prescriptive rebates/incentives. Installation of the fan controller takes 1-2 hours, so the labor cost is estimated at $135.76. Normalized per ton, the measure labor cost is $63.44. Refer to Attachment 5 for the cost calculation [G].

Measure Case Cost= Measure Equipment Cost + Measure Labor Cost
= $28.50+ $135.76
= $164.26/unit

Measure Case Cost= Measure Equipment Cost + Measure Labor Cost
= $13.32+ $63.44
= $76.76/ton

4.3 GROSS AND INCREMENTAL MEASURE COST

4.3.1 Gross Measure Cost

For REA measures, the gross measure cost (GMC) is the measure equipment material costs plus installation labor. From section 4.2 above, the GMC is equal to $164.26/unit and $76.76/ton.

4.3.2 Incremental Measure Cost

For REA measures, Incremental Measure Cost is the same as Gross Measure Cost.

ATTACHMENTS

1. Efficient Fan Controller for Residential Air Conditioners_Final.xlsm

2. Efficient_Fan_Controller_for_Residential_Air_Conditioners_SFM_Results_v4.xlsb (**available upon request due to size**)

3. Efficient_Fan_Controller_for_Residential_Air_Conditioners_MFM_Results_v4.xlsb (**available upon request due to size**)

4. Efficient_Fan_Controller_for_Residential_Air_Conditioners_DMO_Results_v4.xlsb (**available upon request due to size**)

5. Cost Calc.xlsx

6. ET11SCE1130_Evap Fan Delay_Final.pdf

REFERENCES

Reference List_06_10_2014.xlsx

[31]
[208]
[351]
[355]
[436]

[A] Effects of Delaying Evaporator Fan Cycle Off Time for Residential Air-Conditioning Units. Design and Engineering Services, Emerging Technologies Program. March 20, 2012. - Attachment

[B] Energy Conservation Standards for Residential Central Air Conditioners and Heat Pumps http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_cac_hp.html

[C] Attachment 1. Calculation Template 2015 v4.xlsm

[D] Attachment 2. Efficient_Fan_Controller_for_Residential_Air_Conditioners_SFM_Results_v4.xlsb

[E] Attachment 3. Efficient_Fan_Controller_for_Residential_Air_Conditioners_MFM_Results_v4.xlsb

[F] Attachment 4. Efficient_Fan_Controller_for_Residential_Air_Conditioners_DMO_Results_v4.xlsb

[G] Attachment 5. Cost Calcs.xlsx

Appendix A – SCE/ED Application Types

SCE Program Type	ED Application Type	1st Baseline Savings	2nd Baseline Savings	1st Baseline Cost	2nd Baseline Cost	1st Baseline Life	2nd Baseline Life
New	New Construction (Nc)	Above Code/Standard	N/A	Incremental Cost	N/A	EUL	0
Replace on Burnout (ROB)	Replace on Burnout (Rob)/Normal Replacement (NR)	Above Code/Standard	N/A	Incremental Cost	N/A	EUL	0
Retrofit (RET)	Early Replacement (ER)	Above Cust. Existing	Above Code/Standard	Full Cost	Incremental Cost	RUL	EUL-RUL
Retrofit – First Baseline Only (REF)	Early Replacement RUL (ErRul)	Above Cust. Existing	N/A	Full Cost	N/A	EUL	0
Retrofit Add-on (REA)	N/A	Above Cust. Existing	N/A	Full Cost	N/A	EUL	0

Work Paper EFC173PHVC108
Revision 0

Efficient Fan Controller® (EFC™) for Residential HVAC Systems

December 21, 2016

At a Glance Summary

Measure Name:	Efficient Fan Controller® (EFC™) – Residential
Savings Impacts Energy Common Units (ECU):	Household or tons for Residential Air Conditioner (RAC) or Residential Heat Pump (RHP) or Residential AC with Hydronic (RAH) or kBtuh for Residential Gas Furnace (RGF) space heating only
Measure Description:	The patented GreenFan® EFC™ improves HVAC efficiency and saves energy by detecting HVAC system type and mode of operation based on signals present on the thermostat or equipment terminals and provides an energy efficient fan-off time delay based on HVAC system type, mode of operation, and cool or heat source operational time. The EFC™ recovers and delivers more sensible cooling or heating capacity to the space to exceed thermostat setpoint temperatures, lengthen off-cycles, improve thermal comfort, and reduce cooling or heating on-cycles. The heat source run time indicates how much heat is stored in the heat exchanger. The air conditioner run time indicates how much cold water is condensed on the evaporator coil and evaporative cooling is available. For some gas furnace systems, the EFC™ provides high speed fan operation to increase efficiency and reduce operation. The EFC™ can be installed on systems with a fixed fan-off time delay for cooling or heating or a pre-existing cooling-only enhanced time delay and is cost effective for all prototypes and climate zones except single family (SFM) RGF in zone 15 and multi-family (MFM) RGF in zones 6, 7, 8, and 15.
Customer Base Case Description:	The customer base case heating, ventilating, and air conditioning (HVAC) system has either zero, fixed fan-off time delay, or cooling-only enhanced time delay. Most fans turn off when compressor turns off and about 10% continue to operate the fan for a fixed fan-off time delay of 30 to 90 seconds after the compressor turns off. Systems with gas furnaces operating in heating mode have a fixed 30 to 120 second fan-off time delay. Most heat pumps and hydronic systems operating in heating mode have a zero fan-off time delay and 10% have a fixed 30 to 65 second time delay. Many gas furnace fans operate at low or medium speed in heating.
Code Base Case Description:	Same as the customer base case description (above).
Costs Common Units:	Household or tons or kBtuh
Measure Equipment Cost ($/unit):	50
Measure Incremental Cost ($/unit):	150 (SFM and double-wide mobile home, DMO), 100 (MFM)
Measure Installed Cost ($/unit):	150 (SFM and DMO), 100 (MFM)
Measure Load Shape:	26 = Res. Central Air Conditioning
Effective Useful Life (years):	8
Program Type:	Retrofit
TOU AC Adjustment:	100%
Net-to-Gross Ratios:	0.85
Average TRC:	3.29 +/- 0.26
Important Comments:	DEER Vintage Weighting

Document Revision History

Revision	Date:	Section-by-Section Description of Revisions	Author, Company
Revision 0	03-16-2012	Original Submittal: Work Paper PGE0077 California HVAC Upgrade: Efficient Fan Controller® (EFC™) – Residential and Work Paper SCG0077 California HVAC Upgrade: Efficient Fan Controller® (EFC™) – Residential.[1] Includes field measurements of gas furnaces and split-system air conditioners, laboratory test data of split-system air conditioners, calibrated DEER eQuest simulations of energy savings and customer satisfaction survey results.	Robert Mowris, Verified® Inc.
Revision 0	12-21-2016	Updated Submittal: Work Paper EFC173PHVC138 Efficient Fan Controller® (EFC™) for Residential HVAC Systems. Reorganized and revised workpaper per CPUC template. Includes third-party Intertek® laboratory test data of packaged and split-system air conditioners, gas furnaces, heat pumps and hydronic heating systems. Annual energy and peak demand savings based on DEER2016 Unit Energy Consumption (UEC) and eQuest simulations by building type and climate zone and Energy Common Units (ECU) per household, per ton (RCA, RHP, RAH) or per kBtuh (RGF). Participant surveys to evaluate Net-to-Gross Ratios (NTGR) and customer satisfaction. Retention study of 68 sites where EFC™ was installed for approximately 5 years to evaluate Effective Useful Life (EUL) and Remaining Useful Life (RUL).	Robert Mowris, Verified® Inc. and Intertek® Inc. Third-Party Laboratory Tests

Citation

Mowris, R. 2016. Efficient Fan Controller® (EFC™) for Residential HVAC Systems. Work Paper EFC173PHVC138. Prepared by Verified® Inc.

[1] Based on previous EFC™ workpapers submitted by Verified® Inc. 2012. Work Paper PGE0077 California HVAC Upgrade: Efficient Fan Controller® (EFC™) - Residential. March 16, 2012. US Copyright TX 8-247-632. Verified® Inc. 2012. Work Paper SCG0077 California HVAC Upgrade: Efficient Fan Controller® (EFC™) - Residential. April 4, 2013. US Copyright TX 8-187-702.

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1. General Measure & Baseline Data

1.1 Measure Description & Background

This work paper provides laboratory test data and engineering analysis of a patented and trademarked retrofit add-on Efficient Fan Controller® (EFC™) installed on residential single-family, multi-family, or double-wide mobile home split-system, or packaged Heating, Ventilating, and Air Conditioning (HVAC) systems with direct-expansion cooling and gas furnace or heat pump heating or forced-air hydronic heating for multi-family units.[2] The EFC™ can be cost-effectively installed on direct-expansion cooling and gas furnace or heat pump heating or forced-air hydronic heating systems with no fan-off time delay, fixed fan-off time delay, or cooling-only enhanced fan-off time delay. The EFC™ provides an extended variable fan-off time delay for cooling and heating based on the cool source or hear source operational time. The EFC™ also controls the gas furnace heating ventilation fan from a default speed to a higher fan speed after the heat exchanger has reached operating temperature for systems so enabled to satisfy the heating thermostat sooner and reduce heat-source operational times. The EFC™ automatically detects the HVAC system type (including heat pumps) and the mode of operation to recover and deliver extra heating or cooling capacity, lengthen the off cycle, increase thermal comfort, and improve efficiency. The workpaper base case is a 13 SEER HVAC AC unit without an EFC or a 13 SEER HVAC unit with a cooling-only standard enhanced fan-off time delay. Based on survey responses from 68 randomly selected participants with the EFC™ installed for approximately 5 years, the overall customer satisfaction was 94 +/- 2.8% in terms of providing more comfortable space heating and cooling. The following tables provide the base, standard, and measure cases and the measure name and measure codes.

Table 1: Base, Standard, and Measure Cases

Case	Description of Typical Scenario
Measure	Installation of Efficient Fan Controller® to control a cooling or heating fan after standard cooling or heating on-cycles
Existing Condition	Split-system or packaged HVAC system with direct-expansion cooling and gas furnace or heat pump heating or forced-air hydronic heating with no fan-off time delay, fixed fan-off time delay, or cooling-only enhanced fan-off time delay
Code/Standard	N/A
Industry Standard Practice	N/A

Table 2: Measures and Codes

Measure Code				Measure Name
SCG	SDG&E	SCE	PG&E	
NA	NA	NA	NA	HVAC System – Efficient Fan Controller®

This measure is cross cutting for use in the residential single-family, multi-family, and mobile home market sector.

[2] US Patent 8763920, US Patent 9328933 and US Patent 9500386. US Trademark Efficient Fan Controller™ Serial Number 87015109 (First Use 03-01-2012), EFC™ Serial Number 87015117 (First Use 03-01-2012)

The work paper provides baseline Unit Energy Consumption (UEC) data, common units, energy savings, incremental measure costs, and E3 Calculator cost effectiveness values for the GreenFan® EFC™ based on laboratory tests, engineering analysis, and eQuest building energy simulations. Energy savings are based on laboratory tests performed by Intertek of the EFC™ installed on split-system and packaged HVAC units, heat pumps, and hydronic forced-air heating systems. Installation costs for the EFC™ are $150 per unit for single family (SFM) and double-wide mobile homes (DMO), and $100 per unit for multi-family homes (MFM). The EUL is 8 years based on the retention study and net-to-gross ratio is 0.85 based on the emerging technologies and hard-to-reach NTGR. Approximately 59,000 GreenFan® EFC™ units have been installed in California since 2012.

The values used to forecast the measure's impacts are as follows:

- Incremental Measure Cost: $150 per air conditioner, furnace, or heat pump HVAC system for single family and mobile homes and $100 per air conditioner, furnace, heat pump, or hydronic HVAC system for multi-family homes,
- Annual Energy Savings and demand reduction,
- Effective Useful Life: 8 years based on retention study and "repair-eligible" equipment, and
- Net to Gross Ratio: 0.85 based on emerging technologies and hart-to-reach default (participant survey responses provided a NTGR of 0.98 +/- 0.2).

Laboratory tests were performed of the EFC™ installed on a 13-SEER 3-ton split-system air conditioner with 80% AFUE gas furnace heating system, 13 SEER 3-ton packaged unit with 80% AFUE gas furnace heating system, 13-SEER and 7.7 HSPF 1.5-ton heat pump heating and air conditioning system, and 1.5-ton hydronic heating system with direct expansion air conditioning system. Tests were conducted at the Intertek® laboratory in Plano, Texas under the direction of Ean Jones and Robert Mowris (see **Appendix A** and **Appendix B**). Equipment setup and testing was performed by Intertek technicians managed by Gilbert Taracena, Craig Grider, and Chris Haws.

1.1.1 Measure Requirements

The measure requirements include eligibility, non-feasibility, implementation, and documentation.

Eligibility Requirements

The baseline HVAC system may have no pre-existing fan-off time delay for cooling and/or heating or a pre-existing fixed fan-off time delay for cooling and/or heating. HVAC units with a pre-existing variable fan-off time delay for cooling only that have no variable fan-off time delay or fixed fan-off time delay for heating are also eligible for installation of the measure. The measure applies to residential split-system and packaged HVAC units with forced-air direct-expansion cooling and/or forced-air heating provided by a gas furnace, heat pump, electric resistance, or hydronic heating system. The EFC™ measure must meet the following eligibility requirements.

- UL-listed.
- Capable of providing a variable fan-off time delay for both cooling and heating based on the cooling or heating operational time and automatically detecting HVAC system type and mode of operation for the variable fan-off time delay to function properly.

- Capable of controlling a gas furnace heater fan from a default speed to a high-speed after the heat exchanger has reached operating temperature for systems so enabled.
- Automatically detecting whether or not the HVAC system type is a heat pump and mode of operation is cooling or heating.
- Capable of maintaining the same heat pump reversing valve position during heating or cooling throughout the fan-off time delay for EFC™ enabled products. Some thermostats de-energize the reversing valve at the end of the heat or cool source operational time which will equalize high-to-low side refrigerant pressure and reduce available cooling or heating capacity during the extended variable fan-off time delay period.

Non-Feasibility Requirements

The measure cannot be installed in HVAC systems with the following non-feasibility issues.

- HVAC system is not a central FAU (package unit, split system, heat pump, gas or electric furnace, or hydronic system).
- HVAC system is inaccessible, non-operational, or in need of service or repair.
- HVAC system has a hazardous condition that cannot be feasibly corrected (e.g., gas leak, electrical hazard, cracked firebox).
- HVAC system has a refrigerant leak or other defect requiring service.
- HVAC system is on a recall list from a manufacturer or the Consumer Product Safety Commission (CPSC).
- Customer refuses the installation.

Implementation Requirements

For the EFC™ measure to be installed, each residential dwelling unit must be cooled and/or heated by an existing central split-system or packaged forced-air HVAC system with direct-expansion cooling and/or heating provided by a gas or electric furnace, heat pump, or hydronic forced-air heating system. The residential HVAC unit must be operating safely and properly, and have a 24 VAC thermostat and blower control. The measure can be installed in all California climate zones in any single family, multi-family, and double-wide mobile home HVAC system. For multi-family buildings the EFC™ measure is installed on all HVAC units serving dwelling units and common areas (halls, recreation, and common areas).

Documentation Requirements

Documentation requirements should include customer address and contact information, cooling and heating capacity and make, model, and serial number of HVAC equipment, and date of installation. Heating and cooling capacity provide information to evaluate energy savings, cost effectiveness, retention, customer satisfaction, and warranty.

1.2 Technical Description

The Efficient Fan Controller® (EFC™) recovers and delivers additional heating and cooling capacity to operate the HVAC equipment at higher efficiency, lengthen the off-cycle time, improve thermal comfort, and shorten the daily on-cycle operational time. The patented GreenFan® EFC™ adjusts fan operation for heating based on heat source operational time, and fan operation for cooling based on cool source operation time. The amount of time the fan operates after the heat source is off or after the compressor is off varies with the amount of time the heat source or compressor are on. The heat source run time indicates how much heat is stored in the heat exchanger. The air conditioner run time indicates how much cold water is condensed on the evaporator coil and residual cooling is available. Most furnaces fans operate at low speed and this reduces airflow and heating efficiency. For some systems, the EFC™ provides high speed fan operation in heating mode to increase heating efficiency and reduce furnace run time.[3] The measure applies to standard and high efficiency air conditioners with furnaces in cooling or heating mode, heat pumps in cooling or heating mode, and air conditioners with hydronic heating. The EFC™ provides electricity energy savings of cooling-only enhanced fan-off time delays plus heating energy savings for gas furnaces (therms), heat pumps (kWh), hydronic heating (therms or kWh), and electric resistance (kWh) heating systems. The EFC™ automatically detects the HVAC system type (including heat pumps) and the mode of operation to recover and deliver extra heating or cooling capacity, lengthen the off cycle, improve thermal comfort and efficiency. The EFC™ product can maintain the same heat pump reversing valve position during heating or cooling throughout the fan-off time delay with patent pending installation instructions. Some thermostats de-energize the reversing valve at the end of the heat or cool source operational time which will equalize high-to-low side refrigerant pressure and reduce available cooling or heating capacity during the extended variable fan-off time delay period. The workpaper base case is a 13 SEER HVAC AC unit without an EFC or a 13 SEER HVAC unit with a cooling-only standard enhanced fan-off time delay.[4] The direct-expansion cooling savings assume a baseline fan-off time delay of zero-seconds, 30-seconds, 60-seconds, 65-seconds, or 90-seconds. The split-system gas furnace heating savings estimates assume a baseline fan-off time delay of 120-seconds. The packaged unit gas furnace heating savings estimates assume a baseline fan-off time delay of 45-seconds or 120-seconds. The heat pump heating systems savings estimates assume a baseline fan-off time delay of zero-seconds or 65-seconds. The hydronic heating system savings estimates assume a baseline fan-off time delay of zero-seconds or 60-seconds. The energy savings power function regression equations include a weighted average of all of the existing fan-off time delay options compared to the EFC™ variable fan-off time delay based on the Intertek laboratory tests. The EFC™ can be cost-effectively installed on split-system and packaged direct-expansion cooling and gas furnace or heat pump heating or forced-air hydronic heating systems with no fan-off time delay, fixed fan-off time delay, or cooling-only enhanced fan-off time delay. If an HVAC unit includes a high efficiency fan motor, the savings will be higher due to lower power consumption of the fan motor.

Conventional fan controllers typically operate the ventilation fan for 0 to 120 seconds after the furnace or compressor turn off and this wastes heating and cooling energy that is not delivered to the conditioned space. The EFC™ recovers and delivers more heating and cooling energy to the conditioned space than is possible with conventional fan controllers. The EFC™ improves the

[3] Some newer heating systems with standard 90-second time delay do not allow high speed fan operation without switching the fan control jumper or controlling the fan speed with an EFC™ high-voltage relay embodiment.

[4] The 13-SEER was de-rated in the eQuest simulations based on laboratory tests of 13-SEER units where the average tested efficiency ranged from 3.95 to 8.94 depending on operational time and the average efficiency was 8.4 EER which is equivalent to an Electric Input Ratio (EIR) of 0.355. The DEER eQuest prototype EIR values are 0.384 for SFM, 0.345 for MFM, and 0.338 for DMO prototypes and the average EIR for the three prototypes is 0.355.

efficiency of HVAC equipment by delivering additional heating or cooling capacity for a small amount of additional fan electric energy (kWh).

Air conditioners cool conditioned spaces by removing sensible and latent heat from the return air which reduces the supply air temperature and humidity. Latent heat is removed as water vapor is condensed out of the air due to the temperature of the evaporator coil being less than the return air dew point temperature.[5] Most evaporators are cold and wet (below 40 to 50°F) after the compressor turns off. Cooling energy left on the evaporator coil after the compressor turns off is generally wasted. The evaporator absorbs heat from the attic and cold water on the coil flows down the condensate drain. The EFC™ recovers the remaining cooling energy from evaporator coil by operating the fan after the compressor turns off to cool the conditioned space.

Average human skin temperature is approximately 90F +/-1F (EJAP 2000). Furnace fan run time can be extended without discomfort if the supply air temperature is warmer than skin temperature and does not blow directly on people. Most furnace heat exchangers are still hot (above 135 to 270°F) after the furnace fan turns off. The patented GreenFan® EFC™ shown in **Figure 1** is the UL-listed (E356046) microprocessor-based device that monitors HVAC system type, mode of operation, and duration of either the air conditioning compressor or heat source (i.e., furnace, heat pump, or hydronic heating) operation and varies the fan-off time delay of the indoor blower fan based on HVAC system type, mode of operation, and operational time of the air conditioner compressor or heating system (referred to as "time delay").[6] The EFC™ recovers the remaining heat energy from the hot furnace heat exchanger after the furnace turns off and delivers this heat to the conditioned space. Most furnaces fans operate at low speed and this reduces airflow and heating efficiency. For applicable gas furnace heating systems, the EFC™ can save heating energy by increasing fan speed from low- or medium-speed to high-speed after the furnace is turned on and the heat exchanger has heated up.[7] Standard furnace fans operate at low speed delivering less heating capacity to conditioned space at lower efficiency compared to operating the fan at a higher speed. If the default fan speed controlled by the fan switch is set to the same speed as heating, then the EFC™ will save heating energy based on extended fan operation after the furnace turns off. For most existing HVAC gas furnace systems operating in heating mode, the fan speed controlled by the fan relay is set to the high speed used for cooling. GreenFan® manufacturers an EFC™ that includes a high-voltage relay to enable high fan speed on new or existing HVAC systems where high fan speed operation is not enabled using only the "G" wire signal.

The GreenFan® EFC™ also provides extended variable fan-off time delay control for heat pumps and HVAC systems with hydronic heating by detecting the type of system the EFC™ is connected to and providing the appropriate fan-off time delay to recover heating and cooling energy to optimize energy efficiency. The GreenFan® EFC™ improves HVAC efficiency and saves energy by providing longer variable fan-off time delays based on HVAC system type, mode of operation,

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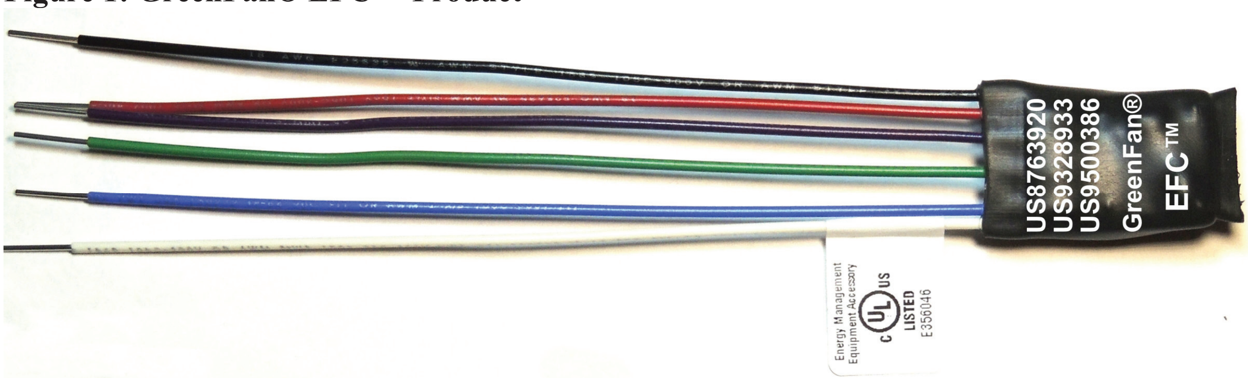
[5] Latent heat is the quantity of heat absorbed or released by air undergoing a change of state, such as water vapor condensing out of the air as water onto a cold evaporator coil or cold water evaporating to water vapor which will cool the air.

[6] US 8763920 and US 9328933 and US 9500386.

[7] Tests are also performed at low or medium speed since some furnaces do not enable high speed from the G terminal.

and cooling or heating operational time. The EFC™ recovers and delivers more sensible cooling or heating capacity to the space to enhance thermostat setpoint temperatures, lengthen off-cycles, reduce daily on-cycles, improve thermal comfort, and save energy.

Figure 1: GreenFan® EFC™ Product



1.3 Installation Types and Delivery Mechanisms

The following measure installation type and delivery mechanisms are provided per the Remote Ex-Ante Database Interface (READI) data requirements. 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.

Table 3: Installation Type Descriptions

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

Table 4: 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.

Table 5: Incentive Method Descriptions

Delivery Method	**Description**
Down-Stream Customer 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.
Down-Stream Contractor Incentive	The contractor 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 contractor. Such an incentive may be deemed or customized.
Direct Install	The program implements energy efficiency measures for qualifying customers, at no cost to the customer.

1.4 Measure Parameters

The following measure parameters are provided regarding DEER difference data, spillage (i.e., spillover), and installation rate.

1.4.1 DEER Supporting Data

The following table provides the DEER difference summary information.

Table 6: DEER Difference Summary

DEER Item	**Used for Workpaper**
Modified DEER methodology	Yes
Scaled DEER measure	No
DEER Base Case	Yes
DEER Measure Case	No
DEER Building Types	Yes (SFM, MFM, and DMO)
DEER Operating Hours	Yes
DEER eQUEST Prototypes	Yes with some modifications
DEER Version	DEER, 2014, DEER 2015, READI v2.3.0
Reason for Deviation from DEER	DEER prototypical HVAC systems were modified to model heat pump heating and cooling and hydronic forced-air heating and direct-expansion cooling. DEER eQuest Building Description Language (BDL) inputs were revised to more accurately model actual HVAC systems (see Section 2.1 DEER eQuest Prototypes). Hourly system output variables were used to calculate sensible cooling and heating part load ratios which were correlated to laboratory test data to develop energy and peak demand savings.
DEER Net to Gross Ratio	No. The NTGR is 0.85 based on Emerging Technologies and Hard-to-Reach default. Participant survey responses from 68 customers provided a 0.98 +/- 0.2 NTGR. DEER default values are not applicable to EFC™ measure which is almost impossible to install at customer sites without downstream contractor incentives.
DEER EUL	No. The default DEER EUL for HVAC retrofit measures is 5 years. Based on retention survey data from 68 randomly selected site inspections, the estimated EUL for the EFC™ is 8.4 years and the 80% lower bound estimate is 6.8 years and 80% upper bound estimate of EUL and RUL is 10.6 years. The “null hypothesis” is rejected since the 5-year DEER EUL is less than the lower bound 80 percent effective useful life of 6.8 years. The EFC™ EUL and RUL are rounded down to the nearest integer and established at 8 years (see Section 1.6).
DEER Measure IDs Used	N/A

Spillage Rate

Spillage or spillover (participant and non-participant) is the reduction in energy consumption and/or demand caused by the presence of an energy efficiency program or measure, beyond the program-related gross savings of the participants and without financial or technical assistance from the program or measure. Participant spillover is the additional energy savings that occur when a program participant independently installs incremental energy efficiency measures or applies energy-saving practices after having participated in the efficiency program as a result of the program's influence. Non-participant spillover refers to energy savings that occur when a program non-participant installs energy efficiency measures or applies energy savings practices as a result of a program's influence. The term "free-drivers" may also be used for measures with spillover effects. This workpaper does not provide estimates of spillage or spillover rates.

Installation Rate

The IR values were obtained using the DEER READI tool as shown in the following table.

Table 7: Installation Rate

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

1.4.2 Codes and Standards Analysis

There are currently no federal, state, or regional codes that impact Efficient Fan Controllers® for residential HVAC systems. However, starting in 2015 federal code requires a residential AC unit installed in California to have a SEER (Seasonal Energy Efficiency Ratio) rating of at least 14. This efficiency rating was used to establish the baseline AC unit for this measure. For application in 2014 programs the savings are conservative as the 2014 code requires SEER 13.

Table 8: Code Summary

Code	Reference	Effective Dates
Title 24 (2013)	N/A	N/A
Title 20 (2014)	N/A	N/A

1.5 Net-to-Gross Ratio (NTGR)

The Net-to-Gross Ratio (NTGR) is defined as one minus the ratio of units that would not have been installed without the program divided by the total number of units installed through the program. Participant surveys are used to evaluate the NTGR for calculating net kW and kWh savings. The NTGR is used to estimate the fraction of free riders who would have otherwise installed the EFC™ measure in the absence of the program. **Table 9** provides the NTGR participant survey questions and scoring methodology. The NTGR score for each completed participant survey is the average score based on answers to questions 14 through 22. No score is assigned to responses of "don't know," "refused to answer," or "other."

Follow-up NTGR surveys with 68 randomly selected participants indicated that only 1 of these participants would have installed the EFC™ without the downstream or direct-install incentives paid to contractors. Based on responses to the survey, the EFC™ NTGR is 0.98 +/- 0.02. The DEER default NTGR for Emerging Technologies is 0.85 and is assumed to be the "null hypothesis" which is presumed to be true until or unless a preponderance of statistical evidence is provided to nullify it for an alternative hypothesis. Based on evidence provided by the survey responses and site inspections, the "null hypothesis" can be rejected since the DEER default 0.85 NTGR is less than the lower bound 0.96 NTGR. Based on survey findings and the fact that the EFC™ cannot be purchased online or in stores, and no other data exists to the contrary, an alternative hypothesis of 0.98 NTGR can be established. Nevertheless, for this workpaper the DEER default 0.85 NTGR for Emerging Technologies is used for cost effectiveness calculations. Based on survey responses from 68 randomly selected participants with the EFC™ installed for about 5 years, the overall customer satisfaction was 94 +/- 2.8% in terms of providing more comfortable space heating and cooling.[8]

Table 9: Net-to-Gross Ratio Participant Survey Questions and Scores

#	Question	Answer	Score
1	Are you aware that an EFC™ was installed in your HVAC system?	Yes, No	1=Y, 2=N
2	Is the EFC™ still installed?	Yes, No	1=Y, 2=N
3	Do you mind if we visit your home to make sure the EFC™ is still installed?	Yes, No	1=Y, 2=N
4	Did you ever have any issues with the EFC™? YES, Continue, No SKIP to Q6	Yes, No	1=Y, 2=N
5	Please describe the issue?	Answer	
6	When was your heating and cooling system installed? (estimated year of installation)	Year	Year
7	Do you plan on installing a new HVAC unit in 5, 10, 15, 20 or longer (years estimate)?	Yes, No	Years
8	Does the EFC™ provide more comfortable heating on a scale of 1 to 10? (10=more, 5=same, 1=less).	1 to 10	0=1, 10=0
9	Does the EFC™ provide more comfortable cooling on a scale of 1 to 10? (10=more, 5=same, 1=less).	1 to 10	0=1, 10=0
10	Does the EFC™ save energy compared to not using it?	Yes, No	% Savings
11	How satisfied are you with the EFC™ on a scale of 1 to 10? (1=Low, 10=High).	1 to 10	0=1, 10=0
12	Do you have any comments to share about your experience with the EFC™?	Comments	
13	When and how did you first learn about the EFC™? Didn't know there was a program then STOP	Internet, etc.	Date
14	Did you understand the value of the EFC™ BEFORE or AFTER you decided to install it?	1 = After, 2 = Before	1 or 2
15	Would you have installed the EFC™ without the Utility program?	Yes, No	1=Y, 2=N
16	On a scale from 0 to 10, with 0 being no influence at all and 10 being very influential, how much influence did the incentive have on your decision to install the EFC™?	0 to 10	0=0, 10=1
17	If contractor incentives for free installation had not been available how likely is it you would have done exactly the same thing? Please use scale from 0 to 10, with 0 being not likely and 10 very likely.	0 to 10	0=0, 10=1
18	What role did the utility program play in your decision to install the EFC™?	1 = Reminded	0.25
		2 = Speeded Up (i.e., early replacement)	0.5
		3 = Showed Benefits Didn't Know Before	1
		4 = Clarified Benefits	0.75
		5 = No role	0
19	The utility program was nice but not necessary to install the EFC™. (0=Disagree, 10=Agree).	0 to 10	0=0, 10=1
20	The Utility program was a critical factor to install the EFC™. (0=Disagree, 10=Agree).	0 to 10	0=0, 10=1
21	I would not have installed the EFC™ without the Utility Program. (0=Disagree, 10=Agree).	0 to 10	0=0, 10=1
22	If the EFC was not installed in the Utility program, when would you have installed the EFC™ measure?	Within 6 months	0
		< 1 year	0.125
		1 to 2 years	0.25
		2 to 3 years	0.5
		3 to 4 years	0.75
		4 or more years	1
		Never	1

Table 10: Net to Gross Ratio (NTGR)

NTGR ID	Description	Sector	Bldg Type	Measure Delivery	NTGR
NA	Efficient Fan Controller®	All	Any	Any	0.98
NA	Emerging Technologies and HTR	All	Any	Any	0.85

[8] Customer satisfaction score for improving thermal comfort was 97 +/- 2.6% for cooling and 91 +/- 3.5% for heating.

1.6 Effective Useful Life (EUL) and Remaining Useful Life (RUL)

The effective useful life (EUL) of a measure is defined as "the median number of years that the measure is still in place and operable." The remaining useful life (RUL) is defined as "the median number of remaining years that a system is estimated to be in place and operable in accordance with its intended purpose before warranting replacement." The median number of years wherein a measure is still in place and operable can be determined based on hazard rate and survival function analysis. The hazard and survival analysis uses removal data from 68 site inspections randomly selected from a database of 1,633 EFC™ units installed in 2012 with survey code dates. The survival functions are derived using a three-step process.[9] First, hazard rates are developed based on site inspection findings. Second, hazard rate functions are developed based on the hazard rates.[10] Third, survival functions are developed using the estimated hazard rate function. The steps in the parametric procedure for estimating the survival functions are as follows:

1) Prepare site inspection data for calculation of the hazard rate.
2) Estimate the hazard function.
3) Use hazard rate function to determine the survival function.
4) Estimate the effective useful life of measures from the survival function.

Estimating the hazard rate function is an essential component in this analytical procedure. Two of the distributions used for survival analysis are the exponential distribution and the Weibull distribution. The probability density functions and associated hazard functions, as well as the survival functions for these distributions are shown in **Table 11**.

Table 11: Hazard and Survival Functions for Exponential and Weibull Distributions

Exponential Distribution	
Probability Density Function	$f(t) = \gamma \exp(-\gamma t)$
Hazard Function	$h(t) = \gamma$
Survival Function	$S(t) = \exp(-\gamma t)$
Weibull Distribution	
Probability Density Function	$f(t) = \alpha\beta t^{\beta-1}\exp(-\alpha t^{\beta})$
Hazard Function	$h(t) = \alpha\beta t^{\beta-1}$
Survival Function	$S(t) = \exp(-\alpha t^{\beta})$

Source: NIST 2012.

The exponential distribution can be used to represent a hazard rate that is constant. The associated survival function is also exponential. However, the exponential distribution does not represent hazards that increase or decrease over time. If the hazard rate increases or decreases with age, the

[9] National Institute of Standards and Technology (NIST). 2012. Engineering Statistics Handbook. NIST/SEMATECH e-Handbook of Statistical Methods, U.S. Department of Commerce. http://www.itl.nist.gov/div898/handbook/eda/section3/eda3668.htm

[10] Hazard functions are used to forecast the probability of removal or failure for a measure, given that the measure has survived to the present.

Weibull distribution can be used to represent the hazard function and the survival function. The Weibull distribution, α is defined as the scale parameter, while β is defined as the shape parameter. The shape factor, β, is the slope of the probability regression and is greater than one for an "aging" process where parts or equipment are more likely to fail as time goes on. The scale parameter, α, has the same effect on the distribution as a change in the abscissa scale (i.e., increasing the scale while holding the shape constant will stretch out the probability distribution function).

The hazard rates are developed using removal information about the lifetime of the measure. The lifetime of the measure is calculated as the difference between the date that the measure was removed and the date the measure was installed. The date the measure was installed was obtained from the program participant database. The date that the measure was removed is identified in the retention survey database as the survey code date (i.e., month/day/year). Survey code dates were obtained from surveys and site visits of participating customers conducted during the onsite inspections. Hazard rates are calculated using the following equation based on removals and measures installed at the start of the year. The removals for each year are calculated using the following equation.

Equation 1 $$h(t) = \frac{r(t)}{M(t)}$$

Where, $h(t)$ = hazard rate in year, t, for the sample of measures with survey code dates,
$r(t)$ = removals in year, t, and
$M(t)$ = Measures at start of year.

With an initial survey sample of 68 EFC™ units and 1 unit removed in the first year implies a hazard rate of 1.47 percent. With 1 unit removed during the first year, there were 67 EFC™ units "at risk" in the sample at the start of the second year. With 2 units in the survey sample removed in the second year implies a hazard rate of 2.99 percent and 65 units "at risk" in the third year. Similar calculations provide hazard rate estimates for years 3, 4, and 5. There were a total of 17 removals in the survey sample and zero EFC™ failures. The removals were due to the following issues: 9 EFC™ units were removed during HVAC equipment replacements, 7 EFC™ units were removed during fan motor replacements, and 1 EFC™ unit was removed during a motor start capacitor replacement. All customers at these sites indicated that the EFC™ units worked properly until they were removed when equipment or parts were replaced. Current programs mitigate removals by training technicians to check and replace failing fan relays and motor-start capacitors, contactors, transformers, wiring, thermostat batteries, and thermostats during installation. Current programs also educate property owners and manager, maintenance personnel, technicians, tenants, and customers to not remove the EFC™ if equipment is replaced. Current programs also clean condenser coils and notify maintenance or occupants to replace dirty air filters.

Calculated hazard rates based on the retention study findings are shown in **Table 12**. The hazard rates vary from 1.47 percent (%) at the end of the first year to 10.53% at the end of the fifth year. The hazard rate variation indicates that the survival function cannot be represented properly by exponential distribution, since the hazard rate for an exponential survival function is constant. The

Weibull distribution allows for hazard rates that increase over time. Therefore, the Weibull distribution is used for estimating the hazard function based on a power function linear regression curve fit to the retention survey hazard rate data. The calculated hazard rates and Weibull distribution hazard rate function are plotted in **Figure 2**. The Weibull distribution hazard rate function is defined by the following equation.

Equation 2 $h(t) = \alpha\beta t^{\beta-1}$

Where, $h(t)$ = Weibull distribution hazard rate function,
α = scale parameter, and
β = shape parameter.

The Weibull distribution survival function is defined by the following equation.

Equation 3 $S(t) = e^{-\alpha t^{\beta}}$

Where, $S(t)$ = Weibull distribution survival function.

The median effective useful life of the Weibull distribution survival function is calculated by solving the survival function for the time where $S(t)$ = 0.5 as defined by the following equation.

Equation 4 $\breve{T} = \left(\frac{\ln(2)}{\alpha}\right)^{(1/\beta)}$

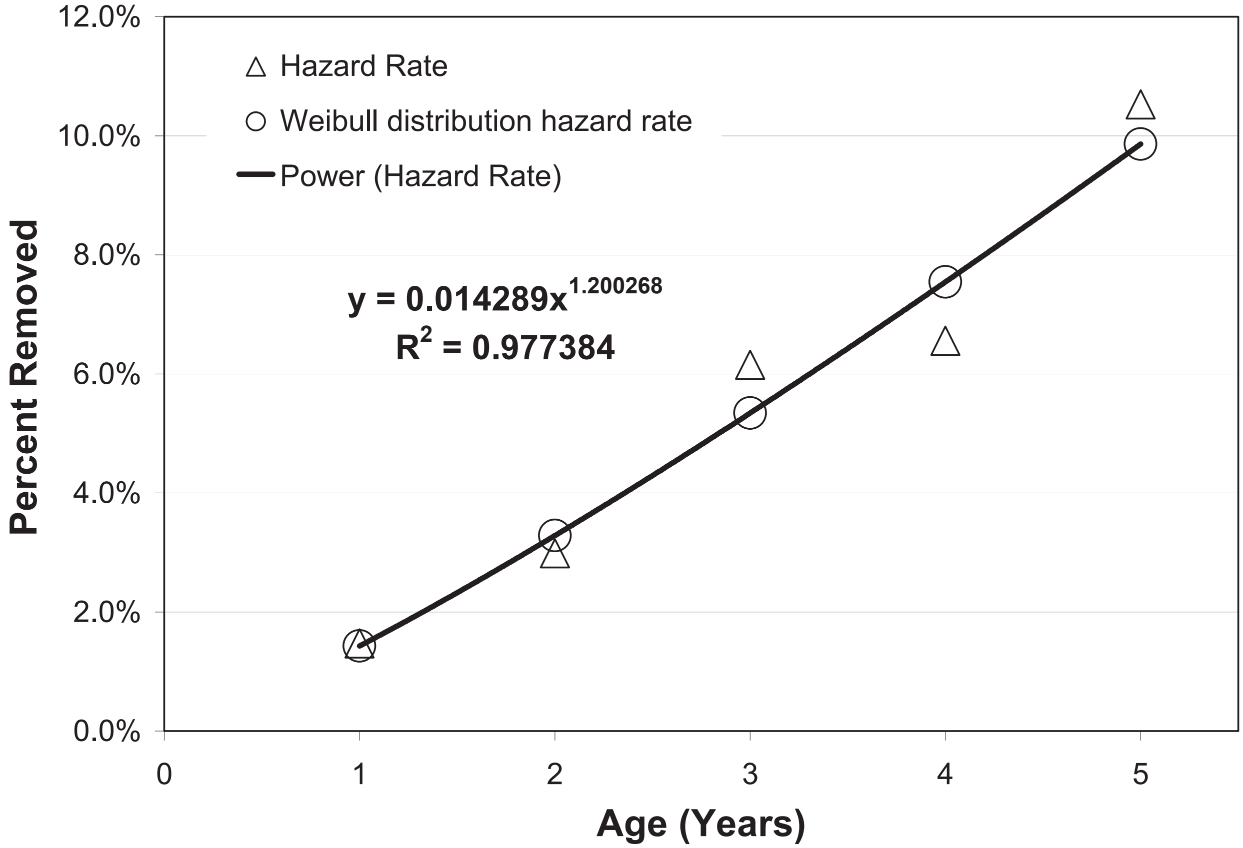
Where, $\breve{T}$ = median EUL of the Weibull distribution survival function.

Table 12: Hazard Rates Based on EFC™ Units with Survey Code Dates

Year	EFC™ Units at Start of year	EFC™ Units Removed during year	Hazard Rate (Rate of Removal)
1	68	1	1.47%
2	67	2	2.99%
3	65	4	6.15%
4	61	4	6.56%
5	55	6	10.53%
Total		17	

The power function linear regression curve fit to the hazard rate data in **Table 12** provides estimates of the parameters for the Weibull distribution hazard rate. The parameters estimated through the power function curve fits and the estimated scale and shape parameters of the Weibull distribution hazard rate function are reported in **Table 13**.

Figure 2: Hazard Rates for EFC™ Units with Survey Code Dates

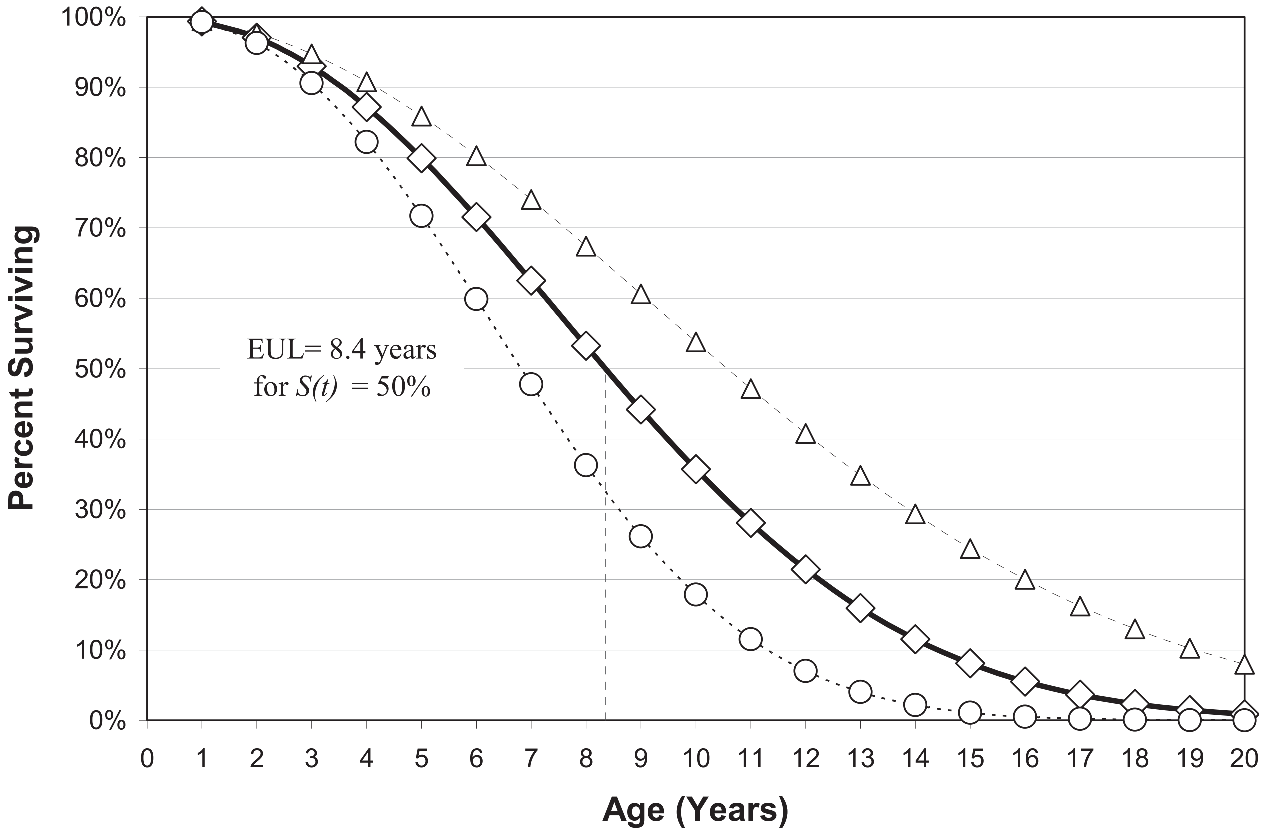


The EM&V Protocols require a statistical test of whether the *ex post* estimate of useful life is significantly different from the *ex ante* estimate. This test can be accomplished by constructing an 80% confidence interval around the *ex post* estimate and determining whether the *ex ante* estimate falls within this confidence interval. That is, if the *ex ante* estimate falls inside the constructed confidence interval, then the hypothesis of “no difference between the *ex ante* and *ex post* estimates” cannot be rejected. If the *ex ante* estimate falls outside the constructed confidence interval, then the hypothesis of “no difference between the *ex ante* and *ex post* estimates” can be rejected.

To estimate the useful lives of the EFC™ measures sampled in this study, an 80% confidence interval for the estimated median life of a measure is calculated. This approach includes using the regression fit of the power curve coefficients at the 80% confidence levels. The power curve regression analysis for each measure provided three sets of parameters for the Weibull hazard rate function: the “best fit” parameters and parameters for the upper and lower bounds of the 80% confidence interval. The analysis provided an estimate of the “best” Weibull distribution hazard rate function and the survival function for the EFC™ measure, plus estimates of the functions for the upper and lower bounds of the 80% confidence interval.

Figure 3 shows the Weibull distribution survival functions with the 80% lower and upper confidence interval boundaries. The Effective Useful Life (EUL) is estimated as the median survival time of 8.4 years based on the Weibull distribution hazard rate functions and associated survival functions. The median survival time is defined as the age where the survival function value equals 50%, indicating 50% of the measures have been removed.

Figure 3: Weibull Distribution Survival Functions with 80% Lower and Upper Boundaries



The DEER default EUL and the estimated median survival EUL and RUL and 80% lower and upper bounds are reported in **Table 14**. The median estimated EUL and RUL for the EFC™ is 8.4 years based on **Equation 4** and the 5-year retention study findings. The 80% lower bound estimate is 6.8 years and 80% upper bound estimate is 10.6 years. Previous workpapers provided a DEER default ex ante EUL of 5 years for the cooling-only enhanced time delay based on one-third of the estimated ex ante EUL of 15 years for HVAC equipment. The 5-year DEER default is assumed to be the "null hypothesis" where no statistical significance exists in a set of given observations, no variation exists between variables or that a single variable is no different than its mean. The "null hypothesis" is presumed to be true until or unless a preponderance of statistical evidence is provided to nullify it for an alternative hypothesis. Based on the evidence provided by the retention survey data for 68 randomly selected site inspections, the "null hypothesis" can be rejected since the DEER default 5-year EUL estimate is less than the lower bound 80% effective useful life of 6.8 years.

Based on the 5-year retention study findings from 68 site inspections with survey code data and the fact that no other data exists to the contrary, an alternative hypothesis of 8.4 years for the EUL and RUL is provided for the EFC™. For cost effectiveness calculations provided in this workpaper, the EUL and RUL are rounded down to the nearest integer and established at 8 years.

Table 13: Hazard Rate Estimation for EFC™ Units

	Weibull Distribution Hazard Function Power Curve Fit			Weibull Distribution Parameters	
Measure	$a = \alpha \times \beta$	$b = \beta - 1$	R-squared	α (Scale)	β (Shape)
EFC™	0.014289	1.200268	0.977384	0.006494	2.200268

Table 14: DEER Default and Retention Study EUL and RUL for EFC™ Units

Measure	DEER Default Ex Ante EUL and RUL	Retention Study 80% Lower Bound EUL and RUL	Retention Study Estimated Median EUL and RUL	Retention Study 80% Upper Bound EUL and RUL	Ex Ante Different From Retention Study EUL at 80% Confidence Level ± 20 Percent?
EFC™	5	6.8	8.4	10.6	Yes

Table 15: Effective Useful Life and Remaining Useful Life Based on Retention Study Data

EUL ID	Description	Sector	Use Category	EUL (Years)	RUL (Years)
	Efficient Fan Controller®	Res	HVAC	8	8

Note: EUL and RUL are rounded down to 8 years from 8.4 years

1.7 Market Share and Potential

Table 16 provides the estimated market share of HVAC systems by building type in California for buildings with space conditioning equipment.[11] These estimates are based data available from the California Energy Commission Residential Appliance Saturation Study (RASS), Lawrence Berkeley National Laboratory (LBNL), and program tracking data.[12] The CEC 2009 RASS study provides estimates of HVAC system market shares by utility service area. The 1997 LBNL study provides market shares from 1980 to 1995 for different types of HVAC systems based on sales data. The program tracking data provides market shares for a population of 59,000 HVAC systems in California. Based on this data, the estimated market share of HVAC systems in single family buildings is 88% gas furnace with direct expansion (DX) cooling, 9% heat pump, and 3% electric resistance heating with DX cooling.[13] The estimated market share for multi-family buildings is 49%

[11] The table does not include approximately 11 to 24% of residential buildings with room air conditioners and heaters or 22 to 31% of residential buildings with unknown space conditioning equipment.

[12] KEMA, Inc. 2010. 2009 California Residential Appliance Saturation Study (RASS). California Energy Commission. CEC-200-2010-004-ES. http://www.energy.ca.gov/2010publications/CEC-200-2010-004/CEC-200-2010-004-ES.PDF.
Wenzel, T., Koomey, J., Rosenquist, G., Sanchez, M., Hanford J. 1997. Energy Data Sourcebook for the US Residential Sector. LBL-40297. http://enduse.lbl.gov/Projects/RED.html.
Walsh. J. 2016. Program Tracking Data of 59,000 HVAC Systems. GreenFan, Inc.

[13] Multi-family buildings with hydronic heating and DX cooling typically have a gas water heater and small pump to circulate hot water to a hot water coil in the forced air unit which also has a DX cooling coil. Hydronic systems are

gas furnace with DX cooling, 40% heat pump, 9% hydronic, and 2% electric resistance heating with DX cooling. The estimated market share for mobile homes is 89% gas furnace with DX cooling, 10% heat pump, and 1% electric resistance heating with DX cooling.

Table 16: Estimated Market Share of HVAC Systems by Building Type in California

Building Type	Gas Furnace Heat with DX Market Share	Heat Pump Market Share	Hydronic Heat with DX Market Share	Electric Resistance Heat with DX Market Share
Single Family	88%	9%	-	3%
Multi-Family	49%	40%	9%	2%
Mobile Home	89%	10%	-	1%

The EFC™ can be installed as a retrofit measure on any existing or new residential air conditioner (RAC) with gas furnace, residential heat pump (RHP), residential gas furnace only (RGF), and RAC with hydronic heating (RAH). An estimated 10 million homes in California have central air conditioning and heating systems, and the EFC™ can be installed as a retrofit measure on all of these units.[14]

1.8 Laboratory Tests

Laboratory tests were performed with and without the EFC™ installed on direct expansion cooling systems, gas furnaces, heat pumps, and hydronic forced-air heating systems. Tests were performed at the Intertek Laboratory in Plano, Texas, from 01/05/2015 through 01/17/15 and from 11/07/2016 through 11/22/2016. **Appendix A** provides a performance evaluation based on Intertek test data of the GreenFan® EFC™ installed on split and packaged direct-expansion air conditioners with gas furnace heating systems. **Appendix B** provides a performance evaluation based on Intertek test data of the GreenFan® EFC™ installed on heat pump and hydronic split systems. The heat pump provides direct-expansion air conditioning and heating and the hydronic system provides direct-expansion air conditioning and hydronic heating using a water-to-air heating coil, circulating pump, and storage water heater. Intertek measured sensible cooling and heating capacities in British thermal units (Btu) per hour.[15] The sensible cooling or heating capacity are based on the measured airflow rates in standard cubic feet per minute (scfm), specific volume (ft^3/lbm), and temperature difference in degrees Fahrenheit (F) between the return air entering the evaporator and the supply air leaving the evaporator or heat exchanger.[16] Non-steady state tests were performed by Intertek for cooling and heating with no fan-off time delays or fixed fan-off time delays and EFC™ variable

common in Southern California multi-family buildings but uncommon in single-family and mobile home buildings.

[14] Estimate of 10 million air conditioning systems installed in California is based on 100 million air conditioners installed in US homes. United States Energy Information Agency (USEIA). 2011. Air conditioning in nearly 100 million U.S. homes. https://www.eia.gov/consumption/residential/reports/2009/air-conditioning.php

[15] The British thermal unit (Btu) is heat required to raise the temperature of one pound of water one degree Fahrenheit (°F). The Btu is equivalent to 1055.06 joules or 251.997 calories.

[16] Sensible cooling capacity supplied to the space reduces the sensible drybulb temperature controlled by the thermostat, and excludes latent cooling which dehumidifies or removes moisture from the air and is not controlled by drybulb thermostats.

fan-off time delays to measure the sensible cooling or heating capacity and efficiency for the split-system or packaged HVAC systems. Engineering equations used to calculate GreenFan® EFC™ energy efficiency impacts based on Intertek laboratory test data are provided in **Appendices A** and **B**.

1.8.1 Description of Laboratory Test Units

The Intertek laboratory test equipment schematic drawings are provided in **Appendices A** and **B**. The characteristics of 3-ton test units are described in **Table 17**. The rated cooling capacity of the 3-ton split-system HVAC unit is 33,800 Btu per hour and the rated heating capacity is 54,000 Btu per hour. The 3-ton split-system default cooling time delay is either 0 seconds or 90 seconds after the air conditioning compressor turns off, and the default heating time delay is 120 seconds after the furnace turns off. The rated cooling capacity of the 3-ton packaged HVAC unit is 35,800 Btu per hour and the rated heating capacity is 55,200 Btu per hour. The 3-ton packaged unit default cooling time delay is 0 seconds, 30 seconds, or 60 seconds after the air conditioning compressor turns off, and the heating default time delay is either 45 seconds or 120 seconds after the furnace turns off. The GreenFan® varies the fan-off time delay depending on compressor or furnace operational time.

Table 17: Description of Test Units – 3-ton Split-System and Packaged Unit

Description	3-ton Split-System HVAC Unit	3-ton Packaged HVAC Unit
ID Model Number	CNRHP3617ATA	GPG1336070M41BA
Input Voltage	208/230 VAC	208/230 VAC
Input Frequency and Phase	60 HZ and Single Phase	60 HZ and Single Phase
Type	Ducted Evaporator	Packaged Unit
Rated Cooling Capacity	33800 Btu/hr 1200 scfm at 0.5 IWC	35800 Btu/hr 1188 scfm at 0.5 IWC
OD Model Number	24ABS336A300	GPG1336070M41BA
Fan Speed and RPM	Low 1050, Medium 1080, High 1100 RPM	Low 850, Medium 980, High 1040 RPM
Fan Time Delay Cooling	0 or 90 seconds Cooling	0, 30, or 60 seconds Cooling
Fan Time Delay Heating	120 seconds Heating	45 or 120 seconds Heating
Type	Air Cooled Condenser	Air Cooled Condenser
Furnace Model Number	58STA070-12	GPG1336070M41BA
Rated Heating Capacity	54000 Btu/hr 1140 scfm at 0.5 IWC	55200 Btu/hr and 1073 scfm @ 0.5 IWC

The characteristics of 1.5-ton test units are described in **Table 18**. The 1.5-ton split-system Heat Pump (HP) total rated cooling capacity is 17,600 Btu per hour (Btuh) and the sensible cooling capacity is 13,900 Btuh at 95 degrees Fahrenheit (F) outdoor air temperature (OAT) and 525 scfm evaporator airflow with 80F indoor drybulb and 67F indoor wetbulb temperatures. The total rated cooling capacity is 17,000 Btuh and sensible cooling capacity is 13,600 Btuh at test conditions of 95F OAT and 75F indoor drybulb and 62F indoor wetbulb temperatures. The rated heating capacity is 18,000 Btu per hour at 47F OAT and 70F indoor temperature. The heat pump rated cooling efficiency is 13-SEER and the heating coefficient of performance (COP) is 3.76 at 47 degrees Fahrenheit (F) outdoor air temperature (OAT). The heat pump cooling or heating fan-off time delays are fixed during setup at either 0 seconds or 65 seconds after the cool or heat source turns off.

The 1.5-ton hydronic (HYD) split-system rated total cooling capacity is 17,500 Btu per hour at 95F OAT and 80F indoor drybulb and 67F indoor wetbulb temperature. The hydronic system rated cooling efficiency is 13 SEER with the model MHH-19-410 condensing coil and 95F OAT and 550 scfm evaporator airflow with 80F indoor drybulb and 67F indoor wetbulb temperatures. The rated heating capacity is 18,000 Btu per hour with 550 cfm airflow at 70F entering air drybulb temperature and 3 gallons per minute (gpm) at 140F hot water supply temperature. The rated hot water heating efficiency is 78%. The hydronic heating coil is designed to receive 1 to 3 gpm of 120 to 180 Fahrenheit (F) hot water circulated by a 1/25th hp (30W) pump where the water is heated by a storage water heater. The hydronic unit default cooling or heating time delay is fixed during setup at either 0 seconds or 60 seconds after the cool or heat source turns off.

Table 18: Description of Test Units – 1.5-ton Heat Pump and 1.5-ton Hydronic System

Unit Description	1.5-ton Split-System Heat Pump	1.5-ton Split-System Hydronic
ID Model Number	ARUF25B14AA	19CDX-HW
Input Voltage	208/230 VAC	208/230 VAC
Input Frequency and Phase	60 HZ and Single Phase	60 HZ and Single Phase
Type	Ducted Heat Pump Coil	Ducted Evaporator Coil/HW Coil
Rated Cooling Capacity	17,600 Btu/hr 525 scfm at 0.4 IWC	17,500 Btu/hr 550 scfm at 0.3 IWC
OD Model Number	GSZ140181KD	MHH-19-410
Fan Speed and RPM	1043 RPM	1550 RPM
Fan Time Delay Cooling	0 or 65 seconds Cooling	0 or 60 seconds Cooling
Fan Time Delay Heating	0 or 65 seconds Heating	0 or 60 seconds Heating
Refrigerant Charge	R410A 92 Ounces	R410A 106 Ounces
Type	Air Cooled Condenser	Air Cooled Condenser
Heating Model Number	ARUF25B14AA	19CDX-HW
Rated Heat Capacity	18,000 Btu/hr 555 scfm at 0.47 IWC	18,000 Btu/hr 550 scfm at 0.4 IWC

1.8.2 Laboratory Test Methods

The 3-ton units were tested under AHRI 210/240 test conditions and ANSI Z21.47 to verify manufacturer published efficiency ratings. The AHRI 210/240 cooling verification tests were performed according to ANSI/AHRI 2008 Standard for Performance Rating of Unitary Air-Conditioning and Air-Source Heat Pump Equipment Standard 210/240. Verification tests were conducted according to **Table 19** (ANSI/AHRI Standard 210/240-2008, Table 11) and **Table 20**.[17]

[17] ANSI/AHRI 2008 Standard for Performance Rating of Unitary Air-Conditioning and Air-Source Heat Pump Equipment Standard 210/240. American National Standards Institute. Air-Conditioning Heating and Refrigeration Institute.

Thermal Efficiency verification tests were performed according to ANSI Z21.47-5th Edition 2006/CSA 2.3-5th Edition 2006.[18]

The 3-ton split-system unit was tested in cooling mode under non-steady state field conditions to measure sensible cooling capacity and efficiency with a baseline fan-off time delay of zero seconds, and 90 seconds. The 3-ton packaged unit was tested in cooling mode under non-steady state field conditions to measure sensible cooling capacity and efficiency with a baseline fan-off time delay of zero seconds, 30 seconds, and 60 seconds. The 1.5-ton split-system heat pump unit was tested in cooling mode under non-steady state field conditions to measure sensible cooling capacity and efficiency with a baseline fan-off time delay of zero seconds and 65 seconds. Non-steady state cooling tests were performed with the GreenFan® EFC™ providing a variable fan-off time delay for the evaporator fan based on compressor operational time.

The 3-ton split-system gas furnace unit was tested in heating mode under non-steady state field conditions to measure the sensible heating capacity and efficiency with a fixed time delay of 120 seconds after the gas furnace turned off. For the split-system, non-steady state heating tests were performed with the EFC™ providing increased fan speed from low-to-high or medium-to-high speed after a specific period of time when the furnace heat exchanger reached operating temperatures and variable fan-off time delay for the heater fan based on furnace operational time.

The 3-ton packaged unit gas furnace was tested in heating mode under non-steady state field conditions to measure the sensible heating capacity and efficiency with a fixed time delay of 45-seconds or 120 seconds after the gas furnace turned off. For the packaged unit gas furnace, non-steady state heating tests were performed at medium speed with the EFC™ providing a variable fan-off time delay for the heater fan based on furnace operational time. Tests were also performed with the EFC™ providing increased fan speed from low-to-high or medium-to-high speed after a specific period of time when the furnace heat exchanger reached operating temperatures with variable fan-off time delay for the heater fan based on furnace operational time.

The 1.5-ton split-system heat pump was tested in cooling and heating modes under non-steady state field conditions to measure sensible cooling or heating capacity and efficiency with no time delay or fixed time delay of 65 seconds. The 1.5-ton hydronic split-system was tested in heating mode under non-steady-state field conditions to measure heating capacity and efficiency with no time delay or fixed time delay of 60 seconds after the heat source turned off. Non-steady state cooling and heating tests were performed with the patented GreenFan® EFC™ product providing a variable time delay on the fan depending on length of time the cool or heat source operated.

Non-steady state testing did not include an evaluation of SEER or AFUE impacts.

[18] ANSI Z21.47-5th Edition 2006/CSA 2.3-5th Edition 2006– Standard for Gas-Fired Central Furnaces. American National Standards Institute.

Table 19: ANSI/AHRI 210/240 Minimum External Static Pressure for Ducted Systems

Table 11. Minimum External Static Pressure for Ducted Systems Tested with an Indoor Fan Installed

Rated Cooling(1) or Heating(2) Capacity		Minimum External Resistance(3)			
		All Other Systems		Small-Duct, High-Velocity Systems(4,5)	
Btu/h	kW	in H_2O	Pa	in H_2O	Pa
Up thru 28,800	Up thru 8.44	0.10	25	1.10	275
29,000 to 42,500	8.5 to 12.4	0.15	37	1.15	288
43,000 and Above	12.6 thru 19.0	0.20	50	1.20	300

(1) For air conditioners and heat pumps, the value cited by the manufacturer in published literature for the unit's capacity when operated at the A or A_2 Test conditions.
(2) For heating-only heat pumps, the value the manufacturer cites in published literature for the unit's capacity when operated at the H1 or $H1_2$ Test conditions.
(3) For ducted units tested without an air filter installed, increase the applicable tabular value by 0.08 in H_2O [20 Pa].
(4) See Definition 1.35 of Appendix C to determine if the equipment qualifies as a small-duct, high-velocity system.
(5) If a closed-loop, air-enthalpy test apparatus is used on the indoor side, limit the resistance to airflow on the inlet side of the indoor blower coil to a maximum value of 0.10 in H_2O [25 Pa]. Impose the balance of the airflow resistance on the outlet side of the indoor blower.

Table 20: ANSI/AHRI 210/240 Table 3. Cooling Mode Test Conditions

Table 3. Cooling Mode Test Conditions for Units Having a Single-Speed Compressor and a Fixed-Speed Indoor Fan, a Constant Air Volume Rate Indoor Fan, or No Indoor Fan

Test Description	Air Entering Indoor Unit Temperature				Air Entering Outdoor Unit Temperature				Cooling Air Volume Rate
	Dry-Bulb		Wet-Bulb		Dry-Bulb		Wet-Bulb		
	°F	°C	°F	°C	°F	°C	°F	°C	
A Test - required (steady, wet coil)	80.0	26.7	67.0	19.4	95.0	35.0	75.0(1)	23.9(1)	Cooling Full-load (2)
B Test - required (steady, wet coil)	80.0	26.7	67.0	19.4	82.0	27.8	65.0(1)	18.3(1)	Cooling Full-load (2)
C Test - optional (steady, dry coil)	80.0	26.7	(3)		82.0	27.8	–		Cooling Full-load (2)
D Test - optional (cyclic, dry coil)	80.0	26.7	(3)		82.0	27.8	–		(4)

Notes:

(1) The specified test condition only applies if the unit rejects condensate to the outdoor coil.
(2) Defined in section 6.1.3.3.1.
(3) The entering air must have a low enough moisture content so no condensate forms on the indoor coil. (It is recommended that an indoor wet-bulb temperature of 57.0 °F [13.9 °C] or less be used.)
(4) Maintain the airflow nozzles static pressure difference or velocity pressure during the ON period at the same pressure difference or velocity pressure as measured during the C Test.

1.8.3 Laboratory Test Equipment and Calibration

The psychrometric room is designed and built to ASHRAE 37 specifications. Measurement equipment calibration is completed annually and is maintained under one Intertek ID number. Individual calibration records are available upon request. All calibration is conducted per ISO 17025 requirements by an ILAC accredited calibration provider. Intertek gas furnace heating equipment performance and AFUE tests are performed per ANSI Z21.47 specifications.

1.9 Baseline Unit Energy Consumption Data and Common Units

The Database for Energy Efficiency Resources (www.deeresources.com) does not provide energy savings for the EFC™ measure. Previous workpapers submitted by the IOU provided information for a cooling-only enhanced time delay per PGE3PHVC150 R2 Enhanced Time Delay Relay, PGECOHVC150 R4 Enhanced Time Delay Relay, and SCE13HC052 (see http://www.deeresources.net/workpapers). These workpapers provided no information regarding heating energy savings for HVAC systems with gas furnace, heat pump, or hydronic heating systems with an EFC™ variable fan-off time delay installed. The cooling, heating, and ventilation Unit Energy Consumption (UEC) values for residential air conditioners (RAC) and residential gas furnaces (RGF) are based on the DEER (Version: DEER2016) UEC values. Measure Analysis

Software Control (MASControl) was used to generate eQUEST version 3.65 building energy simulation prototypes (http://www.deeresources.com/).[19]

1.9.1 Baseline UEC Data

The weighted baseline unit energy consumption (UEC) values are provided for the Single Family (SFM), Multifamily (MFM), and Double-wide Mobile (DMO) prototypical buildings. The SFM weighted baseline UEC values for Residential Air Conditioner (RAC) with Gas Furnace (GF) are shown in **Table 21**. The SFM weighted baseline UEC values for Residential Heat Pump (RHP) are shown in **Table 22**. The SFM weighted baseline UEC values for Residential Gas Furnace (RGF) are shown in **Table 23**.

Table 21: SFM Weighted Baseline UEC – RAC with GF (DEER MISer)

DEER ImpactID	Weighted Building Vintage Climate Zone	Baseline Annual Gas Heating (therm/yr)	Baseline Annual Heating Elec Ventilation (kWh/yr)	Baseline Annual Cooling Elec Ventilation (kWh/yr)	Baseline Annual Elec Cooling (kWh/yr)	Baseline Annual Elec Cooling (kW)	Baseline Annual Elec Ventilation (kW)
SFM-w01-ResAC-tWt-eMsr	1	341.3	131.0	5.3	35.9	1.017	0.181
SFM-w02-ResAC-tWt-eMsr	2	313.6	118.6	62.5	420.9	1.905	0.258
SFM-w03-ResAC-tWt-eMsr	3	304.0	112.4	29.4	197.9	1.658	0.225
SFM-w04-ResAC-tWt-eMsr	4	242.3	89.1	116.1	618.7	2.284	0.296
SFM-w05-ResAC-tWt-eMsr	5	319.7	120.9	21.1	142.2	1.266	0.18
SFM-w06-ResAC-tWt-eMsr	6	187.9	61.2	148.7	839.6	1.878	0.255
SFM-w07-ResAC-tWt-eMsr	7	133.1	47.3	118.1	721.8	1.864	0.258
SFM-w08-ResAC-tWt-eMsr	8	162.6	55.7	184.3	1188.9	2.538	0.336
SFM-w09-ResAC-tWt-eMsr	9	194.8	66.5	230.1	1551.2	3.123	0.39
SFM-w10-ResAC-tWt-eMsr	10	214.3	73.7	209.3	1377.8	2.724	0.341
SFM-w11-ResAC-tWt-eMsr	11	285.4	106.8	234.9	1548.5	3.221	0.415
SFM-w12-ResAC-tWt-eMsr	12	275.1	99.9	161.4	1300.7	2.700	0.338
SFM-w13-ResAC-tWt-eMsr	13	269.7	97.6	270.7	1849.8	3.028	0.379
SFM-w14-ResAC-tWt-eMsr	14	281.6	106.9	382.6	2610.5	3.686	0.473
SFM-w15-ResAC-tWt-eMsr	15	111.4	42.3	544.2	3662.0	3.963	0.509
SFM-w16-ResAC-tWt-eMsr	16	602.4	227.9	113.5	763.8	2.534	0.337
SFM-w-ResAC-tWt-eMsr	Weighted	282.5	106.9	169.2	1,104.10	2.672	0.34

[19] http://www.doe2.com/download/DEER/MAStool/ and eQUEST software developed by James J. Hirsch & Associates (JJH), version 3.65 (http://www.doe2.com/).

Table 22: SFM Weighted Baseline UEC – RHP Heat Pump (DEER MISer)

DEER ImpactID	Weighted Building Vintage Climate Zone	Baseline Annual Heat Pump Heating (kWh/yr)	Baseline Annual Heating Elec Ventilation (kWh/yr)	Baseline Annual Cooling Elec Ventilation (kWh/yr)	Baseline Annual Elec Cooling (kWh/yr)	Baseline Annual Elec Cooling (kW)	Baseline Annual Elec Ventilation (kW)
SFM-w01-ResHP-tWt-eMsr	1	3,719.1	283.7	5.3	35.9	1.017	0.181
SFM-w02-ResHP-tWt-eMsr	2	3,624.4	282.9	62.5	420.9	1.905	0.258
SFM-w03-ResHP-tWt-eMsr	3	2,688.8	238.0	29.4	197.9	1.658	0.225
SFM-w04-ResHP-tWt-eMsr	4	2,955.8	224.6	116.1	618.7	2.284	0.296
SFM-w05-ResHP-tWt-eMsr	5	2,873.2	224.3	21.1	142.2	1.266	0.18
SFM-w06-ResHP-tWt-eMsr	6	2,076.4	131.7	148.7	839.6	1.878	0.255
SFM-w07-ResHP-tWt-eMsr	7	1,903.8	120.0	118.1	721.8	1.864	0.258
SFM-w08-ResHP-tWt-eMsr	8	2,033.3	137.5	184.3	1188.9	2.538	0.336
SFM-w09-ResHP-tWt-eMsr	9	2,262.9	146.4	230.1	1551.2	3.123	0.39
SFM-w10-ResHP-tWt-eMsr	10	2,672.5	193.5	209.3	1377.8	2.724	0.341
SFM-w11-ResHP-tWt-eMsr	11	3,901.9	308.8	234.9	1548.5	3.221	0.415
SFM-w12-ResHP-tWt-eMsr	12	3,538.0	261.3	161.4	1300.7	2.700	0.338
SFM-w13-ResHP-tWt-eMsr	13	3,033.3	203.1	270.7	1849.8	3.028	0.379
SFM-w14-ResHP-tWt-eMsr	14	3,892.5	319.1	382.6	2610.5	3.686	0.473
SFM-w15-ResHP-tWt-eMsr	15	1,317.6	74.7	544.2	3662.0	3.963	0.509
SFM-w16-ResHP-tWt-eMsr	16	7,853.7	696.0	113.5	763.8	2.534	0.337
SFM-w-ResHP-tWt-eMsr	Weighted	2,768.0	203.3	169.2	1,104.10	2.672	0.34

Table 23: SFM Weighted Baseline UEC – RGF Gas Furnace (DEER MISer)

DEER ImpactID	Weighted Building Vintage Climate Zone	Baseline Annual Gas Heating (therm/yr)	Baseline Annual Heating Elec Ventilation (kWh/yr)	Baseline Annual Cooling Elec Ventilation (kWh/yr)	Baseline Annual Elec Cooling (kWh/yr)	Baseline Annual Elec Cooling (kW)	Baseline Annual Elec Ventilation (kW)
SFM-w01-ResGF-tWt-eMsr	1	341.3	131.0				
SFM-w02-ResGF-tWt-eMsr	2	313.6	118.6				
SFM-w03-ResGF-tWt-eMsr	3	304.0	112.4				
SFM-w04-ResGF-tWt-eMsr	4	242.3	89.1				
SFM-w05-ResGF-tWt-eMsr	5	319.7	120.9				
SFM-w06-ResGF-tWt-eMsr	6	187.9	61.2				
SFM-w07-ResGF-tWt-eMsr	7	133.1	47.3				
SFM-w08-ResGF-tWt-eMsr	8	162.6	55.7				
SFM-w09-ResGF-tWt-eMsr	9	194.8	66.5				
SFM-w10-ResGF-tWt-eMsr	10	214.3	73.7				
SFM-w11-ResGF-tWt-eMsr	11	285.4	106.8				
SFM-w12-ResGF-tWt-eMsr	12	275.1	99.9				
SFM-w13-ResGF-tWt-eMsr	13	269.7	97.6				
SFM-w14-ResGF-tWt-eMsr	14	281.6	106.9				
SFM-w15-ResGF-tWt-eMsr	15	111.4	42.3				
SFM-w16-ResGF-tWt-eMsr	16	602.4	227.9				
SFM-w-ResGF-tWt-eMsr	Weighted	282.5	106.9				

The DMO weighted baseline UEC values for Residential Air Conditioner (RAC) with Gas Furnace (GF) are shown in **Table 24**. The weighted baseline UEC values for Residential Heat Pump (RHP) are shown in **Table 25**. The weighted baseline UEC values for Residential Gas Furnace (RGF) are shown in **Table 26**.

Table 24: DMO Weighted Baseline UEC – RAC with GF (DEER MISer)

DEER ImpactID	Weighted Building Vintage Climate Zone	Baseline Annual Gas Heating (therm/yr)	Baseline Annual Heating Elec Ventilation (kWh/yr)	Baseline Annual Cooling Elec Ventilation (kWh/yr)	Baseline Annual Elec Cooling (kWh/yr)	Baseline Annual Elec Cooling (kW)	Baseline Annual Elec Ventilation (kW)
DMO-w01-ResAC-tWt-eMsr	1	311.5	102.5	41.5	377.7	2.203	0.214
DMO-w02-ResAC-tWt-eMsr	2	275.4	97.5	215.1	1,755.2	3.806	0.317
DMO-w03-ResAC-tWt-eMsr	3	241.8	89.2	143.5	1,079.5	2.968	0.249
DMO-w04-ResAC-tWt-eMsr	4	218.6	72.8	241.3	2,062.6	3.598	0.307
DMO-w05-ResAC-tWt-eMsr	5	316.9	101.6	113.2	1,029.3	2.815	0.226
DMO-w06-ResAC-tWt-eMsr	6	147.3	43.9	260.2	2,210.6	2.732	0.254
DMO-w07-ResAC-tWt-eMsr	7	123.8	41.2	206.6	1,932.1	3.164	0.277
DMO-w08-ResAC-tWt-eMsr	8	179.6	51.4	424.5	4,113.1	4.568	0.389
DMO-w09-ResAC-tWt-eMsr	9	170.1	64.4	317.8	3,281.1	4.703	0.381
DMO-w10-ResAC-tWt-eMsr	10	188.9	71.5	372.0	4,035.1	4.999	0.404
DMO-w11-ResAC-tWt-eMsr	11	328.1	115.8	368.5	3,384.3	5.391	0.447
DMO-w12-ResAC-tWt-eMsr	12	264.3	84.0	304.5	2,753.0	4.800	0.388
DMO-w13-ResAC-tWt-eMsr	13	252.2	95.4	367.8	4,001.0	5.190	0.415
DMO-w14-ResAC-tWt-eMsr	14	339.4	128.4	568.0	5,592.6	6.053	0.500
DMO-w15-ResAC-tWt-eMsr	15	158.2	59.9	573.7	7,451.6	6.332	0.500
DMO-w16-ResAC-tWt-eMsr	16	558.0	214.6	203.6	1,939.2	4.165	0.354
DMO-w-ResAC-tWt-eMsr	Weighted	293.7	111.1	310.5	2,887.8	4.717	0.389

Table 25: DMO Weighted Baseline UEC – RHP Heat Pump (DEER MISer)

DEER ImpactID	Weighted Building Vintage Climate Zone	Baseline Annual Heat Pump Heating (kWh/yr)	Baseline Annual Heating Elec Ventilation (kWh/yr)	Baseline Annual Cooling Elec Ventilation (kWh/yr)	Baseline Annual Elec Cooling (kWh/yr)	Baseline Annual Elec Cooling (kW)	Baseline Annual Elec Ventilation (kW)
DMO-w01-ResHP-tWt-eMsr	1	4,114.7	166.1	41.5	377.7	2.203	0.214
DMO-w02-ResHP-tWt-eMsr	2	3,905.0	173.4	215.1	1,755.2	3.806	0.317
DMO-w03-ResHP-tWt-eMsr	3	3,313.8	130.1	143.5	1,079.5	2.968	0.249
DMO-w04-ResHP-tWt-eMsr	4	3,266.9	134.2	241.3	2,062.6	3.598	0.307
DMO-w05-ResHP-tWt-eMsr	5	3,465.0	132.5	113.2	1,029.3	2.815	0.226
DMO-w06-ResHP-tWt-eMsr	6	2,176.6	68.1	260.2	2,210.6	2.732	0.254
DMO-w07-ResHP-tWt-eMsr	7	1,926.3	61.2	206.6	1,932.1	3.164	0.277
DMO-w08-ResHP-tWt-eMsr	8	2,161.4	75.1	424.5	4,113.1	4.568	0.389
DMO-w09-ResHP-tWt-eMsr	9	2,180.2	74.8	317.8	3,281.1	4.703	0.381
DMO-w10-ResHP-tWt-eMsr	10	2,559.4	101.7	372.0	4,035.1	4.999	0.404
DMO-w11-ResHP-tWt-eMsr	11	3,961.0	177.2	368.5	3,384.3	5.391	0.447
DMO-w12-ResHP-tWt-eMsr	12	3,947.7	168.5	304.5	2,753.0	4.800	0.388
DMO-w13-ResHP-tWt-eMsr	13	3,143.2	135.3	367.8	4,001.0	5.190	0.415
DMO-w14-ResHP-tWt-eMsr	14	3,837.1	199.5	568.0	5,592.6	6.053	0.500
DMO-w15-ResHP-tWt-eMsr	15	1,665.7	66.3	573.7	7,451.6	6.332	0.500
DMO-w16-ResHP-tWt-eMsr	16	6,496.3	370.0	203.6	1,939.2	4.165	0.354
DMO-w-ResHP-tWt-eMsr	Weighted	2,917.8	119.3	310.5	2,887.8	4.717	0.389

Table 26: DMO Weighted Baseline UEC – RGF Gas Furnace (DEER MISer)

DEER ImpactID	Weighted Building Vintage Climate Zone	Baseline Annual Gas Heating (therm/yr)	Baseline Annual Heating Elec Ventilation (kWh/yr)	Baseline Annual Cooling Elec Ventilation (kWh/yr)	Baseline Annual Elec Cooling (kWh/yr)	Baseline Annual Elec Cooling (kW)	Baseline Annual Elec Ventilation (kW)
DMO-w01-ResGF-tWt-eMsr	1	311.5	102.5				
DMO-w02-ResGF-tWt-eMsr	2	275.4	97.5				
DMO-w03-ResGF-tWt-eMsr	3	241.8	89.2				
DMO-w04-ResGF-tWt-eMsr	4	218.6	72.8				
DMO-w05-ResGF-tWt-eMsr	5	316.9	101.6				
DMO-w06-ResGF-tWt-eMsr	6	147.3	43.9				
DMO-w07-ResGF-tWt-eMsr	7	123.8	41.2				
DMO-w08-ResGF-tWt-eMsr	8	179.6	51.4				
DMO-w09-ResGF-tWt-eMsr	9	170.1	64.4				
DMO-w10-ResGF-tWt-eMsr	10	188.9	71.5				
DMO-w11-ResGF-tWt-eMsr	11	328.1	115.8				
DMO-w12-ResGF-tWt-eMsr	12	264.3	84.0				
DMO-w13-ResGF-tWt-eMsr	13	252.2	95.4				
DMO-w14-ResGF-tWt-eMsr	14	339.4	128.4				
DMO-w15-ResGF-tWt-eMsr	15	158.2	59.9				
DMO-w16-ResGF-tWt-eMsr	16	558.0	214.6				
DMO-w-ResGF-tWt-eMsr	Weighted	293.7	111.1				

The MFM weighted baseline UEC values for Residential Air Conditioner (RAC) with Gas Furnace (GF) are shown in **Table 27**. The weighted baseline UEC values for Residential Heat Pump (RHP) are shown in **Table 28**. The weighted baseline UEC values for Residential AC with Hydronic Heat (RAH) are shown in **Table 29**. The weighted baseline UEC values for Residential Gas Furnace (RGF) are shown in **Table 30**.

Table 27: MFM Weighted Baseline UEC – RAC with GF (DEER MISer)

DEER ImpactID	Weighted Building Vintage Climate Zone	Baseline Annual Gas Heating (therm/yr)	Baseline Annual Heating Elec Ventilation (kWh/yr)	Baseline Annual Cooling Elec Ventilation (kWh/yr)	Baseline Annual Elec Cooling (kWh/yr)	Baseline Annual Elec Cooling (kW)	Baseline Annual Elec Ventilation (kW)
MFM-w01-ResAC-tWt-eMsr	1	209.3	55.3	6.8	61.5	0.392	0.073
MFM-w02-ResAC-tWt-eMsr	2	125.6	45.9	34.4	222	0.722	0.095
MFM-w03-ResAC-tWt-eMsr	3	124.9	45.7	6.5	59	0.428	0.068
MFM-w04-ResAC-tWt-eMsr	4	93.7	35.4	35.8	194.9	0.672	0.093
MFM-w05-ResAC-tWt-eMsr	5	82.8	31.3	6.1	43.9	0.248	0.049
MFM-w06-ResAC-tWt-eMsr	6	64.1	23.9	39.4	235.2	0.616	0.09
MFM-w07-ResAC-tWt-eMsr	7	51.0	17.9	33.7	199.9	0.616	0.085
MFM-w08-ResAC-tWt-eMsr	8	59.2	20.8	71.3	464.8	0.85	0.117
MFM-w09-ResAC-tWt-eMsr	9	84.8	25.9	136.9	903.9	1.246	0.169
MFM-w10-ResAC-tWt-eMsr	10	94.8	33.6	103.9	699.9	1.173	0.148
MFM-w11-ResAC-tWt-eMsr	11	137.0	49.5	118.5	760.1	1.301	0.167
MFM-w12-ResAC-tWt-eMsr	12	135.5	53.5	75.5	466.4	1.055	0.132
MFM-w13-ResAC-tWt-eMsr	13	114.1	41.1	147.4	1055.7	1.308	0.164
MFM-w14-ResAC-tWt-eMsr	14	153.6	59.0	244.4	1744.3	1.781	0.231
MFM-w15-ResAC-tWt-eMsr	15	55.9	19.6	366.5	2868.6	2.112	0.252
MFM-w16-ResAC-tWt-eMsr	16	257.7	83.0	87.2	562.8	1.093	0.149
MFM-w-ResAC-tWt-eMsr	Weighted	122.4	43.4	82.4	506.4	0.98	0.126

Table 28: MFM Weighted Baseline UEC – RHP Heat Pump (DEER MISer)

DEER ImpactID	Weighted Building Vintage Climate Zone	Baseline Annual Heat Pump Heating (kWh/yr)	Baseline Annual Heating Elec Ventilation (kWh/yr)	Baseline Annual Cooling Elec Ventilation (kWh/yr)	Baseline Annual Elec Cooling (kWh/yr)	Baseline Annual Elec Cooling (kW)	Baseline Annual Elec Ventilation (kW)
MFM-w01-ResHP-tWt-eMsr	1	2,215.9	89.1	6.8	61.5	0.392	0.073
MFM-w02-ResHP-tWt-eMsr	2	1,465.2	61.1	34.4	222	0.722	0.095
MFM-w03-ResHP-tWt-eMsr	3	1,456.5	54.5	6.5	59	0.428	0.068
MFM-w04-ResHP-tWt-eMsr	4	897.7	36.4	35.8	194.9	0.672	0.093
MFM-w05-ResHP-tWt-eMsr	5	805.5	31.2	6.1	43.9	0.248	0.049
MFM-w06-ResHP-tWt-eMsr	6	737.5	24.8	39.4	235.2	0.616	0.09
MFM-w07-ResHP-tWt-eMsr	7	453.0	15.7	33.7	199.9	0.616	0.085
MFM-w08-ResHP-tWt-eMsr	8	561.6	21.3	71.3	464.8	0.85	0.117
MFM-w09-ResHP-tWt-eMsr	9	751.7	27.5	136.9	903.9	1.246	0.169
MFM-w10-ResHP-tWt-eMsr	10	732.5	30.6	103.9	699.9	1.173	0.148
MFM-w11-ResHP-tWt-eMsr	11	1,448.7	63.7	118.5	760.1	1.301	0.167
MFM-w12-ResHP-tWt-eMsr	12	1,351.3	58.0	75.5	466.4	1.055	0.132
MFM-w13-ResHP-tWt-eMsr	13	1,069.7	45.6	147.4	1055.7	1.308	0.164
MFM-w14-ResHP-tWt-eMsr	14	1,404.6	70.6	244.4	1744.3	1.781	0.231
MFM-w15-ResHP-tWt-eMsr	15	514.2	21.5	366.5	2868.6	2.112	0.252
MFM-w16-ResHP-tWt-eMsr	16	2,957.7	158.3	87.2	562.8	1.093	0.149
MFM-w-ResHP-tWt-eMsr	Weighted	988.7	40.7	82.4	506.4	0.98	0.126

Table 29: MFM Weighted Baseline UEC – RAH Hydronic (DEER MISer)

DEER ImpactID	Weighted Building Vintage Climate Zone	Baseline Annual Hydronic Heating (therm/yr)	Baseline Annual Heating Elec Vent + Pump (kWh/yr)	Baseline Annual Cooling Elec Ventilation (kWh/yr)	Baseline Annual Elec Cooling (kWh/yr)	Baseline Annual Elec Cooling (kW)	Baseline Annual Elec Ventilation (kW)
MFM-w01-ResAH-tWt-eMsr	1	212.5	65.7	6.8	61.5	0.392	0.073
MFM-w02-ResAH-tWt-eMsr	2	152.3	54.3	34.4	222.0	0.722	0.095
MFM-w03-ResAH-tWt-eMsr	3	131.8	52.3	6.5	59.0	0.428	0.068
MFM-w04-ResAH-tWt-eMsr	4	113.8	41.0	35.8	194.9	0.672	0.093
MFM-w05-ResAH-tWt-eMsr	5	107.2	35.7	6.1	43.9	0.248	0.049
MFM-w06-ResAH-tWt-eMsr	6	65.2	26.0	39.4	235.2	0.616	0.09
MFM-w07-ResAH-tWt-eMsr	7	53.4	19.2	33.7	199.9	0.616	0.085
MFM-w08-ResAH-tWt-eMsr	8	65.9	23.1	71.3	464.8	0.85	0.117
MFM-w09-ResAH-tWt-eMsr	9	85.2	29.6	136.9	903.9	1.246	0.169
MFM-w10-ResAH-tWt-eMsr	10	97.5	39.6	103.9	699.9	1.173	0.148
MFM-w11-ResAH-tWt-eMsr	11	143.5	55.5	118.5	760.1	1.301	0.167
MFM-w12-ResAH-tWt-eMsr	12	147.2	59.5	75.5	466.4	1.055	0.132
MFM-w13-ResAH-tWt-eMsr	13	115.0	40.6	147.4	1055.7	1.308	0.164
MFM-w14-ResAH-tWt-eMsr	14	160.6	71.3	244.4	1744.3	1.781	0.231
MFM-w15-ResAH-tWt-eMsr	15	78.5	23.7	366.5	2868.6	2.112	0.252
MFM-w16-ResAH-tWt-eMsr	16	321.5	97.0	87.2	562.8	1.093	0.149
MFM-w-ResAH-tWt-eMsr	Weighted	106.2	45.6	82.4	506.4	0.98	0.126

Table 30: MFM Weighted Baseline UEC – RGF Gas Furnace (DEER MISer)

DEER ImpactID	Weighted Building Vintage Climate Zone	Baseline Annual Gas Heating (therm/yr)	Baseline Annual Heating Elec Ventilation (kWh/yr)	Baseline Annual Cooling Elec Ventilation (kWh/yr)	Baseline Annual Elec Cooling (kWh/yr)	Baseline Annual Elec Cooling (kW)	Baseline Annual Elec Ventilation (kW)
MFM-w01-ResGF-tWt-eMsr	1	209.3	55.3				
MFM-w02-ResGF-tWt-eMsr	2	125.6	45.9				
MFM-w03-ResGF-tWt-eMsr	3	124.9	45.7				
MFM-w04-ResGF-tWt-eMsr	4	93.7	35.4				
MFM-w05-ResGF-tWt-eMsr	5	82.8	31.3				
MFM-w06-ResGF-tWt-eMsr	6	64.1	23.9				
MFM-w07-ResGF-tWt-eMsr	7	51.0	17.9				
MFM-w08-ResGF-tWt-eMsr	8	59.2	20.8				
MFM-w09-ResGF-tWt-eMsr	9	84.8	25.9				
MFM-w10-ResGF-tWt-eMsr	10	94.8	33.6				
MFM-w11-ResGF-tWt-eMsr	11	137.0	49.5				
MFM-w12-ResGF-tWt-eMsr	12	135.5	53.5				
MFM-w13-ResGF-tWt-eMsr	13	114.1	41.1				
MFM-w14-ResGF-tWt-eMsr	14	153.6	59.0				
MFM-w15-ResGF-tWt-eMsr	15	55.9	19.6				
MFM-w16-ResGF-tWt-eMsr	16	257.7	83.0				
MFM-w-ResGF-tWt-eMsr	Weighted	122.4	43.4				

The UEC values are from the DEER MISer (DEER 2015). The baseline and energy savings can be defined in “Common energy units” rather than per household to allow for multiple EFC units to be installed at one home.

1.9.2 Energy Common Units

Energy common units for residential air conditioners (RAC) and residential gas furnaces (RGF) are shown in **Table 31**.

Table 31: Energy Common Units for RAC and RGF HVAC Systems

DEER2008 ImpactID	Weighted Building Vintage Climate Zone	HVAC System	Energy Common Units description	Number Energy Common Units	Energy Common Units 1 description	Number Energy Common Units
SFM-w01-ResAC-tWt-eMsr	1	RAC	tons cool cap	3.0	kBtuh furnace	64.0
SFM-w02-ResAC-tWt-eMsr	2	RAC	tons cool cap	3.5	kBtuh furnace	64.0
SFM-w03-ResAC-tWt-eMsr	3	RAC	tons cool cap	3.0	kBtuh furnace	64.0
SFM-w04-ResAC-tWt-eMsr	4	RAC	tons cool cap	3.5	kBtuh furnace	64.0
SFM-w05-ResAC-tWt-eMsr	5	RAC	tons cool cap	3.0	kBtuh furnace	64.0
SFM-w06-ResAC-tWt-eMsr	6	RAC	tons cool cap	3.5	kBtuh furnace	64.0
SFM-w07-ResAC-tWt-eMsr	7	RAC	tons cool cap	3.5	kBtuh furnace	64.0
SFM-w08-ResAC-tWt-eMsr	8	RAC	tons cool cap	3.5	kBtuh furnace	64.0
SFM-w09-ResAC-tWt-eMsr	9	RAC	tons cool cap	4.0	kBtuh furnace	64.0
SFM-w10-ResAC-tWt-eMsr	10	RAC	tons cool cap	4.0	kBtuh furnace	72.0
SFM-w11-ResAC-tWt-eMsr	11	RAC	tons cool cap	4.0	kBtuh furnace	72.0
SFM-w12-ResAC-tWt-eMsr	12	RAC	tons cool cap	4.5	kBtuh furnace	72.0
SFM-w13-ResAC-tWt-eMsr	13	RAC	tons cool cap	5.0	kBtuh furnace	72.0
SFM-w14-ResAC-tWt-eMsr	14	RAC	tons cool cap	5.0	kBtuh furnace	72.0
SFM-w15-ResAC-tWt-eMsr	15	RAC	tons cool cap	5.0	kBtuh furnace	72.0
SFM-w16-ResAC-tWt-eMsr	16	RAC	tons cool cap	5.0	kBtuh furnace	72.0
SFM-w-ResAC-tWt-eMsr	Weighted	RAC	tons cool cap	3.9	kBtuh furnace	67.0
MFM-w01-ResAC-tWt-eMsr	1	RAC	tons cool cap	2.0	kBtuh furnace	34.0
MFM-w02-ResAC-tWt-eMsr	2	RAC	tons cool cap	2.0	kBtuh furnace	34.0
MFM-w03-ResAC-tWt-eMsr	3	RAC	tons cool cap	2.0	kBtuh furnace	34.0
MFM-w04-ResAC-tWt-eMsr	4	RAC	tons cool cap	2.0	kBtuh furnace	34.0
MFM-w05-ResAC-tWt-eMsr	5	RAC	tons cool cap	2.0	kBtuh furnace	34.0
MFM-w06-ResAC-tWt-eMsr	6	RAC	tons cool cap	2.0	kBtuh furnace	34.0
MFM-w07-ResAC-tWt-eMsr	7	RAC	tons cool cap	2.0	kBtuh furnace	34.0
MFM-w08-ResAC-tWt-eMsr	8	RAC	tons cool cap	2.0	kBtuh furnace	34.0
MFM-w09-ResAC-tWt-eMsr	9	RAC	tons cool cap	2.0	kBtuh furnace	34.0
MFM-w10-ResAC-tWt-eMsr	10	RAC	tons cool cap	2.0	kBtuh furnace	34.0
MFM-w11-ResAC-tWt-eMsr	11	RAC	tons cool cap	2.0	kBtuh furnace	34.0
MFM-w12-ResAC-tWt-eMsr	12	RAC	tons cool cap	2.0	kBtuh furnace	34.0
MFM-w13-ResAC-tWt-eMsr	13	RAC	tons cool cap	2.0	kBtuh furnace	34.0
MFM-w14-ResAC-tWt-eMsr	14	RAC	tons cool cap	2.0	kBtuh furnace	34.0
MFM-w15-ResAC-tWt-eMsr	15	RAC	tons cool cap	2.0	kBtuh furnace	34.0
MFM-w16-ResAC-tWt-eMsr	16	RAC	tons cool cap	2.0	kBtuh furnace	34.0
MFM-w-ResAC-tWt-eMsr	Weighted	RAC	tons cool cap	2.0	kBtuh furnace	34.0
DMO-w01-ResAC-tWt-eMsr	1	RAC	tons cool cap	3.5	kBtuh furnace	54.0
DMO-w02-ResAC-tWt-eMsr	2	RAC	tons cool cap	3.5	kBtuh furnace	54.0
DMO-w03-ResAC-tWt-eMsr	3	RAC	tons cool cap	3.5	kBtuh furnace	54.0
DMO-w04-ResAC-tWt-eMsr	4	RAC	tons cool cap	3.5	kBtuh furnace	54.0
DMO-w05-ResAC-tWt-eMsr	5	RAC	tons cool cap	3.5	kBtuh furnace	54.0
DMO-w06-ResAC-tWt-eMsr	6	RAC	tons cool cap	3.5	kBtuh furnace	54.0
DMO-w07-ResAC-tWt-eMsr	7	RAC	tons cool cap	3.5	kBtuh furnace	54.0
DMO-w08-ResAC-tWt-eMsr	8	RAC	tons cool cap	3.5	kBtuh furnace	54.0
DMO-w09-ResAC-tWt-eMsr	9	RAC	tons cool cap	3.5	kBtuh furnace	54.0
DMO-w10-ResAC-tWt-eMsr	10	RAC	tons cool cap	3.5	kBtuh furnace	54.0
DMO-w11-ResAC-tWt-eMsr	11	RAC	tons cool cap	3.5	kBtuh furnace	54.0
DMO-w12-ResAC-tWt-eMsr	12	RAC	tons cool cap	3.5	kBtuh furnace	54.0
DMO-w13-ResAC-tWt-eMsr	13	RAC	tons cool cap	3.5	kBtuh furnace	54.0
DMO-w14-ResAC-tWt-eMsr	14	RAC	tons cool cap	3.5	kBtuh furnace	54.0
DMO-w15-ResAC-tWt-eMsr	15	RAC	tons cool cap	3.5	kBtuh furnace	54.0
DMO-w16-ResAC-tWt-eMsr	16	RAC	tons cool cap	3.5	kBtuh furnace	54.0
DMO-w-ResAC-tWt-eMsr	Weighted	RAC	tons cool cap	3.5	kBtuh furnace	54.0

Energy common units for residential heat pumps (RHP) are shown in **Table 32.**

Table 32: Energy Common Units for Heat Pump (RHP) HVAC Systems

DEER2008 ImpactID	Weighted Building Vintage Climate Zone	HVAC System	Energy Common Units description	Number Energy Common Units	Energy Common Units 1 description	Number Energy Common Units
SFM-w01-ResAC-tWt-eMsr	1	RHP	tons cool cap	3.0	kBtuh heat pump	36.0
SFM-w02-ResAC-tWt-eMsr	2	RHP	tons cool cap	3.5	kBtuh heat pump	36.0
SFM-w03-ResAC-tWt-eMsr	3	RHP	tons cool cap	3.0	kBtuh heat pump	36.0
SFM-w04-ResAC-tWt-eMsr	4	RHP	tons cool cap	3.5	kBtuh heat pump	42.0
SFM-w05-ResAC-tWt-eMsr	5	RHP	tons cool cap	3.0	kBtuh heat pump	36.0
SFM-w06-ResAC-tWt-eMsr	6	RHP	tons cool cap	3.5	kBtuh heat pump	42.0
SFM-w07-ResAC-tWt-eMsr	7	RHP	tons cool cap	3.5	kBtuh heat pump	42.0
SFM-w08-ResAC-tWt-eMsr	8	RHP	tons cool cap	3.5	kBtuh heat pump	42.0
SFM-w09-ResAC-tWt-eMsr	9	RHP	tons cool cap	4.0	kBtuh heat pump	48.0
SFM-w10-ResAC-tWt-eMsr	10	RHP	tons cool cap	4.0	kBtuh heat pump	48.0
SFM-w11-ResAC-tWt-eMsr	11	RHP	tons cool cap	4.0	kBtuh heat pump	48.0
SFM-w12-ResAC-tWt-eMsr	12	RHP	tons cool cap	4.5	kBtuh heat pump	54.0
SFM-w13-ResAC-tWt-eMsr	13	RHP	tons cool cap	5.0	kBtuh heat pump	60.0
SFM-w14-ResAC-tWt-eMsr	14	RHP	tons cool cap	5.0	kBtuh heat pump	60.0
SFM-w15-ResAC-tWt-eMsr	15	RHP	tons cool cap	5.0	kBtuh heat pump	60.0
SFM-w16-ResAC-tWt-eMsr	16	RHP	tons cool cap	5.0	kBtuh heat pump	60.0
SFM-w-ResAC-tWt-eMsr	Weighted	RHP	tons cool cap	3.9	kBtuh heat pump	46.5
MFM-w01-ResAC-tWt-eMsr	1	RHP	tons cool cap	2.0	kBtuh heat pump	24.0
MFM-w02-ResAC-tWt-eMsr	2	RHP	tons cool cap	2.0	kBtuh heat pump	24.0
MFM-w03-ResAC-tWt-eMsr	3	RHP	tons cool cap	2.0	kBtuh heat pump	24.0
MFM-w04-ResAC-tWt-eMsr	4	RHP	tons cool cap	2.0	kBtuh heat pump	24.0
MFM-w05-ResAC-tWt-eMsr	5	RHP	tons cool cap	2.0	kBtuh heat pump	24.0
MFM-w06-ResAC-tWt-eMsr	6	RHP	tons cool cap	2.0	kBtuh heat pump	24.0
MFM-w07-ResAC-tWt-eMsr	7	RHP	tons cool cap	2.0	kBtuh heat pump	24.0
MFM-w08-ResAC-tWt-eMsr	8	RHP	tons cool cap	2.0	kBtuh heat pump	24.0
MFM-w09-ResAC-tWt-eMsr	9	RHP	tons cool cap	2.0	kBtuh heat pump	24.0
MFM-w10-ResAC-tWt-eMsr	10	RHP	tons cool cap	2.0	kBtuh heat pump	24.0
MFM-w11-ResAC-tWt-eMsr	11	RHP	tons cool cap	2.0	kBtuh heat pump	24.0
MFM-w12-ResAC-tWt-eMsr	12	RHP	tons cool cap	2.0	kBtuh heat pump	24.0
MFM-w13-ResAC-tWt-eMsr	13	RHP	tons cool cap	2.0	kBtuh heat pump	24.0
MFM-w14-ResAC-tWt-eMsr	14	RHP	tons cool cap	2.0	kBtuh heat pump	24.0
MFM-w15-ResAC-tWt-eMsr	15	RHP	tons cool cap	2.0	kBtuh heat pump	24.0
MFM-w16-ResAC-tWt-eMsr	16	RHP	tons cool cap	2.0	kBtuh heat pump	24.0
MFM-w-ResAC-tWt-eMsr	Weighted	RHP	tons cool cap	2.0	kBtuh heat pump	24.0
DMO-w01-ResAC-tWt-eMsr	1	RHP	tons cool cap	3.5	kBtuh heat pump	42.0
DMO-w02-ResAC-tWt-eMsr	2	RHP	tons cool cap	3.5	kBtuh heat pump	42.0
DMO-w03-ResAC-tWt-eMsr	3	RHP	tons cool cap	3.5	kBtuh heat pump	42.0
DMO-w04-ResAC-tWt-eMsr	4	RHP	tons cool cap	3.5	kBtuh heat pump	42.0
DMO-w05-ResAC-tWt-eMsr	5	RHP	tons cool cap	3.5	kBtuh heat pump	42.0
DMO-w06-ResAC-tWt-eMsr	6	RHP	tons cool cap	3.5	kBtuh heat pump	42.0
DMO-w07-ResAC-tWt-eMsr	7	RHP	tons cool cap	3.5	kBtuh heat pump	42.0
DMO-w08-ResAC-tWt-eMsr	8	RHP	tons cool cap	3.5	kBtuh heat pump	42.0
DMO-w09-ResAC-tWt-eMsr	9	RHP	tons cool cap	3.5	kBtuh heat pump	42.0
DMO-w10-ResAC-tWt-eMsr	10	RHP	tons cool cap	3.5	kBtuh heat pump	42.0
DMO-w11-ResAC-tWt-eMsr	11	RHP	tons cool cap	3.5	kBtuh heat pump	42.0
DMO-w12-ResAC-tWt-eMsr	12	RHP	tons cool cap	3.5	kBtuh heat pump	42.0
DMO-w13-ResAC-tWt-eMsr	13	RHP	tons cool cap	3.5	kBtuh heat pump	42.0
DMO-w14-ResAC-tWt-eMsr	14	RHP	tons cool cap	3.5	kBtuh heat pump	42.0
DMO-w15-ResAC-tWt-eMsr	15	RHP	tons cool cap	3.5	kBtuh heat pump	42.0
DMO-w16-ResAC-tWt-eMsr	16	RHP	tons cool cap	3.5	kBtuh heat pump	42.0
DMO-w-ResAC-tWt-eMsr	Weighted	RHP	tons cool cap	3.5	kBtuh heat pump	42.0

Energy common units for residential air conditioners with hydronic heating systems (RAH) are shown in **Table 33.**

Table 33: Energy Common Units for Hydronic (RAH) HVAC Systems

DEER2008 ImpactID	Weighted Building Vintage Climate Zone	HVAC System	Energy Common Units description	Number Energy Common Units	Energy Common Units 1 description	Number Energy Common Units
MFM-w01-ResAC-tWt-eMsr	1	RAH	tons cool cap	2.0	kBtuh hydronic heat	24.0
MFM-w02-ResAC-tWt-eMsr	2	RAH	tons cool cap	2.0	kBtuh hydronic heat	24.0
MFM-w03-ResAC-tWt-eMsr	3	RAH	tons cool cap	2.0	kBtuh hydronic heat	24.0
MFM-w04-ResAC-tWt-eMsr	4	RAH	tons cool cap	2.0	kBtuh hydronic heat	24.0
MFM-w05-ResAC-tWt-eMsr	5	RAH	tons cool cap	2.0	kBtuh hydronic heat	24.0
MFM-w06-ResAC-tWt-eMsr	6	RAH	tons cool cap	2.0	kBtuh hydronic heat	24.0
MFM-w07-ResAC-tWt-eMsr	7	RAH	tons cool cap	2.0	kBtuh hydronic heat	24.0
MFM-w08-ResAC-tWt-eMsr	8	RAH	tons cool cap	2.0	kBtuh hydronic heat	24.0
MFM-w09-ResAC-tWt-eMsr	9	RAH	tons cool cap	2.0	kBtuh hydronic heat	24.0
MFM-w10-ResAC-tWt-eMsr	10	RAH	tons cool cap	2.0	kBtuh hydronic heat	24.0
MFM-w11-ResAC-tWt-eMsr	11	RAH	tons cool cap	2.0	kBtuh hydronic heat	24.0
MFM-w12-ResAC-tWt-eMsr	12	RAH	tons cool cap	2.0	kBtuh hydronic heat	24.0
MFM-w13-ResAC-tWt-eMsr	13	RAH	tons cool cap	2.0	kBtuh hydronic heat	24.0
MFM-w14-ResAC-tWt-eMsr	14	RAH	tons cool cap	2.0	kBtuh hydronic heat	24.0
MFM-w15-ResAC-tWt-eMsr	15	RAH	tons cool cap	2.0	kBtuh hydronic heat	24.0
MFM-w16-ResAC-tWt-eMsr	16	RAH	tons cool cap	2.0	kBtuh hydronic heat	24.0
MFM-w-ResAC-tWt-eMsr	Weighted	RAH	tons cool cap	2.0	kBtuh hydronic heat	24.0

1.10 Cost Effectiveness Information – E3 Calculator

The following tables provide cost effectiveness information for the EFC™ based on the E3 Calculator. The tables provide E3 cost effectiveness data based on building type, building vintage, climate zone, and HVAC system type, above code energy and demand savings, incremental measure costs, effective useful life (EUL), net-to-gross ratio, and total resource cost (TRC) test. The SFM and DMO tables provide E3 data for single family and mobile homes including residential air conditioning (RAC) with gas furnace heating, residential heat pumps (RHP), and residential gas furnace only (RGF). The MFM tables provide E3 data for multi-family homes including RAC and RHP and residential air conditioning with hydronic heating (RAH). The E3 Calculator tables indicate that removing an existing cooling-only fan delay product and installing an EFC™ that saves both electric cooling and gas heating energy is cost effective. The average total resource cost (TRC) test is 3.29 +/- 0.26 based on E3 calculator data for 170 residential single-family, multi-family, and mobile home building energy simulations across 16 climate zones.

1.10.1 Cost Effectiveness for Single-Family (SFM) Applications

Table 34 through **Table 36** provide E3 Calculator cost effectiveness data for single family (SFM) homes.

Table 34: E3 Calculator Data – EFC™ for SFM RAC Cooling/Gas Heating

Measure Description	Building Type	Building Vintage	Climate Zone	Above Code Annual Electric Cooling Savings (kWh/unit)	Above Code Peak Electric Demand Reduction (kW/unit)	Above Code Annual Heating Savings (Therm/unit)	Incremental Measure Cost ($/unit)	Effective Useful Life (years)	Net to Gross Ratio	Total Resource Cost (TRC) Test
EFC	SFM	Weighted	1	-23.6	0.133	47.1	150	8	0.85	2.10
EFC	SFM	Weighted	2	48.9	0.181	42.8	150	8	0.85	2.52
EFC	SFM	Weighted	3	1.5	0.153	45.6	150	8	0.85	2.24
EFC	SFM	Weighted	4	69.4	0.159	35.3	150	8	0.85	2.33
EFC	SFM	Weighted	5	6.8	0.119	46.4	150	8	0.85	2.33
EFC	SFM	Weighted	6	150.6	0.147	31.9	150	8	0.85	2.87
EFC	SFM	Weighted	7	134.3	0.157	23.0	150	8	0.85	2.29
EFC	SFM	Weighted	8	190.3	0.138	26.3	150	8	0.85	2.93
EFC	SFM	Weighted	9	236.5	0.189	31.1	150	8	0.85	3.57
EFC	SFM	Weighted	10	188.6	0.224	33.2	150	8	0.85	3.26
EFC	SFM	Weighted	11	185.2	0.195	39.2	150	8	0.85	3.52
EFC	SFM	Weighted	12	176.4	0.217	39.9	150	8	0.85	3.48
EFC	SFM	Weighted	13	287.2	0.232	42.1	150	8	0.85	4.54
EFC	SFM	Weighted	14	413.4	0.251	38.6	150	8	0.85	5.47
EFC	SFM	Weighted	15	586.6	0.307	17.0	150	8	0.85	5.91
EFC	SFM	Weighted	16	79.6	0.209	70.4	150	8	0.85	4.13
EFC	SFM	Weighted	Weighted	168.4	0.182	43.9	150	8	0.85	3.60

Table 35: E3 Calculator Data – EFC™ for SFM RHP Heat Pump

Measure Description	Building Type	Building Vintage	Climate Zone	Above Code Annual Electric Cooling Savings (kWh/unit)	Above Code Peak Electric Demand Reduction (kW/unit)	Above Code Annual Heating Savings (kWh/unit)	Incremental Measure Cost ($/unit)	Effective Useful Life (years)	Net to Gross Ratio	Total Resource Cost (TRC) Test
EFC	SFM	Weighted	1	10.4	0.133	344.3	150	8	0.85	3.04
EFC	SFM	Weighted	2	79.0	0.181	311.0	150	8	0.85	3.21
EFC	SFM	Weighted	3	32.1	0.153	258.8	150	8	0.85	2.46
EFC	SFM	Weighted	4	93.5	0.159	287.6	150	8	0.85	3.12
EFC	SFM	Weighted	5	34.0	0.119	253.8	150	8	0.85	2.41
EFC	SFM	Weighted	6	169.7	0.147	275.2	150	8	0.85	3.48
EFC	SFM	Weighted	7	147.8	0.157	259.6	150	8	0.85	3.20
EFC	SFM	Weighted	8	206.5	0.138	252.0	150	8	0.85	3.55
EFC	SFM	Weighted	9	259.1	0.189	295.8	150	8	0.85	4.28
EFC	SFM	Weighted	10	210.4	0.224	293.3	150	8	0.85	3.96
EFC	SFM	Weighted	11	213.5	0.195	350.1	150	8	0.85	4.49
EFC	SFM	Weighted	12	207.8	0.217	373.1	150	8	0.85	4.61
EFC	SFM	Weighted	13	321.9	0.232	384.8	150	8	0.85	5.45
EFC	SFM	Weighted	14	447.3	0.251	387.8	150	8	0.85	6.31
EFC	SFM	Weighted	15	614.9	0.307	222.6	150	8	0.85	6.00
EFC	SFM	Weighted	16	142.7	0.209	624.8	150	8	0.85	6.34
EFC	SFM	Weighted	Weighted	194.2	0.182	321.1	150	8	0.85	4.04

Table 36: E3 Calculator Data – EFC™ for SFM RGF Gas Furnace Only

Measure Description	Building Type	Building Vintage	Climate Zone	Above Code Annual Electric Ventilation Savings (kWh/unit)	Above Code Peak Electric Demand Reduction (kW/unit)	Above Code Annual Heating Savings (therm/unit)	Incremental Measure Cost ($/unit)	Effective Useful Life (years)	Net to Gross Ratio	Total Resource Cost (TRC) Test
EFC	SFM	Weighted	1	-34.0		47.1	150	8	0.85	2.01
EFC	SFM	Weighted	2	-30.1		42.8	150	8	0.85	1.83
EFC	SFM	Weighted	3	-30.6		45.6	150	8	0.85	1.96
EFC	SFM	Weighted	4	-24.1		35.3	150	8	0.85	1.52
EFC	SFM	Weighted	5	-27.1		46.4	150	8	0.85	2.03
EFC	SFM	Weighted	6	-19.1		31.9	150	8	0.85	1.40
EFC	SFM	Weighted	7	-13.6		23.0	150	8	0.85	1.01
EFC	SFM	Weighted	8	-16.3		26.3	150	8	0.85	1.15
EFC	SFM	Weighted	9	-22.6		31.1	150	8	0.85	1.33
EFC	SFM	Weighted	10	-21.9		33.2	150	8	0.85	1.44
EFC	SFM	Weighted	11	-28.3		39.2	150	8	0.85	1.67
EFC	SFM	Weighted	12	-31.4		39.9	150	8	0.85	1.68
EFC	SFM	Weighted	13	-34.7		42.1	150	8	0.85	1.76
EFC	SFM	Weighted	14	-33.9		38.6	150	8	0.85	1.60
EFC	SFM	Weighted	15	-28.4		17.0	150	8	0.85	0.59
EFC	SFM	Weighted	16	-63.0		70.4	150	8	0.85	2.90
EFC	SFM	Weighted	Weighted	-25.0		43.9	150	8	0.85	1.93

1.10.2 Cost Effectiveness for Double Wide Mobile (DMO) Applications

Table 37 through **Table 39** provide E3 Calculator cost effectiveness data for double wide mobile home (DMO) applications.

Table 37: E3 Calculator Data – EFC™ for DMO RAC Cooling/Gas Heating

Measure Description	Building Type	Building Vintage	Climate Zone	Above Code Annual Electric Cooling Savings (kWh/unit)	Above Code Peak Electric Demand Reduction (kW/unit)	Above Code Annual Heating Savings (Therm/unit)	Incremental Measure Cost ($/unit)	Effective Useful Life (years)	Net to Gross Ratio	Total Resource Cost (TRC) Test
EFC	DMO	Weighted	1	87.2	0.129	51.9	150	8	0.85	3.29
EFC	DMO	Weighted	2	282.0	0.178	41.5	150	8	0.85	4.47
EFC	DMO	Weighted	3	228.2	0.164	42.5	150	8	0.85	4.05
EFC	DMO	Weighted	4	363.6	0.163	35.3	150	8	0.85	4.88
EFC	DMO	Weighted	5	279.4	0.129	52.8	150	8	0.85	5.00
EFC	DMO	Weighted	6	428.4	0.146	28.3	150	8	0.85	5.10
EFC	DMO	Weighted	7	389.1	0.155	23.4	150	8	0.85	4.51
EFC	DMO	Weighted	8	605.1	0.148	32.9	150	8	0.85	6.85
EFC	DMO	Weighted	9	487.9	0.165	31.0	150	8	0.85	5.74
EFC	DMO	Weighted	10	569.6	0.181	31.1	150	8	0.85	6.45
EFC	DMO	Weighted	11	441.2	0.175	46.4	150	8	0.85	6.09
EFC	DMO	Weighted	12	377.4	0.173	39.8	150	8	0.85	5.21
EFC	DMO	Weighted	13	505.5	0.175	37.0	150	8	0.85	6.19
EFC	DMO	Weighted	14	686.4	0.173	45.3	150	8	0.85	8.16
EFC	DMO	Weighted	15	874.6	0.186	26.2	150	8	0.85	8.86
EFC	DMO	Weighted	16	286.1	0.159	65.7	150	8	0.85	5.69
EFC	DMO	Weighted	Weighted	477.7	0.163	40.2	150	8	0.85	6.10

Table 38: E3 Calculator Data – EFC™ for DMO RHP Heat Pump

Measure Description	Building Type	Building Vintage	Climate Zone	Above Code Annual Electric Cooling Savings (kWh/unit)	Above Code Peak Electric Demand Reduction (kW/unit)	Above Code Annual Heating Savings (kWh/unit)	Incremental Measure Cost ($/unit)	Effective Useful Life (years)	Net to Gross Ratio	Total Resource Cost (TRC) Test
EFC	DMO	Weighted	1	98.7	0.154	555.0	150	8	0.85	5.66
EFC	DMO	Weighted	2	293.8	0.302	448.1	150	8	0.85	6.43
EFC	DMO	Weighted	3	234.1	0.317	511.7	150	8	0.85	6.46
EFC	DMO	Weighted	4	370.2	0.281	443.3	150	8	0.85	7.05
EFC	DMO	Weighted	5	291.3	0.420	516.2	150	8	0.85	6.99
EFC	DMO	Weighted	6	437.0	0.215	409.4	150	8	0.85	7.33
EFC	DMO	Weighted	7	396.0	0.269	364.5	150	8	0.85	6.59
EFC	DMO	Weighted	8	609.5	0.278	363.4	150	8	0.85	8.43
EFC	DMO	Weighted	9	492.1	0.294	364.4	150	8	0.85	7.42
EFC	DMO	Weighted	10	577.5	0.289	362.9	150	8	0.85	8.14
EFC	DMO	Weighted	11	455.7	0.321	457.2	150	8	0.85	7.91
EFC	DMO	Weighted	12	386.5	0.300	502.8	150	8	0.85	7.70
EFC	DMO	Weighted	13	516.5	0.284	382.7	150	8	0.85	7.79
EFC	DMO	Weighted	14	693.9	0.330	371.0	150	8	0.85	9.22
EFC	DMO	Weighted	15	880.8	0.304	245.3	150	8	0.85	9.75
EFC	DMO	Weighted	16	291.9	0.354	468.1	150	8	0.85	6.58
EFC	DMO	Weighted	Weighted	494.6	0.342	411.2	150	8	0.85	7.85

Table 39: E3 Calculator Data – EFC™ for DMO RGF Gas Furnace Only

Measure Description	Building Type	Building Vintage	Climate Zone	Above Code Annual Electric Ventilation Savings (kWh/unit)	Above Code Peak Electric Demand Reduction (kW/unit)	Above Code Annual Heating Savings (therm/unit)	Incremental Measure Cost ($/unit)	Effective Useful Life (years)	Net to Gross Ratio	Total Resource Cost (TRC) Test
EFC	DMO	Weighted	1	-24.2		51.9	150	8	0.85	2.33
EFC	DMO	Weighted	2	-21.2		41.5	150	8	0.85	1.84
EFC	DMO	Weighted	3	-18.8		42.5	150	8	0.85	1.92
EFC	DMO	Weighted	4	-17.0		35.3	150	8	0.85	1.58
EFC	DMO	Weighted	5	-24.2		55.1	150	8	0.85	2.48
EFC	DMO	Weighted	6	-10.8		28.3	150	8	0.85	1.29
EFC	DMO	Weighted	7	-8.9		23.4	150	8	0.85	1.06
EFC	DMO	Weighted	8	-13.2		32.9	150	8	0.85	1.49
EFC	DMO	Weighted	9	-12.9		31.0	150	8	0.85	1.40
EFC	DMO	Weighted	10	-16.4		31.1	150	8	0.85	1.38
EFC	DMO	Weighted	11	-24.2		46.4	150	8	0.85	2.06
EFC	DMO	Weighted	12	-20.4		39.8	150	8	0.85	1.77
EFC	DMO	Weighted	13	-19.4		37.0	150	8	0.85	1.64
EFC	DMO	Weighted	14	-24.3		45.3	150	8	0.85	2.00
EFC	DMO	Weighted	15	-12.2		26.2	150	8	0.85	1.18
EFC	DMO	Weighted	16	-36.1		65.7	150	8	0.85	2.90
EFC	DMO	Weighted	Weighted	-16.3		48.0	150	8	0.85	2.21

1.10.3 Cost Effectiveness for Multi-Family (MFM) Applications

Table 40 through **Table 43** provide E3 Calculator cost effectiveness data for multi-family (MFM) applications.

Table 40: E3 Calculator Data – EFC™ for MFM RAC Cooling/Gas Heating

Measure Description	Building Type	Building Vintage	Climate Zone	Above Code Annual Electric Cooling Savings (kWh/unit)	Above Code Peak Electric Demand Reduction (kW/unit)	Above Code Annual Heating Savings (Therm/unit)	Incremental Measure Cost ($/unit)	Effective Useful Life (years)	Net to Gross Ratio	Total Resource Cost (TRC) Test
EFC	MFM	Weighted	1	-2.5	0.059	34.7	100	8	0.85	2.42
EFC	MFM	Weighted	2	26.1	0.133	20.5	100	8	0.85	1.78
EFC	MFM	Weighted	3	-1.3	0.124	22.0	100	8	0.85	1.54
EFC	MFM	Weighted	4	33.0	0.163	15.8	100	8	0.85	1.53
EFC	MFM	Weighted	5	2.0	0.069	14.8	100	8	0.85	1.07
EFC	MFM	Weighted	6	47.3	0.069	12.5	100	8	0.85	1.48
EFC	MFM	Weighted	7	41.0	0.113	9.8	100	8	0.85	1.21
EFC	MFM	Weighted	8	75.3	0.079	10.7	100	8	0.85	1.70
EFC	MFM	Weighted	9	118.3	0.073	15.7	100	8	0.85	2.59
EFC	MFM	Weighted	10	88.4	0.056	15.8	100	8	0.85	2.22
EFC	MFM	Weighted	11	78.0	0.069	20.8	100	8	0.85	2.45
EFC	MFM	Weighted	12	50.7	0.072	20.5	100	8	0.85	2.08
EFC	MFM	Weighted	13	113.3	0.048	16.1	100	8	0.85	2.56
EFC	MFM	Weighted	14	160.2	0.055	21.9	100	8	0.85	3.55
EFC	MFM	Weighted	15	282.7	0.053	9.7	100	8	0.85	4.22
EFC	MFM	Weighted	16	47.2	0.061	33.4	100	8	0.85	2.95
EFC	MFM	Weighted	Weighted	83.2	0.085	20.3	100	8	0.85	2.48

Table 41: E3 Calculator Data – EFC™ for MFM RHP Heat Pump

Measure Description	Building Type	Building Vintage	Climate Zone	Above Code Annual Electric Cooling Savings (kWh/unit)	Above Code Peak Electric Demand Reduction (kW/unit)	Above Code Annual Heating Savings (kWh/unit)	Incremental Measure Cost ($/unit)	Effective Useful Life (years)	Net to Gross Ratio	Total Resource Cost (TRC) Test
EFC	MFM	Weighted	1	12.9	0.059	284.8	100	8	0.85	3.87
EFC	MFM	Weighted	2	38.5	0.133	178.1	100	8	0.85	2.81
EFC	MFM	Weighted	3	13.1	0.124	214.7	100	8	0.85	2.96
EFC	MFM	Weighted	4	43.2	0.163	121.7	100	8	0.85	2.14
EFC	MFM	Weighted	5	9.6	0.069	118.9	100	8	0.85	1.67
EFC	MFM	Weighted	6	54.2	0.069	128.0	100	8	0.85	2.37
EFC	MFM	Weighted	7	46.0	0.113	78.3	100	8	0.85	1.62
EFC	MFM	Weighted	8	80.4	0.079	85.6	100	8	0.85	2.16
EFC	MFM	Weighted	9	125.0	0.073	119.5	100	8	0.85	3.18
EFC	MFM	Weighted	10	97.8	0.056	94.8	100	8	0.85	2.50
EFC	MFM	Weighted	11	92.7	0.069	160.1	100	8	0.85	3.28
EFC	MFM	Weighted	12	66.4	0.072	157.0	100	8	0.85	2.90
EFC	MFM	Weighted	13	126.2	0.048	123.7	100	8	0.85	3.25
EFC	MFM	Weighted	14	179.0	0.055	141.7	100	8	0.85	4.17
EFC	MFM	Weighted	15	288.6	0.053	70.2	100	8	0.85	4.66
EFC	MFM	Weighted	16	69.2	0.061	216.8	100	8	0.85	3.72
EFC	MFM	Weighted	Weighted	92.9	0.085	141.1	100	8	0.85	3.04

Table 42: E3 Calculator Data – EFC™ for MFM RAH Cooling/Hydronic Heating

Measure Description	Building Type	Building Vintage	Climate Zone	Above Code Annual Electric Cooling Savings (kWh/unit)	Above Code Peak Electric Demand Reduction (kW/unit)	Above Code Annual Heating Savings (therm/unit)	Incremental Measure Cost ($/unit)	Effective Useful Life (years)	Net to Gross Ratio	Total Resource Cost (TRC) Test
EFC	MFM	Weighted	1	2.7	0.059	31.1	100	8	0.85	2.32
EFC	MFM	Weighted	2	30.3	0.133	21.9	100	8	0.85	2.00
EFC	MFM	Weighted	3	3.6	0.124	21.6	100	8	0.85	1.63
EFC	MFM	Weighted	4	36.4	0.163	17.5	100	8	0.85	1.75
EFC	MFM	Weighted	5	2.8	0.069	18.1	100	8	0.85	1.36
EFC	MFM	Weighted	6	48.0	0.069	12.8	100	8	0.85	1.56
EFC	MFM	Weighted	7	41.5	0.113	10.4	100	8	0.85	1.30
EFC	MFM	Weighted	8	75.8	0.079	11.5	100	8	0.85	1.83
EFC	MFM	Weighted	9	119.1	0.073	14.9	100	8	0.85	2.64
EFC	MFM	Weighted	10	91.6	0.056	14.5	100	8	0.85	2.25
EFC	MFM	Weighted	11	84.9	0.069	19.6	100	8	0.85	2.54
EFC	MFM	Weighted	12	58.1	0.072	20.1	100	8	0.85	2.23
EFC	MFM	Weighted	13	120.4	0.048	15.8	100	8	0.85	2.72
EFC	MFM	Weighted	14	171.0	0.055	18.9	100	8	0.85	3.61
EFC	MFM	Weighted	15	284.7	0.053	12.0	100	8	0.85	4.58
EFC	MFM	Weighted	16	59.9	0.061	34.2	100	8	0.85	3.29
EFC	MFM	Weighted	Weighted	86.2	0.085	17.3	100	8	0.85	2.39

Table 43: E3 Calculator Data – EFC™ for MFM RGF Gas Heating Only

Measure Description	Building Type	Building Vintage	Climate Zone	Above Code Annual Electric Ventilation Savings (kWh/unit)	Above Code Peak Electric Demand Reduction (kW/unit)	Above Code Annual Heating Savings (Therm/unit)	Incremental Measure Cost ($/unit)	Effective Useful Life (years)	Net to Gross Ratio	Total Resource Cost (TRC) Test
EFC	MFM	Weighted	1	-13.6		34.7	100	8	0.85	2.37
EFC	MFM	Weighted	2	-8.2		20.5	100	8	0.85	1.40
EFC	MFM	Weighted	3	-8.0		22.0	100	8	0.85	1.51
EFC	MFM	Weighted	4	-6.2		15.8	100	8	0.85	1.08
EFC	MFM	Weighted	5	-5.4		14.8	100	8	0.85	1.02
EFC	MFM	Weighted	6	-4.1		12.5	100	8	0.85	0.86
EFC	MFM	Weighted	7	-3.3		9.8	100	8	0.85	0.68
EFC	MFM	Weighted	8	-3.9		10.7	100	8	0.85	0.73
EFC	MFM	Weighted	9	-5.7		15.7	100	8	0.85	1.08
EFC	MFM	Weighted	10	-6.4		15.8	100	8	0.85	1.07
EFC	MFM	Weighted	11	-8.8		20.8	100	8	0.85	1.41
EFC	MFM	Weighted	12	-8.7		20.5	100	8	0.85	1.39
EFC	MFM	Weighted	13	-7.2		16.1	100	8	0.85	1.09
EFC	MFM	Weighted	14	-9.8		21.9	100	8	0.85	1.48
EFC	MFM	Weighted	15	-4.0		9.7	100	8	0.85	0.66
EFC	MFM	Weighted	16	-14.9		33.4	100	8	0.85	2.26
EFC	MFM	Weighted	Weighted	-6.4		16.5	100	8	0.85	1.41

2. Energy Savings and Demand Reduction Calculations

Energy savings and peak demand reduction calculations are based on the Intertek laboratory test measurements of sensible cooling and heating capacities, electricity and/or natural gas energy consumption, and sensible energy efficiency impacts with the GreenFan® EFC™ installed on the 3-ton split-system, 3-ton packaged unit, 1.5-ton heat pump unit, and 1.5-ton hydronic unit. The laboratory test data is used to develop application-specific regression equations of energy savings versus the sensible cooling or heating Part Load Ratio (PLR) and the regression equations are applied to hourly eQuest building energy simulations of the DEER residential prototypes to calculate energy and peak demand savings. The eQuest simulations provide hourly sensible PLR values which are a conservative estimate of actual PLR values which would generally consist of multiple on-cycles with smaller PLR values within a single hour. For example, an hourly PLR of 0.5 might consist of 1 to 5 compressor operational times depending on building characteristics, HVAC system type and capacity, weather conditions, and thermostat set points. Cooling and heating capacities vary by building type and climate zone based on the DEER single-family (SFM), double-wide mobile home (DMO), and multi-family (MFM) prototypes which are the most recent updates to include the Title 24 2008 and Title 24 2013 code based vintages. These prototypes are used in conjunction with typical meteorological year (TMY) weather data files to calculate energy and peak demand savings. Four hourly electric/fuel meter end-use variables and five system variables are obtained from the eQuest simulations to calculate cooling and heating energy and peak demand savings. The four electric/fuel meter end-use variables include: heating end use energy (kWh), cooling end use energy (kWh), vent fan end use energy (kWh), and heating end use (Btu/hr). The five system variables include: variable 6 total central cool coil output (Btu/hr), variable 48 latent part of total cool (Btu/hr), variable 71 sensible cool capacity (Btu/hr), variable 5 total central heat coil output (Btu/hr), and variable 78 total heat capacity (Btu/hr).

2.1 DEER eQuest Prototypes

The eQuest building energy software v3.65 and DEER eQuest residential single-family, multi-family, and mobile home building prototypes were used to evaluate the baseline HVAC energy use and peak demand for each building prototype and climate zone.[20] The DEER single-family prototypes are shown in **Figure 4**, multi-family prototypes are shown in **Figure 5**, and double-wide mobile home (DMO) prototypes are shown in **Figure 6**. The single-family DEER prototypes have four HVAC systems (single-story, two-story, two orientations), but only the single story prototypes are included in the analysis since the two-story prototypes have larger floor area and larger HVAC systems. The double-wide mobile home prototypes have 2 systems. The multi-family prototypes have 24 systems serving units and 4 systems serving common areas (two-story buildings with 12 units each and two orientations).

[20] Database for Energy Efficiency Resources (DEER) at http://www.deeresources.com/ and http://doe2.com/equest/. RSFm1175RRCh1 - Baseline.bdl.

The DEER models used Packaged Variable-Volume Variable Temperature (PVVT) HVAC systems with system sizing ratio set to 1.3 and undersized cooling capacities of 3.184 tons for SFM, 2.123 tons for DMO, and 1.122 tons for MFM prototypes. Heating capacities for most of the models were randomly high or low depending on building type. Some models used cooling and heating capacities of 12,000 Btuh (1 ton) per 400 square feet of floor area and other buildings used 12,000 Btuh per 800 square feet of floor area or more. Using different capacities can have a large influence on results especially for measures that are designed to improve efficiency by recovering energy from heat exchangers or cooling evaporators. The DEER model system types, capacities, and controls are not representative of actual HVAC systems. To properly model actual buildings, the fan power parameters fan electric input ratio (EIR) was set to "Residential Fixed Vol-Fan EIR," system sizing ratio was set to 1.0, and cooling and heating capacities were adjusted to more accurately model actual HVAC systems serving representative buildings for each California climate zone (as shown in **Tables 31**, **32**, and **33**). The multi-family prototypes were revised to model heat pump and hydronic forced-air heating systems with direct expansion (DX) cooling commonly found in about 9 to 40% of multi-family units in California. The fan power (kW/cfm) and airflow varied depending on eQuest model, but the DEER prototype fan power was not calibrated to field or laboratory test data. Miscellaneous equipment and lighting loads (Watts per unit area) were unrealistically high for some models and low for other models and these loads impact heating and cooling energy use. For example, the default multi-family prototypes were setup to model all internal loads as miscellaneous equipment with no lighting loads. The DEER prototypes were revised to reduce uncertainty and provide accurate results. Default thermostat and equipment schedules were adjusted to calibrate to baseline energy use. Building energy simulations were performed for the 16 California climate zones. Annual cooling and heating energy savings were calculated based on the Part Load Ratio (PLR) of hourly cooling coil sensible capacity to total coil sensible capacity and hourly heating coil capacity to total coil sensible capacity. Detailed descriptions of the cooling and heating energy savings analyses, equations, and methodologies are provided for each system type.

Figure 4: DEER Single-Family Prototypes used to Calculate Hourly PLR Values

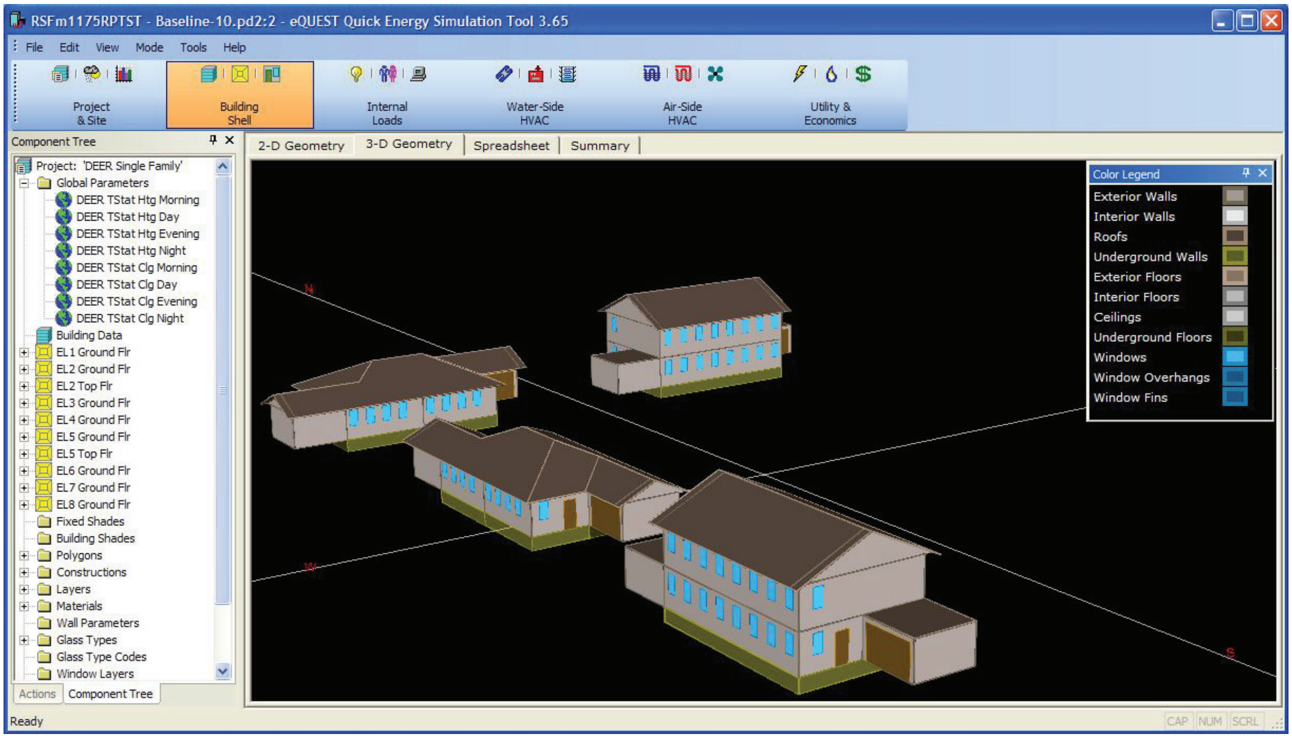


Figure 5: DEER Multi-Family Prototypes used to Calculate Hourly PLR Values

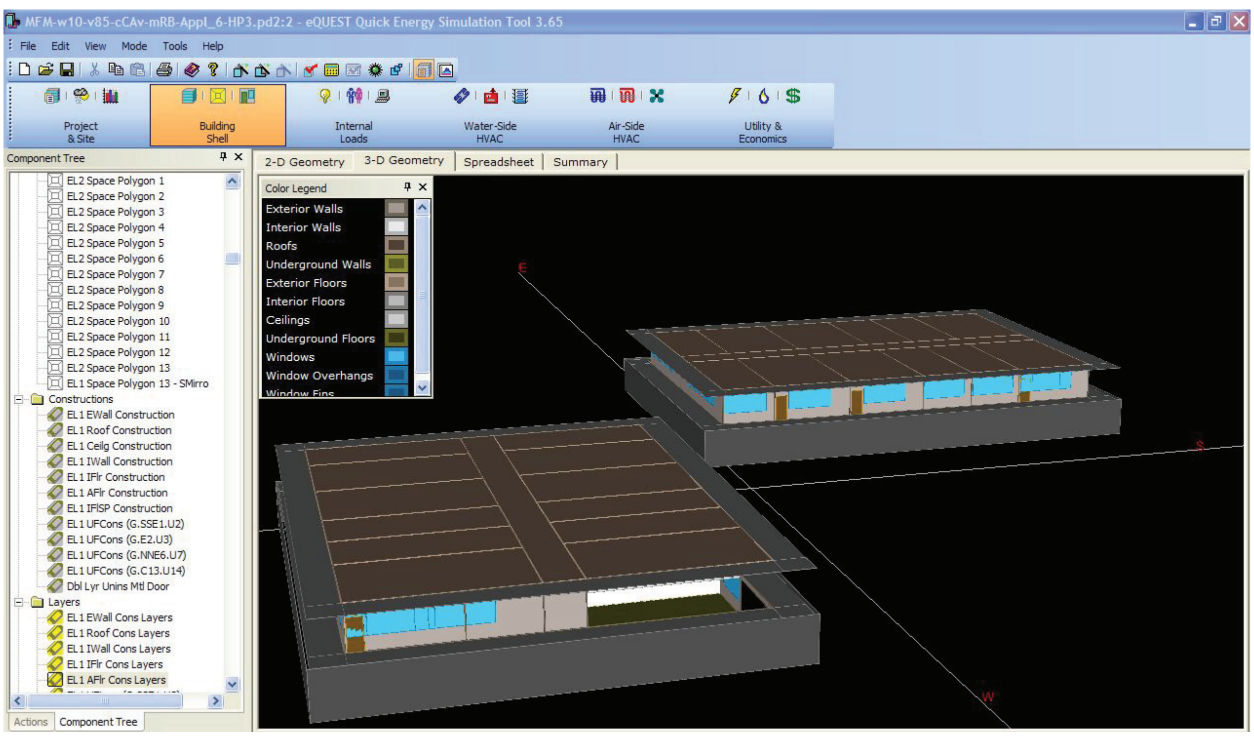


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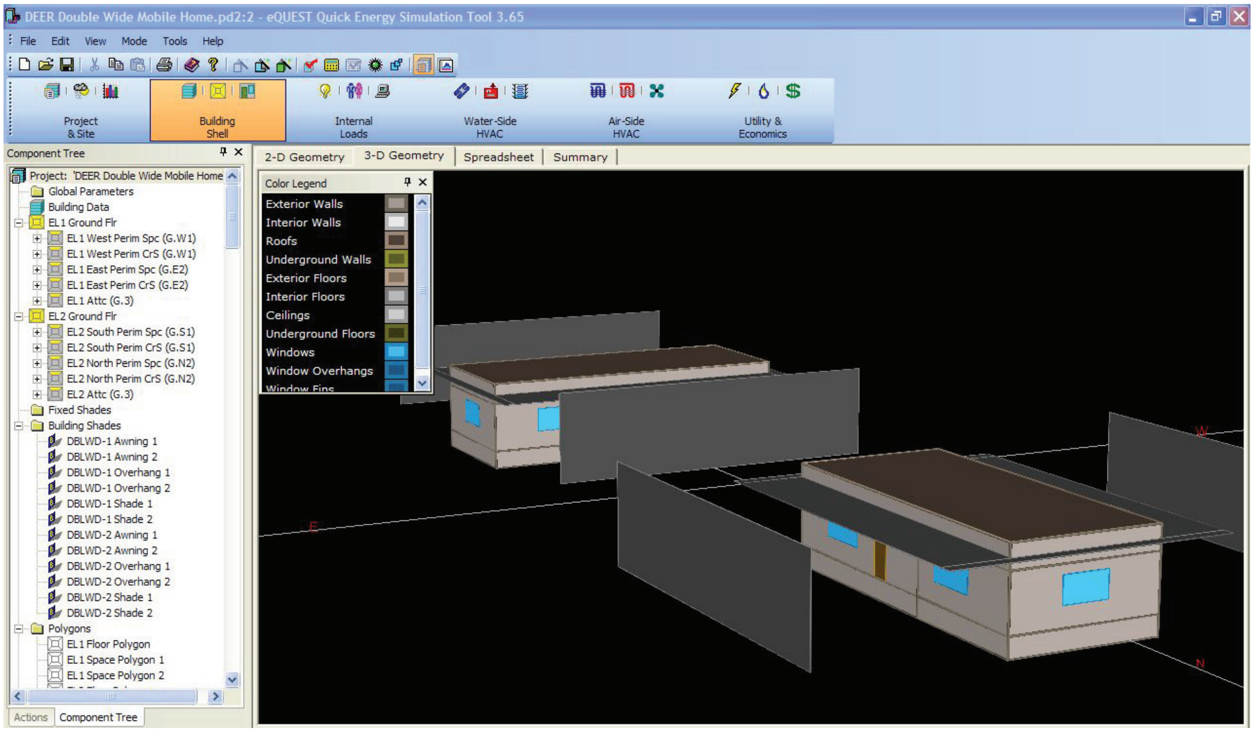
Figure 6: DEER Mobile Home Prototypes used to Calculate Hourly PLR Values



2.2 Cooling Energy Savings Analysis and Methodology

The cooling energy savings analysis is based on Intertek laboratory test measurements of the additional cooling capacity (and energy savings) provided by the Efficient Fan Controller® using a variable fan-off time delay which varies as a function of the cool-source operational time compared to the baseline system with no time delay or a fixed fan-off time delay. The cooling energy savings methodology is based on the mathematical relationship between the part load ratio of sensible cooling coil output divided by the total sensible cooling capacity and the energy savings provided by the EFC ™. The sensible cooling capacity for each laboratory test and the total sensible cooling capacity of the air conditioner (as measured by Intertek at the same test conditions) are used to calculate the PLR for each cooling test scenario using **Equation 5**.

Equation 5 $$PLR_c = \frac{Q_{c_o}}{Q_{c_r}}$$

Where, PLR_c = part load ratio of delivered sensible cooling capacity to total sensible cooling capacity (dimensionless),

Q_{c_o} = non-steady-state sensible cooling capacity delivered by the air conditioner over measurement interval for each test (Btu), and

Q_{c_r} = total sensible cooling capacity for one hour at the same test conditions (Btu).

The sensible cooling capacity delivered to the conditioned space over the measurement interval is calculated using **Equation 6**.

Equation 6 $$Q_{c_o} = \frac{cfm \times 60}{v} \times c_p \times (T_r - T_s)$$

Where,

Q_{c_o} = sensible cooling energy delivered to the conditioned space over the measurement interval (i.e., Btu/hr),
cfm= volumetric airflow rate in cubic feet per minute (cfm),
v = specific volume per pound of dry air (ft^3/lbm),
c_p = specific heat of dry air at constant pressure = 0.24 Btu/lbm-°F,
T_r = dry bulb temperature of return air entering the system (°F), and
T_s = dry bulb temperature of supply air leaving the system (°F).

Intertek performed 22 cooling tests at 75F return air drybulb and 62F return air wetbulb temperatures and 95F OAT with and without the GreenFan® EFC™. **Table 45** provides cooling part load ratios and energy savings with the GreenFan® EFC™ based on 22 Intertek split- and packaged system cooling tests. Intertek performed 24 split-system heat pump cooling tests at 75F return air drybulb and 62F return air wetbulb temperatures and 95F OAT with and without the GreenFan® EFC™. **Table 46** provides cooling part load ratios and energy savings with the GreenFan® EFC™ based on 24 Intertek heat pump cooling tests at 75F return air drybulb and 62F return air wetbulb temperatures and 95F and 82F OAT. Cooling energy savings and the average cooling energy savings per test scenario are plotted in **Figure 7**. Regression **Equation 7** is based on average cooling energy savings per test scenario and is used to calculate EFC™ sensible cooling energy savings based on the part load ratio (PLR).

Equation 7 $$\Delta\eta_{sc} = \left(0.0390\,(PLR_c)^{-0.8870}\right)100$$

Where, $\Delta\eta_{sc}$ = sensible cooling savings with EFC™ compared to baseline.

Average energy savings impacts are calculated for each climate zone and building type using **Equation 8**.

Equation 8 $$\overline{\Delta\eta} = \sum_{i=1}^{n} w_i \Delta\eta_i$$

Where, $\overline{\Delta\eta}$ = average energy savings impacts (dimensionless),
$\Delta\eta_i$ = energy efficiency improvement for each climate zone (dimensionless),
w_i = weight based on housing stock ratio in each climate zone (dimensionless), and
n = 8,760 annual hours of operation.

The hourly cooling energy use is calculated as follows.

Equation 9 $e_{c_i} = e_{cc_i} + e_{cf_i}$

Where, e_{c_i} = hourly cooling energy use (kWh),
e_{cc_i} = hourly cooling compressor end use energy (kWh), and
e_{cf_i} = hourly cooling fan end use energy (kWh).

The hourly sensible cooling PLR is calculated as follows.

Equation 10 $PLR_{c_i} = \frac{q_{tc_i} - q_{lc_i}}{q_{tsc_i}} = \frac{Var\ 6 - Var\ 48}{Var\ 71}$

Where, PLR_{c_i} = sensible cooling part load ratio (dimensionless),
q_{tc_i} = total central cooling coil output [system variable 6] (Btu/hr),
q_{lc_i} = latent part of total cooling capacity [system variable 48] (Btu/hr), and
q_{tsc_i} = total sensible cooling capacity [system variable 71] (Btu/hr).

The hourly sensible PLR is used to calculate the energy savings percentage using **Equation 7** based on Intertek laboratory test data and the functional relationship between cooling energy savings and PLR. See **Figure 7** and test data provided in **Table 45** and **Table 46**. Annual cooling energy savings are calculated using the following equation.

Equation 11 $E_c = \sum_{i=1}^{n} e_{c_i} \left(0.0390\left(PLR_{c_i}\right)^{-0.8870}\right)$

Where, E_c = total cooling energy savings for EFC™ based on DEER eQuest prototypical hourly simulation data (kWh), and
e_{c_i} = hourly cooling energy use (kWh).

Peak demand savings are calculated based on the peak demand reduction (DR) during the peak demand period for the weekday periods for each climate zone from June 1st through September 30th and between the hours of 12:00 PM and 6:00 PM. The total peak demand savings are based on the sum of the peak demand reduction divided by the number of hours of during the peak period, as shown in the following equation.

Equation 12 $DR_c = \frac{\sum_{i=1}^{m} \Delta dr_{c_i}}{m}$

Where, DR_c = demand reduction for cooling (kW), and

Δdr_{c_i} = cooling peak demand reduction during the peak period (kW), and
m = number of hours during peak period.

The DEER peak demand periods shown in the following table are used to calculate the peak demand reduction for the California Title 24 Climate Zones (CZ) based on the DEER peak demand definition, adopted by D.12-05-015.[21] These periods occur from June 1st through September 30th and provide the highest peak and average temperatures from noon to 6 PM over three-day periods.

Table 44: DEER Peak Demand Periods

CZ	2005 DEER Update Peak Demand Period	Peak Temp (F)	Average Temp (F)	2014 DEER Update Peak Demand Period	Peak Temp (F)	Average Temp (F)
1	Sep 6-8	80	58	Sep 16-18	81	60
2	Jul 22-24 and Aug 20-22	99	78	Jul 8-10	103	76
3	Jul 17-19 and Sep 25-27	89	65	Jul 8-10	91	69
4	Jul 17-19 and Aug 26-28	97	71	Sep 1-3	99	78
5	Sep 3-5	93	68	Sep 8-10	87	65
6	Sep 24-26	85	69	Sep 1-3	102	77
7	Sep 9-12	92	70	Sep 1-3	90	74
8	Sep 23-26	98	78	Sep 1-3	105	80
9	Sep 23-26	101	78	Sep 1-3	107	87
10	Aug 12-14 and Sep 18-20	104	84	Jul 8-10	109	86
11	Aug 21-23 and Sep 16-18	104	81	Jul 8-10	113	88
12	July 22-24 and Aug 19-21	103	87	Jul 8-10	109	82
13	Jul 30-Aug 3 and Aug 19-21	106	88	Jul 8-10	108	87
14	Jul 15-17 and Sep 11-13	106	90	Aug 26-28	105	87
15	Sep 9-13	114	96	Aug 25-27	112	98
16	Aug 26-28 and Sep 3-5	96	73	Jul 8-10	90	79

The energy and peak demand savings can be normalized by capacity (i.e., tons for cooling or kBtu/hr for heating) based on the DEER prototypes.

[21] See http://deeresources.com/files/DEER2017/download/E-4795_2016-08-16_Attachment.pdf. J.J. Hirsch & Associates, 2008, Definition of Demand (kW) Impacts Used in the 2005 DEER Update. https://ethree.com/CPUC/3-21-06UpdateAttach3.pdf..J.J Hirsch & Associates, 2014, DEER2014 — Codes and Standards Update for the 2013-14 Cycle. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014UpdateDocumentation_2-12-2014.pdf.

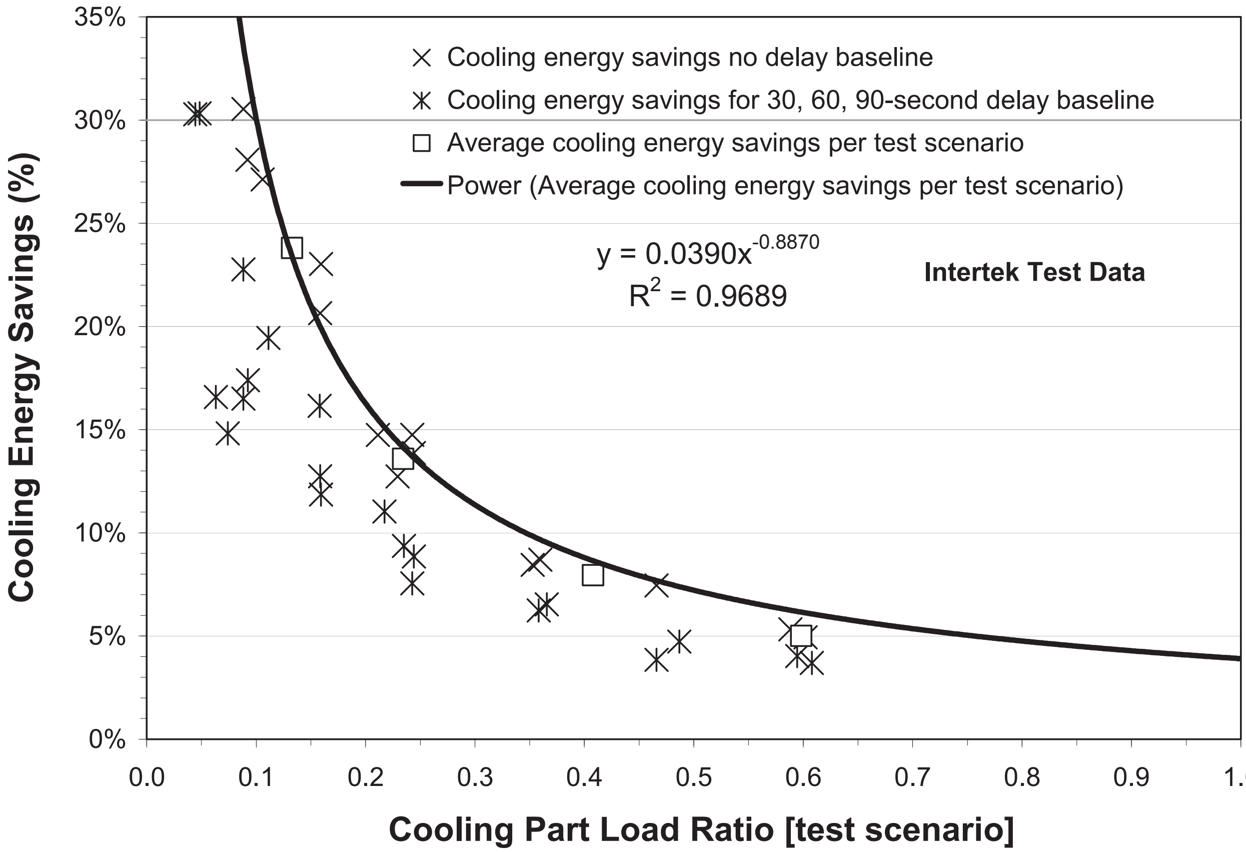
Table 45: Cooling PLR and Energy Savings with EFC™ at 95F OAT

Test	HVAC System	Base Fan Delay (sec)	Part Load Ratio	AC Input without EFC™ kWh [a]	AC Output without EFC™ Btu [b]	AC Efficiency without EFC™ (Btu/Wh) [c=a/b/1000]	AC Input with EFC™ kWh [d]	AC Output with EFC™ Btu [e]	AC Efficiency with EFC™ (Btu/Wh) [f=e/d/1000]	Energy Savings with EFC™ % [g=1-c/f]
1	Split	0	0.063	0.264	870	3.29	0.287	1,622	5.65	41.8%
2	Split	0	0.074	0.270	1,109	4.11	0.293	1,901	6.49	36.8%
3	Split	0	0.159	0.541	2,981	5.51	0.57	4,088	7.15	23.0%
4	Split	0	0.243	0.825	5,120	6.21	0.855	6,225	7.28	14.8%
5	Split	0	0.466	1.666	10,872	6.53	1.696	11,958	7.05	7.4%
6	Split	90	0.063	0.276	1,300	4.71	0.287	1,622	5.65	16.7%
7	Split	90	0.074	0.281	1,556	5.54	0.293	1,901	6.49	14.7%
8	Split	90	0.159	0.553	3,485	6.30	0.564	3,861	6.85	7.9%
9	Split	90	0.243	0.836	5,628	6.73	0.855	6,225	7.28	7.5%
10	Split	90	0.466	1.677	11,371	6.78	1.696	11,958	7.05	3.8%
27	Pkg	0	0.088	0.283	1,611	5.69	0.307	2,522	8.21	30.7%
28	Pkg	0	0.159	0.59	3,402	5.77	0.614	4,359	7.10	18.8%
29	Pkg	0	0.244	0.883	5,789	6.56	0.916	6,971	7.61	13.9%
30	Pkg	0	0.487	1.764	12,660	7.18	1.797	13,896	7.73	7.2%
31	Pkg	60	0.088	0.29	1,993	6.87	0.31	2,522	8.14	15.5%
32	Pkg	60	0.159	0.6	3,793	6.32	0.61	4,359	7.15	11.5%
33	Pkg	60	0.244	0.89	6,184	6.95	0.92	6,971	7.58	8.3%
34	Pkg	60	0.487	1.77	13,057	7.37	1.80	13,896	7.73	4.7%
59	Pkg	30	0.088	0.287	1,818	6.33	0.307	2,522	8.21	22.9%
60	Pkg	30	0.158	0.594	3,615	6.09	0.614	4,359	7.10	14.3%
61	Pkg	30	0.244	0.887	6,008	6.77	0.916	6,971	7.61	11.0%
62	Pkg	30	0.487	1.768	12,879	7.28	1.797	13,896	7.73	5.8%

Table 46: Heat Pump Cooling PLR and Energy Savings with EFC™ at 95 and 82F OAT

Test	OAT (F)	Base Fan Delay (sec)	Part Load Ratio	AC Input without EFC™ kWh [a]	AC Output without EFC™ Btu [b]	AC Efficiency without EFC™ (Btu/Wh) [c=a/b/1000]	AC Input with EFC™ kWh [d]	AC Output with EFC™ Btu [e]	AC Efficiency with EFC™ (Btu/Wh) [f=e/d/1000]	Energy Savings with EFC™ [g=1-c/f]
101	95	0	0.010	0.047	33	0.69	0.052	107	2.05	66.1%
102	95	0	0.057	0.122	295	2.42	0.133	589	4.45	45.6%
103	95	0	0.139	0.244	991	4.07	0.258	1,439	5.58	27.1%
104	95	0	0.277	0.486	2,380	4.90	0.500	2,874	5.75	14.7%
105	95	0	0.471	0.730	4,381	6.00	0.744	4,893	6.58	8.7%
106	95	0	0.771	1.218	7,488	6.15	1.232	8,002	6.49	5.3%
107	95	65	0.015	0.051	86	1.69	0.056	153	2.72	38.0%
108	95	65	0.063	0.126	421	3.35	0.136	656	4.81	30.3%
109	95	65	0.146	0.248	1,152	4.65	0.262	1,512	5.77	19.4%
110	95	65	0.285	0.490	2,555	5.22	0.504	2,956	5.86	11.0%
111	95	65	0.479	0.734	4,562	6.22	0.748	4,974	6.65	6.5%
112	95	65	0.779	1.222	7,670	6.28	1.236	8,084	6.54	4.0%
113	82	0	0.012	0.042	28	0.67	0.048	116	2.43	72.5%
114	82	0	0.055	0.107	272	2.54	0.118	552	4.68	45.8%
115	82	0	0.128	0.216	863	3.99	0.231	1,279	5.54	28.1%
116	82	0	0.319	0.431	2,688	6.24	0.445	3,182	7.15	12.7%
117	82	0	0.491	0.642	4,383	6.83	0.656	4,895	7.46	8.4%
118	82	0	0.838	1.077	7,843	7.28	1.092	8,361	7.66	4.9%
119	82	65	0.017	0.046	90	1.96	0.052	174	3.37	41.9%
120	82	65	0.059	0.111	391	3.52	0.122	615	5.05	30.3%
121	82	65	0.124	0.220	1,011	4.59	0.231	1,284	5.56	17.4%
122	82	65	0.314	0.435	2,863	6.59	0.449	3,263	7.27	9.4%
123	82	65	0.479	0.646	4,563	7.07	0.660	4,973	7.54	6.2%
124	82	65	0.813	1.081	8,024	7.42	1.095	8,441	7.71	3.7%

Figure 7: Cooling Energy Savings versus Part Load Ratio for EFC™



Hourly data of single-family (SFM) air conditioner energy use from DEER eQuest building energy simulation models were used to calculate hourly PLR and energy savings values which were used to calculate annual PLR values and the annual average energy savings shown in **Table 47**. The average annual PLR values range from 0.12 to 0.28 depending on climate zone with an average of 0.22. The average annual cooling energy savings are 194.2 ± 10.6 kWh/yr or 15.2 ± 0.8% based on average savings and housing stock weights for each climate zone from US Census Data.[22] Average peak demand savings are 0.182 ± 0.02 kW.

[22] US Census Bureau. 2010. Population, Housing Units, Area, and Density: 2010 - United States - County by State. http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk

Table 47: SFM Average Cooling Energy Savings Based on Hourly PLR from DEER eQuest

California Climate Zone	Average Sensible PLR	Base Energy Use kWh/yr	Energy Savings kWh/yr	Peak Demand Savings kW	Housing Stock Weight	Annual Energy Savings %
1	0.12	41.2	10.4	0.133	0.009	25.2%
2	0.20	483.4	79.0	0.181	0.03	16.3%
3	0.23	227.3	32.1	0.153	0.078	14.1%
4	0.26	734.8	93.5	0.159	0.077	12.7%
5	0.15	163.3	34.0	0.119	0.009	20.8%
6	0.19	988.3	169.7	0.147	0.158	17.2%
7	0.18	839.9	147.8	0.157	0.085	17.6%
8	0.22	1,373.2	206.5	0.138	0.077	15.0%
9	0.23	1,781.3	259.1	0.189	0.126	14.5%
10	0.25	1,587.1	210.4	0.224	0.059	13.3%
11	0.28	1,783.4	213.5	0.195	0.032	12.0%
12	0.23	1,462.1	207.8	0.217	0.136	14.2%
13	0.22	2,120.5	321.9	0.232	0.061	15.2%
14	0.22	2,993.1	447.3	0.251	0.051	14.9%
15	0.23	4,206.2	614.9	0.307	0.004	14.6%
16	0.20	877.3	142.7	0.209	0.01	16.3%
Average	**0.22**	**1,305.5**	**194.2 ± 10.6**	**0.182 ± 0.03**		**15.2 ± 0.8**

Hourly data of double-wide mobile home (DMO) air conditioner energy use from DEER eQuest building energy simulation models were used to calculate hourly PLR and energy savings values which were used to calculate annual PLR values and the annual average energy and peak demand savings shown in **Table 48**. The average annual PLR values range from 0.11 to 0.31 depending on climate zone with an average of 0.21. The average annual cooling energy savings including compressor plus cooling fan ventilation energy are 486.8 ± 40.8 kWh/yr or 15.4 ± 1.3% based on average savings and housing stock weights for each climate zone from US Census Data.[23] Average peak demand savings are 0.163 ± 0.01 kW.

[23] US Census Bureau. 2010. Population, Housing Units, Area, and Density: 2010 - United States - County by State. http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk

Table 48: DMO Average Cooling Energy Savings Based on Hourly PLR from DEER eQuest

California Climate Zone	Average Sensible PLR	Base Energy Use kWh/yr	Energy Savings kWh/yr	Peak Demand Savings kW	Housing Stock Weight	Annual Energy Savings %
1	0.11	419.2	111.4	0.129	0.009	26.6%
2	0.21	1,970.3	303.2	0.178	0.03	15.4%
3	0.16	1,223.0	247.0	0.164	0.078	20.2%
4	0.20	2,303.9	380.6	0.163	0.077	16.5%
5	0.11	1,142.5	303.6	0.129	0.009	26.6%
6	0.18	2,470.8	439.2	0.146	0.158	17.8%
7	0.17	2,138.7	398.0	0.155	0.085	18.6%
8	0.24	4,537.6	618.3	0.148	0.077	13.6%
9	0.24	3,598.9	500.8	0.165	0.126	13.9%
10	0.25	4,407.1	586.1	0.181	0.059	13.3%
11	0.27	3,752.8	465.5	0.175	0.032	12.4%
12	0.26	3,057.5	397.9	0.173	0.136	13.0%
13	0.28	4,368.8	524.9	0.175	0.061	12.0%
14	0.29	6,160.6	710.7	0.173	0.051	11.5%
15	0.31	8,025.3	886.8	0.186	0.004	11.0%
16	0.22	2,142.8	322.2	0.159	0.01	15.0%
Average	**0.21**	**3,151.1**	**486.8 ± 40.8**	**0.163 ± 0.01**		**15.4 ± 1.3**

Hourly data of multi-family (MFM) air conditioner energy use from DEER eQuest models were used to calculate hourly PLR and energy savings values which were used to calculate annual PLR values and the annual average energy savings shown in **Table 49**. The average annual PLR values range from 0.16 to 0.39 depending on climate zone with an average of 0.22. The average annual cooling energy savings are 92.9 ± 9.4 kWh/yr or 15.2 ± 1.7% based on average savings and housing stock weights for each climate zone from US Census Data. Average peak demand savings are 0.085 ± 0.04 kW.

Table 49: MFM Average Cooling Energy Savings Based on Hourly PLR from DEER eQuest

California Climate Zone	Average Sensible PLR	Base Energy Use kWh/yr	Energy Savings kWh/yr	Peak Demand Savings kW	Housing Stock Weight	Annual Energy Savings %
1	0.17	68.3	12.9	0.059	0.009	18.9%
2	0.22	256.4	38.5	0.133	0.03	15.0%
3	0.16	65.5	13.1	0.124	0.078	20.0%
4	0.17	230.7	43.2	0.163	0.077	18.7%
5	0.17	50.0	9.6	0.069	0.009	19.2%
6	0.16	274.6	54.2	0.069	0.158	19.7%
7	0.16	233.6	46.0	0.113	0.085	19.7%
8	0.22	536.1	80.4	0.079	0.077	15.0%
9	0.28	1040.8	125.0	0.073	0.126	12.0%
10	0.28	803.8	97.8	0.056	0.059	12.2%
11	0.33	878.6	92.7	0.069	0.032	10.5%
12	0.28	541.9	66.4	0.072	0.136	12.3%
13	0.33	1203.1	126.2	0.048	0.061	10.5%
14	0.39	1988.7	179.0	0.055	0.051	9.0%
15	0.39	3235.1	288.6	0.053	0.004	8.9%
16	0.32	650.0	69.2	0.061	0.01	10.7%
Average	**0.22**	**610.8**	**92.9 ± 9.4**	**0.085 ± 0.04**		**15.2 ± 1.7**

2.2.1 Field Tests of Cooling Energy Savings

Field tests of cooling energy savings were performed at a single-family residential building located in Reno, Nevada. The HVAC system includes a 3.5-ton split-system air conditioner with a Seasonal Energy Efficiency Rating (SEER) of 10 and a gas furnace with an Annual Fuel Utilization Efficiency (AFUE) of 80% with total heating capacity of 100,000 Btu/hr. The return duct system is located in the attic and the supply duct system is located in the crawl space. The measured duct leakage is 21% at 25 Pascal (Pa) of total system pressure. The airflow was measured with a TrueFlow grid and a balometer. The cooling airflow is 1236 cfm at 1.0 inch water column (IWC) total static pressure. The heating airflow is 1023 cfm at 0.91 IWC total static pressure.

Field measurements and equipment accuracy are provided in **Table 50**.

Table 50: Field Measurements, Measurement Equipment, and Accuracy

Field Measurement	Measurement Equipment	Measurement Accuracy
Relative humidity (%) and temperature in degrees Fahrenheit (°F) of return and supply, thermostat, and outdoor condenser entering air	Platinum Resistance Pt100 1/3 Class B 6-channel humidity and temperature data loggers.	Temperature: 0.1°C or 0.18°F RH: ± 0.5 RH at 23°C and 10, 20, 30, 40, 50, 60, 70, 80, 90 % RH
Airflow in cubic feet per minute (cfm) across air conditioner evaporator coil	Digital pressure gauge and fan-powered flow hood, flow meter pitot tube array, and electronic balometer	Fan-powered flowhood: ± 3% Flow meter pitot tube array: ± 7% Electronic balometer: ± 4%
Total power in kilowatts (kW) of air conditioner compressor and fans	True RMS 4-channel power data loggers and 4-channel power analyzer	Data loggers, CTs, PTs: ± 1% Power analyzer: ± 1%
Total gas energy use (Btu) of furnace	Natural gas utility diaphragm flow meter	± 1% of reading
Combustion efficiency, CO	Digital combustion analyzer	Combustion efficiency: ±0.1% CO: ± 5%, O2: ±0.3%

Tests were performed with air sampling sensors located upstream and downstream of the forced air unit. Temperature and power were measured at intervals of 5 seconds. Airflow was measured before and after making any changes to the supply/return ducts, opening vents, or installing new air filters that would affect airflow. Return and supply air specific volumes for air density were calculated from temperature measurements using standard psychrometric algorithms (REFPROP 2010). The "application" sensible EER* is calculated from the combination of temperature, airflow, and power measurements. Measurements of air conditioner performance were made continuously and logged every 5 seconds.

Table 51 provides test results for compressor on time (minutes), energy use (kWh), sensible cooling capacity (Btu), sensible efficiency (Btu/W), efficiency improvement, and cooling energy savings are provided for the base unit without the EFC® installed and the same AC unit with the EFC® installed. Tests were performed with air sampling sensors located upstream and downstream of the forced air unit located in an unconditioned crawl space with ducts located in a hot attic. Both the base and EFC® field test calculations include 21% duct leakage.

Table 51: Field Test Results of Base and EFC® Sensible EER* with 21% Duct Leakage

Description	1	2	3	4	5	6	7
Compressor On Time (minutes)	5	10	15	20	30	45	60
Base Zero Delay AC Energy (kWh) [a]	0.347	0.703	1.067	1.429	2.148	3.237	4.361
Base Zero Delay Sensible Cooling (Btu) [b]	1,720	3,718	5,776	7,909	12,215	18,506	25,122
Base Zero Delay Sensible Efficiency (Btu/W) [c=b/a/1000]	4.96	5.29	5.41	5.53	5.69	5.72	5.76
EFC® AC Energy (kWh) [d]	0.378	0.753	1.118	1.479	2.199	3.287	4.411
EFC® Sensible Cooling (Btu) [e]	2,479	4,784	6,852	9,003	13,371	19,627	26,231
EFC® Sensible Efficiency (Btu/W) [f=e/d/1000]	6.56	6.35	6.13	6.09	6.08	5.97	5.95
EFC® Sensible Efficiency Improvement [g=f/c-1]	32.2%	20.1%	13.3%	10.0%	6.9%	4.4%	3.2%
EFC® Extra Fan Energy (kWh)	0.031	0.050	0.051	0.050	0.051	0.050	0.050
No Delay Energy Equal to EFC (kWh) [h=e/c/1000]	0.499	0.904	1.266	1.627	2.352	3.433	4.553
EFC® Energy Savings (kWh) [i=h-d	0.122	0.151	0.148	0.147	0.153	0.146	0.142
EFC® Cooling Energy Savings [j=(1-c/f) or j=i/h]	**24.4%**	**16.7%**	**11.7%**	**9.1%**	**6.5%**	**4.2%**	**3.1%**

Figure 8 shows time series data for the base and EFC® application sensible Energy Efficiency Ratio (EER*) versus PLR with 21% duct leakage, total AC power (kW), outdoor air temperature (°F), and thermostat temperature (°F).

Figure 8: Field Measured Sensible EER* versus PLR with 21% Duct Leakage

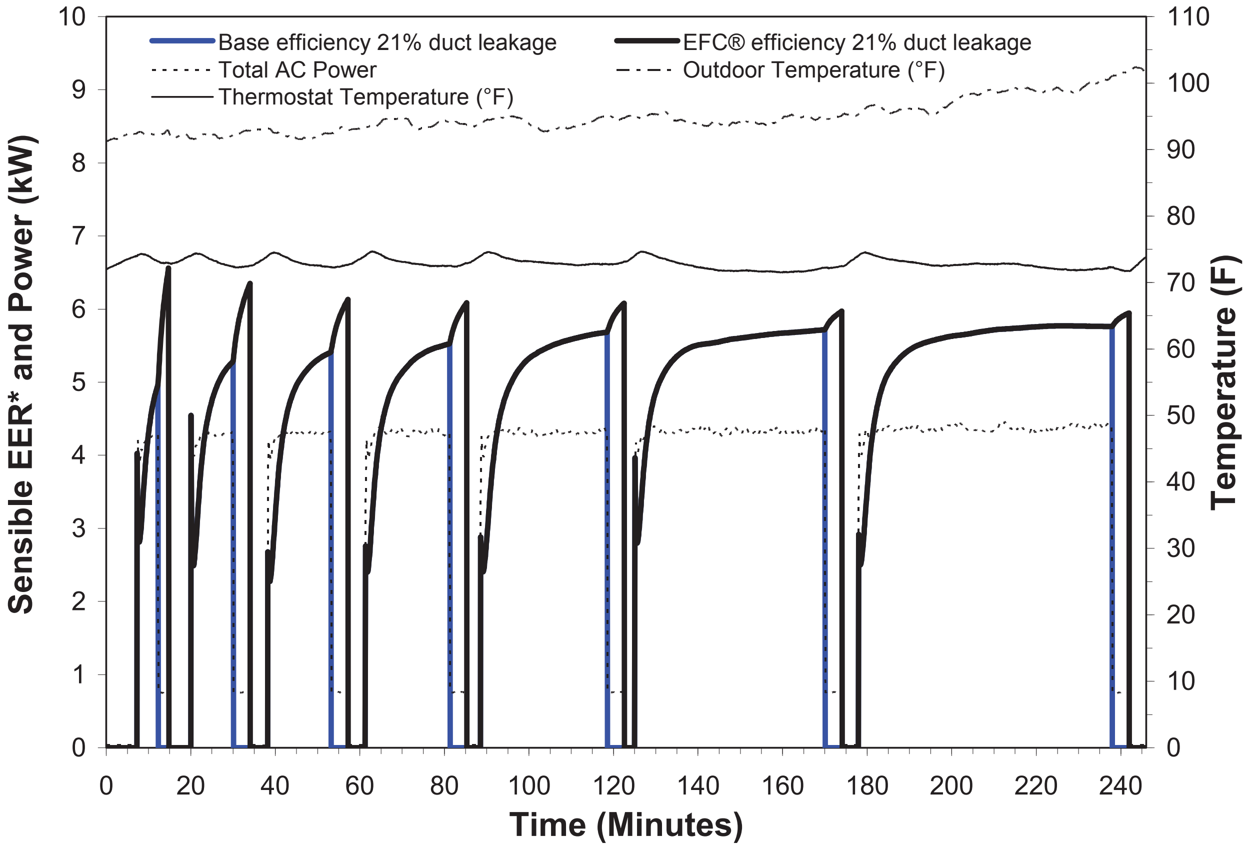


Figure 9 compares cooling energy savings based on laboratory and field tests. The relationship between energy savings and PLR with duct leakage is provided in the power function regression **Equation 13**.

Equation 13 $\Delta\eta_{sc_d} = 0.0343\, PLR_s^{-0.8393}$

Where, $\Delta\eta_{sc_d}$ = EFC® sensible cooling savings with duct leakage.

Figure 9: Cooling Energy Savings versus Part Load Ratio for EFC™

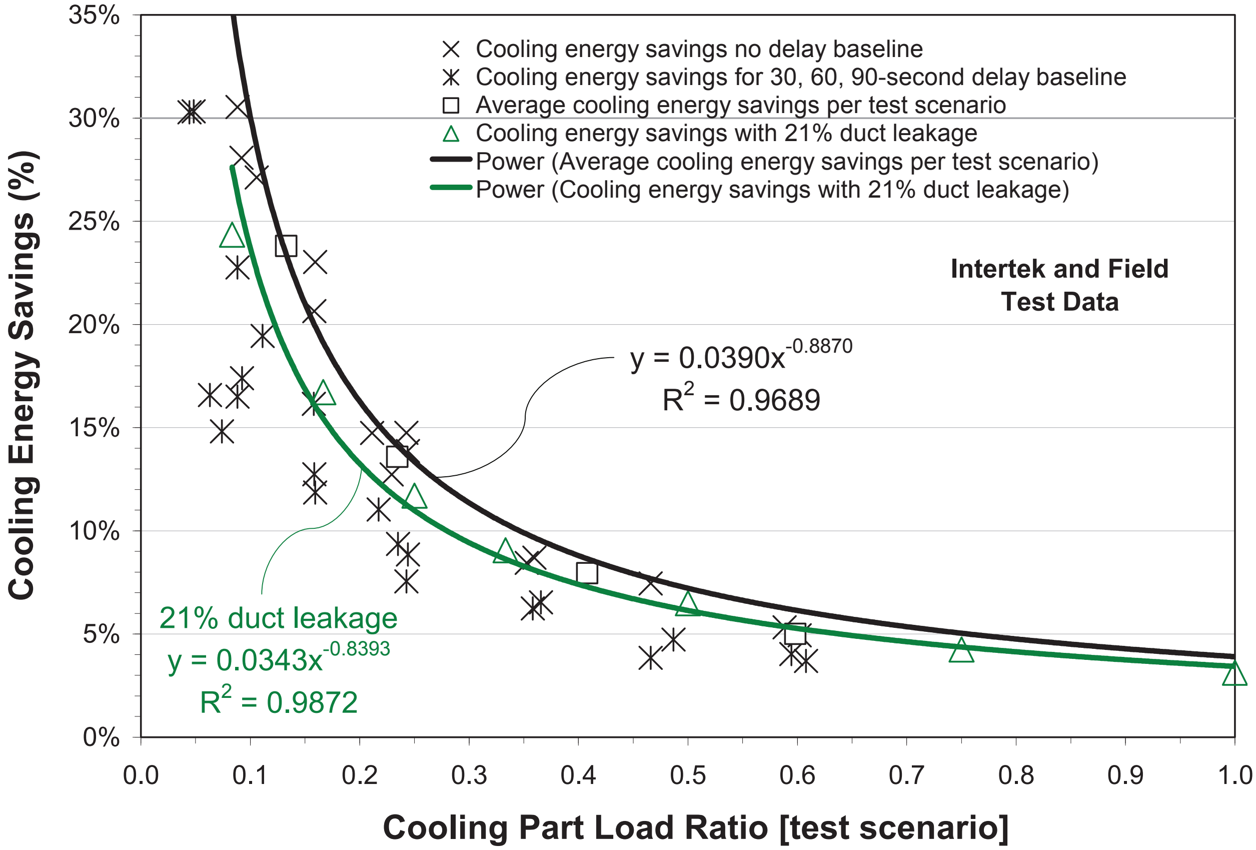


Table 52 compares the difference between laboratory and field test cooling energy savings versus PLR. The field tests are within 1.3 +/- 0.4% of laboratory test results for PLR values from 0.17 to 1.0. Field tests are within 11% of laboratory tests for PLR of 0.08. These tests indicate duct leakage has a larger impact on cooling energy savings for short cycle PLR values. Otherwise, the field and lab tests provide comparable energy savings (i.e., duct leakage has less impact on cooling energy savings for compressor on times greater than 5 minutes (i.e., PLR greater than 0.1).

Table 52: Comparison of Laboratory Tests to Field Tests with 21% Duct Leakage

Description	1	2	3	4	5	6	7
Compressor On Time (minutes)	5	10	15	20	30	45	60
Part Load Ratio (PLR)	0.08	0.17	0.25	0.33	0.50	0.75	1.00
Eq. 6 Laboratory test cooling energy savings [k]	35.3%	19.1%	13.3%	10.3%	7.2%	5.0%	3.9%
Field test cooling energy savings with duct leakage [l]	24.4%	16.7%	11.7%	9.1%	6.5%	4.2%	3.1%
Difference laboratory and field test energy savings [m=k-l]	-11.0%	-2.4%	-1.6%	-1.3%	-0.7%	-0.8%	-0.8%

2.2.2 SCE Laboratory Test Cooling Energy Savings

Southern California Edison (SCE) Design and Engineering Services performed laboratory tests of the cooling-only EFC™ in 2012.[24] SCE conducted 10 test scenarios for one hour each. Cooling loads in the indoor test chamber were set to 0.9, 1.3, and 1.8 tons by using portable heaters to impose a constant sensible load on the A/C unit during the test period. The portable heater input power was set to 1.85 kilowatt (kW) for 0.9-ton test runs, 3.28 kW for 1.3-ton test runs, and 5.00 kW for 1.8-ton runs. Ultrasonic humidifiers were used to impose constant latent loads on the A/C unit. For all test runs, humidifiers introduced 4 pounds-per-hour (lbs/hr) of moisture into the indoor test chamber. The outdoor test chamber was maintained 115°F drybulb temperature and the indoor thermostat was set to 75°F with a hysteresis of ± 0.7°F. The indoor wetbulb was 67.2, 63.5 and 60.8°F and the relative humidity was 62, 50.4, and 39.8 for the 0.9, 1.3, and 1.8 ton tests. The indoor test chamber sensible heat ratios were 0.59, 0.72, and 0.79. The SCE latent load was fixed while the sensible load varied. The latent loads were 41.4, 28.5, and 20.7% of the total cooling load for the 0.9, 1.3, and 1.8 ton total cooling loads.

The SCE part load ratios (PLR) are based on the total cooling load divided by the total cooling capacity for each set of tests. The reported part load ratios are 0.34, 0.53, and 0.76 for the 0.9, 1.3, and 1.8 ton test scenarios. The SCE PLR values are calculated as the sum of the induced sensible space heating loads divided by the sum of the latent loads plus induced space heating loads for a set of tests as shown in **Equation 14** for the 0.9 ton tests.

Equation 14
$$PLR_t = \frac{\sum_{i=1}^{s} ISL_i + \sum_{i=1}^{s} ILL_i}{TC_r} = \frac{6314 + 4452}{31660} = 0.34$$

Where, PLR_t = part load ratio based on total capacity for all tests (dimensionless),

ISL_i = total imposed sensible load of electric space heater = 1.85 kW times 3,413 Btuh/kW or 6314 Btuh,

ILL_i = total imposed latent load = 4 lb/hr moisture times 1,113 Btu/lb or 4452 Btuh,

TC_r = total rated cooling capacity at 115F OAT, 75F DB and 67W WB or 31,660 Btuh per the manufacturer, and

s = the number of tests for each test scenario.

The SCE PLR calculation incorrectly sums the sensible and latent loads for each set of tests instead of calculating the PLR for each individual test where the variable fan-off time delay recovers latent cooling energy to provide additional sensible cooling capacity to the conditioned space. The SCE report also used manufacturer rated sensible cooling capacities instead of measured sensible cooling capacities. The measured sensible cooling capacities are shown in **Table 50** (column H). For the 1.8-ton scenario the cooling system operated for 54 minutes and delivered sensible cooling capacity of 17,065 Btu/hr. For 60 minutes the cooling system will deliver sensible cooling capacity of

[24] SCE 2012. Effects of Delaying Evaporator Fan Cycle Off Time for Residential Air-Conditioning Units. Design and Engineering Services, Emerging Technologies Program. SCE ET11SCE1130 Report. March 20, 2012.

18,961Btu/hr at 115F outdoor air temperature, 75F indoor drybulb and 61F indoor wetbulb temperatures (i.e., 60/54 × 17065 = 18961 Btu/hr). The measured total sensible cooling capacity for the 0.9-ton scenario is 13,333 Btu/hr and the measured total sensible cooling capacity for the 1.3-ton scenario is 17,554 Btu/hr. The measured PLR is defined as the ratio of delivered sensible cooling capacity divided by the total sensible cooling capacity at the same test conditions. The SCE report should have calculated the average sensible PLR based on the total sensible coil load, divided by the measured sensible cooling capacity at the test conditions, divided by the number of tests for each test scenario. The following equation provides the correct calculation for the sensible PLR for the 0.9 ton tests.

Equation 15 $$PLR_s = \frac{\sum_{i=1}^{s} ISL_i}{s \times TSC_c} = \frac{6314}{6 \times 13{,}333} = 0.08$$

Where, PLR_s = part load ratio based on the average sensible cooling capacity for all tests (dimensionless),

ISL_i = total imposed sensible load of 6314 Btuh,

TSC_r = measured sensible cooling capacity at 115°F OAT, 75°F DB and 67°F WB or 13,333 Btuh, and

s = 6 tests for the 0.9-ton test scenario.

The following table provides a comparison of the SCE total PLR values and the average SCE PLR values.[25] The SCE total cooling PLR values (column C) are not correlated to the energy savings. Each compressor operational time includes a fan-off time delay providing evaporative cooling after the compressor turns off. The total cooling savings for all tests divided by the total cooling capacity does not provide the correct functional relationship between energy savings and PLR. The average measured sensible PLR (column I) provides the correct functional relationship between energy savings and PLR, but the 0.9 and 1.3-ton scenarios consist of unrealistically short compressor operational times at 115°F OAT. The 0.9-ton scenario only includes three 5-minute and three 4-minute compressor operational times and the 1.3 ton scenario only includes one 6-minute, one 8-minute, and four 7-minute compressor operational times. The 1.8-ton scenario includes one 28 minute and one 26-minute compressor operational times which are more realistic. The SCE reported PLR values for each test scenario versus the average measured sensible PLR (column I) based on the measured sensible cooling capacity (column G) are shown in **Table 53**. The SCE reported PLR values for the 0.9 ton and 1.3 ton scenarios are 1.7 to 5 times greater than the average measured sensible PLR values (column C versus column I). The SCE reported energy savings confidence intervals (shown in column D) are equal to or greater than the savings due to small sample sizes, large standard deviations, and unrealistic compressor operational times.

[25] Trane. 2012. Model 4TTB3036. Split Systems Air Conditioning (Ducted Type) 3.0 - 5.0 Tons - R410a - 50Hz. SSA-PRC011A-E4. Performance Data Cooling. ODB 115°F, IDB 75°F, IDWB 67°F, 63°F, 61°F. www.comfortsite.com

Table 53: SCE Reported PLR versus Average Measured Sensible PLR

Test Scenario (tons)	SCE Imposed Total Load (Btuh) [A]	SCE Reported Total Cooling Capacity (Btuh) [B]	SCE Reported Total PLR [C=A/B]	SCE Reported Energy Savings [D]	SCE Imposed Sensible Load (Btuh) [E]	Manufacturer Rated Sensible Cooling Capacity at 115°F (Btuh) [F]	Measured Sensible Cooling Capacity at 115°F (Btuh) [G]	Tests [H]	Average Measured Sensible PLR [I=E/(G×H)]
0.9	10,766	31,660	0.34	20.6 ± 20.4%	6,314	15,890	13,333	6	0.08
1.3	15,647	29,520	0.53	14.6 ± 14.9%	11,195	20,650	17,554	6	0.11
1.8	21,517	28,310	0.76	4.5 ± 12.1%	17,065	23,030	18,961	2	0.45

Figure 10 shows the uncorrected SCE PLR values compared to the corrected PLR values based on Intertek test data. Also plotted in **Figure 8** are the cooling energy savings versus average sensible PLR values from **Table 53**. The SCE logarithmic regression **Equation 16** is based on cooling energy savings per test scenario versus total part load ratio (PLR) (see Figure 11, page 15 of the SCE report).

Equation 16 $\Delta\eta_{tc} = -0.2\,\mathrm{Ln}(PLR_t) + 0.0006$

Where, $\Delta\eta_{tc}$ = total cooling savings with EFC™ based on SCE total PLR, and

PLR_t = PLR based on total cooling capacity.

For PLR values ranging from 0.16 to 0.47, the SCE logarithmic regression **Equation 16** provides cooling energy savings of 15.1 to 36.7%. For the same PLR values, the Intertek power function regression **Equation 7** provides cooling energy savings of 7.5 to 19.5% which are 47 to 52% less than the SCE logarithmic equation. The SCE cooling savings versus average sensible PLR are plotted in **Figure 10** and the corrected SCE regression equation curve fit is provided in **Equation 17**.

Equation 17 $\Delta\eta_{sc} = 0.0228\,PLR_s^{-0.8509}$

Where, $\Delta\eta_{sc}$ = sensible cooling savings with EFC™ based on average sensible PLR, and

PLR_s = PLR based on average sensible cooling capacity.

Figure 10 shows that the SCE cooling energy savings based on uncorrected PLR values and average measured sensible PLR values. The average corrected SCE PLR values and exponential power curve regression equation are closer to the exponential power curve regression equation based on the Intertek test data. The uncorrected SCE logarithmic curve and intercept are unrealistic compared to the PLR regression equations based on measured sensible cooling capacity. **Figure 10** also shows energy savings versus PLR with 21% duct leakage, outdoor air temperatures of 95 +/- 0.1F, and hot attic based on data provided in **Table 51**.

Figure 10: SCE and Intertek Cooling Energy Savings versus PLR for the EFC™

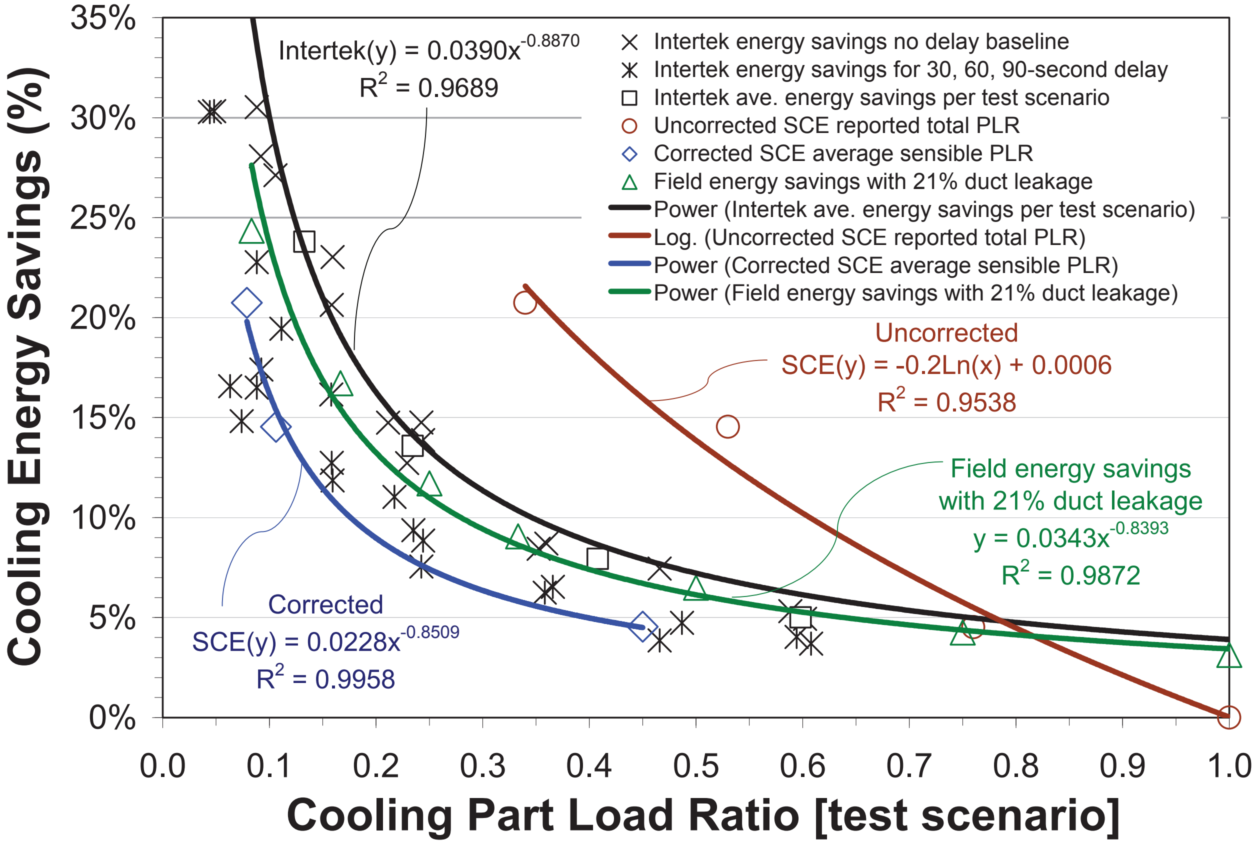


Table 54 provides a comparison of the uncorrected SCE Cooling PLR values versus measured cooling PLR based on SCE test data at the 80% lower and upper bounds. The uncorrected SCE PLR values are greater than the measured PLR values based on SCE test data. The uncorrected SCE PLR values are assumed to be the "null hypothesis" where no statistical significance exists in a set of given observations, no variation exists between variables or that a single variable is no different than its mean. The "null hypothesis" is presumed to be true until or unless a preponderance of statistical evidence is provided to nullify it for an alternative hypothesis. Based on the evidence provided by the SCE test data, the "null hypothesis" can be rejected since the uncorrected PLR values are greater than the measured PLR values based on SCE test data.

Table 54: Uncorrected SCE PLR versus Measured PLR based on SCE Test Data

Test Scenario (tons)	SCE Uncorrected Cooling PLR	Estimated 80% Lower Bound Cooling PLR based on SCE Uncertainty	Measured Cooling PLR Based on SCE Test Data	Estimated 80% Upper Bound Cooling PLR based on SCE Uncertainty	Uncorrected SCE PLR Different From Measured PLR based on Intertek Test Data at 80% Confidence Level ± 20 Percent?
0.9	0.34	0.064	0.079	0.102	Yes
1.3	0.53	0.091	0.106	0.127	Yes
1.8	0.76	0.396	0.450	0.520	Yes

The SCE test procedure and logarithmic regression equation based on the total PLR over predict energy savings. Table 1 of the SCE report (page ii) provides annual cooling Unit Energy Consumption (UEC) and for the 16 California climate zones based on eQuest simulations to report hourly data on four variables: 1) cooling load of the building, 2) cooling capacity of the A/C unit, 3) condensing unit energy, and 4) indoor fan energy. The SCE hourly PLR values were calculated as the total cooling load divided by total cooling capacity (per Eq. 7, page 23). The percentage energy savings for each hour were calculated using **Equation 16**. The SCE average single-family UEC is 2,694.3 kWh/yr and the estimated cooling energy savings are 361.1 kWh/yr or 16.8%. Based on the eQuest simulations, the SCE weighted average PLR is 0.47. For a PLR of 0.47, the Intertek regression **Equation 7** provides 7.5% energy savings which is 55% less than the SCE savings estimate. SCE regression **Equation 17** provides 4.3% savings which is 74% less than the original SCE savings estimate based on the total PLR.

The SCE laboratory report over predicts cooling energy savings for the following reasons: 1) all tests were performed at 115°F OAT and the 0.9 and 1.3-ton compressor operational times of 4.5 and 7 minutes are unrealistically low at 115°F OAT, 2) SCE test procedure introduced high latent loads and relative humidity for the 0.9 and 1.3-ton scenarios, 3) PLR calculations are based on total cooling loads divided by total cooling capacity for all tests within each scenario instead of sensible cooling loads divided by total sensible cooling capacity for each test, and 4) rated sensible cooling capacities were used instead of tested sensible cooling capacities to calculate the regression equation PLR values. The sensible cooling capacity determines whether or not the equipment can meet the cooling load and satisfy the sensible thermostat temperature setpoint which determines how long the cooling system operates and how much energy is used. Twelve out of 14 tests have compressor operational times of 4 to 8 minutes with an average time of 5.75 +/- 0.68 minutes which are unrealistic at 115°F OAT. The combination of performing all tests with the outdoor chamber at 115°F, high indoor humidity, short compressor operational times, and using a logarithmic regression equation based on total PLR for all tests provides specific energy savings as a function of PLR that are two times greater than the Intertek tests and 2.2 times greater than using a power function regression equation based on average SCE PLR values.

This workpaper provides savings estimates based on calibrated DEER eQuest prototype models, sensible cooling, and power curve regression equations based on tested sensible capacities. The average residential single-family cooling energy savings are 194.2 kWh/yr, and this represents

15.2% of the 1,305.5 kWh/yr average space cooling UEC for these buildings in California (see **Table 47**). The SCE laboratory report provided average single-family cooling savings of 361.1 kWh/yr or 16.8% of the 2694.3 kWh/yr UEC for these buildings. The SCE report provides 86% greater annual kWh savings (i.e., 361.1/194.2-1 = 86%) due to using higher UEC values. The SCE report provides 10.5% greater percentage savings (i.e., 16.8/15.2-1=10.5%) due to differences in the eQuest hourly PLR calculation methodologies. This workpaper provides an average single-family cooling PLR of 0.22 and the SCE derived PLR is 0.47. The differences between these two PLR estimates are due different calculation methodologies and different eQuest input assumptions for cooling capacities. The SCE report used 3.5-ton cooling capacities for all eQuest climate zones. This workpaper uses 3 to 5-ton cooling capacities with an average of 3.9 tons for all single-family prototypes. The SCE report used the total cooling load of the building and total cooling capacities of the A/C unit to determine the hourly PLR values. This workpaper uses sensible cooling coil output and measured total sensible cooling capacities to calculate hourly sensible PLR values. The SCE report used total PLR in regression **Equation 16** based on the total PLR for each SCE test scenario. This workpaper uses sensible PLR in **Equation 7** based on average sensible PLR values for each Intertek test scenario.

Table 55 provides a comparison of the SCE reported cooling energy savings for each test scenario versus calculated cooling savings based on the Intertek power curve at the 80% lower and upper bounds. The SCE reported energy savings for all test scenarios are outside the 80% lower and upper bounds based on Intertek test data. Based on the evidence provided by the Intertek test data for 46 cooling tests, the "null hypothesis" is rejected since the SCE reported cooling energy savings percentages for all test scenarios are outside the 80% lower and upper bound savings estimates based on Intertek test data.

Table 55: SCE Reported Cooling Energy Savings versus Savings Based on Intertek Test Data

Test Scenario (tons)	SCE Reported Cooling Energy Savings	Estimated 80% Lower Bound Savings based on SCE Uncertainty	Calculated Cooling Savings based on Intertek Power Curve	Estimated 80% Upper Bound Savings based on SCE Uncertainty	SCE Savings Different From Intertek Savings at 80% Confidence Level ± 20 Percent?
0.9	20.6%	29.5%	37.1%	44.7%	Yes
1.3	14.6%	24.2%	28.5%	32.7%	Yes
1.8	4.5%	7.0%	7.9%	8.9%	Yes

SCE, SDG&E and PG&E workpapers provide cooling energy savings for a cooling-only enhanced time delay measure based on the 2012 SCE laboratory test report of the Efficient Fan Controller®.[26] The SCE 2012 laboratory report represents the ex ante "null hypothesis" which is presumed to be true until a preponderance of evidence is provided to nullify it for an alternative hypothesis. The

[26] SCE. 2012. Workpaper SCE13HC052 Efficient Fan Controller for Residential Air Conditioners. SCE 2014. Work Paper SCE15HC052. Efficient Fan Controller for Residential Air Conditioners and Furnaces. PG&E. 2014. Work Paper PGE3PHVC150 R2 Enhanced Time Delay Relay, PG&E. 2016. Work Paper PGE3PHVC15. R4 Enhanced Time Delay Relay, SDG&E 2016 workpaper WPSDGEREHC0024.2 Efficient Fan Controller for Residential Air Conditioners, http://www.deeresources.net/workpapers.

SCE laboratory tests provided average annual residential single-family cooling kWh savings estimates that are 86% greater than this workpaper. The specific cooling energy savings per PLR are 2 times greater than specific savings PLR based on the Intertek laboratory tests. If SCE had used average measured sensible PLR values based on the SCE test data, then the SCE PLR values and the SCE reported percentage energy savings estimates would be consistent with this workpaper which is based on independent third-party tests performed by Intertek. Based on a preponderance of evidence regarding use of average measured sensible PLR values and the Intertek laboratory test data regarding the performance evaluation of the EFC™, the "null hypothesis" can be rejected and the alternative hypothesis of cooling energy savings, measured sensible PLR values, and the exponential power curve regression equations provided in this workpaper are recommended for the use in California residential energy efficiency programs.

California Investor Owned Utility (IOU) workpapers SCE15HC052.2, WPSDGEREHC0024.2, and PGE3PHVC150.2 provide incorrect measure descriptions.[27] The IOU workpapers also provide incorrect measure cost data (IOU workpapers provide $28.50 cost and correct cost is $50), incorrect installation costs ($135.76/unit based on 2 hours of labor at $67.88/hour and the EFC® only 15 to 20 minutes to install), incorrect measure life, and incorrect energy savings information based on incorrect or incomplete laboratory tests, incorrect engineering analysis, and incorrect log-based algorithms (savings vs. part load ratio).[28] Most importantly, the IOU workpapers provide no baseline Unit Energy Consumption (UEC) values or percentage savings. The IOU workpapers provided the following incorrect measure description of the EFC® in Section 1.2 which only includes cooling.

> "EFC devices delay the evaporator fan cycle off time to take advantage of the residual liquid refrigerant remaining in the evaporator after the compressor cycles off."[29]

The correct EFC® technical description is as follows.

> "Moisture condenses on the evaporator coil during compressor operation where the evaporator temperature is below the dewpoint temperature of the return air. The patented EFC® method includes "monitoring a duration of the air conditioner compressor cycle and determining an amount of time fan operation is extended after the cooling cycle based on the duration" (see Claim 6 of U.S. Patent 8,763,920). The EFC® variable fan-off delay continues moving warm return air across the evaporator coil after the compressor turns off which cools air by evaporating moisture off the evaporator coil which lowers the sensible air temperature delivered to the conditioned space which reduces the thermostat temperature and lengthens the off-cycle time which reduces compressor operation and saves cooling energy. The patented EFC® heating method includes "monitoring a duration of a thermostat call for heating time P3 defined from when the thermostat is initiating a call for heating until when the thermostat is terminating the call for heating; and continuing the heating system ventilation fan operation for a variable

[27] See http://www.deeresources.net/workpapers. SCE15HC052.2 [page 3], WPSDGEREHC0024.2 [Table 1, page 3], and PGE3PHVC150.2 [page 1].
[28] Ibid.
[29] See http://www.deeresources.net/workpapers. SCE15HC052.2 [page 3], WPSDGEREHC0024.2 [Table 1, page 3], and PGE3PHVC150.2 [page 1].

period of time P2 after the thermostat call for heating has ended based on the duration of the thermostat call for heating time P3 (Claim 33of U.S. Patent 9,797,405). On gas furnaces so enabled, the EFC® heating method also includes "energizing the fan relay, normally controlled by the thermostat G terminal switches the ventilation fan to a fan speed higher than a low heater ventilation fan speed (Claim 28 of U.S. Patent 9,797,405)."

2.3 Gas Furnace Heating Energy Savings Analysis

The gas furnace heating energy savings analysis is based on laboratory test measurements of the additional heating capacity (and energy savings) provided by the Efficient Fan Controller® using a variable fan-off time delay which varies as a function of the heat-source operational time and low-to-high or medium-to-high speed fan operation while the heat-source is operating (for systems with this capability) compared to the baseline system with no time delay or a fixed fan-off time delay. The gas furnace heating energy savings methodology is based on the mathematical relationship between the part load ratio of delivered-to-rated heating capacity and energy savings provided by the EFC™. The heating capacity delivered by the gas furnace for each laboratory test and the rated heating capacity of the furnace (as measured by Intertek) are used to calculate the PLR for each test scenario using the following equation.

Equation 18 $PLR_h = \frac{Q_{h_o}}{Q_{h_r}}$

Where, PLR_h = part load ratio of delivered heating capacity to rated heating capacity (dimensionless),
Q_{h_o} = non-steady-state heating capacity delivered by the heating system for each test with the GreenFan® EFC as measured by Intertek (Btu), and
Q_{h_r} = rated heating capacity for one hour as measured by Intertek (Btu).

Intertek performed 48 gas furnace heating tests at 70F return air drybulb and 42F OAT with and without the GreenFan® EFC™. **Table 56** provides heating part load ratios and energy savings with the GreenFan® EFC™ based on 48 Intertek heating tests (24 baseline tests and 24 measure tests). Heating energy savings and the average heating energy savings per test scenario are plotted in **Figure 11** based on average heating energy savings per test scenario. Gas furnace heating energy savings with the GreenFan® EFC™ are calculated using regression **Equation 19** based on the part load ratio (PLR).

Equation 19 $\Delta\eta_h = \left(0.0442\ (PLR_h)^{-0.6052}\right)100$

Where, $\Delta\eta_h$ = gas furnace heating energy savings with EFC™ compared to baseline.

The hourly heating PLR is calculated as follows.

Equation 20 $PLR_{h_i} = \frac{q_{h_i}}{q_{thc_i}} = \frac{Var\ 5}{Var\ 78}$

Where, PLR_{h_i} = heating part load ratio (dimensionless),

q_{h_i} = total central coil heating capacity output [system variable 5] (Btu/hr), and

q_{thc_i} = total heating capacity [system variable 78] (Btu/hr).

The hourly heating PLR is used to calculate the energy savings percentage using **Equation 19** based on Intertek laboratory test data and the functional relationship between heating energy savings and PLR. See **Figure 11** and test data provided in **Table 56**. Annual heating energy savings are calculated using the following equation.

Equation 21 $E_h = \sum_{i=1}^{n} e_{h_i} \left(0.0442\left(PLR_{h_i}\right)^{-0.6052}\right)$

Where, E_h = total heating energy savings for EFC™ based on DEER eQuest prototypical hourly simulation data (Btu),

e_{h_i} = hourly heating energy use (Btu), and

n = 8,760 annual hours of operation.

The annual extra heating fan-off time delay energy use is calculated using the following equation.

Equation 22 $E_{hf} = \sum_{i=1}^{n} e_{hf_i} \left(0.0442\left(PLR_{h_i}\right)^{-0.6052} - \frac{t_{efc_i}}{60 PLR_{h_i}}\right)$

Where, E_{hf} = total annual extra heating fan-off time delay energy use based on DEER eQuest prototypical hourly simulation data (kWh),

e_{hf_i} = heating fan end use energy (kWh) from eQuest hourly simulation data,

t_{efc_i} = variable fan-off time delay based on heat-source operational time (minutes), and

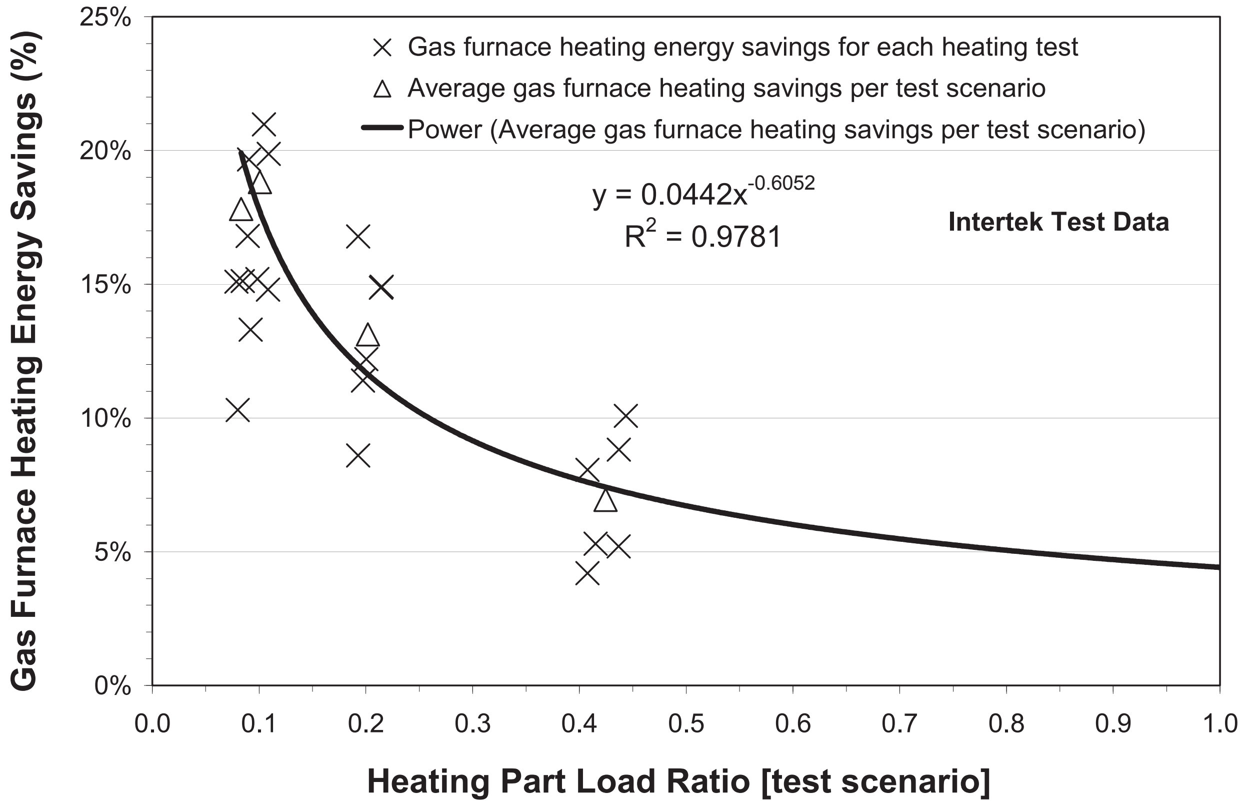
PLR_{h_i} = heating part load ratio from eQuest hourly simulation data and **Eq. 14**.

Hourly calculations are performed for each building prototype and climate zone using the DEER eQuest building prototypes.

Table 56: Gas Furnace Heating PLR and Energy Savings with the EFC™ at 42F OAT

Test	Fan Speed	Base Time Delay (sec)	Part Load Ratio	Furnace Input without EFC™ Btu [a]	Furnace Output without EFC™ Btu [b]	Furnace Efficiency without EFC™ [c=a/b]	Furnace Input with EFC™ Btu [d]	Furnace Output with EFC™ Btu [e]	Furnace Efficiency with EFC™ % [f=e/d]	Energy Savings With EFC™ [g=1-c/f]
11/12	Low-Hi	120	0.085	7,378	3,989	54.1%	7,375	4,698	63.7%	15.1%
13/14	Low-Hi	120	0.105	8,559	4,650	54.3%	8,440	5,803	68.8%	21.0%
15/16	Low-Hi	120	0.214	16,519	10,111	61.2%	16,520	11,877	71.9%	14.9%
17/18	Low-Hi	120	0.443	33,407	22,083	66.1%	33,474	24,609	73.5%	10.1%
19/20	Med-Hi	120	0.080	7,406	3,989	53.9%	7,385	4,434	60.0%	10.3%
21/22	Med-Hi	120	0.098	8,515	4,613	54.2%	8,546	5,458	63.9%	15.2%
23/24	Med-Hi	120	0.200	16,476	9,813	59.6%	16,396	11,118	67.8%	12.2%
25/26	Med-Hi	120	0.415	33,387	21,793	65.3%	33,409	23,036	69.0%	5.3%
35/36	Low-Hi	120	0.091	7,888	4,129	52.3%	7,837	5,107	65.2%	19.7%
37/38	Low-Hi	120	0.109	9,027	4,955	54.9%	8,963	6,140	68.5%	19.9%
39/40	Low-Hi	120	0.215	17,101	10,392	60.8%	16,954	12,108	71.4%	14.9%
41/42	Low-Hi	120	0.437	34,189	22,539	65.9%	34,085	24,643	72.3%	8.8%
43/44	Med-Hi	120	0.089	7,878	4,233	53.7%	7,801	5,036	64.6%	16.8%
45/46	Med-Hi	120	0.108	9,012	5,242	58.2%	8,948	6,111	68.3%	14.8%
47/48	Med-Hi	120	0.197	16,974	9,936	58.5%	16,841	11,126	66.1%	11.4%
49/50	Med-Hi	120	0.437	34,254	23,229	67.8%	34,427	24,625	71.5%	5.2%
51/52	Med	120	0.079	7,774	3,770	48.5%	7,774	4,443	57.2%	15.1%
53/54	Med	120	0.092	8,952	4,504	50.3%	8,952	5,192	58.0%	13.3%
55/56	Med	120	0.193	16,081	9,927	61.7%	16,081	10,866	67.6%	8.6%
57/58	Med	120	0.408	32,695	22,028	67.4%	32,695	22,982	70.3%	4.2%
63/64	Med	45	0.075	7,774	2,981	38.3%	7,774	4,252	54.7%	29.9%
65/66	Med	45	0.092	8,952	3,697	41.3%	8,952	5,192	58.0%	28.8%
67/68	Med	45	0.193	16,081	9,042	56.2%	16,081	10,866	67.6%	16.8%
69/70	Med	45	0.408	32,695	21,129	64.6%	32,695	22,982	70.3%	8.1%

Figure 11: Gas Furnace Heating Energy Savings versus Part Load Ratio for EFC™



Hourly data of single-family (SFM) gas furnace energy use from DEER eQuest models were used to calculate hourly PLR and energy savings values which were used to calculate annual average and maximum PLR values and the annual average energy savings shown in **Table 57**. The average PLR ranges from 0.11 to 0.20 with an average of 0.13. The weighted average annual heating energy savings are 36.1 ± 1.2 therm/yr or 15.5 ± 0.5% based on average savings and housing stock weights for each climate zone from US Census Data. The weighted average annual extra heating fan energy for the variable fan-off time delay is -25 ±0.1 kWh/yr. The extra heating fan energy represents 12.9% of the 194.2 kWh/yr average cooling energy savings for the single family (SFM) prototypes shown in **Table 47** (i.e., 25/194.2 = 12.9%).

Table 57: SFM Furnace Heating Energy Savings Based on Hourly PLR from DEER eQuest

California Climate Zone	Average Heating PLR	Base Energy Use therm/yr	Energy Savings therm/yr	Extra Fan Energy kWh/yr	Housing Stock Weight	Annual Energy Savings %
1	0.15	341.3	47.1	-34.0	0.009	13.8%
2	0.16	313.6	42.8	-30.1	0.03	13.6%
3	0.13	304.0	45.6	-30.6	0.078	15.0%
4	0.14	242.3	35.3	-24.1	0.077	14.6%
5	0.14	319.7	46.4	-27.1	0.009	14.5%
6	0.11	187.9	31.9	-19.1	0.158	17.0%
7	0.11	133.1	23.0	-13.6	0.085	17.2%
8	0.12	162.6	26.3	-16.3	0.077	16.2%
9	0.12	194.8	31.1	-22.6	0.126	16.0%
10	0.13	214.3	33.2	-21.9	0.059	15.5%
11	0.15	285.4	39.2	-28.3	0.032	13.8%
12	0.14	275.1	39.9	-31.4	0.136	14.5%
13	0.12	269.7	42.1	-34.7	0.061	15.6%
14	0.15	281.6	38.6	-33.9	0.051	13.7%
15	0.13	111.4	17.0	-28.4	0.004	15.3%
16	0.20	602.4	70.4	-63.0	0.01	11.7%
Average	**0.13**	**232.3**	**36.1 ± 1.2**	**-25 ± 0.1**		**15.5 ± 0.5**

Hourly data of double-wide mobile home (DMO) gas furnace energy use from DEER eQuest models were used to calculate hourly PLR and energy savings values which were used to calculate annual average and maximum PLR values and the annual average energy savings shown in **Table 58**. The average PLR ranges from 0.09 to 0.20 with an average of 0.12. The weighted average annual heating energy savings are 35.2 ± 1.8 therm/yr or 16.3 ± 0.8% based on average savings and housing stock weights for each climate zone from US Census Data. The weighted average annual extra heating fan energy is -16.3 ±0.1 kWh/yr for the EFC™ variable fan-off time delay. The extra heating fan energy is 3.3% of the 486.8 kWh/yr average cooling energy savings for the double-wide mobile home (DMO) prototypes shown in **Table 48** (i.e., 16.3/486.8 = 3.3%).

Table 58: DMO Furnace Heating Energy Savings Based on Hourly PLR from DEER eQuest

California Climate Zone	Average Heating PLR	Base Energy Use therm/yr	Energy Savings therm/yr	Extra Fan Energy kWh/yr	Housing Stock Weight	Annual Energy Savings %
1	0.11	311.5	51.9	-24.2	0.009	16.7%
2	0.13	275.4	41.5	-21.2	0.03	15.1%
3	0.10	241.8	42.5	-18.8	0.078	17.6%
4	0.12	218.6	35.3	-17.0	0.077	16.2%
5	0.11	316.9	52.8	-24.2	0.009	16.7%
6	0.09	147.3	28.3	-10.8	0.158	19.2%
7	0.09	123.8	23.4	-8.9	0.085	18.9%
8	0.10	179.6	32.9	-13.2	0.077	18.3%
9	0.10	170.1	31.0	-12.9	0.126	18.2%
10	0.11	188.9	31.1	-16.4	0.059	16.5%
11	0.15	328.1	46.4	-24.2	0.032	14.1%
12	0.13	264.3	39.8	-20.4	0.136	15.0%
13	0.14	252.2	37.0	-19.4	0.061	14.7%
14	0.16	339.4	45.3	-24.3	0.051	13.3%
15	0.11	158.2	26.2	-12.2	0.004	16.6%
16	0.20	558.0	65.7	-36.1	0.01	11.8%
Average	**0.12**	**215.2**	**35.2 ± 1.8**	**-16.3 ± 0.1**		**16.3 ± 0.8**

Hourly data of multi-family (MFM) gas furnace energy consumption from DEER eQuest models were used to calculate hourly PLR and energy savings values which were used to calculate annual average and maximum PLR values and the annual average energy savings shown in **Table 59**. The average PLR ranges from 0.09 to 0.17 with an average of 0.11. The average annual heating energy savings are 16.5 ± 0.8 therm/yr or 16.6 ± 0.8% based on average savings and housing stock weights for each climate zone from US Census Data. The weighted average annual extra heating fan energy for the variable fan-off time delay is -6.4 ±1.8 kWh/yr. The extra heating fan energy represents 6.8% of the 92.9 kWh/yr average cooling energy savings for the multi-family (MFM) prototypes shown in **Table 49** (i.e., 6.4/92.9 = 6.8%).

Table 59: MFM Furnace Heating Energy Savings Based on Hourly PLR from DEER eQuest

California Climate Zone	Average Heating PLR	Base Energy Use therm/yr	Energy Savings therm/yr	Extra Fan Energy kWh/yr	Housing Stock Weight	Annual Energy Savings %
1	0.11	209.3	34.7	-13.6	0.009	16.6%
2	0.12	125.6	20.5	-8.2	0.03	16.3%
3	0.10	124.9	22.0	-8.0	0.078	17.6%
4	0.11	93.7	15.8	-6.2	0.077	16.9%
5	0.10	82.8	14.8	-5.4	0.009	17.9%
6	0.09	64.1	12.5	-4.1	0.158	19.5%
7	0.09	51	9.8	-3.3	0.085	19.3%
8	0.10	59.2	10.7	-3.9	0.077	18.1%
9	0.09	84.8	15.7	-5.7	0.126	18.5%
10	0.11	94.8	15.8	-6.4	0.059	16.6%
11	0.13	137	20.8	-8.8	0.032	15.2%
12	0.13	135.5	20.5	-8.7	0.136	15.1%
13	0.15	114.1	16.1	-7.2	0.061	14.1%
14	0.14	153.6	21.9	-9.8	0.051	14.3%
15	0.11	55.9	9.7	-4.0	0.004	17.3%
16	0.17	257.7	33.4	-14.9	0.01	13.0%
Average	**0.11**	**99.1**	**16.5 ± 0.8**	**-6.4 ± 1.8**		**16.6 ± 0.8**

2.4 Heat Pump Heating Energy Savings Analysis

The heat pump heating energy savings analysis is based on laboratory test measurements of the additional heating capacity (and energy savings) provided by the Efficient Fan Controller® using a variable fan-off time delay which varies as a function of the heat-source operational time compared to the baseline system with no time delay or a fixed fan-off time delay. The heat pump heating energy savings methodology is based on the mathematical relationship between the part load ratio of delivered-to-rated heating capacity and energy savings provided by the EFC™. The heating capacity delivered by the heat pump for each laboratory test and the rated heating capacity of the heat pump (as measured by Intertek) are used to calculate the PLR for each test scenario using **Equation 18**.

The GreenFan® EFC™ was installed and tested on a 1.5-ton split-system heat pump. Intertek performed tests at 70F return air drybulb and 47F, 17F, 35F, and 62F OAT. **Table 60** through **Table 63** provide heating part load ratios and energy savings with the GreenFan® EFC™ based on Intertek heating tests at 47F, 17F, 35F, and 62F OAT.[30] Heating energy savings and the average heating energy savings per test scenario are plotted in **Figure 12**. Based on 48 heat pump heating tests, the GreenFan® EFC™ provided heating energy savings of 3 to 62% compared to no fan-off time delay or a fixed 65-second time delay. Heat pump heating energy savings with the GreenFan® EFC™ are calculated using regression **Equation 23** based on the average heat pump heating energy savings per test scenario.

[30] Heat pump input Btu values are based on measured kWh times 3412 Btu/h.

Equation 23 $\Delta\eta_h = \left(0.0275\left(PLR_h\right)^{-0.7411}\right)100$

Where, $\Delta\eta_h$ = heat pump heating energy savings with EFC™ compared to baseline.

The hourly heat pump heating PLR is used to calculate the energy savings based on Intertek laboratory test data and the functional relationship between heat pump heating energy savings and PLR. See **Figure 12** and test data provided in **Table 57** through **Table 60**. Annual heat pump heating energy savings are calculated using the following equation.

Equation 24 $E_h = \sum_{i=1}^{n} e_{h_i}\left(0.0275\left(PLR_{h_i}\right)^{-0.7411}\right)$

Where, E_h = annual heat pump heating energy savings for EFC™ based on DEER eQuest prototypical hourly simulation data (kWh),

e_{h_i} = hourly heat pump heating energy use (kWh), and

n = 8,760 annual hours of operation.

Table 60: Heat Pump Heating PLR and Energy Savings with the EFC™ at 47F OAT

Test	Base Time Delay (sec)	Part Load Ratio	HP Input without EFC™ kWh [a]	HP Output without EFC™ Btu [b]	HP Efficiency without EFC™ [c=b/a/3412]	HP Input with EFC™ kWh [d]	HP Output with EFC™ Btu [e]	HP Efficiency with EFC™ [f=e/d/3412]	Energy Savings with EFC™ [g=1-c/f]
125	0	0.006	0.044	36	0.24	0.048	91	0.56	57.7%
126	0	0.027	0.111	262	0.69	0.116	417	1.06	34.2%
127	0	0.084	0.226	971	1.26	0.233	1,293	1.63	22.6%
128	0	0.233	0.466	3,066	1.93	0.475	3,569	2.20	12.5%
129	0	0.385	0.709	5,453	2.25	0.716	5,906	2.42	6.8%
130	0	0.696	1.198	10,206	2.50	1.205	10,676	2.60	3.8%
131	65	0.010	0.048	96	0.58	0.052	149	0.84	30.9%
132	65	0.033	0.114	376	0.96	0.119	505	1.24	22.3%
133	65	0.092	0.230	1,157	1.48	0.235	1,412	1.76	16.3%
134	65	0.241	0.470	3,312	2.07	0.475	3,702	2.28	9.6%
135	65	0.396	0.713	5,716	2.35	0.718	6,075	2.48	5.3%
136	65	0.707	1.202	10,478	2.55	1.206	10,852	2.64	3.1%

Table 61: Heat Pump Heating PLR and Energy Savings with the EFC™ at 17F OAT

Test	Base Time Delay (sec)	Part Load Ratio	HP Input without EFC™ kWh [a]	HP Output without EFC™ Btu [b]	HP Efficiency without EFC™ [c=b/a/3412]	HP Input with EFC™ kWh [d]	HP Output with EFC™ Btu [e]	HP Efficiency with EFC™ [f=e/d/3412]	Energy Savings with EFC™ [g=1-c/f]
137	0	0.004	0.042	13	0.09	0.046	37	0.24	62.1%
138	0	0.017	0.107	106	0.29	0.112	177	0.46	37.3%
139	0	0.073	0.219	552	0.74	0.226	762	0.99	25.3%
140	0	0.212	0.444	1,854	1.22	0.453	2,207	1.43	14.3%
141	0	0.385	0.678	3,685	1.59	0.685	3,998	1.71	6.9%
142	0	0.701	1.127	6,974	1.81	1.134	7,289	1.88	3.7%
143	65	0.006	0.046	39	0.25	0.050	60	0.35	29.3%
144	65	0.021	0.110	158	0.42	0.116	213	0.54	22.4%
145	65	0.081	0.223	673	0.89	0.228	838	1.08	17.8%
146	65	0.221	0.448	2,027	1.33	0.453	2,296	1.49	10.7%
147	65	0.396	0.681	3,867	1.66	0.686	4,111	1.76	5.2%
148	65	0.712	1.131	7,157	1.85	1.136	7,403	1.91	2.9%

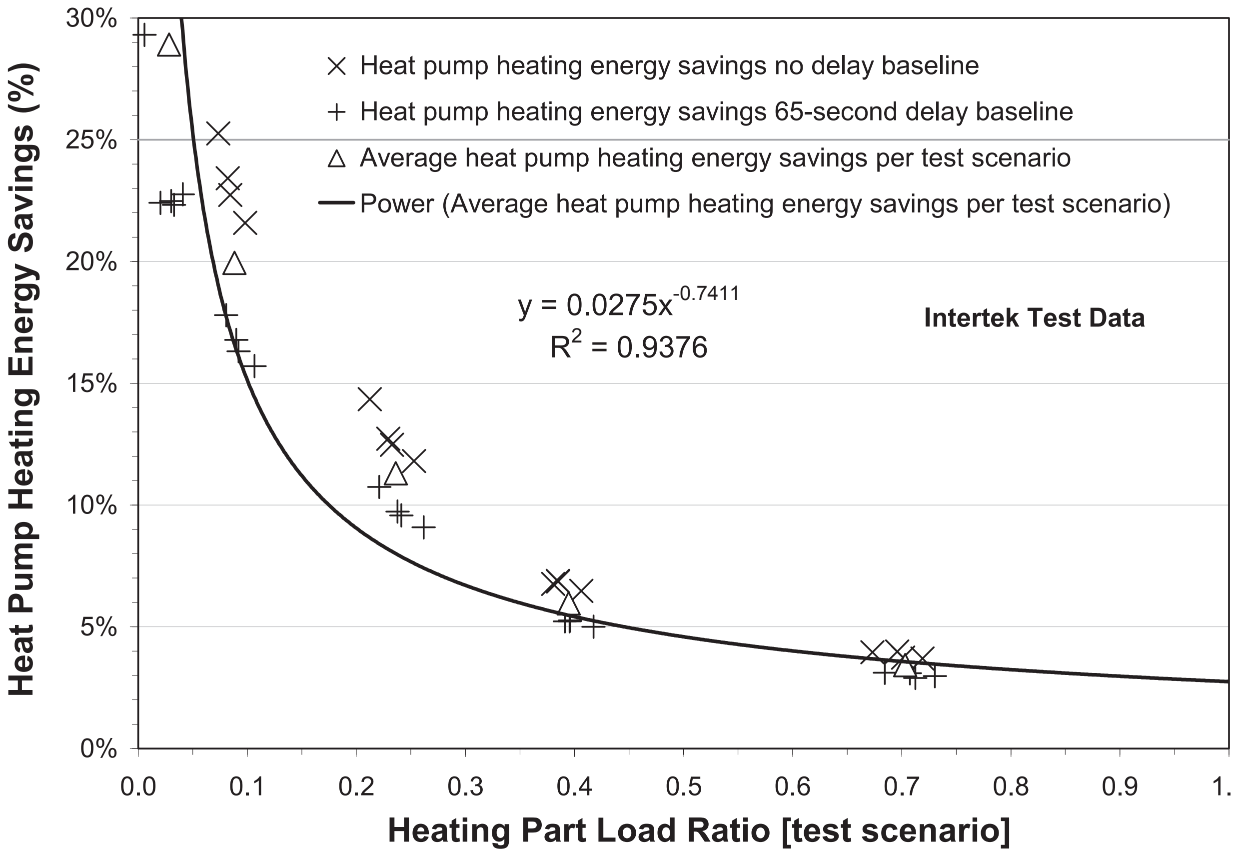
Table 62: Heat Pump Heating PLR and Energy Savings with the EFC™ at 35F OAT

Test	Base Time Delay (sec)	Part Load Ratio	HP Input without EFC™ kWh [a]	HP Output without EFC™ Btu [b]	HP Efficiency without EFC™ [c=b/a/3412]	HP Input with EFC™ kWh [d]	HP Output with EFC™ Btu [e]	HP Efficiency with EFC™ [f=e/d/3412]	Energy Savings with EFC™ [g=1-c/f]
149	0	0.005	0.043	25	0.17	0.047	67	0.42	59.5%
150	0	0.025	0.108	211	0.57	0.114	339	0.87	34.9%
151	0	0.082	0.222	832	1.10	0.229	1,120	1.43	23.4%
152	0	0.229	0.456	2,677	1.72	0.465	3,126	1.97	12.7%
153	0	0.380	0.693	4,790	2.03	0.700	5,189	2.17	6.8%
154	0	0.673	1.163	8,767	2.21	1.170	9,183	2.30	4.0%
155	65	0.008	0.047	71	0.44	0.050	110	0.64	30.8%
156	65	0.030	0.112	305	0.80	0.117	410	1.03	22.5%
157	65	0.090	0.226	998	1.30	0.231	1,226	1.56	16.8%
158	65	0.238	0.460	2,896	1.85	0.465	3,243	2.04	9.7%
159	65	0.391	0.697	5,022	2.11	0.702	5,336	2.23	5.2%
160	65	0.685	1.167	9,008	2.26	1.172	9,337	2.34	3.1%

Table 63: Heat Pump Heating PLR and Energy Savings with the EFC™ at 62F OAT

Test	Base Time Delay (sec)	Part Load Ratio	HP Input without EFC™ kWh [a]	HP Output without EFC™ Btu [b]	HP Efficiency without EFC™ [c=b/a/3412]	HP Input with EFC™ kWh [d]	HP Output with EFC™ Btu [e]	HP Efficiency with EFC™ [f=e/d/3412]	Energy Savings with EFC™ [g=1-c/f]
161	0	0.008	0.046	53	0.33	0.050	130	0.77	56.4%
162	0	0.034	0.114	356	0.91	0.120	569	1.39	34.6%
163	0	0.098	0.234	1,259	1.57	0.241	1,653	2.01	21.6%
164	0	0.253	0.483	3,697	2.24	0.492	4,267	2.54	11.8%
165	0	0.406	0.735	6,351	2.53	0.742	6,855	2.71	6.5%
166	0	0.719	1.239	11,618	2.75	1.246	12,132	2.85	3.7%
167	65	0.013	0.050	137	0.80	0.053	212	1.16	30.7%
168	65	0.041	0.118	512	1.27	0.123	691	1.64	22.8%
169	65	0.107	0.238	1,486	1.83	0.243	1,800	2.17	15.7%
170	65	0.262	0.487	3,976	2.39	0.492	4,417	2.63	9.1%
171	65	0.417	0.739	6,644	2.64	0.744	7,043	2.78	5.0%
172	65	0.730	1.242	11,916	2.81	1.247	12,324	2.90	3.0%

Figure 12: Heat Pump Heating Energy Savings versus Part Load Ratio for EFC™



Hourly data of single-family (SFM) heat pump heating energy use from DEER eQuest models were used to calculate hourly PLR and energy savings values which were used to calculate annual PLR values and the annual average energy savings shown in **Table 64**. The average annual PLR values range from 0.09 to 0.27 depending on climate zone with an average of 0.16. The average annual heat pump heating energy savings are 321.1 ± 21 kWh/yr and 11 ± 0.7% based on average savings and housing stock weights for each climate zone from US Census Data. Extra heating fan energy is included within the heat pump electric energy savings.

Table 64: SFM Heat Pump Heating Savings Based on Hourly PLR from DEER eQuest

California Climate Zone	Average Heating PLR	Base Energy Use kWh/yr	Energy Savings kWh/yr	Housing Stock Weight	Annual Energy Savings %
1	0.21	4,002.8	344.3	0.009	8.6%
2	0.24	3,907.3	311.0	0.03	8.0%
3	0.21	2,926.8	258.8	0.078	8.8%
4	0.20	3,180.4	287.6	0.077	9.0%
5	0.23	3,097.5	253.8	0.009	8.2%
6	0.13	2,208.1	275.2	0.158	12.5%
7	0.13	2,023.8	259.6	0.085	12.8%
8	0.14	2,170.8	252.0	0.077	11.6%
9	0.13	2,409.3	295.8	0.126	12.3%
10	0.17	2,866.0	293.3	0.059	10.2%
11	0.22	4,210.7	350.1	0.032	8.3%
12	0.18	3,799.4	373.1	0.136	9.8%
13	0.14	3,236.4	384.8	0.061	11.9%
14	0.20	4,211.7	387.8	0.051	9.2%
15	0.09	1,392.3	222.6	0.004	16.0%
16	0.27	8,549.7	624.8	0.01	7.3%
Average	**0.16**	**2,969.8**	**321.1 ± 21**		**11 ± 0.7**

Hourly data of double-wide mobile home (DMO) heat pump heating energy use from DEER eQuest models were used to calculate hourly PLR and energy savings values which were used to calculate annual PLR values and the annual average energy savings shown in **Table 65**. The average annual PLR values range from 0.08 to 0.27 depending on climate zone with an average of 0.11. The average annual heat pump heating energy savings are 427.7 ± 41.2 kWh/yr and 14.9 ± 1.4% based on average savings and housing stock weights for each climate zone from US Census Data. Extra heating fan energy is included within the heat pump electric energy savings.

Table 65: DMO Heat Pump Heating Savings Based on Hourly PLR from DEER eQuest

California Climate Zone	Average Heating PLR	Base Energy Use kWh/yr	Energy Savings kWh/yr	Housing Stock Weight	Annual Energy Savings %
1	0.12	4,280.8	567.7	0.009	13.3%
2	0.15	4,078.4	457.5	0.030	11.2%
3	0.10	3,444.0	524.6	0.078	15.2%
4	0.12	3,401.1	453.7	0.077	13.3%
5	0.10	3,597.5	528.5	0.009	14.7%
6	0.08	2,244.6	411.6	0.158	18.3%
7	0.08	1,987.5	366.5	0.085	18.4%
8	0.09	2,236.5	372.2	0.077	16.6%
9	0.09	2,254.9	373.1	0.126	16.5%
10	0.11	2,661.1	371.5	0.059	14.0%
11	0.15	4,138.1	467.0	0.032	11.3%
12	0.13	4,116.2	514.2	0.136	12.5%
13	0.14	3,278.5	391.1	0.061	11.9%
14	0.18	4,036.6	387.8	0.051	9.6%
15	0.11	1,732.0	251.3	0.004	14.5%
16	0.27	6,866.3	498.4	0.010	7.3%
Average	**0.11**	**3,034.4**	**427.7 ± 41.2**		**14.9 ± 1.4**

Hourly data of multi-family (MFM) heat pump heating energy use from DEER eQuest models were used to calculate hourly PLR and energy savings values which were used to calculate annual PLR values and the annual average energy savings shown in **Table 66**. The average annual PLR values range from 0.09 to 0.29 depending on climate zone with an average of 0.11. The average annual heat pump heating energy savings are 141.1 ± 10.6 kWh/yr or 13.7 ± 1% based on average savings and housing stock weights for each climate zone from US Census Data. Extra heating fan energy is included within the heat pump electric energy savings.

Table 66: MFM Heat Pump Heating Savings Based on Hourly PLR from DEER eQuest

California Climate Zone	Average Heating PLR	Base Energy Use kWh/yr	Energy Savings kWh/yr	Housing Stock Weight	Annual Energy Savings %
1	0.13	2,305.0	284.8	0.009	12.4%
2	0.14	1,526.2	178.1	0.03	11.7%
3	0.11	1,510.9	214.7	0.078	14.2%
4	0.12	934.1	121.7	0.077	13.0%
5	0.11	836.8	118.9	0.009	14.2%
6	0.09	762.3	128.0	0.158	16.8%
7	0.09	468.7	78.3	0.085	16.7%
8	0.10	582.9	85.6	0.077	14.7%
9	0.10	779.2	119.5	0.126	15.3%
10	0.13	763.1	94.8	0.059	12.4%
11	0.16	1,512.4	160.1	0.032	10.6%
12	0.15	1,409.3	157.0	0.136	11.1%
13	0.15	1,115.2	123.7	0.061	11.1%
14	0.19	1,475.3	141.7	0.051	9.6%
15	0.12	535.7	70.2	0.004	13.1%
16	0.29	3,116.0	216.8	0.01	7.0%
Average	**0.11**	**1,029.4**	**141.1 ± 10.6**		**13.7 ± 1**

2.5 Hydronic Heating Energy Savings Analysis

The hydronic heating energy savings analysis is based on laboratory test measurements of the additional heating capacity (and energy savings) provided by the Efficient Fan Controller® using a variable fan-off time delay which varies as a function of the heat-source operational time compared to the baseline system with no time delay or a fixed fan-off time delay. The hydronic heating energy savings methodology is based on the mathematical relationship between the part load ratio of delivered-to-rated heating capacity and energy savings provided by the EFC™. The delivered hydronic heating capacity for each laboratory test and the rated heating capacity (as measured by Intertek) are used to calculate the PLR for each test scenario using **Equation 18**.

Intertek performed tests on a 1.5-ton split-system hydronic heating system at 70F return air drybulb temperature and 47F OAT with and without GreenFan® EFC™ installed. Twelve tests were performed with the water heater set at 130F and eight tests were performed with the water heater set at 140F. **Table 67** provides heating part load ratios and energy savings with the GreenFan® EFC™ based on 20 heating tests. Heating energy savings and the average heating energy savings per test scenario are plotted in **Figure 13**. Based on 20 heating tests, the GreenFan® EFC™ energy savings range from 4 to 66.3% compared to zero fan-off time delay which is common for most hydronic heating systems. Compared to a fixed 60-second fan-off time delay on new hydronic heating systems the GreenFan® EFC™ saved 3 to 40.6%. Hydronic heating energy savings are calculated using regression **Equation 25** based on the average hydronic heating energy savings per test scenario.

Equation 25 $$\Delta\eta_h = \left(0.0283(PLR_h)^{-0.6169}\right)100$$

Where, $\Delta\eta_h$ = hydronic heating energy savings with EFC™ compared to baseline.

The hourly hydronic heating PLR is used to calculate the energy savings based on Intertek laboratory test data and the functional relationship between hydronic heating energy savings and PLR. See **Figure 13** and test data provided in **Table 67**. Annual hydronic heating energy savings are calculated using the following equation.

Equation 26 $$E_h = \sum_{i=1}^{n} e_{h_i}\left(0.0283\left(PLR_{h_i}\right)^{-0.6169}\right)$$

Where, E_h = annual hydronic heating energy savings for EFC™ based on DEER eQuest prototypical hourly simulation data (Btu),
e_{h_i} = hourly hydronic heating energy use (Btu), and
n = 8,760 annual hours of operation.

The annual extra hydronic heating fan-off time delay energy use and hydronic circulation pump energy savings are calculated using the following equation.

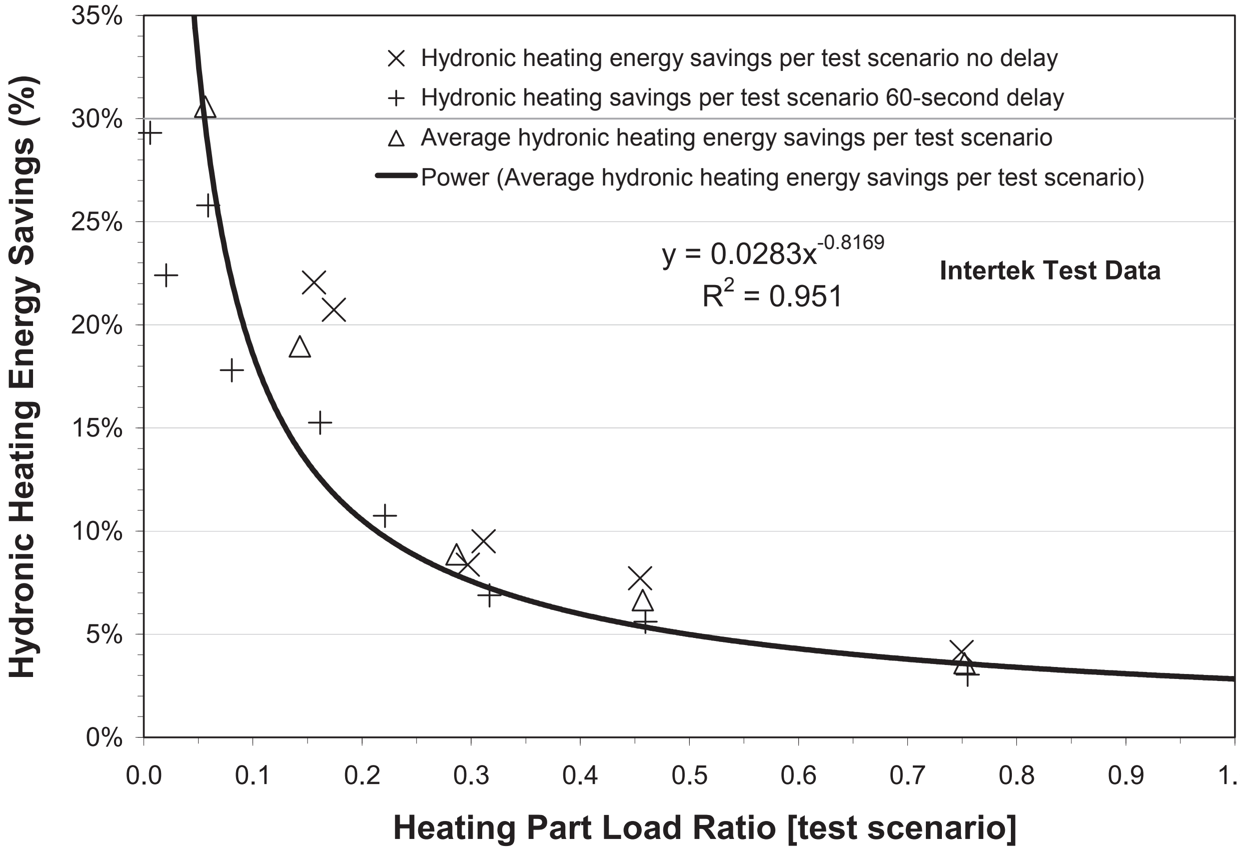
Equation 27 $$E_{hf} = \sum_{i=1}^{n} e_{hf_i}\left(0.0283\left(PLR_{h_i}\right)^{-0.8169} - \frac{t_{efc_i}}{60PLR_{h_i}}\right) + e_{hp_i}\left(0.0283\left(PLR_{h_i}\right)^{-0.8169}\right)$$

Where, E_{hf} = annual extra heating fan-off time delay energy use based on DEER eQuest prototypical hourly simulation data (kWh),
e_{hf_i} = heating fan end use energy (kWh) from eQuest hourly simulation data,
t_{efc_i} = variable fan-off time delay based on heat-source operational time (minutes),
PLR_{h_i} = heating part load ratio from eQuest hourly simulation data and **Eq. 14**, and
e_{hp_i} = hydronic pump end use energy (kWh) from eQuest hourly simulation data.

Table 67: Hydronic Heating PLR and Energy Savings with the EFC™

Test	HW Supply (F)	Base Time Delay (sec)	Part Load Ratio	Hydronic Input without EFC™ Btu [a]	Hydronic Output without EFC™ Btu [b]	Hydronic Efficiency without EFC™ [c=a/b]	Hydronic Input with EFC™ Btu [d]	Hydronic Output with EFC™ Btu [e]	Hydronic Efficiency with EFC™ [f=e/d]	Energy Savings With EFC™ [g=1-c/f]
173	130	0	0.023	970	118	0.12	970	352	0.36	66.3%
174	130	0	0.054	2,365	507	0.21	2,365	831	0.35	39.0%
175	130	0	0.156	4,548	1,857	0.41	4,548	2,382	0.52	22.1%
176	130	0	0.311	9,185	4,307	0.47	9,185	4,759	0.52	9.5%
177	130	0	0.455	14,102	6,414	0.45	14,102	6,950	0.49	7.7%
178	130	0	0.749	23,893	10,976	0.46	23,893	11,451	0.48	4.1%
179	130	60	0.028	970	251	0.26	970	423	0.44	40.6%
180	130	60	0.059	2,365	668	0.28	2,365	901	0.38	25.8%
181	130	60	0.162	4,548	2,093	0.46	4,548	2,469	0.54	15.3%
182	130	60	0.317	9,185	4,507	0.49	9,185	4,840	0.53	6.9%
183	130	60	0.460	14,102	6,632	0.47	14,102	7,026	0.50	5.6%
184	130	60	0.755	23,893	11,185	0.47	23,893	11,535	0.48	3.0%
185	140	0	0.030	874	186	0.21	874	508	0.58	63.3%
186	140	0	0.092	2,507	1,020	0.41	2,507	1,571	0.63	35.1%
187	140	0	0.174	4,433	2,368	0.53	4,433	2,987	0.67	20.7%
188	140	0	0.297	9,540	4,668	0.49	9,540	5,094	0.53	8.4%
191	140	60	0.035	874	372	0.43	874	599	0.69	37.8%
192	140	60	0.098	2,507	1,301	0.52	2,507	1,682	0.67	22.6%
193	140	60	0.180	4,433	2,647	0.60	4,433	3,089	0.70	14.3%
194	140	60	0.302	9,540	4,851	0.51	9,540	5,173	0.54	6.2%

Figure 13: Hydronic Heating Energy Savings versus Part Load Ratio for EFC™



Hourly data of multi-family hydronic heating energy use from DEER eQuest models were used to calculate hourly PLR and energy savings values which were used to calculate annual PLR values and the annual average energy savings shown in **Table 68**. The average annual PLR values range from 0.09 to 0.20 depending on climate zone with an average of 0.12. The maximum PLR is 0.57 The average annual hydronic heating energy savings are 17.3 ± 1.1 therm/yr or 16.3 ± 1.7% based on average savings and housing stock weights for each climate zone from US Census Data. The weighted average annual extra heating fan energy for the variable fan-off time delay is -6.7 ±1 kWh per yr. The extra heating fan minus pump energy represents 7.2% of the 92.9 kWh/yr average cooling energy savings shown in **Table 49** (i.e., 6.7/92.9 = 7.2%).

Table 68: MFM Hydronic Heating Savings Based on Hourly PLR from DEER eQuest

California Climate Zone	Average Heating PLR	Base Energy Use therm/yr	Energy Savings therm/yr	Extra Fan – Pump Energy kWh/yr	Housing Stock Weight	Annual Energy Savings %
1	0.13	212.5	31.1	-10.2	0.009	14.6%
2	0.14	152.3	21.9	-8.2	0.03	14.4%
3	0.12	131.8	21.6	-9.5	0.078	16.4%
4	0.13	113.8	17.5	-6.8	0.077	15.3%
5	0.11	107.2	18.1	-6.8	0.009	16.9%
6	0.09	65.2	12.8	-6.1	0.158	19.6%
7	0.09	53.4	10.4	-4.5	0.085	19.5%
8	0.11	65.9	11.5	-4.6	0.077	17.4%
9	0.11	85.2	14.9	-5.9	0.126	17.5%
10	0.13	97.5	14.5	-6.3	0.059	14.8%
11	0.15	143.5	19.6	-7.8	0.032	13.6%
12	0.15	147.2	20.1	-8.3	0.136	13.7%
13	0.14	115.0	15.8	-5.7	0.061	13.7%
14	0.17	160.6	18.9	-8.0	0.051	11.8%
15	0.13	78.5	12.0	-3.9	0.004	15.3%
16	0.20	321.5	34.2	-9.4	0.01	10.7%
Average	**0.12**	**106.2**	**17.3 ± 1.1**	**-6.7 ± 1**		**16.3 ± 1.7**

The GreenFan® EFC™ requires extra fan energy to recover and deliver additional sensible cooling or heating capacity from the HVAC system evaporator or heat exchanger to improve cooling or heating efficiency, lengthen off-cycles, and save cooling or heating energy. For cooling, the average fan energy increase per cycle with the GreenFan® EFC™ is 0.018 ± 0.002 kWh or 17.8 ± 1.6% of cooling savings (i.e., 1 unit of extra fan energy provides 5.6 ± 0.5 units of cooling energy savings). For gas furnace heating, the average extra fan energy per cycle with the GreenFan® EFC™ is 0.026 ± 0.006 kWh or 12.1 ± 2% of heating savings (i.e., 1 unit of extra fan energy provides 8.2 ± 1.4 units of heating energy savings).[31] For gas furnace heating, the average low-to-high airflow increase was 18% and the average medium-to-high airflow increase was 6.2%. Increasing airflow to high speed during furnace operation supplies more heating capacity to satisfy the space heating thermostat sooner, reduce furnace operation, and save gas energy. For heat pump heating, the average fan energy increase per cycle with the GreenFan® EFC™ is 0.006 ± 0.0004 kWh or 9.2 ± 1.2% of heating savings (i.e., 1 unit of extra fan energy provides 10.9 ± 0.68 units of heating energy savings). For hydronic heating, the average fan energy increase per cycle with the GreenFan® EFC™ is 0.0095 ± 0.0006 kWh or 11.1 ± 1.4% of heating savings (i.e., 1 unit of extra fan energy provides 9.04 ± 0.57 units of heating energy savings).[32]

[31] The EFC™ extra fan energy for heating is valued at 10,354 Btu/kWh based on natural gas electricity generation. US Energy Information Agency (EIA) 2013. Average Tested Heat Rates by Prime Mover and Energy Source, 2007-2013. https://www.eia.gov/electricity/annual/html/epa_08_02.html).

[32] The EFC™ extra fan energy for heating is valued at 10,354 Btu/kWh based on natural gas electricity generation. US Energy Information Agency (EIA) 2013. Average Tested Heat Rates by Prime Mover and Energy Source, 2007-2013. https://www.eia.gov/electricity/annual/html/epa_08_02.html).

3. Load Shapes

Load shapes for the EFC™ measure in this work paper are listed in the table below.

Table 69: 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

4. Costs

The measure costs are based on working with contractors throughout California who have installed more than 59,000 patented EFC™ units from 2012 through 2016.

4.1 Base Case Cost

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

4.2 Measure Case Cost

Previous workpapers provided a measure equipment material cost based on below-market prices for unlicensed products (the trademarked EFC™ is protected by US 8763920 and US 9328933 and US 9500386). The authentic patented EFC™ measure cost is $50 per unit with discounts based on purchased quantities. The EFC™ material cost is normalized on a per-ton basis using the average rated capacities of the HVAC systems in the DEER eQuest models for SFM and DMO and MFM only (which costs less due to less travel time). The rated capacity for SFM is 3.94 and DMO is 3.5 tons and the combined average rated capacity for SFM and DMO is 3.72 tons. The rated capacity for MFM is 2 tons. The average equipment cost is $13.44 per ton for SFM and DMO and $25 per ton for MFM. The labor cost is based on installing more than 59,000 patented EFC™ units from 2012 through 2016. The base labor rate is $90 per hour for the residential HVAC based on surveys of 20 participating HVAC contractors. EFC™ installation for SFM and DMO takes 25 minutes plus 41.67 minutes for travel time (roundtrip), so the estimated labor cost is $100. Normalized per ton, the SFM and DMO measure labor cost is $26.88 per ton. EFC™ installation for MFM takes 25 minutes plus 8.33 minutes of average travel time (5 units installed per trip 41.67/5=8.33), so the estimated labor cost for MFM is $50 and the normalized labor cost is $25 per ton.

SMF and DMO Measure Case Cost = MEC + MLC = $50+ $100 = $150/unit
SFM and DMO Measure Cost per ton = MEC + MLC = $13.44+ $26.88 = $40.32/ton

MFM Measure Case Cost = MEC + MLC = $50+ $50 = $100/unit
MFM Measure Cost per ton = MEC + MLC = $25+ $25 = $50/ton

4.3 Full and Incremental Measure Cost

The full and incremental measure costs are provided in the following tables.

Table 70: Full and Incremental Measure Cost Equations

Installation Type	Incremental Measure Cost	Full Measure Cost	
		1st Baseline	2nd Baseline
REA (SFM and DMO)	MEC + MLC	MEC + MLC	N/A
REA (MFM)	MEC + MLC	MEC + MLC	N/A

MEC = Measure Equipment Cost; MLC = Measure Labor Cost
BEC = Base Case Equipment Cost; BLC = Base Case Labor Cost

Table 71: Full and Incremental Costs

Measure	Installation Type	Incremental Measure Cost	Full Measure Cost	
		1st Baseline	1st Baseline	2nd Baseline
	REA (SFM and DMO)	$150 per unit	MEC + MLC	N/A
	REA (SFM and DMO)	$40.32 per ton	MEC + MLC	N/A
	REA (MFM)	$100 per unit	MEC + MLC	N/A
	REA (MFM)	$50 per ton	MEC + MLC	N/A

5. Conclusions

The following conclusions are provided regarding the performance evaluation tests of the patented GreenFan® EFC™ installed on a 3-ton split-system HVAC unit, 3-ton packaged unit, 1.5 ton heat pump, and 1.5-ton hydronic heating unit.

Based on responses from 68 participants to the participant survey, the EFC™ NTGR is 0.98 +/- 0.02. Based on evidence provided by the survey responses and site inspections, the DEER default 0.85 NTGR "null hypothesis" can be rejected since it is less than the lower bound 0.96 NTGR. Nevertheless, for this workpaper the DEER default 0.85 NTGR for Emerging Technologies is used in this workpaper for cost effectiveness calculations. Based on responses from 68 randomly selected participants with the EFC™ installed for approximately 5 years, the overall customer satisfaction score was 94 +/- 2.8% in terms of providing more comfortable space heating and cooling.

Based on the 5-year retention study findings from 68 site inspections with survey code data the median estimated EUL and RUL for the EFC™ is 8.4 years with an 80% lower bound estimate of 6.8 years and 80% upper bound estimate of 10.6 years. Previous workpapers provided a 5-year ex-ante EUL for the cooling-only enhanced time delay based on one-third of the estimated EUL for HVAC equipment. Based on the retention survey data from 68 randomly selected site inspections, the "null hypothesis" can be rejected since the *ex ante* 5-year EUL estimate is less than the lower bound 80 percent effective useful life of 6.8 years. For this workpaper the EFC™ EUL and RUL are rounded down to the nearest integer and established at 8 years for the E3 cost effectiveness calculations.

Based on 48 cooling tests performed by Intertek, the GreenFan® EFC™ improves sensible cooling efficiency by 3 to 72.5% and provides cooling energy savings of 19.9 +/- 3.9% compared to zero, 30, 60, 65, and 90-second fan-off time delays. Based on hourly building energy simulations of residential single-family, multi-family, and mobile home prototypical buildings across 16 California climate zones, the average annual cooling energy savings are 15.1 ± 1.2%.

Previous SCE and PG&E workpapers provided cooling energy savings for a cooling-only enhanced time delay measure based on the 2012 SCE laboratory test report of the Efficient Fan Controller®.[33] The SCE 2012 laboratory report represents the ex ante "null hypothesis" which is presumed to be true until a preponderance of evidence is provided to nullify it for an alternative hypothesis. The SCE laboratory tests provided average annual residential single-family cooling kWh savings estimates that are 86% greater than this workpaper. The specific cooling energy savings per PLR are 2 times greater than specific savings PLR based on the Intertek laboratory tests. If SCE had used average measured sensible PLR values based on the SCE test data, then the SCE PLR values and energy savings estimates would be much closer to the values provided in this workpaper. Based on a preponderance of evidence regarding use of average sensible PLR values and the Intertek laboratory test data regarding the performance evaluation of the EFC™, the "null hypothesis" can be rejected and the alternative hypothesis of measured sensible PLR values, regression equations, and cooling energy savings provided in this workpaper are recommended for the use in California residential energy efficiency programs.

Based on 48 gas furnace heating tests performed by Intertek, the GreenFan® EFC™ improved heating efficiency by 5.5 to 26.5% and provides heating savings of 5.3 to 21% compared to low- or medium-speed fan operation and fixed 120-second time delay.[34] The EFC™ improved heating efficiency by 4.2 to 54.7% and provides heating savings of 4.2 to 29.9% compared to medium-speed fan operation with a 45- or 120-second fan-off time delay.[35] Based on hourly building energy simulations of residential single-family, multi-family, and mobile home prototypical buildings across 16 California climate zones, the average annual heating energy savings are 16.1 ± 0.6%.

Based on 48 heat pump heating tests performed by Intertek, the GreenFan® EFC™ improved heating efficiency by 3 to 163.6% and provides energy savings of 19 +/- 3.8% compared to zero or 65-second fan-off time delays.[36] Based on hourly building energy simulations of residential single-family, multi-family, and mobile home prototypical buildings across 16 California climate zones, the average annual heat pump heating savings are 13.3 ± 1.1%.

Based on 20 hydronic heating tests performed by Intertek, the GreenFan® EFC™ improved heating efficiency by 3.1 to 197.1% and provides energy savings of 22.7 +/- 7% compared to zero or 60-

[33] SCE. 2012. Workpaper SCE13HC052 Efficient Fan Controller for Residential Air Conditioners. SCE 2014. Work Paper SCE15HC052. Efficient Fan Controller for Residential Air Conditioners and Furnaces. PG&E. 2014. Work Paper PGE3PHVC150 R2 Enhanced Time Delay Relay, PG&E. 2016. Work Paper PGE3PHVC15. R4 Enhanced Time Delay Relay, http://www.deeresources.net/workpapers

[34] Appendix A, Table 6 provides 8-minute furnace tests 13/14 at low-to-high fan speed with efficiency improvement of 26.5% and Table 12 provides 30-minute furnace tests 49/50 with efficiency improvement of 5.5%.

[35] Appendix A, Table 14 provides 7-minute furnace tests 63/64 at medium fan speed with efficiency improvement of 54.7% and Table 13 provides 30-minute furnace tests 57/58 at medium fan speed with efficiency improvement of 4.3%.

[36] Appendix B, Table 10 provides 2-minute heat pump heating test 137 with efficiency improvement of 163.6% and Table 11 provides 50-minute heat pump heating test 148 with efficiency improvement of 3%.

second fan-off time delay.[37] Based on hourly building energy simulations of residential multi-family prototypical buildings across 16 California climate zones, the average annual heat pump heating savings are 15.7 ± 1%.

The average total resource cost-effectiveness (TRC) test is 3.29 +/- 0.26 for the GreenFan® EFC™ based on E3 calculations with the following inputs: 0.85 NTGR, retention study findings supporting an 8-year EUL, laboratory test data providing energy savings as a function of part load ratio (PLR), and energy and peak demand savings for 170 residential single-family, multi-family, and mobile home based on DEER eQuest prototypical building energy simulations across 16 climate zones. The EFC™ is cost effective for all double-wide mobile home (DMO) prototypes and climate zones. The EFC™ is cost effective for all single family (SFM) prototypes and climate zones except the residential gas furnace (RGF-only) prototype in climate zone 15. The EFC™ is cost effective for all multi-family (MFM) prototypes and climate zones except the RGF-only prototype in climate zones 6, 7, 8, and 15. The EFC™ can be cost-effectively installed on direct-expansion cooling and gas furnace or heat pump heating or forced-air hydronic heating systems with no fan-off time delay, fixed fan-off time delay, or cooling-only enhanced fan-off time delay. For most prototypes and climate zones the EFC™ is cost effective to be installed where a pre-existing cooling-only enhanced time delay is already installed. The EFC™ provides cost effective cooling and heating savings in all residential buildings and climate zones to help achieve California's 40% energy savings goal by 2020 per AB 350.[38]

6. Attachments

1. EFC_2017_Workpaper_Calculations.xlsx (**proprietary data available upon request**)

2. EFC_RAC_and_RHP_SFM_Results_v4.xlsx (**proprietary data available upon request**)

3. EFC_RAC_and_HP_MFM_Results_v4.xlsx (**proprietary data available upon request**)

4. EFC_ RAC_and_HP_DMO_Results_v4.xlsx (**proprietary data available upon request**)

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ARI Standard 210/240 2003. Air Conditioning and Refrigeration Institute, Table 3, page 6. (pdf Document: Pages from ARISEER.pdf)

[37] Appendix B Table 16 provides 2-minute hydronic heating test 173 with efficiency improvement of 197.1% and Table 17 provides 50-minute hydronic heating test 184 with an efficiency improvement of 3.1%.

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Appendix A: Performance Evaluation Based on Intertek Test Data of the GreenFan® EFC™ Installed on Split and Packaged Air Conditioners with Gas Furnaces

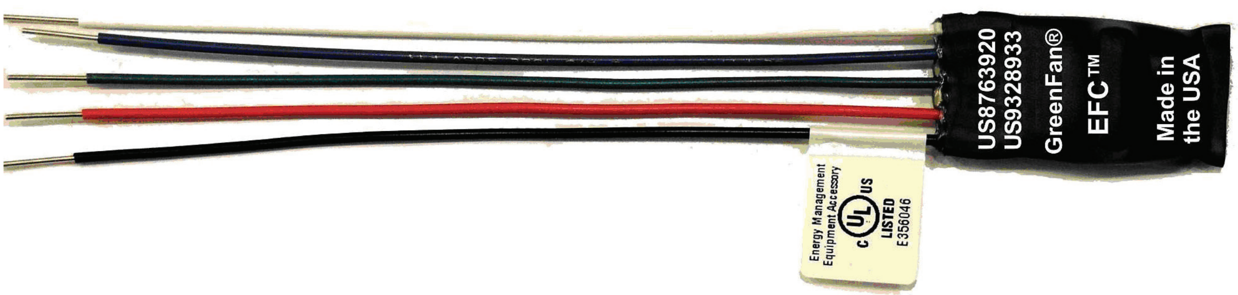
PERFORMANCE EVALUATION BASED ON INTERTEK TEST DATA OF THE GREENFAN® EFC™ INSTALLED ON SPLIT AND PACKAGE AIR CONDITIONERS WITH GAS FURNACES

08/04/2015 Intertek Project No. G101756555
Revised 12-12-16

Report Scope:
This report summarizes the performance evaluation of the GreenFan®, Inc., variable time delay Efficient Fan Controller™ (EFC™) fan controller product installed on a 13-SEER 3-ton split-system air conditioner and a 13 SEER 3-ton packaged unit. Both units have an 80% AFUE rated gas furnace. Testing was conducted at the Intertek® laboratory in Plano, Texas under the direction of Ean Jones and Robert Mowris. Testing was performed by Intertek technicians managed by Gilbert Taracena and Craig Grider.

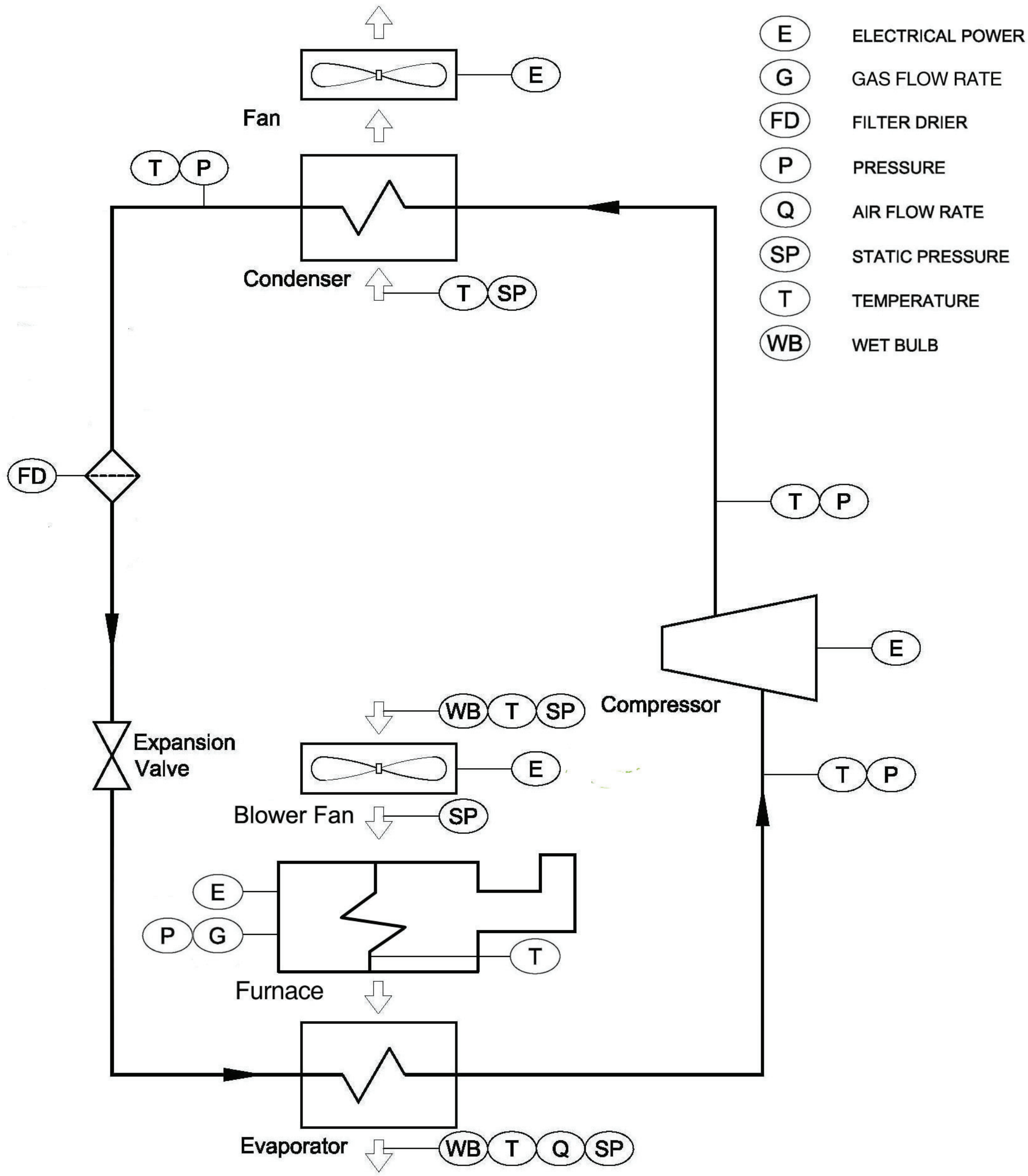
Product Description as Tested:
The GreenFan® EFC™ product shown in **Figure 1** is a microprocessor-based device that monitors the duration of either the air conditioning compressor or furnace operation and varies the duration of the indoor evaporator or furnace fan operation depending on the length of time the air conditioner compressor or furnace operated (referred to as “time delay”). For existing systems in heating mode after four minutes of furnace operation, the GreenFan® EFC™ is designed to increase fan speed from low-to-high or medium-to-high speed and deliver more heating capacity using the same amount of natural gas input and slightly more fan energy. For a given heating load, the GreenFan® EFC™ reduces gas use by delivering increased heating capacity for the same amount of gas input to satisfy the space heating thermostat sooner and extend furnace off time. The GreenFan® EFC™ activates the fan signal from the thermostat as though the fan switch was toggled to the "on" position. If the default fan speed controlled by the fan switch is set to the same speed as heating, then the GreenFan® will only save heating energy based on extended fan operation after the furnace turns off (see **Table 13** and **Table 14**). Increasing airflow to high speed during furnace operation supplies more heating capacity to satisfy the space heating thermostat sooner, reduce furnace operation, and save gas energy. The GreenFan® EFC™ improves HVAC efficiency and saves energy by providing longer variable fan-off time delays based on HVAC system type, mode of operation, and cooling or heating operational time. The EFC™ recovers and delivers more sensible cooling or heating capacity to the space to exceed thermostat setpoint temperatures, lengthen off-cycles, and reduce on-cycles.

Figure 1: GreenFan® EFC™ Product



Description of Test Units
The test equipment schematic is shown in **Figure 2**. The characteristics of the test units are described in **Table 1**. The rated cooling capacity of the 3-ton split-system HVAC unit is 33,800 Btu per hour and the rated heating capacity is 54,000 Btu per hour. The 3-ton split-system default cooling time delay is either 0 seconds or 90 seconds after the air conditioning compressor turns off, and the default heating time delay is 120 seconds after the furnace turns off. The rated cooling capacity of the 3-ton packaged HVAC unit is 35,800 Btu per hour and the rated heating capacity is 55,200 Btu per hour. The 3-ton packaged unit default cooling time delay is either 0 seconds or 60 seconds after the air conditioning compressor turns off, and the heating time delay is 120 seconds after the furnace turns off. The GreenFan® fan-off time delay varies depending on system type, mode of operation, and length of time the cool source or heat source operate.

Figure 2: Test Equipment Schematic



PERFORMANCE EVALUATION BASED ON INTERTEK TEST DATA OF THE GREENFAN® EFC™ INSTALLED ON SPLIT AND PACKAGE AIR CONDITIONERS WITH GAS FURNACES

Table 1: Description of Test Units – 3-ton Split-System HVAC Unit and 3-ton Packaged Unit

Unit Description	3-ton Split-System HVAC Unit	3-ton Packaged HVAC Unit
ID Model Number	CNRHP3617ATA	GPG1336070M41BA
Input Voltage	208/230 VAC	208/230 VAC
Input Frequency	60 HZ	60 HZ
Phase	1 Phase	1 Phase
Type	Ducted Evaporator	Packaged Unit
Rated Cooling Capacity	33800 Btu/hr 1200 scfm at 0.5 IWC	35800 Btu/hr 1188 scfm at 0.5 IWC
OD Model Number	24ABS336A300	GPG1336070M41BA
Fan Speed and RPM	Low 1050, Medium 1080, High 1100 RPM	Low 850, Medium 980, High 1040 RPM
Fan Time Delay Cooling	0 or 90 seconds Cooling	0 or 60 seconds Cooling
Fan Time Delay Heating	120 seconds Heating	120 seconds Heating
Frequency and Phase	60 HZ and Single Phase	60 HZ and Single Phase
Refrigerant Charge	R22 86.4 Ounces	R410A 70 Ounces
Type	Air Cooled Condenser	Air Cooled Condenser
Furnace Model Number	58STA070-12	GPG1336070M41BA
Rated Heating Capacity	54000 Btu/hr 1140 scfm at 0.5 IWC	55200 Btu/hr and 1073 scfm @ 0.5 IWC

Location and Dates of Tests:
Tests were performed at the Intertek Laboratory in Plano, Texas, from 01/05/2015 through 01/17/15.

Test Methods:
Each unit was tested under AHRI 210/240 test conditions and ANSI Z21.47 to verify manufacturer published efficiency ratings. The AHRI 210/240 cooling verification tests were performed according to ANSI/AHRI 2008 Standard for Performance Rating of Unitary Air-Conditioning and Air-Source Heat Pump Equipment Standard 210/240. Verification tests were conducted according to **Table 2** (ANSI/AHRI Standard 210/240-2008, Table 11) and **Table 3**.[1] Thermal Efficiency verification tests were performed according to ANSI Z21.47-5th Edition 2006/CSA 2.3-5th Edition 2006.[2]

Each unit was tested in cooling mode under non-steady state field conditions to measure sensible cooling capacity and efficiency with no time delay or fixed time delay of 60 seconds for the packaged unit or 90 seconds for the split-system after the air conditioning compressor turned off. Non-steady state cooling tests were performed with the patented GreenFan® product providing a variable time delay on the

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[1] ANSI/AHRI 2008 Standard for Performance Rating of Unitary Air-Conditioning and Air-Source Heat Pump Equipment Standard 210/240. American National Standards Institute. Air-Conditioning Heating and Refrigeration Institute.
[2] ANSI Z21.47-5th Edition 2006/CSA 2.3-5th Edition 2006– Standard for Gas-Fired Central Furnaces. American National Standards Institute.

evaporator fan depending on length of time the compressor operated.

Each unit was tested in heating mode under non-steady state field conditions to measure the sensible heating capacity and efficiency with fixed time delay of 120 seconds after the gas furnace turned off. Non-steady state heating tests were performed with the patented GreenFan® product providing increased fan speed from low-to-high or medium-to-high speed after 4 minutes of furnace operation and variable time delay on the fan after the furnace turns off depending on length of time the furnace operated.

Non-steady state testing of GreenFan® did not include an evaluation of SEER or AFUE impacts.

Table 2: ANSI/AHRI 210/240 Table 11. Minimum External Static Pressure for Ducted Systems Tested with an Indoor Fan Installed

Table 11. Minimum External Static Pressure for Ducted Systems Tested with an Indoor Fan Installed

Rated Cooling(1) or Heating(2) Capacity		Minimum External Resistance(3)			
		All Other Systems		Small-Duct, High-Velocity Systems(4,5)	
Btu/h	kW	in H_2O	Pa	in H_2O	Pa
Up thru 28,800	Up thru 8.44	0.10	25	1.10	275
29,000 to 42,500	8.5 to 12.4	0.15	37	1.15	288
43,000 and Above	12.6 thru 19.0	0.20	50	1.20	300

(1) For air conditioners and heat pumps, the value cited by the manufacturer in published literature for the unit's capacity when operated at the A or A_2 Test conditions.
(2) For heating-only heat pumps, the value the manufacturer cites in published literature for the unit's capacity when operated at the H1 or $H1_2$ Test conditions.
(3) For ducted units tested without an air filter installed, increase the applicable tabular value by 0.08 in H_2O [20 Pa].
(4) See Definition 1.35 of Appendix C to determine if the equipment qualifies as a small-duct, high-velocity system.
(5) If a closed-loop, air-enthalpy test apparatus is used on the indoor side, limit the resistance to airflow on the inlet side of the indoor blower coil to a maximum value of 0.10 in H_2O [25 Pa]. Impose the balance of the airflow resistance on the outlet side of the indoor blower.

Table 3: ANSI/AHRI 210/240 Table 3. Cooling Mode Test Conditions

Table 3. Cooling Mode Test Conditions for Units Having a Single-Speed Compressor and a Fixed-Speed Indoor Fan, a Constant Air Volume Rate Indoor Fan, or No Indoor Fan

Test Description	Air Entering Indoor Unit Temperature				Air Entering Outdoor Unit Temperature				Cooling Air Volume Rate
	Dry-Bulb		Wet-Bulb		Dry-Bulb		Wet-Bulb		
	°F	°C	°F	°C	°F	°C	°F	°C	
A Test - required (steady, wet coil)	80.0	26.7	67.0	19.4	95.0	35.0	75.0[1]	23.9[1]	Cooling Full-load [2]
B Test - required (steady, wet coil)	80.0	26.7	67.0	19.4	82.0	27.8	65.0[1]	18.3[1]	Cooling Full-load [2]
C Test - optional (steady, dry coil)	80.0	26.7	[3]		82.0	27.8	–		Cooling Full-load [2]
D Test - optional (cyclic, dry coil)	80.0	26.7	[3]		82.0	27.8	–		[4]

Notes:

(1) The specified test condition only applies if the unit rejects condensate to the outdoor coil.
(2) Defined in section 6.1.3.3.1.
(3) The entering air must have a low enough moisture content so no condensate forms on the indoor coil. (It is recommended that an indoor wet-bulb temperature of 57.0 °F [13.9 °C] or less be used.)
(4) Maintain the airflow nozzles static pressure difference or velocity pressure during the ON period at the same pressure difference or velocity pressure as measured during the C Test.

Test Matrix:
A Test - required (steady, wet-coil)
A Test - customer specified scheduled airflow at 0.4” WC
B Test - required (steady, wet-coil)
C Test - optional (steady, dry-coil)
D Test - optional (cyclic, dry-coil)

Test Equipment Calibration
The psychrometric room is designed to ASHRAE 37 specifications. Calibration for all equipment on this facility is completed annually, and is maintained under one Intertek ID number. Individual calibration records can be made available upon request. All calibration is conducted in accordance to ISO 17025 requirements by an ILAC accredited calibration provider. Intertek gas furnace heating equipment performance and AFUE tests are performed per ANSI Z21.47 specifications.

AHRI and ANSI Performance Evaluation Results
AHRI and ANSI steady-state test parameters and results are summarized in **Figure 3** through **Figure 6**. Detailed test data and results are on file at Intertek.

GreenFan® Performance Evaluation Results
The baseline and GreenFan® non-steady state test parameters and test results for the 3-ton split-system and 3-ton packaged unit in cooling and heating mode are summarized in **Table 4** through **Table 14** and **Figure 7** through **Figure 17**. Detailed test data and results are on file at Intertek.

Figure 3: AHRI 210/240 Performance Baseline Test of the 3-ton Split System Air Conditioner in Cooling Mode

Intertek

SEASONAL ENERGY EFFICIENCY RATIO (SEER) Version C, 2012-02-08, TRS

Section 4.1.1

DOE 10 CFR 430 Appendix M, AHRI 210/240 - 2006

PROJECT / UUT INFORMATION

Client:	GreenFan, Inc.		Manufacturer:	NA	
Project:	GreenFan, Inc.		Model:	24ABS336A003	
Task:	SEER		Serial Number:	3309E02884	
Compressor Type:	Single-Speed	[-]	Blower Type:	Fixed-Speed	[-]
	12.35				
	13.00				

TEST DATA

Test	ID Condition [DB / WB]	OD Condition [DB / WB]		Capacity) [Btu/hr]	Power [W]	Test Report Filename [*]
A	80 / 67	95 / 75*	Req	35607	3163	318-2 A
B	80 / 67	82 / 65*	Req	36889	2794	318-2 B
C	80 / < 57	82 / 65*	Opt	33374	2763	318-2 C
D	80 / < 57	82 / 65*	Opt	Cd =	0.087	318-2 D

SEER CALCULATION

Bin#	Tj	nj/N	BL(Tj)	Speed	qc(Tj)/N	ec(Tj)/N
1	67	0.214	-	-	-	-
2	72	0.231	-	-	-	-
3	77	0.216	-	-	-	-
4	82	0.161	-	-	-	-
5	87	0.104	-	-	-	-
6	92	0.052	-	-	-	-
7	97	0.018	-	-	-	-
8	102	0.004	-	-	-	-
				Totals:	0.00	0.00

		% Rated	% Minimum
SEER:	12.63	97.14%	102.26%

Figure 4: ANSI Z21.47 Thermal Efficiency Performance Baseline Test of the 3-ton Split System Air Conditioner in Heating Mode

Intertek

Thermal Efficiency Test - ANSI Z21.47

Date	Manufacturer	Model	Test Number	Report Number
January 29, 2015	NA	58STA070-12	G101756555	101756555DAL-005B

Unit Type:	Nameplate Input, Btu/hr.	Certified Input, Btu/hr.	Tested Input, Btu/hr.	Input Deviation
Furnace	66,000	66,000	64927.11	1.63%

Type	Certified Thermal Efficiency Rating		Efficiency Deviation
Single Stage	80	82.10	-2.63%

Report Prepared by

Report Reviewed by

Humidity	Barometric	Flue/duct	Gas Manifold	Gas Line	Volts	Amps	Watts	Hertz	Calorimeter
28.9	29.81	0.322	3.96	7.03	115	4.99	482	60	994.02

Oxygen	CO	CO2	Air Free	Flow CFH	Flow Total	Flow Cycle	Heating Input	Flue Temp	Ambient
7.28	37	7.66	57.48	-	-	-	64927.11	355.29	79.41

Air required for complete combustion, SCF per 1,000 Btu of gas burned;
A = 9.4

Carbon Dioxide in flue gases, percent of total dry constituents in the flue gases
C = 7.66

Relative humidity of air supplied for combustion, percent/100;
h = 0.289

Dry Constituents in flue gases from stoichiometric combustion, SCF per 1,000 Btu of gas burned;
P = 8.47

Total constituents in flue gases from stoichiometric combustion, SCF per 1,000 Btu of gas burned;
T = 10.42

Flue gas temperature, degree R;
Tf = 887.74

Room temperature, degree R;
Tr = 611.86

Ultimate carbon dioxide of flue gas, percent;
U = 11.9

Cubic Feet	CF (f^3)		1
Time	min	0 sec	53.77
Gas pressure	in. wc		7.02
Ambient Pressure	in. Hg		29.81
Current Gas Temperature	°F		77.9
Calibrated Atmospheric Pressure	in. Hg		30.00
Calibrated Gas Temperature	°F		60.00
Manifold Pressure	in. wc		3.97

Calorimeter Reading	994.90
Correction Factor	0.9975
BTU/hr	64927.11
Manufacture Declared BTU/hr	66000.00
Percentage	1.63%

V1	66.95	CFH
P1	14.90	PSIA
T1	537.57	°F
V2	65.26	CFH
P2	14.73	PSIA
T2	519.67	°F

KEY
T1 - Current Gas Temperature (Rankines)
T2 - Calibrated Gas Temperature (Rankines)
V1- Clocked cf/h (meter)
V2- Calculated cf/h
P1- Current Ambient Pressure + Gas pressure (meter)
P2- Calibrated Atmospheric Pressure

Gas Meter	
ID# 1205	
Calibration Conditions	
°F	60
inHg	30

Figure 5: AHRI 210/240 Performance Baseline Test of the 3-ton Packaged Air Conditioner in Cooling Mode

Intertek

SEASONAL ENERGY EFFICIENCY RATIO (SEER) Version C, 2012-02-08, TRS

Section 4.1.1

DOE 10 CFR 430 Appendex M, AHRI 210/240 - 2006

PROJECT / UUT INFORMATION

Report Number:			AHRI Number:	NA	
Client:	GreenFan, Inc.		Manufacturer:	NA	
Project:			Model:	GPG1336070M41BA	
Task:	Seer Calculation		Serial Number:	1412149903	
Compressor Type:	Single-Speed	[-]	Blower Type:	Fixed-Speed	[-]
Minimum SEER:	12.35	[-]			
Rated SEER:	13	[-]			

TEST DATA

Test	ID Condition [DB / WB]	OD Condition [DB / WB]		Capacity) [Btu/hr]	Power [W]	Test Report Filename [*]
A	80 / 67	95 / 75*	Req	-	-	
B	80 / 67	82 / 65*	Req	39031	2968	
C	80 / < 57	82 / 65*	Opt	-	-	
D	80 / < 57	82 / 65*	Opt	Cd =	0.026	

SEER CALCULATION

Bin#	Tj	nj/N	BL(Tj)	Speed	qc(Tj)/N	ec(Tj)/N
1	67	0.214	-	-	-	-
2	72	0.231	-	-	-	-
3	77	0.216	-	-	-	-
4	82	0.161	-	-	-	-
5	87	0.104	-	-	-	-
6	92	0.052	-	-	-	-
7	97	0.018	-	-	-	-
8	102	0.004	-	-	-	-
				Totals:	0.00	0.00

		% Rated	% Minimum
SEER:	**12.98**	99.84%	105.10%

Figure 6: ANSI Z21.47 Thermal Efficiency Performance Baseline Test of the 3-ton Packaged Air Conditioner in Heating Mode

Intertek

Thermal Efficiency Test - ANSI Z21.47

Date	Manufacturer	Model	Test Number	Report Number
February 25, 2015	NA	GPG1336070M41BA	G101756555`	101756555DAL-005D

Unit Type:	Nameplate Input, Btu/hr.	Certified Input, Btu/hr.	Tested Input, Btu/hr.	Input Deviation
Furnace	69,000	69,000	68573.00	0.62%
Type	Certified Thermal Efficiency Rating			Efficiency Deviation
Single Stage	80	81.04		-1.30%

Report Prepared by — Report Reviewed by

Humidity (%RH)	Barometric (inHg)	Flue/duct (inWC)	Gas Manifold (inWC)	Gas Line (inWC)	Volts	Amps	Watts	Hertz	Calorimeter (BTU/ft³)
21.53	29.45	0.39	3.94	8.15	230	1.68	379	60	997.61

Oxygen %	CO PPM	CO2 %	Air Free CO PPM	Flow CFH	Flow Total	Flow Cycle	Heating Input (BTU/hr)	Flue Temp (F)	Ambient (F)
8.21	8.1	7.22	13.19				68573	369.56	72.35

Air required for complete combustion, SCF per 1,000 Btu of gas burned;
A = 9.4
Carbon Dioxide in flue gases, percent of total dry constituents in the flue gases
C = 7.22
Relative humidity of air supplied for combustion, percent/100;
h = 0.2153
Dry Constituents in flue gases from stoichiometric combustion, SCF per 1,000 Btu of gas burned;
P = 8.47
Total constituents in flue gases from stoichiometric combustion, SCF per 1,000 Btu of gas burned;
T = 10.42
Flue gas temperature, degree R;
Tf = 902.01
Room temperature, degree R;
Tr = 604.8
Ultimate carbon dioxide of flue gas, percent;
U = 11.9

Cubic Feet	CF (f³)			1
Time	min	0	sec	52.72
Gas Meter Type	Dry			
Gas pressure	in. wc			8.13
Ambient Pressure	in. Hg			29.46
Current Gas Temperature	°F			76.26
Calibrated Atmospheric Pressure	in. Hg			30.00
Calibrated Gas Temperature	°F			70.00
Manifold Pressure	in. wc			3.95

Calorimeter Reading	996.54
Correction Factor	0.9977
HHV (Saturated or Dry)	Saturated
BTU/hr	68573.79
Manufacture Declared BTU/hr	69000.00
Percentage	0.62%

PERFORMANCE EVALUATION BASED ON INTERTEK TEST DATA OF THE GREENFAN® EFC™ INSTALLED ON SPLIT AND PACKAGE AIR CONDITIONERS WITH GAS FURNACES

Sensible Cooling and Heating Capacity and Efficiency Calculations

Sensible cooling and heating capacity for the split-system or packaged HVAC systems with either no time delay or fixed time delay and GreenFan® variable time delay are measured in British thermal units (Btu).[3] The sensible cooling capacity is based on the measured airflow rate in standard cubic feet per minute (cfm), specific volume (ft^3/lbm), and temperature difference in degrees Fahrenheit (F) between the return air entering the evaporator and the supply air leaving the evaporator. **Equation 1** is used to calculate the non-steady state sensible cooling capacity for the air conditioner.

Equation 1 $$Q_{sc} = \sum_{t=0}^{n} q_{sc_t} \left[\frac{t}{3600} \right]$$

Where, Q_{sc} = non-steady-state sensible cooling capacity for the air conditioner (Btu),

t = time measurement interval (5 seconds),

n = number of measurement intervals for test (integer),

$q_{sc_t} = c_p (T_r - T_s) \frac{\dot{V}}{\nu} \left[\frac{60\,\text{min}}{hr} \right]$ = non-steady state cooling capacity per time interval (Btu/hr),

c_p = specific heat of dry air at constant pressure = 0.24 Btu/lbm-°F,

T_r = drybulb temperature of return air entering the evaporator coil (F),

T_s = drybulb temperature of supply air leaving the evaporator coil (F),

$\dot{V}$ = volumetric airflow rate in cubic feet per minute (cfm), and

ν = specific volume per pound of dry air (ft^3/lbm).

The non-steady-state sensible cooling efficiency (η_{sc}) is defined as the sensible cooling capacity (Btu/hr) divided by the electric power consumption (Watts) of the air conditioner (including compressor, fans, and controls). **Equation 2** is used to calculate the non-steady-state sensible cooling efficiency.

Equation 2 $$\eta_{sc} = \sum_{t=0}^{n} \frac{q_{sc_t}}{e_t}$$

Where, η_{sc} = non-steady-state sensible cooling efficiency (Btu/Watt-hour or Btu/Wh), and

e_t = electric power consumption per time interval for the air conditioner (Wh).

Non-steady state cooling tests were performed with no time delay or fixed time delay and GreenFan® variable time delay to measure the sensible cooling capacity and efficiency. The non-steady-state sensible cooling capacity improvement for the GreenFan EFC™ is calculated using **Equation 3**.

Equation 3 $$\Delta Q_{sc} = \left[\frac{Q_{sc_g}}{Q_{sc_o}} - 1 \right] 100$$

Where, ΔQ_{sc} = sensible cooling capacity improvement with GreenFan® EFC™ (%),

Q_{sc_g} = sensible cooling capacity with GreenFan® (Btu), and

Q_{sc_o} = baseline sensible cooling capacity without GreenFan® (Btu).

The non-steady-state sensible cooling efficiency improvement for the GreenFan EFC™ is calculated

[3] The British thermal unit (Btu) is heat required to raise the temperature of one pound of water one degree Fahrenheit (°F). The Btu is equivalent to 1055.06 joules or 251.997 calories.

using **Equation 4**.

Equation 4 $$\Delta\eta_{sc} = \left[\frac{\eta_{sc_g}}{\eta_{sc_o}} - 1\right] 100$$

Where, $\Delta\eta_{sc}$ = sensible cooling efficiency improvement with GreenFan® EFC™ (%),

η_{sc_g} = sensible cooling efficiency with GreenFan® (Btu/Wh), and

η_{sc_o} = sensible cooling efficiency without GreenFan® (Btu/Wh).

The baseline cooling energy to match the GreenFan® EFC™ sensible cooling capacity is calculated using **Equation 5**.

Equation 5 $$E_{c_m} = \left[\frac{Q_{sc_g}}{\eta_o (1000\ W/kW)}\right]$$

Where, E_{c_m} = baseline energy required to match GreenFan® EFC™ cooling capacity (kWh),

Q_{sc_g} = sensible cooling capacity with GreenFan® (Btu), and

η_o = baseline sensible efficiency without GreenFan® (Btu/Wh).

Cooling energy savings with the GreenFan® EFC™ are achieved by providing longer variable fan-off time delays based on cool source operational time to recover and supply more sensible cooling to the space to exceed the thermostat setpoint temperature and lengthen air conditioning off-cycles producing fewer cooling on-cycles. The cooling energy savings are calculated using **Equation 6.** This is the energy required by the baseline system to match the extra cooling capacity supplied with the GreenFan® EFC™ minus energy consumption with the GreenFan® EFC™.

Equation 6 $$\Delta E_c = E_{c_m} - E_{c_g} = \frac{Q_{c_g} - Q_{c_o}}{\eta_{sc_o} (1000\ \text{W/kWh})} + E_{c_o} - E_{c_g}$$

Where, ΔE_c = cooling energy savings with GreenFan® EFC™ compared to baseline (kWh),

Q_{c_o} = cooling capacity supplied by baseline system (Btu),

Q_{cg} = cooling capacity supplied with GreenFan® EFC™ (Btu),

E_{c_o} = baseline energy consumption (kWh), and

E_{c_g} = energy consumption with GreenFan® EFC™ (kWh).

The cooling savings percentage is calculated using **Equation 7**.

Equation 7 $$\Delta e_{cs} = \left[1 - \frac{\eta_{sc_o}}{\eta_{sc_g}}\right] 100$$

Where, Δe_{cs} = cooling savings with GreenFan® EFC™ (%).

An example calculation is provided for the 10-minute cooling test 3 (see **Table 4**) using **Equations 4** through **7**. With the no time delay baseline, the split-system air conditioner uses 0.541 kWh to supply 2981 Btu of sensible cooling to the space with an efficiency of 5.51 Btu/Wh. With the GreenFan® EFC™, the air conditioner uses 0.551 kWh to supply 4088 Btu of sensible cooling to the space with an efficiency of 7.15 Btu/Wh. The cooling efficiency improvement with the GreenFan® EFC™ is calculated using **Equation 4**.

Example Eq. 4 $\Delta\eta_{sc} = \left[\frac{\eta_{sc_g}}{\eta_{sc_o}} - 1\right]100 = \left[\frac{7.15}{5.51} - 1\right]100 = 29.9\%$

Where, $\Delta\eta_{sc}$ = test 3 sensible cooling efficiency improvement with GreenFan® EFC™ = 29.9%
η_{sc_g} = test 3 sensible cooling efficiency with GreenFan® = 7.15 Btu/Wh, and
η_{sc_o} = test 3 sensible cooling efficiency without GreenFan® = 5.51 Btu/Wh.

The test 3 cooling energy required to match the GreenFan® EFC™ sensible cooling capacity at the baseline efficiency is calculated using **Equation 5**.

Example Equation 5 $E_{c_m} = \left[\frac{Q_{sc_g}}{\eta_o (1000)}\right] = \left[\frac{4088}{5.51(1000)}\right] = 0.742 \text{ kWh}$

Where, E_{c_m} = baseline energy required to match GreenFan® EFC™ capacity = 0.742 kWh,
Q_{sc_g} = test 3 sensible cooling capacity with GreenFan® = 4088 Btu, and
η_o = test 3 baseline sensible efficiency without GreenFan® = 5.51 Btu/W.

The test 3 cooling energy savings with GreenFan® are calculated using **Equation 6**.

Example Eq. 6 $\Delta E_c = \frac{Q_{c_g} - Q_{c_o}}{\eta_{sc_o} (1000 \text{ W/kWh})} + E_{c_o} - E_{c_g} = \frac{4088 - 2981}{5.51\ (1000)} + 0.541 - 0.571 = 0.171 \text{ kWh}$

Where, ΔE_c = test 3 cooling energy savings with GreenFan® EFC™ compared to baseline = 0.171 kWh,
Q_{c_o} = test 3 cooling capacity supplied by baseline system = 2981 Btu,
Q_{c_g} = test 3 cooling capacity supplied with GreenFan® EFC™ = 4088 Btu,
E_{c_o} = test 3 baseline energy consumption = 0.541 kWh, and
E_{c_g} = test 3 energy consumption with GreenFan® EFC™ = 0.571 kWh.

The test 3 cooling percentage savings with GreenFan® are calculated using **Equation 7**.

Example Equation 7 $\Delta e_{cs} = 1 - \frac{\eta_{sc_o}}{\eta_{sc_g}} \times 100 = 1 - \frac{5.51}{7.15} \times 100 = 23\%$

Where, Δe_{cs} = test 3 sensible cooling efficiency improvement with GreenFan® EFC™ = 23%,
η_{sc_o} = test 3 baseline sensible cooling efficiency = 5.51 Btu/Wh, and
η_{sc_g} = test 3 sensible cooling efficiency with GreenFan EFC™ = 7.15 Btu/Wh.

The sensible heating capacity is based on the measured airflow rate, specific volume, and sensible temperature difference between the supply air leaving the furnace and return air entering the furnace. **Equation 8** is used to calculate the non-steady state sensible heating capacity.[4]

[4] Sensible heating capacity supplied to the space increases the sensible drybulb temperature controlled by the thermostat.

Equation 8 $$Q_h = \sum_{t=0}^{n} q_{h_t} \left[\frac{t}{3600} \right]$$

Where, Q_h = non-steady-state sensible heating capacity for heating system (Btu),

$q_{h_t} = \dfrac{cfm \times 60}{\nu} \times c_p \times (T_s - T_r)$ = sensible heating capacity per time interval (i.e., Btu/hr),

T_s = dry bulb temperature of supply air leaving the heat source (F), and

T_r = dry bulb temperature of return air entering the heat source (F).

The heating efficiency (η_h) is defined as the non-steady-state sensible heating capacity (Btu/hr) divided by the heat source energy consumption (Btu/hr) per time interval.
Equation 9 is used to calculate the heating efficiency for the heating system.

Equation 9 $$\eta_h = \sum_{t=0}^{n} \frac{q_{h_t}}{e_{h_t}} = \frac{Q_h}{E_h}$$

Where, η_h = heating efficiency (dimensionless),

q_{h_t} = non-steady state heating capacity per time interval (Btu/hr),

e_{h_t} = non-steady-state heating energy consumption per time interval (Btu/hr),

Q_h = sensible heating capacity supplied by heating system (Btu), and

E_h = heat source energy consumption (Btu).

Furnace heating energy consumption is equal to total Btu consumption as shown in **Equation 10**.

Equation 10 $$Q_e = \sum_{t=0}^{n} e_t \left[\frac{t}{3600} \right]$$

Where, Q_e = heat source energy consumption (Btu), and

$e_t = \bar{c}\dot{V}_t$ = non-steady state energy consumption (Btu) per time interval for the furnace as measured by the Intertek calorimeter and Intertek natural gas volumetric flow meter (cubic feet),

$\bar{c}$ = average heat rate of natural gas (Btu/ft^3) at ambient temperature and pressure as measured by the Intertek calorimeter, and

$\dot{V}_t$ = volumetric flow of natural gas (ft^3) per time interval as measured by the Intertek natural gas flow meter (cubic feet).

The heating efficiency improvement for the GreenFan® EFC™ is calculated using **Equation 11**.

Equation 11 $$\Delta\eta_h = \left[\frac{\eta_{h_g}}{\eta_{h_o}} - 1 \right] 100$$

Where, $\Delta\eta_{sc}$ = heating efficiency improvement with GreenFan® EFC™ (%),

η_{h_g} = heating efficiency with GreenFan® (dimensionless), and

η_{h_o} = heating efficiency without GreenFan® (dimensionless).

The baseline heating energy to match the GreenFan® EFC™ heating capacity is calculated using **Equation 12**.

Equation 12 $$E_{h_m} = \left[\frac{Q_{h_g}}{\eta_{h_o}}\right]$$

Where, E_{hm} = energy required to match GreenFan® EFC™ heating capacity (Btu) at baseline efficiency,
Q_{hg} = heating capacity supplied by furnace with GreenFan® EFC™ (Btu),
η_{h_o} = heating efficiency without GreenFan® (dimensionless).

Heating energy savings with the GreenFan® EFC™ are achieved by providing greater furnace heating capacity with high-speed fan operation (where applicable) and longer variable fan-off time delays based on furnace operational time to recover and supply more heat to the space to exceed the thermostat setpoint temperature and lengthen furnace off-cycles producing less frequent or shorter furnace on-cycles. The heating energy savings are calculated using **Equation 13**. This is the energy required by the baseline system to match the extra heating capacity supplied with the GreenFan® EFC™ minus energy consumption with the GreenFan® EFC™.

Equation 13 $$\Delta E_h = E_{h_m} - E_{h_g} = \frac{Q_{h_g} - Q_{h_o}}{\eta_{h_o}} + E_{h_o} - E_{h_g}$$

Where, ΔE_h = furnace heating energy savings with GreenFan® EFC™ compared to baseline (Btu),
Q_{h_o} = heating capacity supplied by baseline furnace (Btu),
Q_{hg} = heating capacity supplied by furnace with GreenFan® EFC™ (Btu),
E_{h_o} = baseline heating energy consumption (Btu), and
E_{h_g} = heating energy consumption with GreenFan® EFC™ (Btu).

The heating energy savings percentage for the GreenFan EFC™ is calculated using **Equation 14**.

Equation 14 $$\Delta e_h = \left[1 - \frac{\eta_{h_o}}{\eta_{h_g}}\right]100$$

Where, Δe_h = heating savings percentage with GreenFan® EFC™ compared to baseline (%),
η_{h_o} = baseline furnace heating efficiency (dimensionless), and
η_{h_g} = furnace heating efficiency with GreenFan® EFC™ (dimensionless).

An example calculation is provided for the 15-minute furnace test 15/16 (**Table 6**) using **Equations 11** through **14**. The baseline furnace uses 16,516 Btu to supply 10,111 Btu with efficiency of 61.2%.[5] With the GreenFan® EFC™, the furnace uses 16,520 Btu to supply 11,877 Btu of heat to the space with a efficiency of 71.9%. The heating efficiency improvement with the GreenFan® EFC™ is calculated using **Equation 11**.

Example Equation 11 $$\Delta\eta_h = \left[\frac{\eta_{hg}}{\eta_{h_o}} - 1\right] \times 100 = \left[\frac{71.9}{61.2} - 1\right] \times 100 = 17.5\%$$

[5] Furnace efficiency is defined as energy output divided by energy input (i.e., Btu out divided by Btu in).

Where, $\Delta\eta_h$ = test 15/16 heating efficiency improvement with GreenFan® EFC™ = 17.5%,
η_{h_g} = test 15/16 furnace heating efficiency with GreenFan EFC™ = 71.9%, and
η_{h_o} = test 15/16 baseline furnace heating efficiency = 61.2%.

The heating energy required to match the GreenFan® EFC™ heating capacity at the baseline efficiency is calculated using **Equation 12**.

Example Equation 12 $$E_{h_m} = \left[\frac{Q_{h_g}}{\eta_{h_o}}\right] = \left[\frac{11877}{0.612}\right] = 19405 \text{ Btu}$$

Where, E_{hm} = energy required to match GreenFan® heating capacity at baseline efficiency = 19405 Btu,
Q_{hg} = heating capacity supplied by furnace with GreenFan® EFC™ = 11877 Btu,
η_{h_o} = heating efficiency without GreenFan® = 0.612.

The heating energy savings with the GreenFan® EFC™ is calculated using **Equation 13**

Example Eq. 13 $$\Delta Q_h = \frac{Q_{h_g} - Q_{h_o}}{\eta_{h_o}} + E_{h_o} - E_{h_g} = \frac{11877 - 10111}{0.612} + 16519 - 16520 = 2886 \text{ Btu}$$

Where, ΔQ_h = test 15/16 heating energy savings with GreenFan® EFC™ = 2,886 Btu,
Q_{h_o} = test 15/16 baseline furnace heating capacity = 10,111 Btu,
Q_{hg} = test 15/16 furnace heating capacity with GreenFan® EFC™ = 11,877 Btu,
η_{h_o} = baseline furnace heating efficiency = 61.2%,
E_{h_o} = baseline furnace energy consumption = 16,519 Btu, and
E_{h_g} = furnace energy consumption with GreenFan® EFC™ = 16,520 Btu.

The heating energy savings with the GreenFan® EFC™ is calculated using **Equation 14**.

Example Equation 14 $$\Delta\eta_h = \left[1 - \frac{\eta_{h_o}}{\eta_{h_g}}\right] \times 100 = \left[1 - \frac{61.2}{71.9}\right] \times 100 = 14.9\%$$

Where, $\Delta\eta_h$ = test 15/16 heating savings percentage with GreenFan® EFC™ = 14.9%,
η_{h_o} = test 15/16 baseline furnace heating efficiency = 61.2%, and
η_{h_g} = test 15/16 furnace heating efficiency with GreenFan EFC™ = 71.9%.

Non-steady state tests for cooling and heating were performed with fixed time delay and GreenFan® variable time delay to measure the sensible cooling or heating capacity and efficiency for the split-system or packaged natural gas furnace. Results for each test are provided in the following tables and figures.

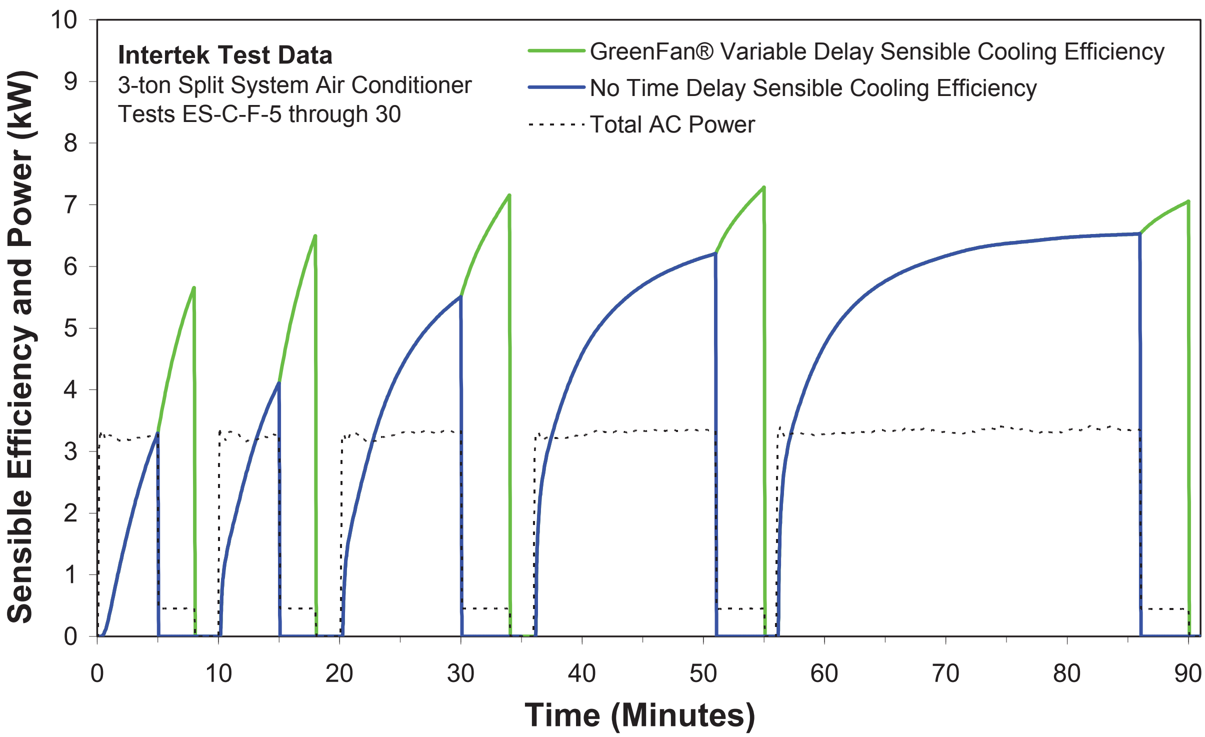
Cooling Tests for 3-ton Split-System with No Delay and EFC™ Variable Time Delay

Cooling tests for the 3-ton split system with no time delay and GreenFan® variable time delay were performed at typical field conditions of 75F DB and 62F WB indoor and 95F outdoor temperatures. **Table 4** and **Figure 7** provide test results. Based on five tests, the GreenFan® improved sensible cooling efficiency by 8 to 71.7% and provides cooling energy savings of 7.4 to 41.8%.

Table 4: 3-ton Split-System Cooling Tests ES-C-F-5 through 30 – No Delay and Variable Delay

Description	Test 1	Test 2	Test 3	Test 4	Test 5
Compressor On Time (minutes)	5	5	10	15	30
No-Time Delay AC Energy (kWh) [a]	0.264	0.270	0.541	0.825	1.666
No-Time Delay Sensible Cooling (Btu) [b]	870	1,109	2,981	5,120	10,872
No-Time Delay Sensible Efficiency (Btu/W) [c=b/a/1000]	3.29	4.11	5.51	6.21	6.53
GreenFan® AC Energy (kWh) [d]	0.287	0.293	0.571	0.855	1.696
GreenFan® Sensible Cooling (Btu) [e]	1,622	1,901	4,088	6,225	11,958
GreenFan® Sensible Efficiency (Btu/W) [f=e/d/1000]	5.65	6.49	7.15	7.28	7.05
GreenFan® Sensible Efficiency Improvement [g=f/c-1]	71.7%	58.1%	29.9%	17.3%	8.0%
GreenFan® Extra Fan Energy (kWh)	0.023	0.023	0.030	0.030	0.030
No Delay Cooling Energy to Match GreenFan® (kWh) [h=e/c/1000]	0.493	0.463	0.742	1.003	1.832
GreenFan® Energy Savings (kWh) [i=h-d or i=(e-b)/c/1000+a-d]	0.206	0.170	0.171	0.148	0.136
GreenFan® Cooling Energy Savings [j=(1-c/f) or j=i/h]	**41.8%**	**36.8%**	**23.0%**	**14.8%**	**7.4%**

Figure 7: 3-ton Split-System Cooling Tests ES-C-F-5 through 30 – No Delay and Variable Delay



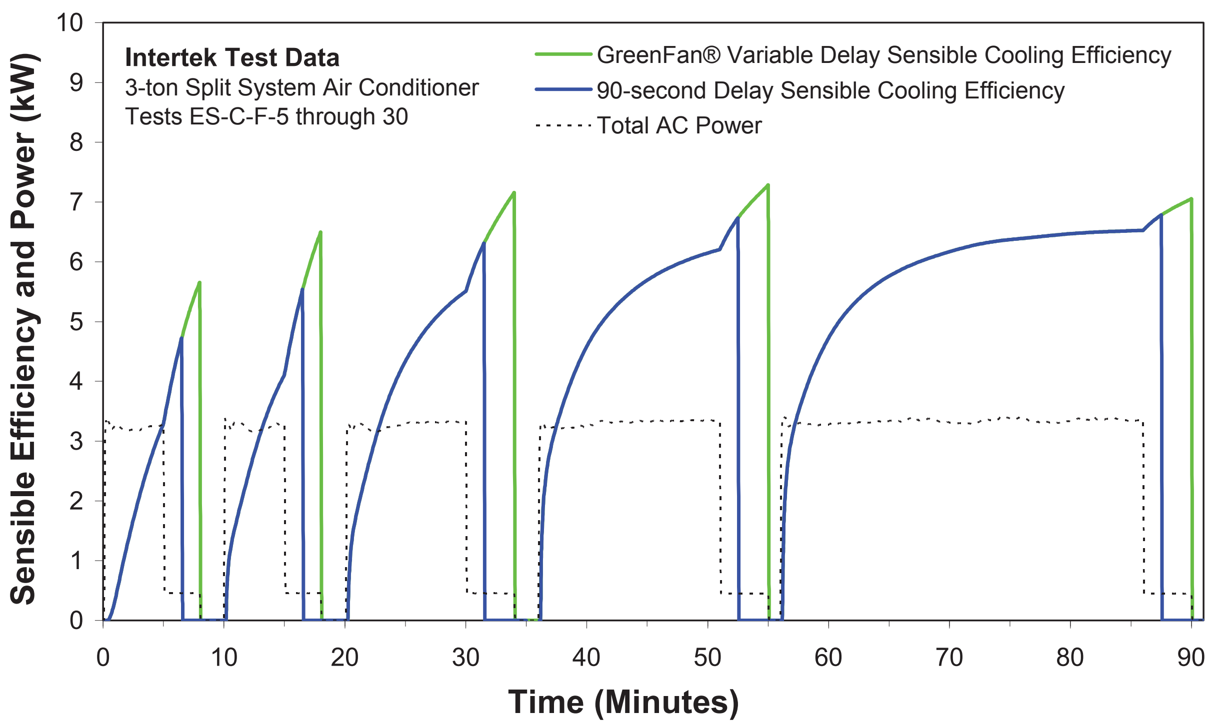
Cooling Tests for 3-ton Split-System with 90-Second and EFC™ Variable Time Delay

Cooling tests for the 3-ton split system with 90-second delay and GreenFan® variable time delay were performed at typical field conditions of 75F DB and 62F WB indoor and 95F outdoor temperatures. **Table 5** and **Figure 8** provide test results. Based on five tests, the GreenFan® improved sensible cooling efficiency by 4 to 19.9% and provides cooling energy savings of 3.9 to 16.6%.

Table 5: 3-ton Split-System Cooling Tests ES-C-F-5 through 30 – 90-Second and Variable Delay

Description	Test 6	Test 7	Test 8	Test 9	Test 10
Compressor On Time (minutes)	5	5	10	15	30
90-Second Delay AC Energy (kWh) [a]	0.276	0.281	0.553	0.836	1.677
90-Second Delay Sensible Cooling (Btu) [b]	1,300	1,556	3,485	5,628	11,371
90-Second Delay Sensible Efficiency (Btu/W) [c=b/a/1000]	4.72	5.53	6.31	6.73	6.78
GreenFan® AC Energy (kWh) [d]	0.287	0.293	0.571	0.855	1.696
GreenFan® Sensible Cooling (Btu) [e]	1,622	1,901	4,088	6,225	11,958
GreenFan® Sensible Efficiency (Btu/W) [f=e/d/1000]	5.65	6.49	7.15	7.28	7.05
GreenFan® Sensible Efficiency Improvement [g=f/c-1]	19.9%	17.4%	13.5%	8.2%	4.0%
GreenFan® Extra Fan Energy (kWh)	0.011	0.011	0.019	0.019	0.019
90-Sec. Delay Cooling Energy to Match GreenFan® (kWh) [h=e/c/1000]	0.344	0.344	0.648	0.925	1.763
GreenFan® Energy Savings (kWh) [i=h-d or i=(e-b)/c/1000+a-d]	0.057	0.051	0.077	0.070	0.068
GreenFan® Cooling Energy Savings [j=(1-c/f) or j=i/h]	**16.6%**	**14.8%**	**11.9%**	**7.6%**	**3.9%**

Figure 8: 3-ton Split-System Cooling Tests ES-C-F-5 through 30 – 90-Second and Variable Delay



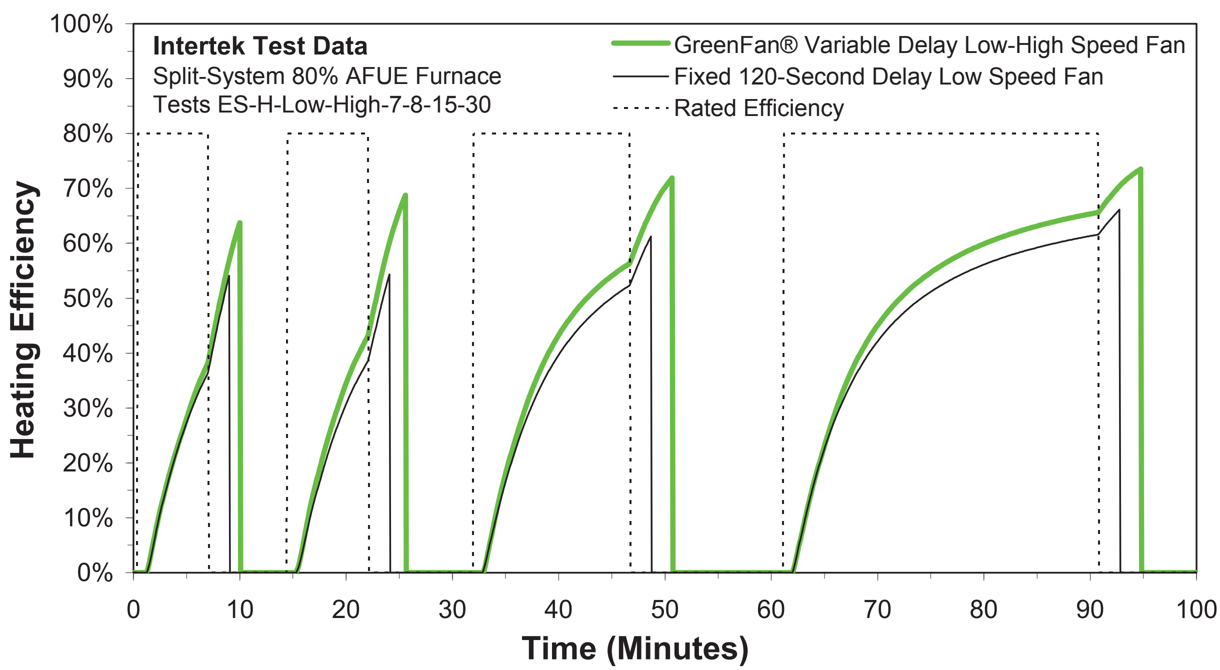
Heating Tests for Split-System with 120-Second and Variable Delay plus Low-High Speed Fan

Heating tests for the 3-ton split-system were performed at typical field conditions of 72F DB and 53F WB indoor and 42F outdoor temperatures. **Table 6** and **Figure 9** provide test results. For the baseline tests the indoor fan operated at low speed with fixed 120-second time delay after furnace turned off. With GreenFan® the indoor fan operated at low speed for first 4-minutes and high speed after with variable time delay after furnace turned off. Each pair of tests used approximately the same gas energy (within 0.08%). High speed provided 11.3% more airflow than low speed. The GreenFan® EFC™ improved heating efficiency by 11.2 to 26.5% and provides heating energy savings of 10.1 to 21%.

Table 6: Split-System Heating Tests – 120-Second and Variable Delay plus Low-High Speed Fan

Description	**Test 11/12**	**Test 13/14**	**Test 15/16**	**Test 17/18**
Furnace On Time (minutes)	7	8	15	30
120-Second Delay Furnace Energy Input (Btu) [a]	7,378	8,559	16,519	33,407
120-Second Delay Heating Capacity (Btu) [b]	3,989	4,650	10,111	22,083
120-Second Time Delay Heating Efficiency [c=b/a]	54.1%	54.3%	61.2%	66.1%
GreenFan® Furnace Energy Input (Btu) [d]	7,375	8,440	16,520	33,474
GreenFan® Delivered Heating Capacity (Btu) [e]	4,698	5,803	11,877	24,609
GreenFan® Heating Efficiency [f=e/d]	63.7%	68.8%	71.9%	73.5%
GreenFan® Heating Efficiency Improvement [g=f/c-1]	17.8%	26.5%	17.5%	11.2%
GreenFan® Extra Fan Energy (kWh)	0.014	0.015	0.030	0.049
120-Sec. Delay Furnace Energy to Match GreenFan® (Btu) [h=e/c]	8,688	10,680	19,405	37,228
GreenFan® Energy Savings (Btu) [i=h-d or i=(e-b)/c+a-d]	1,314	2,240	2,886	3,754
GreenFan® Heating Energy Savings [j=(1-c/f) or j=i/h]	**15.1%**	**21.0%**	**14.9%**	**10.1%**

Figure 9: Split-System Heating Tests – 120-Second and Variable Delay plus Low-High Speed Fan



PERFORMANCE EVALUATION BASED ON INTERTEK TEST DATA OF THE GREENFAN® EFC™ INSTALLED ON SPLIT AND PACKAGE AIR CONDITIONERS WITH GAS FURNACES

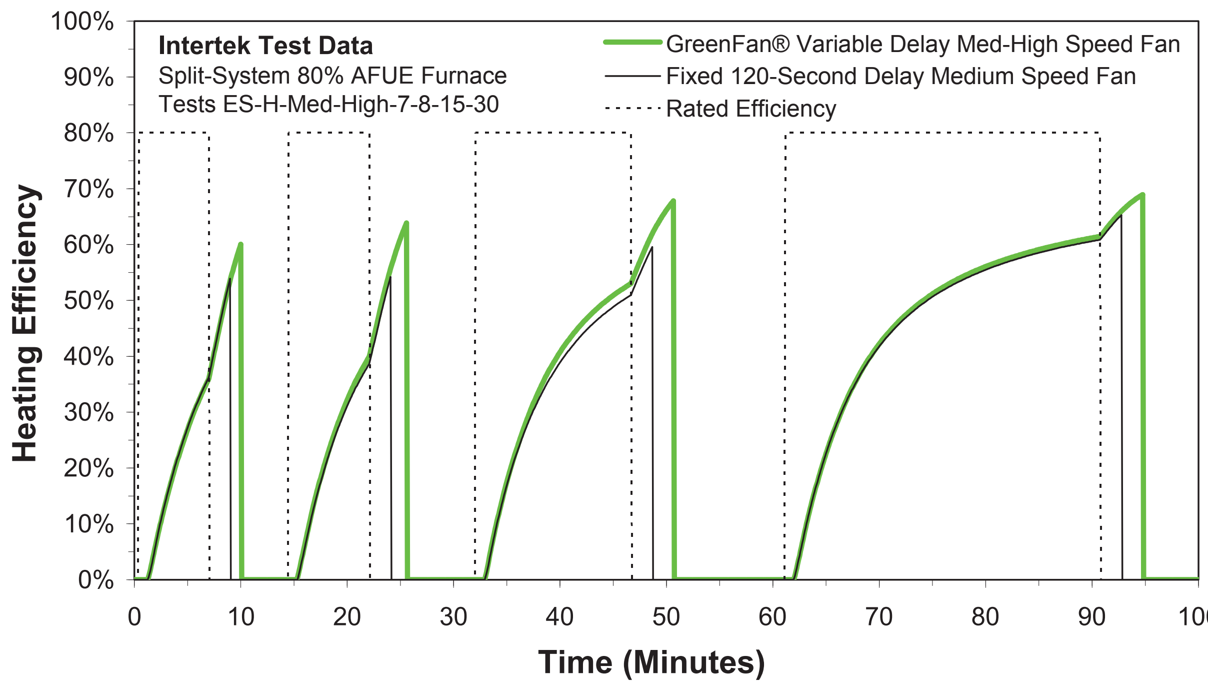
Heating Tests for Split-System with 120-Second and Variable Delay plus Med-High Speed Fan

Heating tests for the 3-ton split-system were performed at typical field conditions of 72F DB and 53F WB indoor and 42F outdoor temperatures. **Table 7** and **Figure 10** provide test results. For baseline heating tests the furnace fan operated at medium speed with fixed 120-second time delay after furnace turned off. With GreenFan® the indoor fan operated at medium speed for the first 4-minutes and high speed afterwards with variable time delay after the furnace turned off. Each pair of tests used approximately the same gas energy (within 0.07%). High speed provided 4.8% more airflow than medium speed. Based on four tests, the GreenFan® EFC™ improved heating efficiency by 5.5 to 17.9% and provides heating energy savings of 5.3 to 15.2%.

Table 7: Split-System Heating Tests – 120-Second and Variable Delay plus Med-High Speed Fan

Description	Test 19/20	Test 21/22	Test 23/24	Test 25/26
Furnace On Time (minutes)	7	8	15	30
120-Second Delay Furnace Energy Input (Btu) [a]	7,406	8,515	16,476	33,387
120-Second Delay Heating Capacity (Btu) [b]	3,989	4,613	9,813	21,793
120-Second Time Delay Heating Efficiency [c=b/a]	53.9%	54.2%	59.6%	65.3%
GreenFan® Furnace Energy Input (Btu) [d]	7,385	8,546	16,396	33,409
GreenFan® Delivered Heating Capacity (Btu) [e]	4,434	5,458	11,118	23,036
GreenFan® Heating Efficiency [f=e/d]	60.0%	63.9%	67.8%	68.9%
GreenFan® Heating Efficiency Improvement [g=f/c-1]	11.3%	17.9%	13.8%	5.5%
GreenFan® Extra Fan Energy (kWh)	0.011	0.015	0.024	0.034
120-Sec. Delay Furnace Energy to Match GreenFan® (Btu) [h=e/c]	8,226	10,070	18,654	35,277
GreenFan® Energy Savings (Btu) [i=h-d or i=(e-b)/c+a-d]	847	1,528	2,270	1,882
GreenFan® Heating Energy Savings [j=(1-c/f) or j=i/h]	**10.3%**	**15.2%**	**12.2%**	**5.3%**

Figure 10: Split-System Heating Tests – 120-Second and Variable Delay plus Med-High Speed Fan



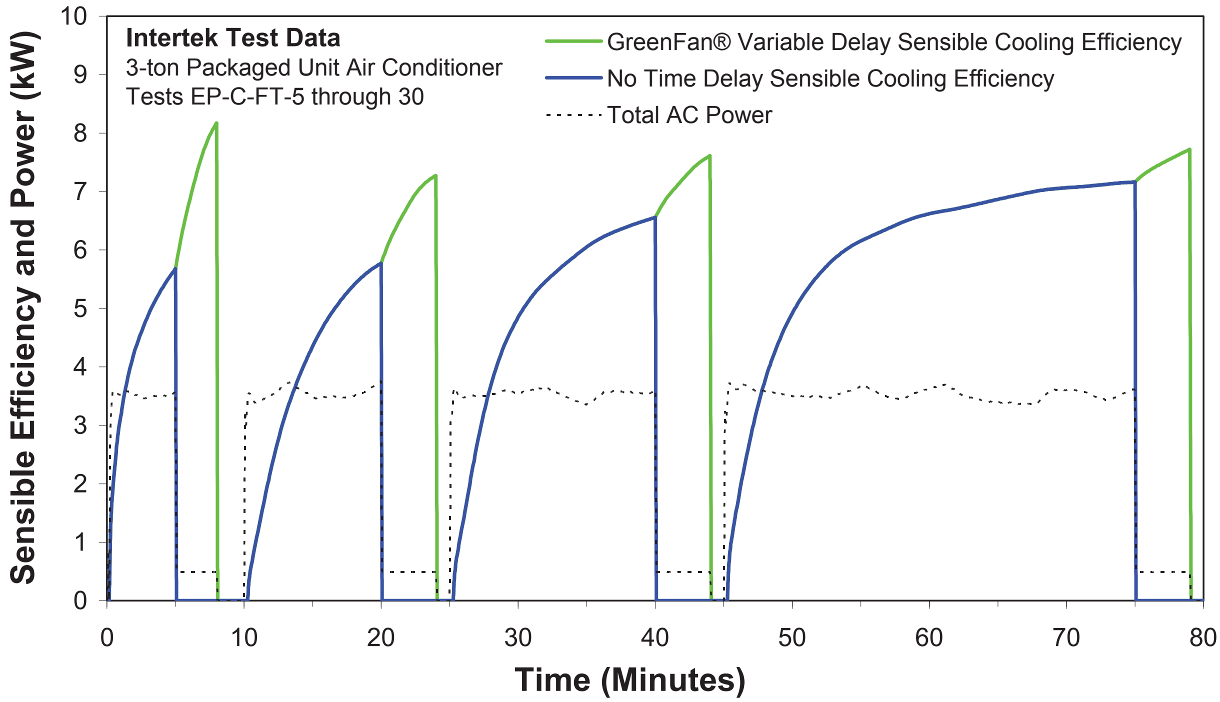
Cooling Tests for 3-ton Packaged Unit with No Delay and EFC™ Variable Time Delay

Cooling tests for the 3-ton packaged unit with no time delay and GreenFan® variable time delay were performed at typical field conditions of 75F DB and 62F WB indoor and 95F outdoor temperatures. **Table 8** and **Figure 11** provide test results. Based on four tests, the GreenFan® EFC™ improved sensible efficiency by 7.8 to 43.9% and provides cooling energy savings of 7.2 to 30.5%.

Table 8: 3-ton Packaged Cooling Tests EP-C-FT-5 through 30 – No Delay and Variable Delay

Description	Test 27	Test 28	Test 29	Test 30
Compressor On Time (minutes)	5	10	15	30
No-Time Delay AC Energy (kWh) [a]	0.283	0.590	0.883	1.764
No-Time Delay Sensible Cooling (Btu) [b]	1,611	3,402	5,789	12,660
No-Time Delay Sensible Efficiency (Btu/W) [c=b/a/1000]	5.70	5.77	6.55	7.18
GreenFan® AC Energy (kWh) [d]	0.307	0.622	0.916	1.797
GreenFan® Sensible Cooling (Btu) [e]	2,522	4,526	6,971	13,896
GreenFan® Sensible Efficiency (Btu/W) [f=e/d/1000]	8.20	7.27	7.61	7.73
GreenFan® Sensible Efficiency Improvement [g=f/c-1]	43.9%	26.0%	16.1%	7.8%
GreenFan® Extra Fan Energy (kWh)	0.025	0.033	0.033	0.033
No Delay Cooling Energy to Match GreenFan® (kWh) [h=e/c/1000]	0.443	0.784	1.064	1.936
GreenFan® Energy Savings (kWh) [i=h-d or i=(e-b)/c/1000+a-d]	0.135	0.162	0.148	0.139
GreenFan® Cooling Energy Savings [j=(1-c/f) or j=i/h]	**30.5%**	**20.6%**	**13.9%**	**7.2%**

Figure 11: 3-ton Packaged Cooling Tests EP-C-FT-5 through 30 – No Delay and Variable Delay



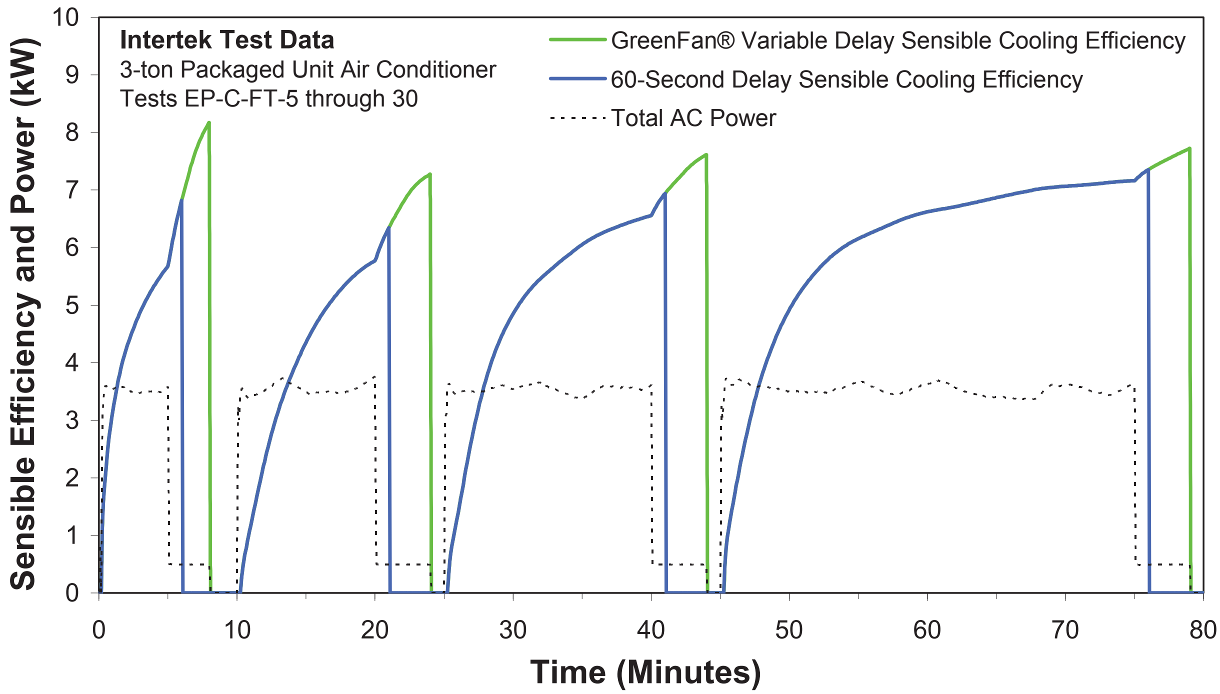
Cooling Tests for 3-ton Packaged Unit with 60-Second and EFC™ Variable Time Delay

Cooling tests for the 3-ton packaged unit with 60-second time delay and GreenFan variable time delay were performed at typical field conditions of 75F DB and 62F WB indoor and 95F outdoor temperatures. **Table 9** and **Figure 12** provide test results. Based on four tests, the GreenFan® EFC™ improved sensible efficiency by 7.8 to 19.8% and provides cooling energy savings of 7.2 to 16.5%.

Table 9: 3-ton Packaged Cooling Tests EP-C-FT-5 through 30 – 60-Second and Variable Delay

Description	Test 31	Test 32	Test 33	Test 34
Compressor On Time (minutes)	5	10	15	25
60-Second Delay AC Energy (kWh) [a]	0.291	0.598	0.891	1.764
60-Second Delay Sensible Cooling (Btu) [b]	1,993	3,793	6,184	12,660
60-Second Delay Sensible Efficiency (Btu/W) [c=b/a/1000]	6.85	6.34	6.94	7.18
GreenFan® AC Energy (kWh) [d]	0.307	0.622	0.916	1.797
GreenFan® Sensible Cooling (Btu) [e]	2,522	4,526	6,971	13,896
GreenFan® Sensible Efficiency (Btu/W) [f=e/d/1000]	8.20	7.27	7.61	7.73
GreenFan® Sensible Efficiency Improvement [g=f/c-1]	19.8%	14.6%	9.7%	7.8%
GreenFan® Extra Fan Energy (kWh)	0.016	0.025	0.025	0.033
60-Sec. Delay Cooling Energy to Match GreenFan® (kWh) [h=e/c/1000]	0.368	0.713	1.005	1.936
GreenFan® Energy Savings (kWh) [i=h-d or i=(e-b)/c/1000+a-d]	0.061	0.091	0.089	0.139
GreenFan® Cooling Energy Savings [j=(1-c/f) or j=i/h]	**16.5%**	**12.7%**	**8.8%**	**7.2%**

Figure 12: 3-ton Packaged Cooling Tests EP-C-FT-5 through 30 – 60-Second and Variable Delay



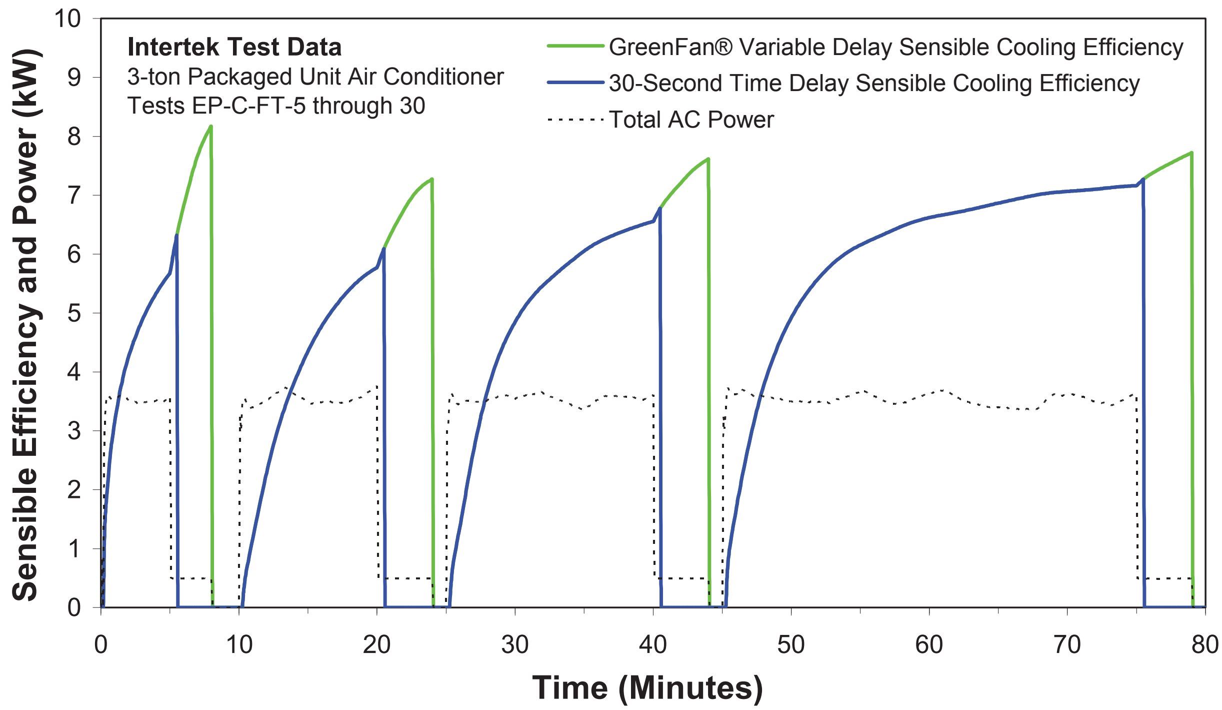
Cooling Tests for 3-ton Packaged Unit with 30-Second and EFC™ Variable Time Delay

Cooling tests for the 3-ton packaged unit with 30-second time delay and GreenFan variable time delay were performed at typical field conditions of 75F DB and 62F WB indoor and 95F outdoor temperatures. **Table 10** and **Figure 13** provide test results. Based on four tests, the GreenFan® EFC™ improved sensible efficiency by 6.2 to 29.5% and sensible cooling efficiency by 5.8 to 22.8%.

Table 10: 3-ton Packaged Cooling Tests EP-C-FT-5 through 30 – 30-Second and Variable Delay

Description	Test 59	Test 60	Test 61	Test 62
Compressor On Time (minutes)	5	10	15	25
30-Second Delay AC Energy (kWh) [a]	0.287	0.594	0.887	1.768
30-Second Delay Sensible Cooling (Btu) [b]	1,818	3,615	6,008	12,879
30-Second Delay Sensible Efficiency (Btu/W) [c=b/a/1000]	6.33	6.09	6.77	7.28
GreenFan® AC Energy (kWh) [d]	0.307	0.622	0.916	1.797
GreenFan® Sensible Cooling (Btu) [e]	2,522	4,514	6,971	13,896
GreenFan® Sensible Efficiency (Btu/W) [f=e/d/1000]	8.20	7.26	7.61	7.73
GreenFan® Sensible Efficiency Improvement [g=f/c-1]	29.5%	19.3%	12.4%	6.2%
GreenFan® Extra Fan Energy (kWh)	0.021	0.028	0.029	0.029
30-Sec. Delay Cooling Energy to Match GreenFan® (kWh) [h=e/c/1000]	0.398	0.742	1.030	1.908
GreenFan® Energy Savings (kWh) [i=h-d or i=(e-b)/c/1000+a-d]	0.091	0.120	0.114	0.111
GreenFan® Cooling Energy Savings [j=(1-c/f) or j=i/h]	**22.8%**	**16.2%**	**11.0%**	**5.8%**

Figure 13: 3-ton Packaged Cooling Tests EP-C-FT-5 through 30 – 30-Second and Variable Delay



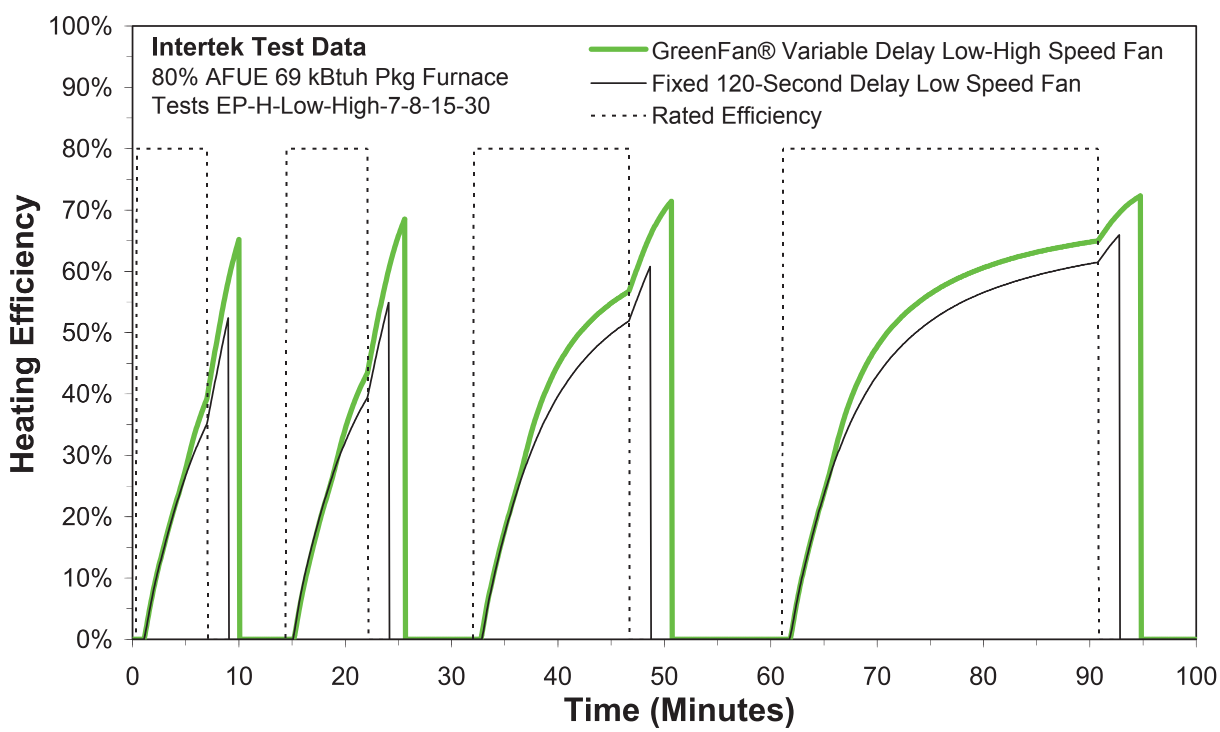
Heating Tests for Packaged Unit with 120-Second and Variable Delay plus Low-High Speed Fan

Heating tests for the 3-ton packaged unit with 120-second time delay and GreenFan variable time delay were performed at typical field conditions of 72F DB and 54F WB indoor and 42F outdoor temperatures. **Table 11** and **Figure 14** provide test results. For baseline heating tests the indoor fan was operated at low speed with fixed 120-second time delay after furnace turned off. With GreenFan® the indoor fan operated at low speed for first 4-minutes and high speed after with variable time delay after furnace turned off. High speed provided 24.4% more airflow than low speed. The GreenFan® EFC™ improves heating efficiency by 9.7 to 24.8% and provides heating energy savings of 8.8 to 19.9%.

Table 11: Packaged Unit Heating Tests – 120-Second and Variable Delay plus Low-High Speed Fan

Description	Test 35/36	Test 37/38	Test 39/40	Test 41/42
Furnace On Time (minutes)	7	8	15	30
120-Second Delay Furnace Energy Input (Btu) [a]	7,888	9,027	17,101	34,189
120-Second Delay Heating Capacity (Btu) [b]	4,129	4,955	10,392	22,539
120-Second Time Delay Heating Efficiency [c=b/a]	52.3%	54.9%	60.8%	65.9%
GreenFan® Furnace Energy Input (Btu) [d]	7,837	8,963	16,954	34,085
GreenFan® Delivered Heating Capacity (Btu) [e]	5,107	6,140	12,108	24,643
GreenFan® Heating Efficiency [f=e/d]	65.2%	68.5%	71.4%	72.3%
GreenFan® Heating Efficiency Improvement [g=f/c-1]	24.5%	24.8%	17.5%	9.7%
GreenFan® Extra Fan Energy (kWh)	0.014	0.021	0.051	0.091
120-Sec. Delay Furnace Energy to Match GreenFan® (Btu) [h=e/c]	9,756	11,186	19,925	37,380
GreenFan® Energy Savings (Btu) [i=h-d or i=(e-b)/c+a-d]	1,919	2,223	2,971	3,296
GreenFan® Heating Energy Savings [j=(1-c/f) or j=i/h]	**19.7%**	**19.9%**	**14.9%**	**8.8%**

Figure 14: Packaged Heating Tests – 120-Second and Variable Delay plus Low-High Speed



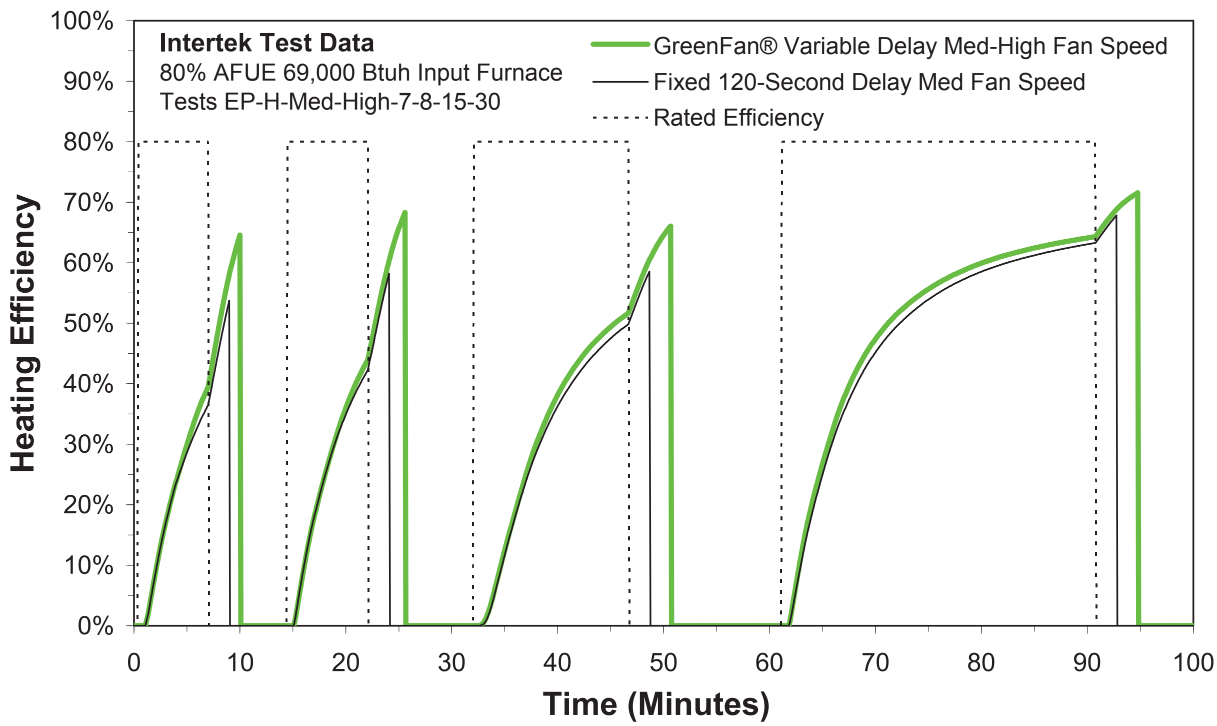
Heating Tests for Packaged Unit with 120-second and Variable Delay plus Med-High Speed Fan

Heating tests for the 3-ton packaged unit with 120-second time delay and GreenFan variable time delay were performed at typical field conditions of 72F DB and 54F WB indoor and 42F outdoor temperatures. **Table 12** and **Figure 15** provide results. For the baseline heating tests the indoor fan operated at medium speed with fixed 120-second time delay after furnace turned off. With GreenFan® the indoor fan operated at medium speed for first 4-minutes and high speed after with variable time delay after furnace turned off. High speed provided 6.8% more airflow than medium speed. The GreenFan® EFC™ improves heating efficiency by 5.5 to 20.2% and provides heating energy savings of 5.2 to 16.8%.

Table 12: Packaged Gas Heating Tests – 120-Second and Variable Delay plus Med-High Speed Fan

Description	Test 43/44	Test 45/46	Test 47/48	Test 49/50
Furnace On Time (minutes)	7	8	15	30
120-Second Delay Furnace Energy Input (Btu) [a]	7,878	9,012	16,974	34,254
120-Second Delay Heating Capacity (Btu) [b]	4,233	5,242	9,936	23,229
120-Second Time Delay Heating Efficiency [c=b/a]	53.7%	58.2%	58.5%	67.8%
GreenFan® Furnace Energy Input (Btu) [d]	7,801	8,948	16,841	34,427
GreenFan® Delivered Heating Capacity (Btu) [e]	5,036	6,111	11,126	24,625
GreenFan® Heating Efficiency [f=e/d]	64.6%	68.3%	66.1%	71.5%
GreenFan® Heating Efficiency Improvement [g=f/c-1]	20.2%	17.4%	12.9%	5.5%
GreenFan® Extra Fan Energy (kWh)	0.020	0.026	0.030	0.048
120-Sec. Delay Furnace Energy to Match GreenFan® (Btu) [h=e/c]	9,374	10,505	19,007	36,313
GreenFan® Energy Savings (Btu) [i=h-d or i=(e-b)/c+a-d]	1,572	1,557	2,166	1,886
GreenFan® Heating Energy Savings [j=(1-c/f) or j=i/h]	**16.8%**	**14.8%**	**11.4%**	**5.2%**

Figure 15: Packaged Unit Heating Tests – 120-Second and Variable Delay + Med-High Speed Fan



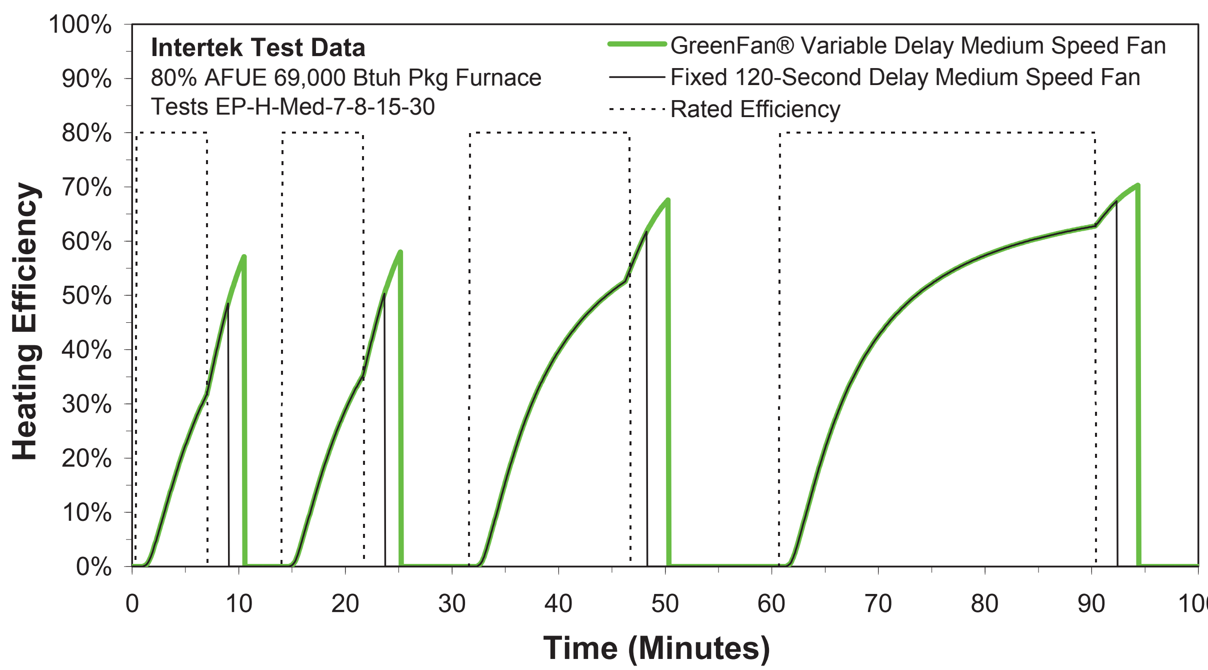
Heating Tests for Packaged Unit with 120-Second and Variable Delay and Medium Speed Fan

Heating tests for the 3-ton packaged unit with 120-second time delay and GreenFan variable time delay were performed at typical field conditions of 72F DB and 54F WB indoor and 42F outdoor temperatures. **Table 13** and **Figure 16** provide test results. For baseline heating tests the indoor fan operated at medium speed with fixed 120-second time delay after furnace turned off. With GreenFan® the indoor fan operated at medium speed with variable time delay after furnace turned off. Each pair of tests used the same gas energy. The GreenFan® EFC™ improves heating efficiency by 4.3 to 17.8% and provides heating energy savings of 4.2 to 15.1%.

Table 13: Packaged Unit Heating Tests – 120-Second and Variable Delay and Medium Speed Fan

Description	Test 51/52	Test 53/54	Test 55/56	Test 57/58
Furnace On Time (minutes)	7	8	15	30
120-Second Delay Furnace Energy Input (Btu) [a]	7,774	8,952	16,081	32,695
120-Second Delay Heating Capacity (Btu) [b]	3,770	4,504	9,927	22,028
120-Second Time Delay Heating Efficiency [c=b/a]	48.5%	50.3%	61.7%	67.4%
GreenFan® Furnace Energy Input (Btu) [d]	7,774	8,952	16,081	32,695
GreenFan® Delivered Heating Capacity (Btu) [e]	4,443	5,192	10,866	22,982
GreenFan® Heating Efficiency [f=e/d]	57.2%	58.0%	67.6%	70.3%
GreenFan® Heating Efficiency Improvement [g=f/c-1]	17.8%	15.3%	9.5%	4.3%
GreenFan® Extra Fan Energy (kWh)	0.009	0.011	0.014	0.014
120-Sec. Delay Furnace Energy to Match GreenFan® (Btu) [h=e/c]	9,161	10,320	17,603	34,111
GreenFan® Energy Savings (Btu) [i=h-d or i=(e-b)/c+a-d]	1,387	1,368	1,522	1,416
GreenFan® Heating Energy Savings [j=(1-c/f) or j=i/h]	**15.1%**	**13.3%**	**8.6%**	**4.2%**

Figure 16: Packaged Unit Heating Tests – 120-Second and Variable Delay and Medium Speed Fan



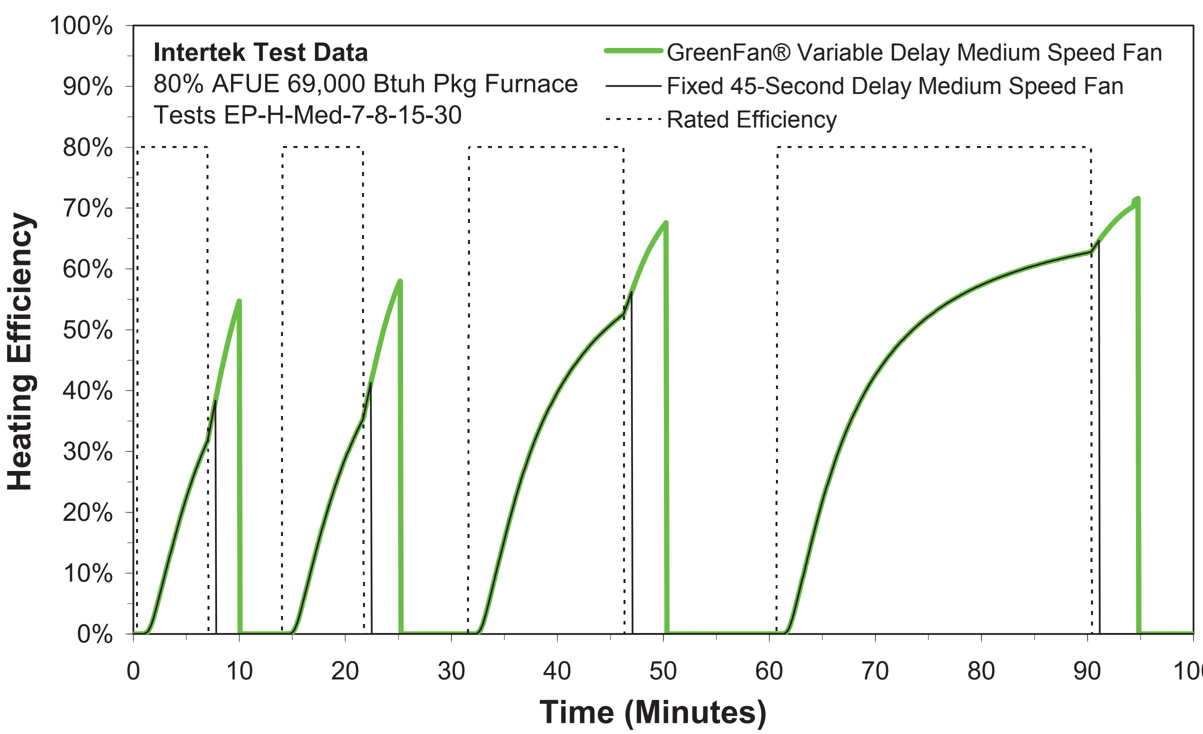
Heating Tests for Packaged Unit with 45-Second and Variable Delay and Medium Fan Speed

Heating tests for the 3-ton packaged unit with 45-second time delay and GreenFan variable time delay were performed at typical field conditions of 72F DB and 54F WB indoor and 42F outdoor temperatures. **Table 14** and **Figure 17** provide test results. For the baseline heating tests the indoor fan operated at medium speed with fixed 45-second time delay after furnace turned off. The GreenFan® heating tests were performed with the variable time delay after the furnace turned off. Each pair of tests used the same amount of gas input energy. The GreenFan® EFC™ improves heating efficiency by 8.8 to 42.7% and provides heating energy savings of 8.1 to 29.9%.

Table 14: Packaged Unit Heating Tests – 45-Second and Variable Delay and Medium Speed Fan

Description	Test 63/64	Test 65/66	Test 67/68	Test 69/70
Furnace On Time (minutes)	7	8	15	30
45-Second Delay Furnace Energy Input (Btu) [a]	7,774	8,952	16,081	32,695
45-Second Delay Heating Capacity (Btu) [b]	2,981	3,697	9,042	21,129
45-Second Time Delay Heating Efficiency [c=b/a]	38.3%	41.3%	56.2%	64.6%
GreenFan® Furnace Energy Input (Btu) [d]	7,774	8,952	16,081	32,695
GreenFan® Delivered Heating Capacity (Btu) [e]	4,252	5,192	10,866	22,982
GreenFan® Heating Efficiency [f=e/d]	54.7%	58.0%	67.6%	70.3%
GreenFan® Heating Efficiency Improvement [g=f/c-1]	42.7%	40.5%	20.2%	8.8%
GreenFan® Extra Fan Energy (kWh)	0.016	0.019	0.023	0.023
45-Sec. Delay Furnace Energy to Match GreenFan® (Btu) [h=e/c]	11,090	12,573	19,325	35,563
GreenFan® Energy Savings (Btu) [i=h-d or i=(e-b)/c+a-d]	3,316	3,621	3,244	2,868
GreenFan® Heating Energy Savings [j=(1-c/f) or j=i/h]	**29.9%**	**28.8%**	**16.8%**	**8.1%**

Figure 17: Packaged Unit Tests – 45-Second and Variable Delay and Medium Speed Fan



PERFORMANCE EVALUATION BASED ON INTERTEK TEST DATA OF THE GREENFAN® EFC™ INSTALLED ON SPLIT AND PACKAGE AIR CONDITIONERS WITH GAS FURNACES

Conclusion

The following conclusions are provided regarding the performance evaluation tests of the patented GreenFan® EFC installed on a 3-ton split-system HVAC unit. Based on 10 cooling tests, the GreenFan® EFC provides cooling energy savings of 7.4 to 41.8% compared to zero fan-off time delay and 3.9 to 16.6% compared to 90-second fan-off time delay. Based on 16 gas furnace heating tests, the GreenFan® EFC™ provides heating energy savings of 5.3 to 21% compared to low- or medium-speed heater fan operation and fixed 120-second time delay.

The following conclusions are provided regarding the performance evaluation tests of the GreenFan® EFC installed on a 3-ton packaged HVAC unit. Based on 12 cooling tests, the GreenFan® EFC™ provides cooling energy savings of by 7.2 to 30.5% compared to zero fan-off time delay, 5.8 to 22.8% compared to 30-second fan-off time delay, and 6.8 to 15.5% compared to 60-second fan-off time delay. Based on 32 gas furnace heating tests, the GreenFan® EFC™ provides heating energy savings of 10.1 to 21% compared to low- or medium-speed heater fan operation and fixed 120-second time delay and 5.3 to 15.2% compared to medium-speed heater fan operation with a 45- or 120-second fan-off time delay.

The GreenFan® EFC™ requires extra fan energy to recover and deliver additional sensible cooling or heating capacity from the HVAC system evaporator or heat exchanger to improve cooling or heating efficiency, lengthen off-cycles, and save cooling or heating energy. For cooling, the average extra fan energy per cycle with the GreenFan® EFC™ is 0.024 ± 0.003 kWh or 19 ± 1.4% of cooling savings (i.e., 1 unit of extra fan energy provides 5.3 ± 0.4 units of cooling energy savings). For heating, the average extra fan energy per cycle with the GreenFan® EFC™ is 0.026 ± 0.006 kWh or 12.1 ± 2% of heating savings (i.e., 1 unit of extra fan energy provides 8.2 ± 1.4 units of heating energy savings).[6] For heating, the average low-to-high airflow increase was 18% and the average medium-to-high airflow increase was 6.2%. Increasing airflow to high speed during furnace operation supplies more heating capacity to satisfy the space heating thermostat sooner, reduce furnace operation, and save gas energy.

Based on 22 cooling tests, the GreenFan® EFC™ improves sensible cooling efficiency by 4 to 71.7% and provides cooling energy savings of 3.9 to 41.8%. Based on 48 gas furnace heating tests, the GreenFan® EFC™ improves heating efficiency by 4.3 to 42.7% and provides heating energy savings of 4.2 to 29.9%.

Report Number	Date	Description
101756555DAL-001A	08-04-15	Original version of report
101756555DAL-001B	12-12-16	Revised text

[6] The EFC™ extra fan energy for heating is valued at 10,354 Btu/kWh based on natural gas electricity generation. US Energy Information Agency (EIA) 2013. Average Tested Heat Rates by Prime Mover and Energy Source, 2007-2013. https://www.eia.gov/electricity/annual/html/epa_08_02.html).

Appendix B: Performance Evaluation Based on Intertek Test Data of the GreenFan® EFC™ Installed on Heat Pump and Hydronic Split Systems

PERFORMANCE EVALUATION BASED ON INTERTEK TEST DATA OF THE GREENFAN® EFC™ INSTALLED ON HEAT PUMP AND HYDRONIC SPLIT-SYSTEMS

12/15/2016 Intertek Project No. G102791047

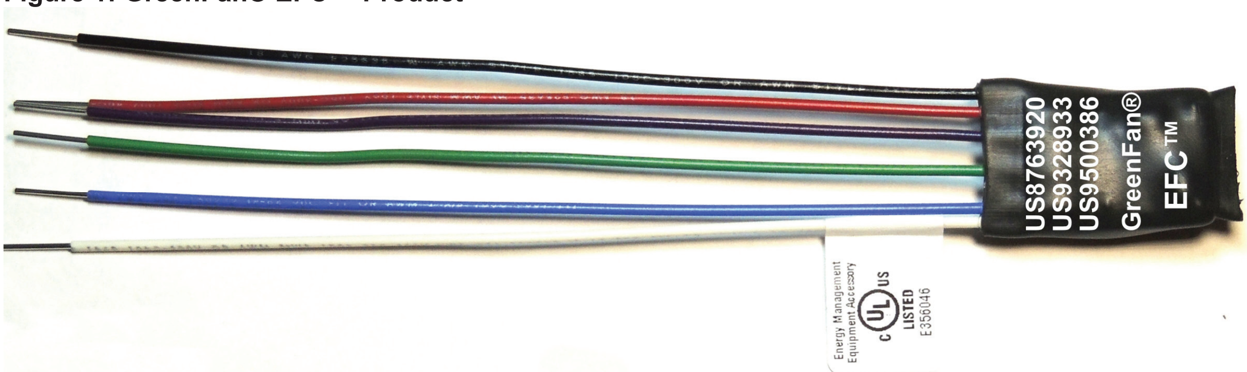
Report Scope:

This report summarizes the performance evaluation of the GreenFan® Efficient Fan Controller™ (EFC™) fan controller installed and tested on a new heat pump and a new hydronic split-system. Testing was conducted at the Intertek® laboratory in Plano, Texas, under the direction of Ean Jones and Robert Mowris. Testing was performed by Intertek technicians managed by Gilbert Taracena and Craig Grider.

Product Description as Tested:

The GreenFan® EFC™ product shown in **Figure 1** is a microprocessor-based device that monitors the operational time of either the cool source (air conditioning compressor) or the heat source (heat pump compressor, furnace, electric, or hydronic heating system) and varies the duration of the indoor evaporator or heating fan operational time (referred to as "time delay") based on the cool or heat source operational time. The GreenFan® automatically detects the type of HVAC system it is connected to and cooling or heating system operational mode. For heat pumps the GreenFan® EFC™ detects heat pump reversing valve operation and maintains the reversing valve position for cooling or heating throughout the fan-off time delay period. The GreenFan® EFC™ activates the fan signal from the thermostat as though the fan switch was toggled to the "on" position to recover and deliver cooling or heating energy to the conditioned space after the cool or heat source operational time has ended. The GreenFan® EFC™ improves HVAC efficiency and saves energy by providing longer variable fan-off time delays based on HVAC system type, mode of operation, and cooling or heating operational time. The EFC™ recovers and delivers more sensible cooling or heating capacity to the space to exceed thermostat setpoint temperatures, lengthen off-cycles, and reduce on-cycles.

Figure 1: GreenFan® EFC™ Product



Description of Test Units

The heat pump test equipment schematic is shown in **Figure 2** and the hydronic test equipment schematic is shown in **Figure 3**. This report provides test results for heat pump heating and cooling tests and hydronic heating tests. The characteristics of the test units are described in **Table 1**.

Figure 2: Heat Pump Test Equipment Schematic

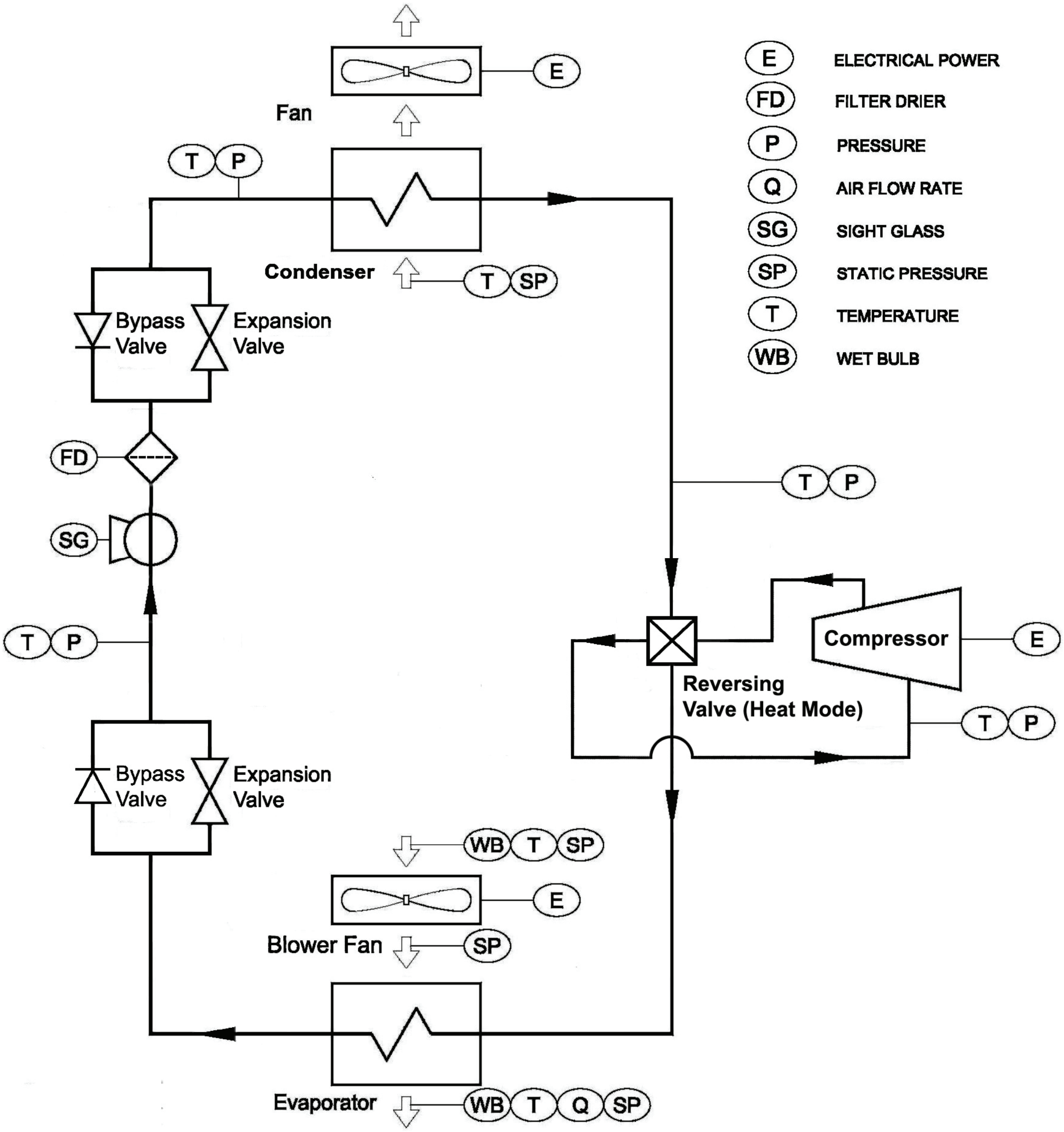
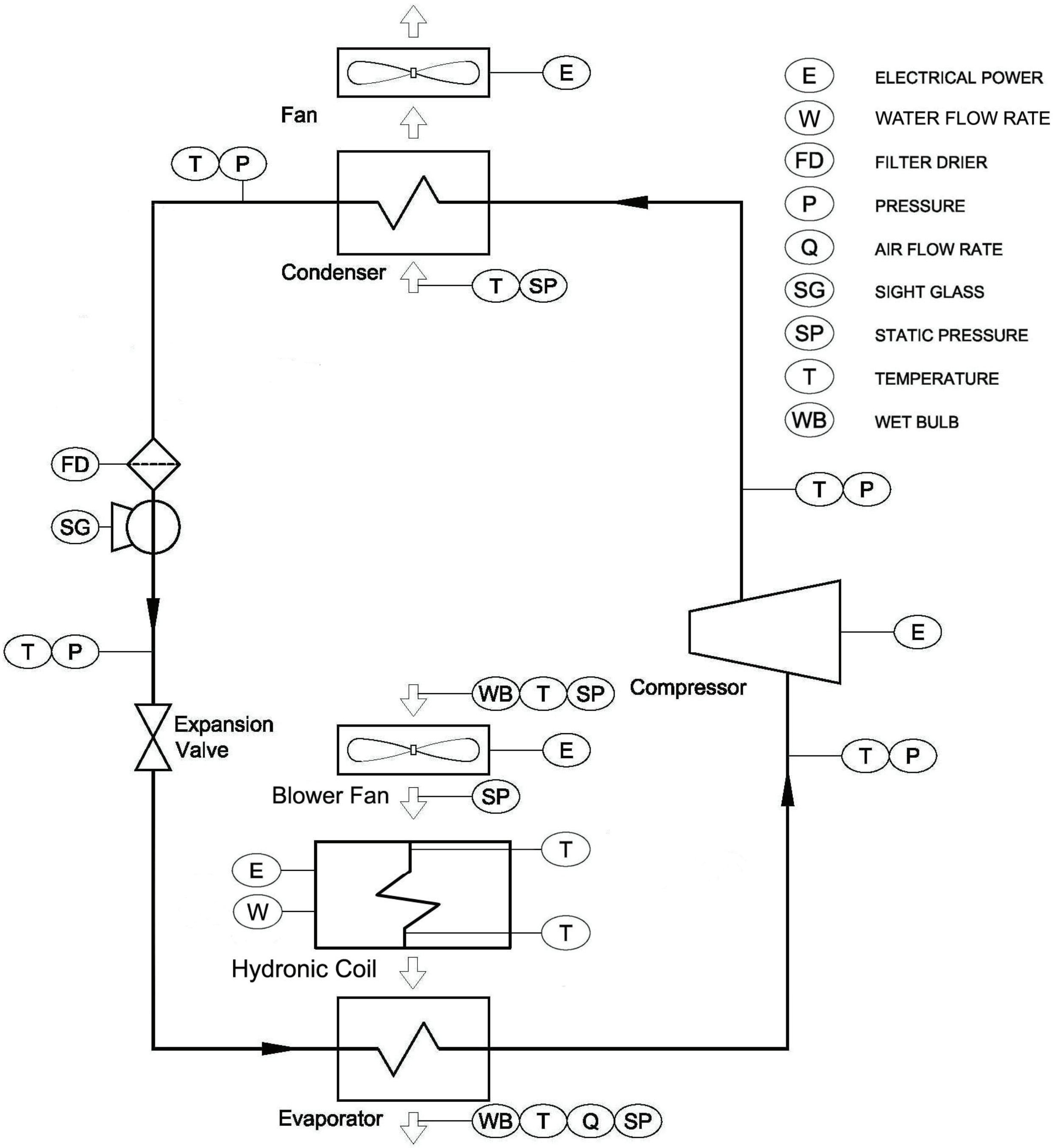


Figure 3: Hydronic Test Equipment Schematic



The 1.5-ton split-system Heat Pump (HP) rated total cooling capacity is 17,600 Btu per hour (Btuh) and the sensible cooling capacity is 13,900 Btuh at 95 degrees Fahrenheit (F) outdoor air temperature (OAT) and 525 cfm evaporator airflow with 80F indoor drybulb and 67F indoor wetbulb temperatures. The rated total cooling capacity is 17,000 Btuh and sensible cooling capacity is 13,600 Btuh at 95F OAT and 75F indoor drybulb and 62F indoor wetbulb temperatures. The rated heating capacity is 18,000 Btu per hour

at 47F OAT. The heat pump rated cooling efficiency is 14-SEER and the heating coefficient of performance (COP) is 3.76 at 47 degrees Fahrenheit (F) outdoor air temperature (OAT). The heat pump cooling or heating fan-off time delays are fixed during setup at either 0 seconds or 65 seconds after the cool or heat source turns off.

The 1.5-ton hydronic (HYD) split-system rated total cooling capacity is 17,500 Btu per hour at 95F OAT and 80F indoor drybulb and 67F indoor wetbulb temperature, The hydronic system rated cooling efficiency is 13 SEER with the model MHH-19-410 condensing coil and 95F OAT and 550 cfm evaporator airflow with 80F indoor drybulb and 67F indoor wetbulb temperatures. The rated heating capacity is 18,000 Btu per hour with 550 cfm airflow at 70F entering air drybulb temperature and 3 gallons per minute (gpm) at 140F hot water supply temperature. The rated hot water heating efficiency is 78%. The hydronic heating coil is designed to receive 1 to 3 gpm of 120 to 180 Fahrenheit (F) hot water circulated by a 1/25th hp (30W) pump where the water is heated by a storage water heater. The hydronic unit default cooling or heating time delay is fixed during setup at either 0 seconds or 60 seconds after the cool or heat source turns off.

Table 1: Description of Test Units – 1.5-ton Split-System Heat Pump and 1.5-ton Hydronic System

Unit Description	1.5-ton Split-System Heat Pump	1.5-ton Split-System Hydronic
ID Model Number	ARUF25B14AA	19CDX-HW
Input Voltage	208/230 VAC	208/230 VAC
Input Frequency	60 HZ	60 HZ
Phase	1 Phase	1 Phase
Type	Ducted Heat Pump Coil	Ducted Evaporator Coil/HW Coil
Rated Cooling Capacity	17,600 Btu/hr 525 scfm at 0.4 IWC	17,500 Btu/hr 550 scfm at 0.3 IWC
OD Model Number	GSZ140181KD	MHH-19-410
Fan Speed and RPM	1043 RPM	1550 RPM
Fan Time Delay Cooling	0 or 65 seconds Cooling	0 or 60 seconds Cooling
Fan Time Delay Heating	0 or 65 seconds Heating	0 or 60 seconds Heating
Frequency and Phase	60 HZ and Single Phase	60 HZ and Single Phase
Refrigerant Charge	R410A 92 Ounces	R410A 106 Ounces
Type	Air Cooled Condenser	Air Cooled Condenser
Heating Model Number	ARUF25B14AA	19CDX-HW
Rated Heat Capacity	18,000 Btu/hr 555 scfm at 0.47 IWC	18,000 Btu/hr 550 scfm at 0.4 IWC

Location and Dates of Tests:
Tests were performed at the Intertek Laboratory in Plano, Texas, from 11/07/2016 through 11/22/16.

Test Methods:
Each unit was tested under AHRI 210/240 test conditions and ANSI Z21.47 to verify manufacturer published efficiency ratings. The AHRI 210/240 cooling verification tests were performed according to ANSI/AHRI 2008 Standard for Performance Rating of Unitary Air-Conditioning and Air-Source Heat Pump Equipment Standard 210/240. Verification tests were conducted according to **Table 2** (ANSI/AHRI

Standard 210/240-2008, Table 11) and **Table 3**.[1]

Each unit was tested in cooling and heating modes under non-steady state field conditions to measure sensible cooling or heating capacity and efficiency with no time delay or fixed time delay of 65 seconds for the split-system heat pump or 60 seconds for the split-system hydronic system after the cool or heat source turned off. Non-steady state cooling and heating tests were performed with the patented GreenFan® EFC™ product providing a variable time delay on the fan depending on length of time the cool or heat source operated.

Non-steady state testing of GreenFan® did not include an evaluation of SEER or AFUE impacts.

Table 2: ANSI/AHRI 210/240 Table 11. Minimum External Static Pressure for Ducted Systems Tested with an Indoor Fan Installed

Table 11. Minimum External Static Pressure for Ducted Systems Tested with an Indoor Fan Installed

Rated Cooling(1) or Heating(2) Capacity		Minimum External Resistance(3)			
		All Other Systems		Small-Duct, High-Velocity Systems(4,5)	
Btu/h	kW	in H_2O	Pa	in H_2O	Pa
Up thru 28,800	Up thru 8.44	0.10	25	1.10	275
29,000 to 42,500	8.5 to 12.4	0.15	37	1.15	288
43,000 and Above	12.6 thru 19.0	0.20	50	1.20	300

(1) For air conditioners and heat pumps, the value cited by the manufacturer in published literature for the unit's capacity when operated at the A or A_2 Test conditions.
(2) For heating-only heat pumps, the value the manufacturer cites in published literature for the unit's capacity when operated at the H1 or $H1_2$ Test conditions.
(3) For ducted units tested without an air filter installed, increase the applicable tabular value by 0.08 in H_2O [20 Pa].
(4) See Definition 1.35 of Appendix C to determine if the equipment qualifies as a small-duct, high-velocity system.
(5) If a closed-loop, air-enthalpy test apparatus is used on the indoor side, limit the resistance to airflow on the inlet side of the indoor blower coil to a maximum value of 0.10 in H_2O [25 Pa]. Impose the balance of the airflow resistance on the outlet side of the indoor blower.

[1] ANSI/AHRI 2008 Standard for Performance Rating of Unitary Air-Conditioning and Air-Source Heat Pump Equipment Standard 210/240. American National Standards Institute. Air-Conditioning Heating and Refrigeration Institute.

Table 3: ANSI/AHRI 210/240 Table 3. Cooling Mode Test Conditions

Table 3. Cooling Mode Test Conditions for Units Having a Single-Speed Compressor and a Fixed-Speed Indoor Fan, a Constant Air Volume Rate Indoor Fan, or No Indoor Fan

Test Description	Air Entering Indoor Unit Temperature				Air Entering Outdoor Unit Temperature				Cooling Air Volume Rate
	Dry-Bulb		Wet-Bulb		Dry-Bulb		Wet-Bulb		
	°F	°C	°F	°C	°F	°C	°F	°C	
A Test - required (steady, wet coil)	80.0	26.7	67.0	19.4	95.0	35.0	75.0(1)	23.9(1)	Cooling Full-load (2)
B Test - required (steady, wet coil)	80.0	26.7	67.0	19.4	82.0	27.8	65.0(1)	18.3(1)	Cooling Full-load (2)
C Test - optional (steady, dry coil)	80.0	26.7	(3)		82.0	27.8	–		Cooling Full-load (2)
D Test - optional (cyclic, dry coil)	80.0	26.7	(3)		82.0	27.8	–		(4)

Notes:

(1) The specified test condition only applies if the unit rejects condensate to the outdoor coil.
(2) Defined in section 6.1.3.3.1.
(3) The entering air must have a low enough moisture content so no condensate forms on the indoor coil. (It is recommended that an indoor wet-bulb temperature of 57.0 °F [13.9 °C] or less be used.)
(4) Maintain the airflow nozzles static pressure difference or velocity pressure during the ON period at the same pressure difference or velocity pressure as measured during the C Test.

Baseline Tests:
AHRI 210/240 tests were performed to verify rated performance at nominal airflow and static pressure.

Test Equipment Calibration
The psychrometric room is designed to ASHRAE 37 specifications. Calibration for all equipment on this facility is completed annually, and is maintained under one Intertek ID number. Individual calibration records can be made available upon request. All calibration is conducted in accordance to ISO 17025 requirements by an ILAC accredited calibration provider.

GreenFan® Performance Evaluation Results
The baseline and GreenFan® non-steady state test parameters and test results for the 1.5-ton split- heat pump system and 1.5-ton split- hydronic system in cooling and heating mode are summarized in **Table 4** through **Table 19** and **Figure 4** through **Figure 19**. Detailed test data and results are on file at Intertek.

Sensible Cooling and Heating Capacity and Efficiency Calculations

Sensible cooling and heating capacity for the split-system or packaged HVAC systems with either no time delay or fixed time delay and GreenFan® variable time delay are measured in British thermal units per hour (Btu/hr).[2] The sensible cooling capacity is based on the measured airflow rate in standard cubic feet per minute (cfm), specific volume (ft^3/lbm), and temperature difference in degrees Fahrenheit (F) between the return air entering the evaporator and the supply air leaving the evaporator. **Equation 1** is used to calculate the non-steady state sensible cooling capacity for the air conditioner.

Equation 1 $$Q_{sc} = \sum_{t=0}^{n} q_{sc_t} \left[\frac{t}{3600} \right]$$

Where, Q_{sc} = non-steady-state sensible cooling capacity (Btu),

t = time measurement interval (5 seconds),

n = number of measurement intervals for test (integer),

$q_{sc_t} = c_p (T_r - T_s) \frac{\dot{V}}{\nu} \left[\frac{60 \text{ min}}{hr} \right]$ = non-steady state cooling capacity per time interval (Btu/hr),

c_p = specific heat of dry air at constant pressure = 0.24 Btu/lbm-°F,

T_r = drybulb temperature of return air entering the evaporator coil (F),

T_s = drybulb temperature of supply air leaving the evaporator coil (F),

$\dot{V}$ = volumetric airflow rate in cubic feet per minute (cfm), and

ν = specific volume per pound of dry air (ft^3/lbm).

The non-steady-state sensible cooling efficiency (η_{sc}) is defined as the sensible cooling capacity (Btu/hr) divided by the electric power consumption (Watts) of the air conditioner (including compressor, fans, and controls). **Equation 2** is used to calculate the non-steady-state sensible cooling efficiency.

Equation 2 $$\eta_{sc} = \sum_{t=0}^{n} \frac{q_{sc_t}}{e_t}$$

Where, η_{sc} = non-steady-state sensible cooling efficiency (Btu/Wh), and

e_t = total cooling electric power consumption per time interval (Watts).

Non-steady state cooling tests were performed with no time delay or fixed time delay and GreenFan® variable time delay to measure the sensible cooling capacity and efficiency. The non-steady-state sensible cooling capacity improvement for the GreenFan® EFC™ is calculated using **Equation 3.**

Equation 3 $$\Delta Q_{sc} = \left[\frac{Q_{sc_g}}{Q_{sc_o}} - 1 \right] 100$$

Where, ΔQ_{sc} = sensible cooling capacity improvement with GreenFan® EFC™ (%),

Q_{sc_g} = sensible cooling capacity with GreenFan® (Btu), and

Q_{sc_o} = baseline sensible cooling capacity without GreenFan® (Btu).

The non-steady-state sensible cooling efficiency improvement for the GreenFan® EFC™ is calculated using **Equation 4**.

[2] The British thermal unit (Btu) is heat required to raise the temperature of one pound of water one degree Fahrenheit (°F). The Btu is equivalent to 1055.06 joules or 251.997 calories.

Equation 4 $$\Delta\eta_{sc} = \left[\frac{\eta_{sc_g}}{\eta_{sc_o}} - 1\right]100$$

Where, $\Delta\eta_{sc}$ = sensible cooling efficiency improvement with GreenFan® EFC™ (%),

η_{sc_g} = sensible cooling efficiency with GreenFan® (Btu/Wh), and

η_{sc_o} = sensible cooling efficiency without GreenFan® (Btu/Wh).

The baseline cooling energy to match the GreenFan® EFC™ sensible cooling capacity is calculated using **Equation 5**.

Equation 5 $$E_{c_m} = \left[\frac{Q_{sc_g}}{\eta_o\,(1000\ W/kW)}\right]$$

Where, E_{c_m} = baseline energy required to match GreenFan® EFC™ cooling capacity (kWh),

Q_{sc_g} = sensible cooling capacity with GreenFan® (Btu), and

η_o = baseline sensible efficiency without GreenFan® (Btu/Wh).

Cooling energy savings with the GreenFan® EFC™ are achieved by providing longer variable fan-off time delays based on cool source operational time to recover and supply more sensible cooling to the space to exceed the thermostat setpoint temperature and lengthen air conditioning off-cycles producing fewer cooling on-cycles. The cooling energy savings are calculated using **Equation 6**. This is the energy required by the baseline system to match the extra cooling capacity supplied with the GreenFan® EFC™ minus energy consumption with the GreenFan® EFC™.

Equation 6 $$\Delta E_c = E_{c_m} - E_{c_g} = \frac{Q_{c_g} - Q_{c_o}}{\eta_{sc_o}\,(1000\ \text{W/kWh})} + E_{c_o} - E_{c_g}$$

Where, ΔE_c = cooling energy savings with GreenFan® EFC™ compared to baseline (kWh),

Q_{c_o} = cooling capacity supplied by baseline system (Btu),

Q_{c_g} = cooling capacity supplied with GreenFan® EFC™ (Btu),

E_{c_o} = baseline energy consumption (kWh), and

E_{c_g} = energy consumption with GreenFan® EFC™ (kWh).

The cooling savings percentage is calculated using **Equation 7**.

Equation 7 $$\Delta e_{cs} = \left[1 - \frac{\eta_{sc_o}}{\eta_{sc_g}}\right]100$$

Where, Δe_{cs} = cooling savings with GreenFan® EFC™ (%).

An example calculation is provided for the 10-minute cooling test 103 (see **Table 4**) using **Equations 4** through **7**. With the no time delay baseline, the split-system air conditioner uses 0.244 kWh to supply 991 Btu of sensible cooling to the space with an efficiency of 4.07 Btu/Wh. With the GreenFan® EFC™, the air conditioner uses 0.258 kWh to supply 1439 Btu of sensible cooling with an efficiency of 5.58 Btu/Wh. The cooling efficiency improvement of 37.2% with the GreenFan® EFC™ is calculated using **Equation 4**.

Example Eq. 4 $\Delta\eta_{sc} = \left[\frac{\eta_{sc_g}}{\eta_{sc_o}} - 1\right]100 = \left[\frac{5.58}{4.07} - 1\right]100 = 37.2\%$

Where, $\Delta\eta_{sc}$ = test 103 sensible cooling efficiency improvement with GreenFan® EFC™ = 37.2%
η_{sc_g} = test 103 sensible cooling efficiency with GreenFan® = 5.58 Btu/Wh, and
η_{sc_o} = test 103 sensible cooling efficiency without GreenFan® = 4.07 Btu/Wh.

The test 103 cooling energy of 0.354 kWh required to match the GreenFan® EFC™ sensible cooling capacity at the baseline efficiency is calculated using **Equation 5**.

Example Equation 5 $E_{c_m} = \left[\frac{Q_{sc_g}}{\eta_o(1000)}\right] = \left[\frac{1439}{4.07(1000)}\right] = 0.354 \text{ kWh}$

Where, E_{c_m} = baseline efficiency energy required to match GreenFan® EFC™ capacity = 0.354 kWh,
Q_{sc_g} = test 103 sensible cooling capacity with GreenFan® = 1439 Btu, and
η_o = test 103 baseline sensible efficiency without GreenFan® = 4.07 Btu/Wh.

The test 103 cooling energy savings of 0.096 kWh with GreenFan® are calculated using **Equation 6**.

Example Eq. 6 $\Delta E_c = \frac{Q_{c_g} - Q_{c_o}}{\eta_{sc_o}(1000 \text{ W/kWh})} + E_{c_o} - E_{c_g} = \frac{1439 - 991}{4.07\ (1000)} + 0.244 - 0.258 = 0.096 \text{ kWh}$

Where, ΔE_c = test 103 cooling energy savings with GreenFan® EFC™ compared to baseline = 0.096 kWh,
Q_{c_o} = test 103 cooling capacity supplied by baseline system = 991 Btu,
Q_{cg} = test 103 cooling capacity supplied with GreenFan® EFC™ = 1439 Btu,
η_{sc_o} = test 103 baseline sensible cooling efficiency = 4.07 Btu/Wh,
E_{c_o} = test 103 baseline energy consumption = 0.244 kWh, and
E_{c_g} = test 103 energy consumption with GreenFan® EFC™ = 0.258 kWh.

The test 103 cooling percentage savings of 27.1% with GreenFan® are calculated using **Equation 7**.

Example Equation 7 $\Delta e_{cs} = 1 - \frac{\eta_{sc_o}}{\eta_{sc_g}} \times 100 = 1 - \frac{4.07}{5.58} \times 100 = 27.1\%$

Where, Δe_{cs} = test 103 sensible cooling efficiency improvement with GreenFan® EFC™ = 27.1%,
η_{sc_o} = test 103 baseline sensible cooling efficiency = 4.07 Btu/Wh, and
η_{sc_g} = test 103 sensible cooling efficiency with GreenFan® EFC™ = 5.58 Btu/Wh.

The heating efficiency (η_h) is defined as the non-steady-state sensible heating capacity (Btu/hr) divided by the heat source energy consumption (Btu/hr) per time interval. **Equation 8** is used to calculate the heating efficiency for the heat pump or hydronic heating system.

Equation 8
$$\eta_h = \sum_{t=0}^{n} \frac{q_{h_t}}{e_{h_t}} = \frac{Q_h}{E_h}$$

Where, η_h = heating efficiency (dimensionless),

$q_{h_t} = c_p(T_s - T_r)\frac{\dot{V}}{\nu}\left[\frac{60 \text{ min}}{hr}\right]$ = non-steady state heating capacity per time interval (Btu/hr),

e_{h_t} = non-steady-state heat pump energy consumption per time interval (Btu/hr),

Q_h = sensible heating capacity supplied by heat pump or hydronic heating system (Btu), and

E_h = heat source energy consumption (Btu).

Heat pump heating energy consumption is equal to total kWh consumption times 3412 Btu per kWh as shown in **Equation 9**.

Equation 9
$$E_h = \sum_{t=0}^{n} e_t\left[\frac{t}{3600}\right]3412$$

Where, E_h = heat pump heating energy consumption (Btu), and

e_t = electric power consumption per time interval for the heat pump (Watts).

Hydronic heating energy consumption is equal total energy delivered by the hot water heating system divided by the efficiency of the hot water heater as shown **Equation 10.**

Equation 10
$$E_h = \sum_{t=0}^{n} e_{h_t}\left[\frac{t}{3600}\right]$$

Where, E_h = hydronic heating energy consumption (Btu), and

$e_{h_t} = \frac{c_w\,(T_i - T_o)\dot{V}}{\eta_{wh}}\left[\frac{8.33 \text{ lbm}}{\text{gal}}\right]\left[\frac{60 \text{ min}}{\text{hr}}\right]$ = hydronic heating energy input (Btu/hr),

c_w = specific heat of water = 1 Btu/lbm-F,

T_i = inlet temperature of hydronic coil (F),

T_o = outlet temperature of hydronic coil (F),

$\dot{V}$ = volumetric water flow rate in gallons per minute (gpm),

η_{wh} = hydronic water heater efficiency = 0.78.

The heating efficiency improvement ($\Delta\eta_h$) for the GreenFan® EFC™ is calculated using **Equation 11**.

Equation 11
$$\Delta\eta_h = \left[\frac{\eta_{h_g}}{\eta_{h_o}} - 1\right]100$$

Where, $\Delta\eta_h$ = heating efficiency improvement with GreenFan® EFC™ (%),

η_{h_g} = heating efficiency with GreenFan® (dimensionless), and

η_{h_o} = heating efficiency without GreenFan® (dimensionless).

The baseline heat pump heating energy to match the GreenFan® EFC™ heating capacity is calculated using **Equation 12**.

Equation 12 $$E_{h_m} = \left[\frac{Q_{h_g}}{\eta_{h_o} (3412 \text{ Btu/kWh})} \right]$$

Where, E_{h_m} = energy to match GreenFan® EFC™ heating capacity at baseline efficiency (kWh),

Q_{h_g} = heat pump heating capacity with GreenFan® EFC™ (Btu),

η_{h_o} = heat pump heating efficiency without GreenFan® (dimensionless).

The baseline hydronic heating energy to match the GreenFan® EFC™ heating capacity is calculated using **Equation 13**.

Equation 13 $$E_{h_m} = \left[\frac{Q_{h_g}}{\eta_{h_o}} \right]$$

Where, E_{h_m} = energy required to match GreenFan® EFC™ heating capacity (Btu) at baseline efficiency,

Q_{h_g} = hydronic heating capacity supplied with GreenFan® EFC™ (Btu),

η_{h_o} = hydronic heating efficiency without GreenFan® (dimensionless).

For heat pump and hydronic heating systems, the GreenFan® EFC™ saves energy by providing longer variable fan-off time delays based on heat source operational time. The EFC™ recovers and supplies more heating capacity to the space to exceed thermostat setpoint temperatures, lengthen off-cycles, and reduce on-cycles. Energy savings are calculated using **Equation 14** for a heat pump in heating mode.

Equation 14 $$\Delta E_h = \frac{Q_{h_g} - Q_{h_o}}{\eta_{h_o} (3412 \text{ Btu/kWh})} + E_{h_o} - E_{h_g}$$

Where, ΔE_h = heat pump heating energy savings with GreenFan® EFC™ compared to baseline (kWh),

Q_{h_o} = heating capacity supplied by baseline heat pump (Btu),

Q_{h_g} = heating capacity supplied by heat pump with GreenFan® EFC™ (Btu),

E_{h_o} = baseline energy consumption (kWh), and

E_{h_g} = energy consumption with GreenFan® EFC™ (kWh).

Energy savings are calculated using **Equation 15** for a hydronic heating system.

Equation 15 $$\Delta E_h = \frac{Q_{h_g} - Q_{h_o}}{\eta_{h_o}} + E_{h_o} - E_{h_g}$$

Where, ΔE_h = hydronic heating energy savings with GreenFan® EFC™ compared to baseline (Btu),

Q_{h_o} = heating capacity supplied by baseline hydronic heating system (Btu),

Q_{h_g} = heating capacity supplied by hydronic heating system with GreenFan® EFC™ (Btu),

E_{h_o} = baseline energy consumption (Btu), and

E_{h_g} = energy consumption with GreenFan® EFC™ (Btu).

The heating energy savings percentage with the GreenFan® EFC™ is calculated using **Equation 16**.

Equation 16 $$\Delta\eta_h = \left[1 - \frac{\eta_{h_o}}{\eta_{h_g}}\right]100$$

Where, $\Delta\eta_h$ = heating savings percentage with GreenFan® EFC™ compared to baseline (%),

η_{h_o} = baseline heat pump or hydronic heating efficiency (dimensionless), and

η_{h_g} = heat pump or hydronic heating efficiency with GreenFan® EFC™ (dimensionless).

An example calculation is provided for heat pump test 128 using **Equations 11** through **16** (**Table 8**). The baseline heat pump uses 0.466 kWh to supply 3,066 Btu with coefficient of performance (COP) efficiency of 1.93.[3] With the GreenFan® EFC™, the heat pump uses 0.475 kWh to supply 3,569 Btu of heat to the space with a COP efficiency of 2.20.

The heating efficiency improvement with GreenFan® EFC™ is calculated using **Equation 11**.

Example Equation 11 $$\Delta\eta_h = \left[\frac{\eta_{hg}}{\eta_{h_o}} - 1\right] \times 100 = \left[\frac{2.2}{1.93} - 1\right] \times 100 = 14.1\%$$

Where, $\Delta\eta_h$ = test 128 heating efficiency improvement with GreenFan® EFC™ = 14.1%,

η_{h_g} = test 128 heat pump heating efficiency with GreenFan® EFC™ = 2.2, and

η_{h_o} = test 128 baseline heat pump heating efficiency = 1.93.

The heat pump heating energy required to match the GreenFan® EFC™ heating capacity at the baseline efficiency is calculated using **Equation 12**.

Example Equation 12 $$E_{h_m} = \left[\frac{Q_{h_g}}{\eta_{h_o}(3412\ \text{Btu/kWh})}\right] = \frac{3569}{1.93(3412)} = 0.543\ \text{kWh}$$

Where, E_{h_m} = energy to match GreenFan® EFC™ heating capacity at baseline efficiency = 0.543 kWh,

Q_{hg} = test 128 heat pump heating capacity with GreenFan® EFC™ = 3569 Btu,

η_{h_o} = test 128 heat pump heating efficiency = 1.93.

The heating energy savings with the GreenFan® EFC™ are calculated using **Equation 14**.

Example Eq. 14 $$\Delta Q_h = \frac{Q_{h_g} - Q_{h_o}}{\eta_{h_o}\ (3412)} + E_{h_o} - E_{h_g} = \frac{3569 - 3066}{1.93\ (3412)} + 0.466 - 0.475 = 0.068\ \text{kWh}$$

Where, ΔQ_h = test 128 heating energy savings with GreenFan® EFC™ = 0.068 kWh,

Q_{h_o} = test 128 baseline heat pump heating capacity = 3569 Btu,

Q_{hg} = test 128 heat pump heating capacity with GreenFan® EFC™ = 3066 Btu,

η_{h_o} = baseline heat pump heating efficiency = 1.93,

E_{h_o} = baseline heat pump energy consumption = 0.466 kWh, and

[3] COP efficiency is defined as energy output divided by energy input (i.e., Btu out divided by kWh times 3412 Btu/kWh).

E_{h_g} = heat pump energy consumption with GreenFan® EFC™ = 3066 kWh.

The HP heating energy savings percentage with GreenFan® EFC™ is calculated using **Equation 16**.

Example Equation 16 $$\Delta\eta_h = 1 - \frac{\eta_{h_o}}{\eta_{h_g}} = 1 - \frac{1.93}{2.20} \times 100 = 12.4\%$$

Where, $\Delta\eta_h$ = test 128 heating efficiency improvement with GreenFan® EFC™ = 12.4%,

η_{h_o} = test 128 baseline heat pump heating efficiency = 1.93, and

η_{h_g} = test 128 heat pump heating efficiency with GreenFan® EFC™ = 2.20.

An example calculation is provided for hydronic test 175 using **Equations 11** through **16** (**Table 16**). The baseline hydronic system uses 4548 Btu to supply 1857 Btu with efficiency of 40.8%. With the GreenFan® EFC™, the hydronic system uses 4548 Btu to supply 2382 Btu of heat with efficiency of 52.4%. The hydronic heating efficiency improvement with GreenFan® EFC™ is calculated using **Equation 11**.

Example Equation 11 $$\Delta\eta_h = \left[\frac{\eta_{hg}}{\eta_{h_o}} - 1\right] \times 100 = \left[\frac{0.524}{0.408} - 1\right] \times 100 = 28.3\%$$

Where, $\Delta\eta_h$ = test 175 heating efficiency improvement with GreenFan® EFC™ = 28.3%,

η_{h_g} = test 175 hydronic heating efficiency with GreenFan® EFC™ = 0.524, and

η_{h_o} = test 175 baseline hydronic pump heating efficiency = 0.408.

The hydronic heating energy required to match the GreenFan® EFC™ heating capacity at the baseline efficiency is calculated using **Equation 12**.

Example Equation 12 $$E_{h_m} = \left[\frac{Q_{h_g}}{\eta_{h_o}}\right] = \frac{2382}{0.408} = 5835 \text{ Btu}$$

Where, E_{h_m} = energy to match GreenFan® EFC™ heating capacity at baseline efficiency = 5835 Btu,

Q_{hg} = test 175 hydronic heating capacity with GreenFan® EFC™ = 2382 Btu,

η_{h_o} = test 175 hydronic heating efficiency without GreenFan® = 40.8%.

The heating energy savings with the GreenFan® EFC™ are calculated using **Equation 15**.

Example Eq. 15 $$\Delta Q_h = \frac{Q_{h_g} - Q_{h_o}}{\eta_{h_o}} + E_{h_o} - E_{h_g} = \frac{2382 - 1857}{0.408} + 4548 - 4548 = 1287 \text{ Btu}$$

Where, ΔQ_h = test 175 heating energy savings with GreenFan® EFC™ = 1287 Btu,

Q_{h_o} = test 175 baseline hydronic heating capacity = 1857 Btu,

Q_{hg} = test 175 hydronic heating capacity with GreenFan® EFC™ = 2382 Btu,

η_{h_o} = test 175 baseline hydronic heating efficiency = 0.408,

E_{h_o} = baseline hydronic energy consumption = 4548 Btu, and

E_{h_g} = hydronic energy consumption with GreenFan® EFC™ = 4548 Btu.

The hydronic heating efficiency improvement with GreenFan® EFC™ is calculated using **Equation 16**.

Example Equation 16 $$\Delta\eta_h = 1 - \frac{\eta_{h_o}}{\eta_{h_g}} = 1 - \frac{0.408}{0.524} \times 100 = 22.1\%$$

Where, $\Delta\eta_h$ = test 175 hydronic heating efficiency improvement with GreenFan® EFC™ = 22.1%,

η_{h_o} = test 175 baseline hydronic heating efficiency = 0.408, and

η_{h_g} = test 175 hydronic heating efficiency with GreenFan® EFC™ = 0.524.

Non-steady state tests for cooling and heating were performed with fixed time delay and GreenFan® variable time delay to measure the sensible cooling and heating capacity and efficiency for the split-system or packaged heat pump or hydronic HVAC systems. Results for each test are provided in the following tables and figures.

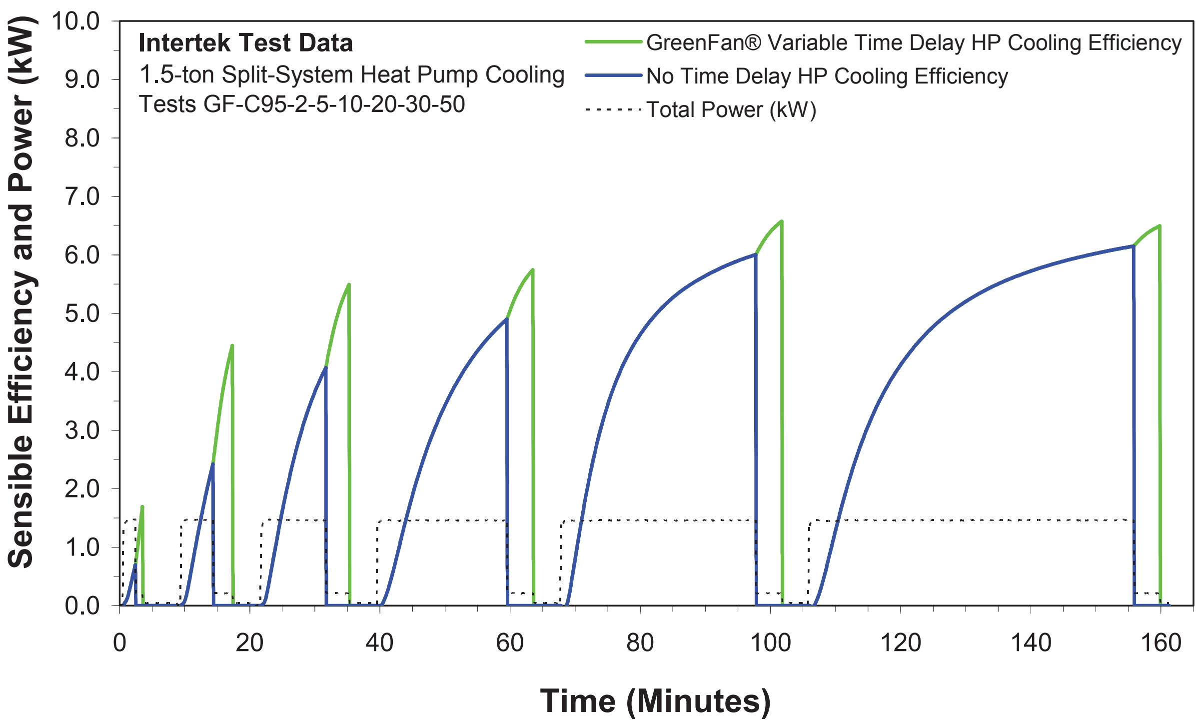
Heat Pump Cooling Tests at 95F OAT with No Delay and EFC™ Variable Time Delay

Cooling tests for the 1.5-ton split system heat pump with no time delay and GreenFan® EFC™ variable time delay were performed at typical field conditions of 75F DB and 62F WB indoor and 95F outdoor temperatures. **Table 4** and **Figure 4** provide test results. Based on six tests, the GreenFan® improved sensible efficiency by 5.6 to 195% and provides cooling energy savings of 5.3 to 66.1%.

Table 4: HP Cooling Tests at 95F OAT GF-C95-2-50 – No Delay and EFC™ Variable Delay

Description	Test 101	Test 102	Test 103	Test 104	Test 105	Test 106
Compressor On Time (minutes)	2	5	10	20	30	50
No Delay AC Energy (kWh) [a]	0.047	0.122	0.244	0.486	0.730	1.218
No Delay Sensible Cooling (Btu) [b]	33	295	991	2,380	4,381	7,488
No Delay Sensible Efficiency (Btu/Wh) [c=b/a/1000]	0.69	2.42	4.07	4.90	6.00	6.15
GreenFan® AC Energy (kWh) [d]	0.052	0.133	0.258	0.500	0.744	1.232
GreenFan® Sensible Cooling (Btu) [e]	107	589	1,439	2,874	4,893	8,002
GreenFan® Sensible Efficiency (Btu/Wh) [f=e/d/1000]	2.05	4.45	5.58	5.75	6.58	6.49
GreenFan® Sensible Efficiency Improvement [g=f/c-1]	195.0%	83.7%	37.2%	17.3%	9.5%	5.6%
GreenFan® Extra Fan Energy (kWh)	0.005	0.011	0.014	0.014	0.014	0.014
No Delay AC Energy to Match EFC™ (kWh) [h=e/c/1000]	0.154	0.244	0.354	0.587	0.815	1.301
GreenFan® Energy Savings (kWh) [i=h-d]	0.102	0.111	0.096	0.087	0.071	0.069
GreenFan® Cooling Energy Savings [j=(1-c/f) or j=i/h]	**66.1%**	**45.6%**	**27.1%**	**14.7%**	**8.7%**	**5.3%**

Figure 4: HP Cooling Tests at 95F OAT GF-C95-2-50 – No Delay and EFC™ Variable Delay



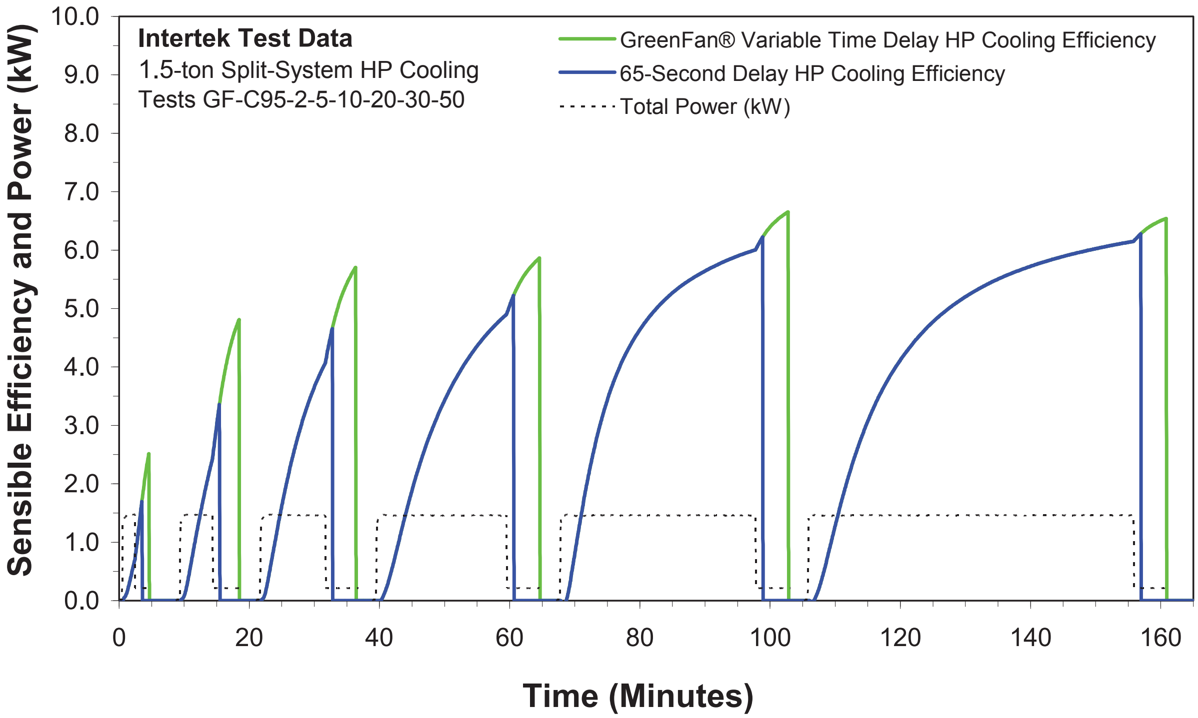
Heat Pump Cooling Tests at 95F OAT with 65-Second and EFC™ Variable Time Delay

Cooling tests for the 1.5-ton split system heat pump with 65-second delay and GreenFan® EFC™ variable time delay were performed at typical field conditions of 75F DB and 62F WB indoor and 95F outdoor temperatures. **Table 5** and **Figure 5** provide test results. Based on six tests, the GreenFan® improved sensible efficiency by 4.2 to 61.4% and provides cooling energy savings of 4 to 38%.

Table 5: HP Cooling Tests at 95F OAT GF-C95-2-50 – 65-Second and EFC™ Variable Delay

Description	**Test 107**	**Test 108**	**Test 109**	**Test 110**	**Test 111**	**Test 112**
Compressor On Time (minutes)	2	5	10	20	30	50
65-Second Delay AC Energy (kWh) [a]	0.051	0.126	0.248	0.490	0.734	1.222
65-Second Delay Sensible Cooling (Btu) [b]	86	421	1,152	2,555	4,562	7,670
65-Sec. Delay Sensible Efficiency (Btu/Wh) [c=b/a/1000]	1.69	3.35	4.65	5.22	6.22	6.28
GreenFan® AC Energy (kWh) [d]	0.056	0.136	0.262	0.504	0.748	1.236
GreenFan® Sensible Cooling (Btu) [e]	153	656	1,512	2,956	4,974	8,084
GreenFan® Sensible Efficiency (Btu/Wh) [f=e/d/1000]	2.72	4.81	5.77	5.86	6.65	6.54
GreenFan® Sensible Efficiency Improvement [g=f/c-1]	61.4%	43.5%	24.1%	12.4%	7.0%	4.2%
GreenFan® Extra Fan Energy (kWh)	0.005	0.011	0.014	0.014	0.014	0.014
65-Sec. Delay AC Energy to Match EFC™ (kWh) [h=e/c/1000]	0.091	0.196	0.325	0.567	0.800	1.288
GreenFan® Energy Savings (kWh) [i=h-d]	0.034	0.059	0.063	0.063	0.052	0.052
GreenFan® Cooling Energy Savings [j=(1-c/f) or j=i/h]	**38.0%**	**30.3%**	**19.4%**	**11.0%**	**6.5%**	**4.0%**

Figure 5: HP Cooling Tests at 95F OAT GF-C95-2-50 – 65-Second and EFC™ Variable Delay



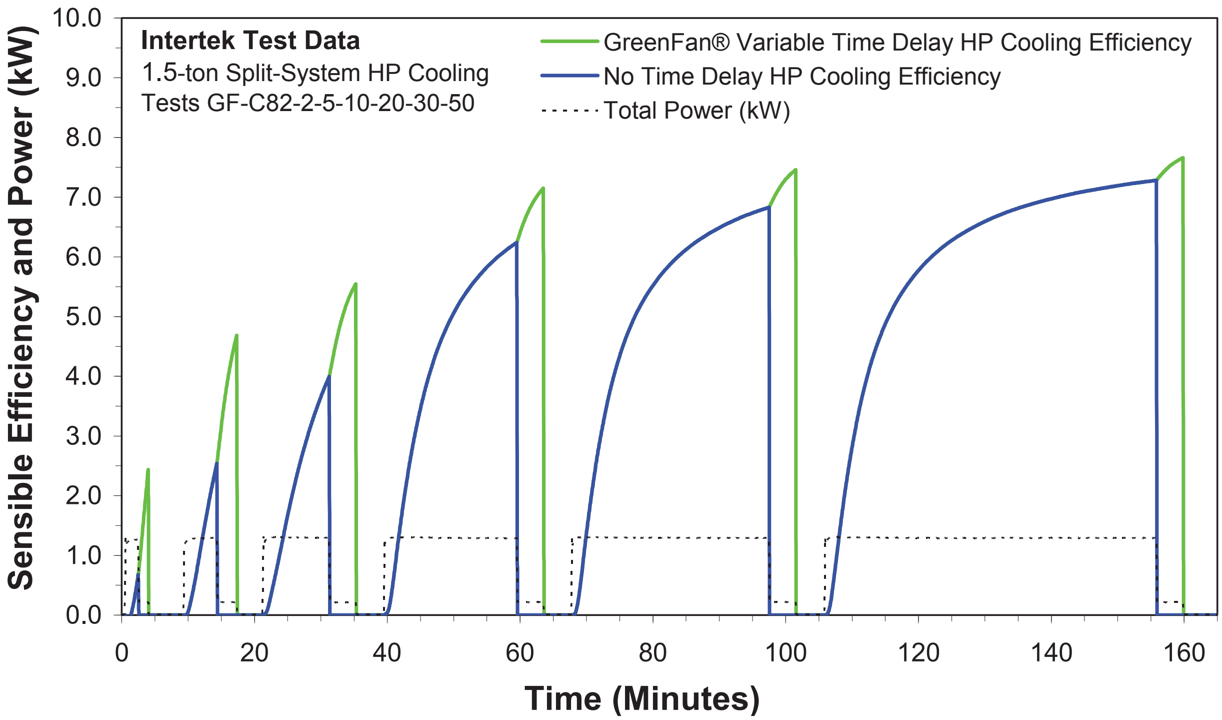
Heat Pump Cooling Tests at 82F OAT with No Delay and EFC™ Variable Time Delay

Cooling tests for the 1.5-ton split system heat pump with no time delay and GreenFan® EFC™ variable time delay were performed at typical field conditions of 75F DB and 62F WB indoor and 82F outdoor temperatures. **Table 6** and **Figure 6** provide test results. Based on six tests, the GreenFan® improved sensible efficiency by 5.2 to 263.4% and provides cooling energy savings of 4.9 to 72.5%.

Table 6: HP Cooling Tests at 82F OAT GF-C82-2-50 – No Delay and EFC™ Variable Delay

Description	Test 113	Test 114	Test 115	Test 116	Test 117	Test 118
Compressor On Time (minutes)	2	5	10	20	30	50
No Delay AC Energy (kWh) [a]	0.042	0.107	0.216	0.431	0.642	1.077
No Delay Sensible Cooling (Btu) [b]	28	272	863	2,688	4,383	7,843
No Delay Sensible Efficiency (Btu/Wh) [c=b/a/1000]	0.67	2.54	3.99	6.24	6.83	7.28
GreenFan® AC Energy (kWh) [d]	0.048	0.118	0.231	0.445	0.656	1.092
GreenFan® Sensible Cooling (Btu) [e]	116	552	1,279	3,182	4,895	8,361
GreenFan® Sensible Efficiency (Btu/Wh) [f=e/d/1000]	2.43	4.68	5.54	7.15	7.46	7.66
GreenFan® Sensible Efficiency Improvement [g=f/c-1]	263.4%	84.5%	39.0%	14.6%	9.2%	5.2%
GreenFan® Extra Fan Energy (kWh)	0.005	0.011	0.014	0.014	0.014	0.014
No Delay AC Energy to Match EFC™ (kWh) [h=e/c/1000]	0.173	0.217	0.321	0.510	0.717	1.148
GreenFan® Energy Savings (kWh) [i=h-d]	0.126	0.100	0.090	0.065	0.061	0.057
GreenFan® Cooling Energy Savings [j=(1-c/f) or j=i/h]	**72.5%**	**45.8%**	**28.1%**	**12.7%**	**8.4%**	**4.9%**

Figure 6: HP Cooling Tests at 82F OAT GF-C82-2-50 – No Delay and EFC™ Variable Delay



PERFORMANCE EVALUATION BASED ON INTERTEK TEST DATA OF THE GREENFAN® EFC™ INSTALLED ON HEAT PUMP AND HYDRONIC SPLIT-SYSTEMS

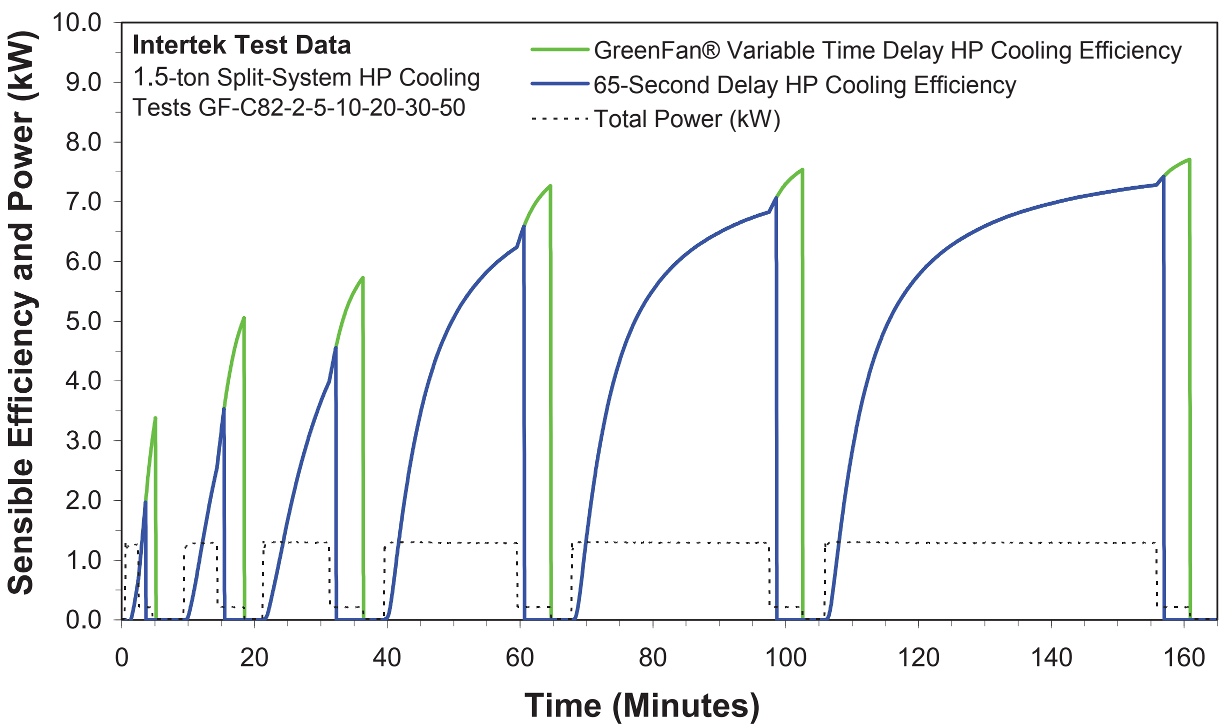
Heat Pump Cooling Tests at 82F OAT with 65-Second and EFC™ Variable Time Delay

Cooling tests for the 1.5-ton split system heat pump with 65-second delay and GreenFan® EFC™ variable time delay were performed at typical field conditions of 75F DB and 62F WB indoor and 82F outdoor temperatures. **Table 7** and **Figure 7** provide test results. Based on six tests, the GreenFan® improved sensible efficiency by 3.8 to 72.2% and provides cooling energy savings of 3.7 to 41.9%.

Table 7: HP Cooling Tests at 82F OAT GF-C82-2-50 – 65-Second and EFC™ Variable Delay

Description	Test 119	Test 120	Test 121	Test 122	Test 123	Test 124
Compressor On Time (minutes)	2	5	10	20	30	50
65-Second Delay AC Energy (kWh) [a]	0.046	0.111	0.220	0.435	0.646	1.081
65-Second Delay Sensible Cooling (Btu) [b]	90	391	1,011	2,863	4,563	8,024
65-Sec. Delay Sensible Efficiency (Btu/Wh) [c=b/a/1000]	1.96	3.52	4.59	6.59	7.07	7.42
GreenFan® AC Energy (kWh) [d]	0.052	0.122	0.231	0.449	0.660	1.095
GreenFan® Sensible Cooling (Btu) [e]	174	615	1,284	3,263	4,973	8,441
GreenFan® Sensible Efficiency (Btu/Wh) [f=e/d/1000]	3.37	5.05	5.56	7.27	7.54	7.71
GreenFan® Sensible Efficiency Improvement [g=f/c-1]	72.2%	43.4%	21.1%	10.3%	6.7%	3.8%
GreenFan® Extra Fan Energy (kWh)	0.005	0.011	0.011	0.014	0.014	0.014
65-Sec. Delay AC Energy to Match EFC™ (kWh) [h=e/c/1000]	0.089	0.175	0.280	0.495	0.704	1.137
GreenFan® Energy Savings (kWh) [i=h-d]	0.037	0.053	0.049	0.046	0.044	0.042
GreenFan® Cooling Energy Savings [j=(1-c/f) or j=i/h]	**41.9%**	**30.3%**	**17.4%**	**9.4%**	**6.2%**	**3.7%**

Figure 7: HP Cooling Tests at 82F OAT GF-C82-2-50 – 65-Second and EFC™ Variable Delay



PERFORMANCE EVALUATION BASED ON INTERTEK TEST DATA OF THE GREENFAN® EFC™ INSTALLED ON HEAT PUMP AND HYDRONIC SPLIT-SYSTEMS

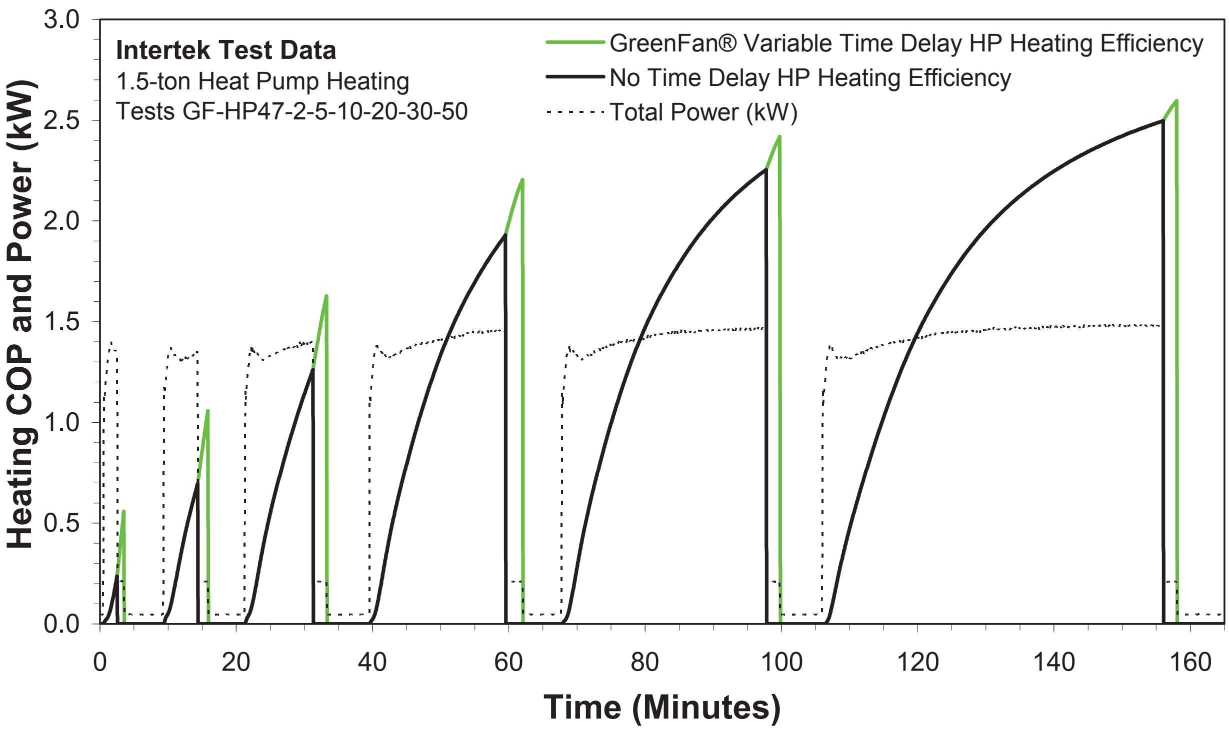
Heat Pump Heating Tests at 47F OAT with No Delay and Variable Delay

Heating tests for the 1.5-ton split-system heat pump were performed at typical field conditions of 70F DB and 55F WB indoor and 47F outdoor temperatures. **Table 8** and **Figure 8** provide test results. For the baseline tests the indoor fan operated with no time delay after the heat source turned off. With GreenFan® the indoor fan operated with variable time delay after heat source turned off. Each pair of tests used the same energy for heating. The GreenFan® EFC™ improved heating efficiency by 4.1 to 137.5% and provides heating energy savings of 4 to 57.9%.

Table 8: HP Heating Tests 47F OAT GF-HP47-2-50 – No Delay and EFC™ Variable Delay

Description	Test 125	Test 126	Test 127	Test 128	Test 129	Test 130
HP Compressor On Time (minutes)	2	5	10	20	30	50
No Delay HP Heating Energy Input (kWh) [a]	0.044	0.111	0.226	0.466	0.709	1.198
No Delay HP Heating Capacity (Btu) [b]	36	262	971	3,066	5,453	10,206
No Delay HP Heating Efficiency [c=b/a/3412]	0.24	0.69	1.26	1.93	2.25	2.50
GreenFan® EFC™ HP Energy Input (kWh [d]	0.048	0.116	0.233	0.475	0.716	1.205
GreenFan® EFC™ HP Heating Capacity (Btu) [e]	91	417	1,293	3,569	5,906	10,676
GreenFan® EFC™ HP Heating Efficiency [f=e/d/3412]	0.56	1.06	1.63	2.2	2.42	2.6
GreenFan® HP Heating Efficiency Improvement [g=f/c-1]	137.5%	52.7%	29.4%	14.1%	7.4%	4.1%
GreenFan® EFC™ Extra Fan Energy (kWh)	0.004	0.005	0.007	0.009	0.007	0.007
No Delay HP Energy to Match EFC™ (kWh) [h=e/c/3412]	0.113	0.176	0.301	0.543	0.768	1.253
GreenFan® EFC™ Energy Savings (kWh) [i=h-d]	0.065	0.060	0.068	0.068	0.052	0.048
GreenFan® EFC™ **Heating Savings** [j=(1-c/f) or j=i/h]	**57.9%**	**34.5%**	**22.7%**	**12.4%**	**6.9%**	**4.0%**

Figure 8: HP Heating Tests 47F OAT GF-HP47-2-50 – No Delay and EFC™ Variable Delay



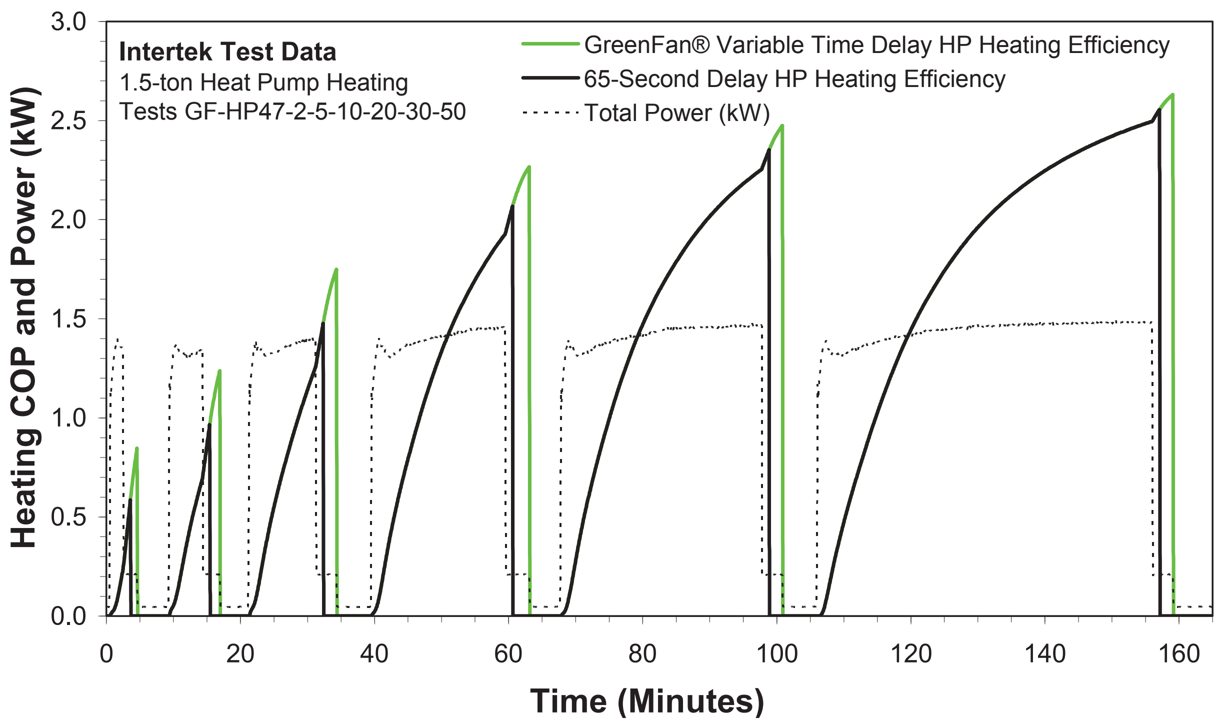
Heat Pump Heating Tests at 47F OAT with 65-Second Delay and Variable Delay

Heating tests for the 1.5-ton split-system heat pump were performed at typical field conditions of 70F DB and 55F WB indoor and 47F outdoor temperatures. **Table 9** and **Figure 9** provide test results. For the baseline tests the indoor fan operated with fixed 65-second time delay after the heat source turned off. With GreenFan® the indoor fan operated with variable time delay after heat source turned off. Each pair of tests used the same energy for heating. The GreenFan® EFC™ improved heating efficiency by 3.2 to 44.7% and provides heating energy savings of 3.1 to 30.9%.

Table 9: HP Heating Tests 47F OAT GF-HP47-2-50 – 65-Second Delay and EFC™ Variable Delay

Description	Test 131	Test 132	Test 133	Test 134	Test 135	Test 136
HP Compressor On Time (minutes)	2	5	10	20	30	50
65-Second Delay HP Heating Energy Input (kWh) [a]	0.048	0.114	0.230	0.470	0.713	1.202
65-Second Delay HP Heating Capacity (Btu) [b]	96	376	1,157	3,312	5,716	10,478
65-Second Delay HP Heating Efficiency [c=b/a/3412]	0.58	0.96	1.48	2.07	2.35	2.55
GreenFan® EFC™ HP Energy Input (kWh) [d]	0.052	0.119	0.235	0.475	0.718	1.206
GreenFan® EFC™ HP Heating Capacity (Btu) [e]	149	505	1,412	3,702	6,075	10,852
GreenFan® EFC™ HP Heating Efficiency [f=e/d/3412]	0.84	1.24	1.76	2.28	2.48	2.64
GreenFan® HP Heating Efficiency Improvement [g=f/c-1]	44.7%	28.7%	19.5%	10.6%	5.5%	3.2%
GreenFan® EFC™ Extra Fan Energy (kWh)	0.004	0.005	0.005	0.005	0.005	0.004
65-Sec. Delay Energy to Match EFC™ (kWh) [h=e/c/3412]	0.075	0.154	0.280	0.525	0.758	1.245
GreenFan® EFC™ Energy Savings (kWh) [i=h-d]	0.023	0.034	0.046	0.050	0.040	0.038
GreenFan® EFC™ **Heating Savings** [j=(1-c/f) or j=i/h]	**30.9%**	**22.3%**	**16.3%**	**9.6%**	**5.3%**	**3.1%**

Figure 9: HP Heating Tests 47F OAT GF-HP47-2-50 – 65-Second Delay and EFC™ Variable Delay



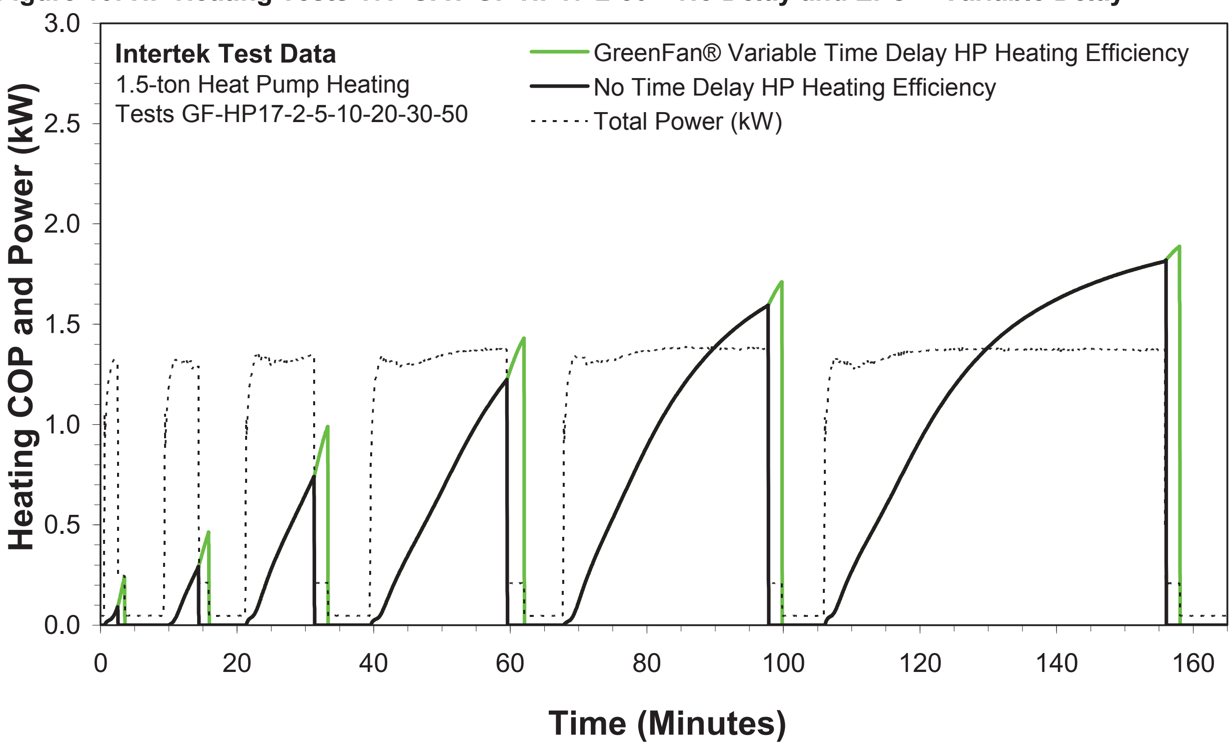
Heat Pump Heating Tests at 17F OAT with No Delay and Variable Delay

Heating tests for the 1.5-ton split-system heat pump were performed at typical field conditions of 70F DB and 55F WB indoor and 17F outdoor temperatures. **Table 10** and **Figure 10** provide test results. For the baseline tests the indoor fan operated with no time delay after the heat source turned off. With GreenFan® the indoor fan operated with variable time delay after heat source turned off. Each pair of tests used the same energy for heating. The GreenFan® EFC™ improved heating efficiency by 3.9 to 163.6% and provides heating energy savings of 3.7 to 62.1%.

Table 10: HP Heating Tests 17F OAT GF-HP17-2-50 – No Delay and EFC™ Variable Delay

Description	Test 137	Test 138	Test 139	Test 140	Test 141	Test 142
HP Compressor On Time (minutes)	2	5	10	20	30	50
No Delay HP Heating Energy Input (kWh) [a]	0.042	0.107	0.219	0.444	0.678	1.127
No Delay HP Heating Capacity (Btu) [b]	13	106	552	1,854	3,685	6,974
No Delay HP Heating Efficiency [c=b/a/3412]	0.09	0.29	0.74	1.22	1.59	1.81
GreenFan® EFC™ HP Energy Input (kWh) [d]	0.046	0.112	0.226	0.453	0.685	1.134
GreenFan® EFC™ HP Heating Capacity (Btu) [e]	37	177	762	2,207	3,998	7,289
GreenFan® EFC™ HP Heating Efficiency [f=e/d/3412]	0.24	0.46	0.99	1.43	1.71	1.88
GreenFan® HP Heating Efficiency Improvement [g=f/c-1]	163.6%	59.4%	33.8%	16.7%	7.4%	3.9%
GreenFan® EFC™ Extra Fan Energy (kWh)	0.004	0.005	0.007	0.009	0.007	0.007
No Delay HP Energy to Match EFC™ (kWh) [h=e/c/3412]	0.120	0.178	0.302	0.528	0.735	1.178
GreenFan® EFC™ Energy Savings (kWh) [i=h-d]	0.075	0.067	0.076	0.076	0.051	0.044
GreenFan® EFC™ **Heating Savings** [j=(1-c/f) or j=i/h]	**62.1%**	**37.3%**	**25.3%**	**14.3%**	**6.9%**	**3.7%**

Figure 10: HP Heating Tests 17F OAT GF-HP17-2-50 – No Delay and EFC™ Variable Delay



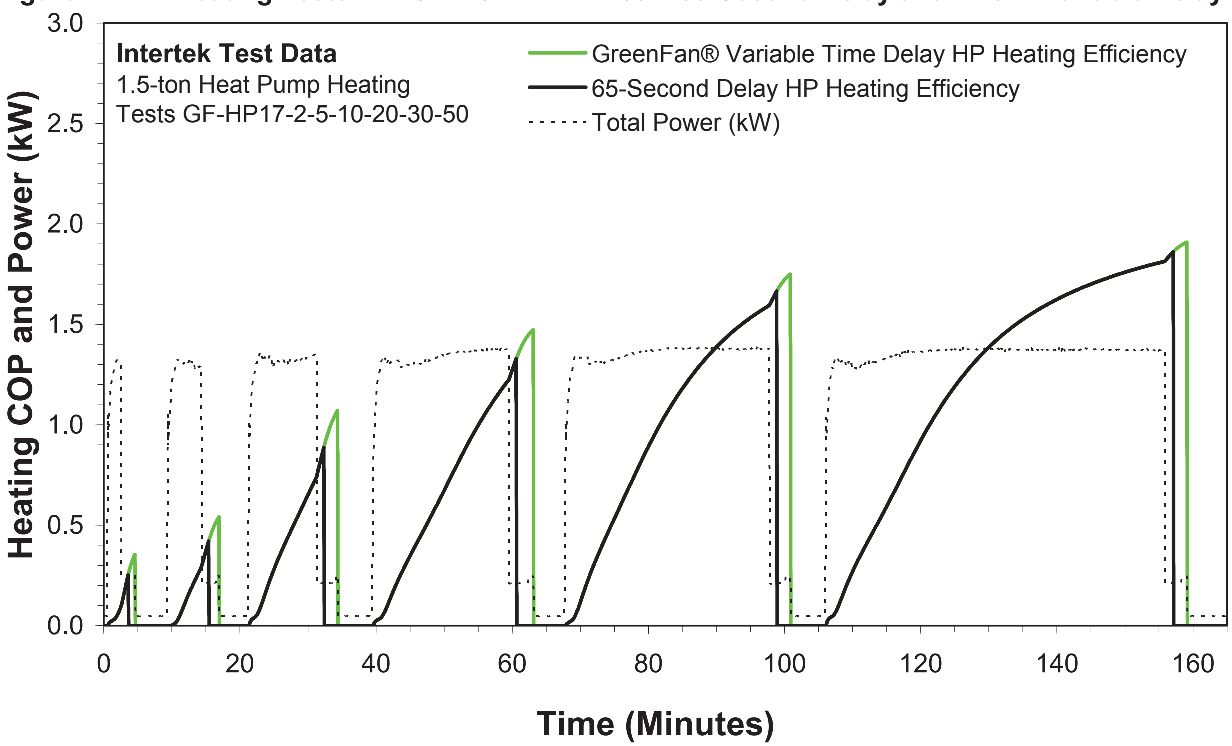
Heat Pump Heating Tests at 17F OAT with 65-Second Delay and Variable Delay

Heating tests for the 1.5-ton split-system heat pump were performed at typical field conditions of 70F DB and 55F WB indoor and 17F outdoor temperatures. **Table 11** and **Figure 11** provide test results. For the baseline tests the indoor fan operated with fixed 65-second time delay after the heat source turned off. With GreenFan® the indoor fan operated with variable time delay after heat source turned off. Each pair of tests used the same energy for heating. The GreenFan® EFC™ improved heating efficiency by 3 to 41.4% and provides heating energy savings of 2.9 to 29.3%.

Table 11: HP Heating Tests 17F OAT GF-HP17-2-50 – 65-Second Delay and EFC™ Variable Delay

Description	Test 143	Test 144	Test 145	Test 146	Test 147	Test 148
HP Compressor On Time (minutes)	2	5	10	20	30	50
65-Second Delay HP Heating Energy Input (kWh) [a]	0.046	0.110	0.223	0.448	0.681	1.131
65-Second Delay HP Heating Capacity (Btu) [b]	39	158	673	2,027	3,867	7,157
65-Second Delay HP Heating Efficiency [c=b/a/3412]	0.25	0.42	0.89	1.33	1.66	1.85
GreenFan® EFC™ HP Energy Input (kWh) [d]	0.050	0.116	0.228	0.453	0.686	1.136
GreenFan® EFC™ HP Heating Capacity (Btu) [e]	60	213	838	2,296	4,111	7,403
GreenFan® EFC™ HP Heating Efficiency [f=e/d/3412]	0.35	0.54	1.08	1.49	1.76	1.91
GreenFan® HP Heating Efficiency Improvement [g=f/c-1]	41.4%	28.9%	21.7%	12.0%	5.5%	3.0%
GreenFan® EFC™ Extra Fan Energy (kWh)	0.004	0.005	0.005	0.005	0.005	0.005
65-Sec. Delay Energy to Match EFC™ (kWh) [h=e/c/3412]	0.071	0.149	0.277	0.507	0.724	1.170
GreenFan® EFC™ Energy Savings (kWh) [i=h-d]	0.021	0.033	0.049	0.054	0.038	0.034
GreenFan® EFC™ **Heating Savings** [j=(1-c/f) or j=i/h]	**29.3%**	**22.4%**	**17.8%**	**10.7%**	**5.2%**	**2.9%**

Figure 11: HP Heating Tests 17F OAT GF-HP17-2-50 – 65-Second Delay and EFC™ Variable Delay



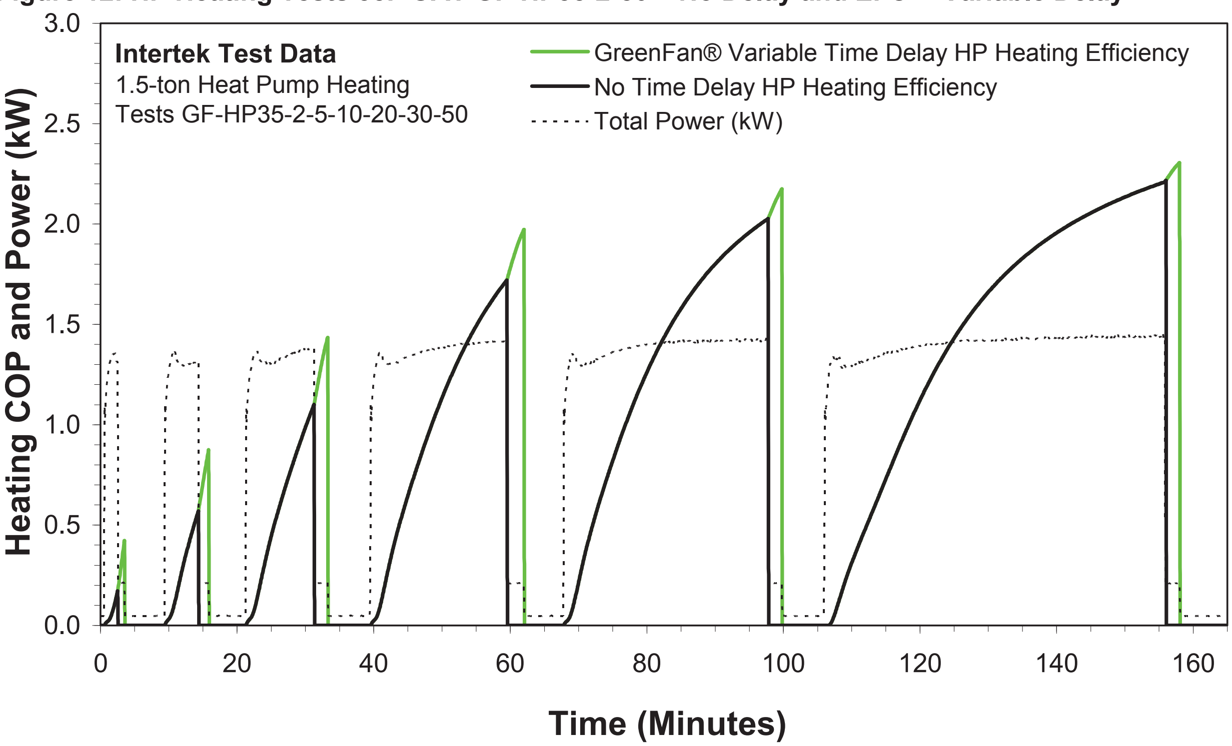
Heat Pump Heating Tests at 35F OAT with No Delay and Variable Delay

Heating tests for the 1.5-ton split-system heat pump were performed at typical field conditions of 70F DB and 55F WB indoor and 35F outdoor temperatures. **Table 12** and **Figure 12** provide test results. For the baseline tests the indoor fan operated with no time delay after the heat source turned off. With GreenFan® the indoor fan operated with variable time delay after heat source turned off. Each pair of tests used the same energy for heating. The GreenFan® EFC™ improved heating efficiency by 4.1 to 146.9% and provides heating energy savings of 4 to 59.5%.

Table 12: HP Heating Tests 35F OAT GF-HP35-2-50 – No Delay and EFC™ Variable Delay

Description	Test 149	Test 150	Test 151	Test 152	Test 153	Test 154
HP Compressor On Time (minutes)	2	5	10	20	30	50
No Delay HP Heating Energy Input (kWh) [a]	0.04	0.11	0.22	0.46	0.69	1.16
No Delay HP Heating Capacity (Btu) [b]	25	211	832	2,677	4,790	8,767
No Delay HP Heating Efficiency [c=b/a/3412]	0.17	0.57	1.10	1.72	2.03	2.21
GreenFan® EFC™ HP Energy Input (kWh) [d]	0.05	0.11	0.23	0.46	0.70	1.17
GreenFan® EFC™ HP Heating Capacity (Btu) [e]	67	339	1,120	3,126	5,189	9,183
GreenFan® EFC™ HP Heating Efficiency [f=e/d/3412]	0.42	0.87	1.43	1.97	2.17	2.30
GreenFan® HP Heating Efficiency Improvement [g=f/c-1]	146.9%	53.5%	30.6%	14.6%	7.3%	4.1%
GreenFan® EFC™ Extra Fan Energy (kWh)	0.004	0.005	0.007	0.009	0.007	0.007
No Delay HP Energy to Match EFC™ (kWh) [h=e/c/3412]	0.115	0.174	0.299	0.533	0.751	1.218
GreenFan® EFC™ Energy Savings (kWh) [i=h-d]	0.069	0.061	0.070	0.068	0.051	0.048
GreenFan® EFC™ **Heating Savings** [j=(1-c/f) or j=i/h]	**59.5%**	**34.9%**	**23.4%**	**12.7%**	**6.8%**	**4.0%**

Figure 12: HP Heating Tests 35F OAT GF-HP35-2-50 – No Delay and EFC™ Variable Delay



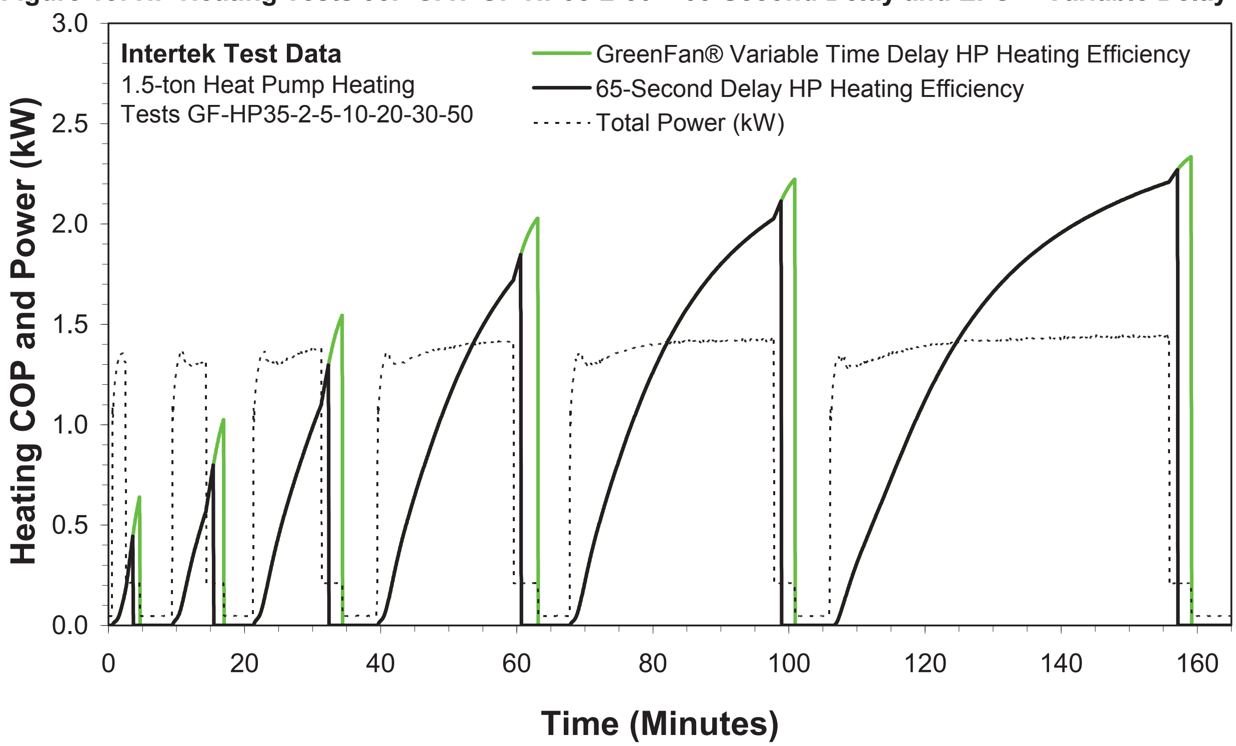
Heat Pump Heating Tests at 35F OAT with 65-Second Delay and Variable Delay

Heating tests for the 1.5-ton split-system heat pump were performed at typical field conditions of 70F DB and 55F WB indoor and 35F outdoor temperatures. **Table 13** and **Figure 13** provide test results. For the baseline tests the indoor fan operated with fixed 65-second time delay after the heat source turned off. With GreenFan® the indoor fan operated with variable time delay after heat source turned off. Each pair of tests used the same energy for heating. The GreenFan® EFC™ improved heating efficiency by 3.2 to 44.5% and provides heating energy savings of 3.1 to 30.8%.

Table 13: HP Heating Tests 35F OAT GF-HP35-2-50 – 65-Second Delay and EFC™ Variable Delay

Description	Test 155	Test 156	Test 157	Test 158	Test 159	Test 160
HP Compressor On Time (minutes)	2	5	10	20	30	50
65-Second Delay HP Heating Energy Input (kWh) [a]	0.05	0.11	0.23	0.46	0.70	1.17
65-Second Delay HP Heating Capacity (Btu) [b]	71	305	998	2,896	5,022	9,008
65-Second Delay HP Heating Efficiency [c=b/a/3412]	0.44	0.80	1.30	1.85	2.11	2.26
GreenFan® EFC™ HP Energy Input (kWh) [d]	0.05	0.12	0.23	0.46	0.70	1.17
GreenFan® EFC™ HP Heating Capacity (Btu) [e]	110	410	1,226	3,243	5,336	9,337
GreenFan® EFC™ HP Heating Efficiency [f=e/d/3412]	0.64	1.03	1.56	2.04	2.23	2.34
GreenFan® HP Heating Efficiency Improvement [g=f/c-1]	44.5%	29.0%	20.2%	10.8%	5.5%	3.2%
GreenFan® EFC™ Extra Fan Energy (kWh)	0.004	0.005	0.005	0.005	0.005	0.005
65-Sec. Delay Energy to Match EFC™ (kWh) [h=e/c/3412]	0.073	0.151	0.277	0.515	0.740	1.210
GreenFan® EFC™ Energy Savings (kWh) [i=h-d]	0.022	0.034	0.047	0.050	0.039	0.038
GreenFan® EFC™ **Heating Savings** [j=(1-c/f) or j=i/h]	**30.8%**	**22.5%**	**16.8%**	**9.7%**	**5.2%**	**3.1%**

Figure 13: HP Heating Tests 35F OAT GF-HP35-2-50 – 65-Second Delay and EFC™ Variable Delay



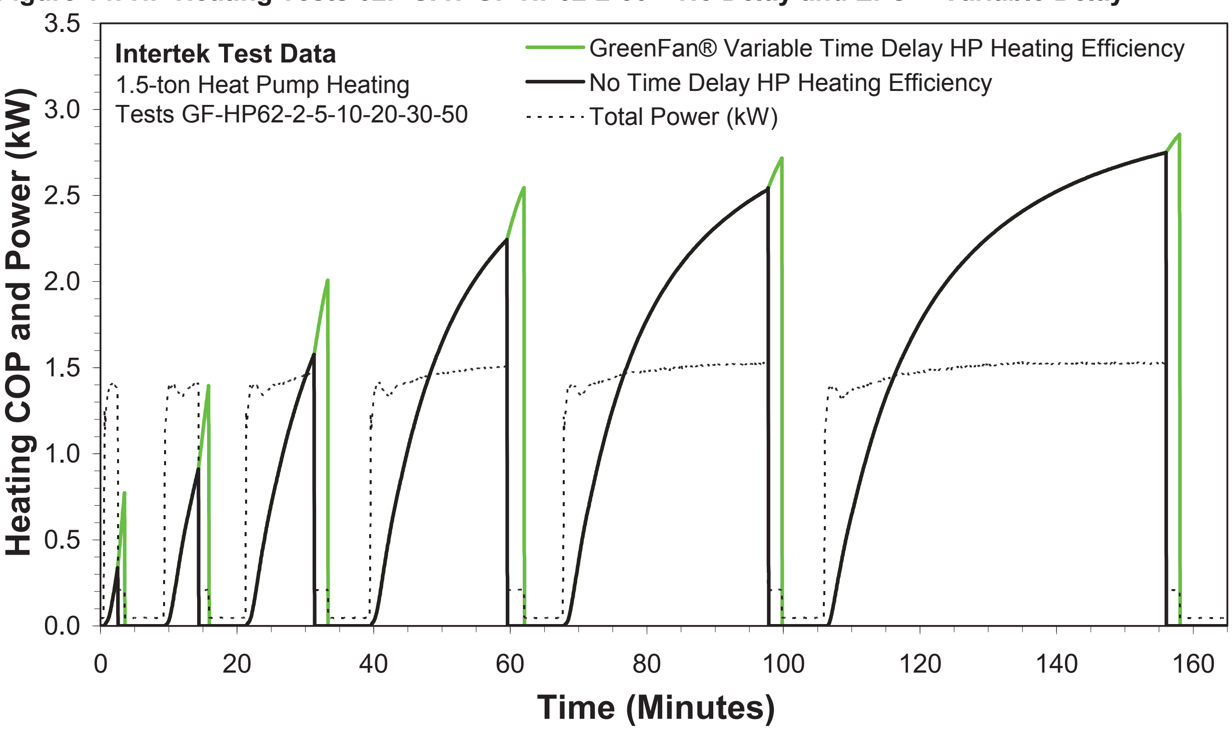
Heat Pump Heating Tests at 62F OAT with No Delay and Variable Delay

Heating tests for the 1.5-ton split-system heat pump were performed at typical field conditions of 70F DB and 55F WB indoor and 62F outdoor temperatures. **Table 14** and **Figure 14** provide test results. For the baseline tests the indoor fan operated with no time delay after the heat source turned off. With GreenFan® the indoor fan operated with variable time delay after heat source turned off. Each pair of tests used the same energy for heating. The GreenFan® EFC™ improved heating efficiency by 3.8 to 129.6% and provides heating energy savings of 3.7 to 56.4%.

Table 14: HP Heating Tests 62F OAT GF-HP62-2-50 – No Delay and EFC™ Variable Delay

Description	Test 161	Test 162	Test 163	Test 164	Test 165	Test 166
HP Compressor On Time (minutes)	2	5	10	20	30	50
No Delay HP Heating Energy Input (kWh) [a]	0.05	0.11	0.23	0.48	0.73	1.24
No Delay HP Heating Capacity (Btu) [b]	53	356	1,259	3,697	6,351	11,618
No Delay HP Heating Efficiency [c=b/a/3412]	0.33	0.91	1.57	2.24	2.53	2.75
GreenFan® EFC™ HP Energy Input (kWh) [d]	0.05	0.12	0.24	0.49	0.74	1.25
GreenFan® EFC™ HP Heating Capacity (Btu) [e]	130	569	1,653	4,267	6,855	12,132
GreenFan® EFC™ HP Heating Efficiency [f=e/d/3412]	0.77	1.39	2.01	2.54	2.71	2.85
GreenFan® HP Heating Efficiency Improvement [g=f/c-1]	129.6%	53.0%	27.5%	13.4%	6.9%	3.8%
GreenFan® EFC™ Extra Fan Energy (kWh)	0.004	0.005	0.007	0.009	0.007	0.007
No Delay HP Energy to Match EFC™ (kWh) [h=e/c/3412]	0.114	0.183	0.308	0.558	0.793	1.293
GreenFan® EFC™ Energy Savings (kWh) [i=h-d]	0.064	0.063	0.066	0.066	0.051	0.048
GreenFan® EFC™ **Heating Savings** [j=(1-c/f) or j=i/h]	**56.4%**	**34.6%**	**21.6%**	**11.8%**	**6.5%**	**3.7%**

Figure 14: HP Heating Tests 62F OAT GF-HP62-2-50 – No Delay and EFC™ Variable Delay



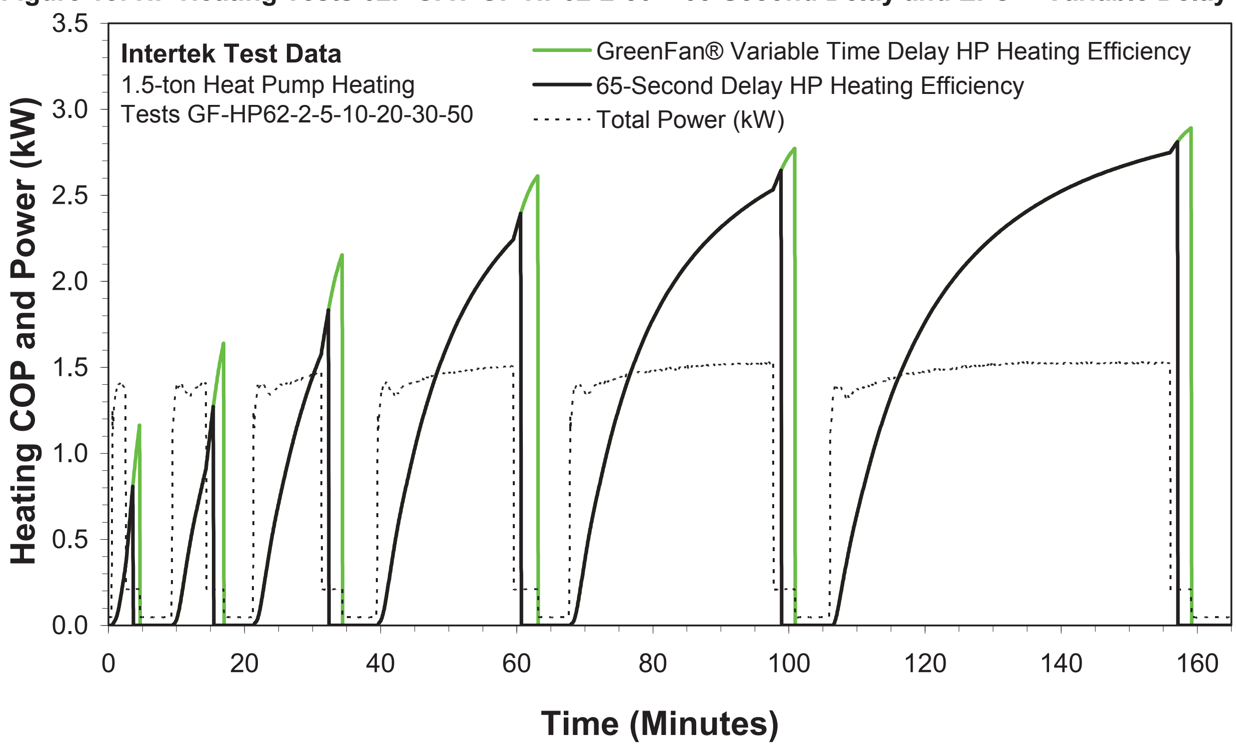
Heat Pump Heating Tests at 62F OAT with 65-Second Delay and Variable Delay

Heating tests for the 1.5-ton split-system heat pump were performed at typical field conditions of 70F DB and 55F WB indoor and 62F outdoor temperatures. **Table 15** and **Figure 15** provide test results. For the baseline tests the indoor fan operated with fixed 65-second time delay after the heat source turned off. With GreenFan® the indoor fan operated with variable time delay after heat source turned off. Each pair of tests used the same energy for heating. The GreenFan® EFC™ improved heating efficiency by 3.1 to 44.4% and provides heating energy savings of 3 to 30.7%.

Table 15: HP Heating Tests 62F OAT GF-HP62-2-50 – 65-Second Delay and EFC™ Variable Delay

Description	Test 167	Test 168	Test 169	Test 170	Test 171	Test 172
HP Compressor On Time (minutes)	2	5	10	20	30	50
65-Second Delay HP Heating Energy Input (kWh) [a]	0.05	0.12	0.24	0.49	0.74	1.24
65-Second Delay HP Heating Capacity (Btu) [b]	137	512	1,486	3,976	6,644	11,916
65-Second Delay HP Heating Efficiency [c=b/a/3412]	0.80	1.27	1.83	2.39	2.64	2.81
GreenFan® EFC™ HP Energy Input (kWh) [d]	0.05	0.12	0.24	0.49	0.74	1.25
GreenFan® EFC™ HP Heating Capacity (Btu) [e]	212	691	1,800	4,417	7,043	12,324
GreenFan® EFC™ HP Heating Efficiency [f=e/d/3412]	1.16	1.64	2.17	2.63	2.78	2.90
GreenFan® HP Heating Efficiency Improvement [g=f/c-1]	44.4%	29.5%	18.6%	10.0%	5.3%	3.1%
GreenFan® EFC™ Extra Fan Energy (kWh)	0.004	0.005	0.005	0.005	0.005	0.004
65-Sec. Delay Energy to Match EFC™ (kWh) [h=e/c/3412]	0.077	0.160	0.288	0.541	0.783	1.285
GreenFan® EFC™ Energy Savings (kWh) [i=h-d]	0.024	0.036	0.045	0.049	0.039	0.038
GreenFan® EFC™ **Heating Savings** [j=(1-c/f) or j=i/h]	**30.7%**	**22.8%**	**15.7%**	**9.1%**	**5.0%**	**3.0%**

Figure 15: HP Heating Tests 62F OAT GF-HP62-2-50 – 65-Second Delay and EFC™ Variable Delay



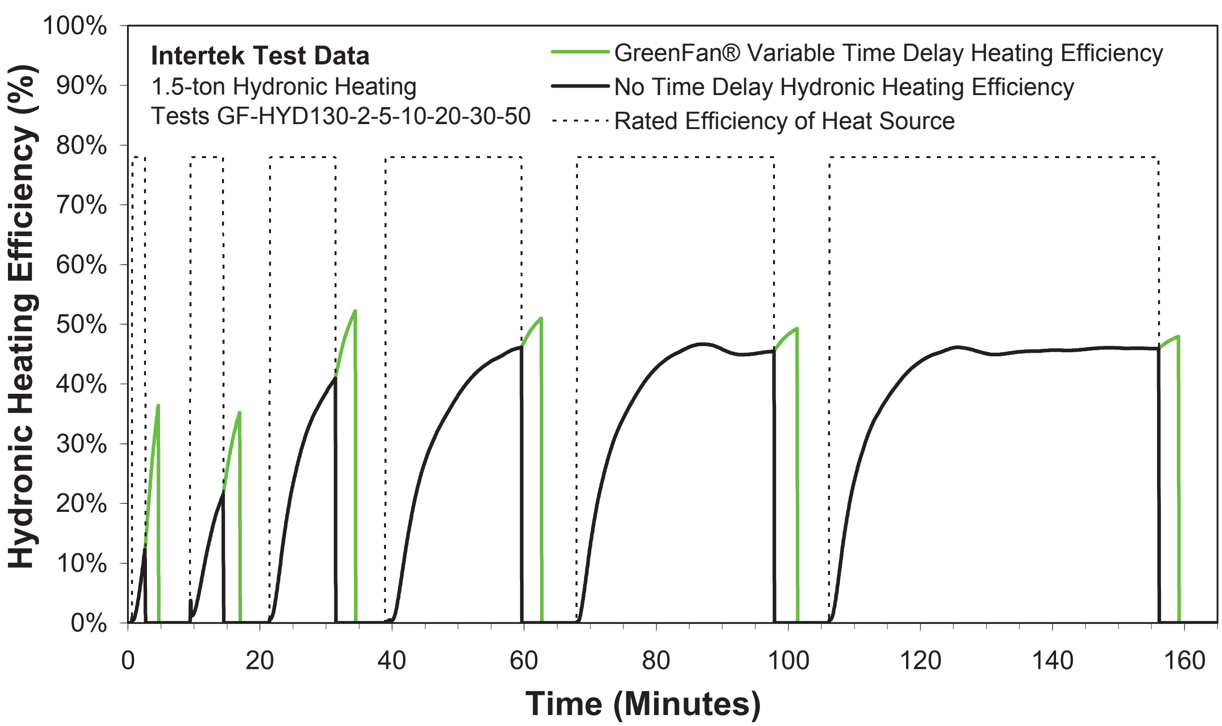
Hydronic Heating Tests with 130F Hot Water with No Delay and Variable Delay

Heating tests for the 1.5-ton split-system hydronic heating system were performed at typical field conditions of 70F DB and 55F WB indoor and 47F outdoor temperatures with average 130F hydronic temperature. **Table 16** and **Figure 16** provide test results. For the baseline tests the indoor fan operated with no time delay after the heat source turned off. With GreenFan® the indoor fan operated with variable time delay after heat source turned off. Each pair of tests used the same energy for heating. The GreenFan® EFC™ improved heating efficiency by 4.3 to 197.1% and provides heating savings of 4.1 to 66.3%. The maximum heating efficiency varies during heat source operation due hot water supply temperatures decreasing below the storage tank setpoint causing the water heater to cycle on and off.

Table 16: Hydronic Heat Tests 130F HW GF-HYD130-2-50 – No Delay and EFC™ Variable Delay

Description	Test 173	Test 174	Test 175	Test 176	Test 177	Test 178
Hydronic On Time (minutes)	2	5	10	20	30	50
No Delay Hydronic Energy Input (Btu) [a]	970	2,365	4,548	9,185	14,102	23,893
No Delay Heating Capacity (Btu) [b]	118	507	1,857	4,307	6,414	10,976
No Time Delay Heating Efficiency [c=b/a]	12.2%	21.4%	40.8%	46.9%	45.5%	45.9%
GreenFan® Hydronic Energy Input (Btu) [d]	970	2,365	4,548	9,185	14,102	23,893
GreenFan® Delivered Heating Capacity (Btu) [e]	352	831	2,382	4,759	6,950	11,451
GreenFan® Hydronic Heating Efficiency [f=e/d]	36.3%	35.2%	52.4%	51.8%	49.3%	47.9%
GreenFan® Heating Efficiency Improvement [g=f/c-1]	197.1%	64.0%	28.3%	10.5%	8.4%	4.3%
GreenFan® Extra Fan Energy (kWh)	0.007	0.009	0.010	0.010	0.012	0.010
No Delay Energy to Match GreenFan® [h=e/c]	2,881	3,877	5,835	10,150	15,280	24,926
GreenFan® Energy Savings (Btu) [i=h-d]	1,911	1,512	1,287	965	1,178	1,033
GreenFan® Heating Energy Savings [j=1-c/f]	**66.3%**	**39.0%**	**22.1%**	**9.5%**	**7.7%**	**4.1%**

Figure 16: Hydronic Heat Tests 130F HW GF-HYD130-2-50 – No Delay and EFC™ Variable Delay



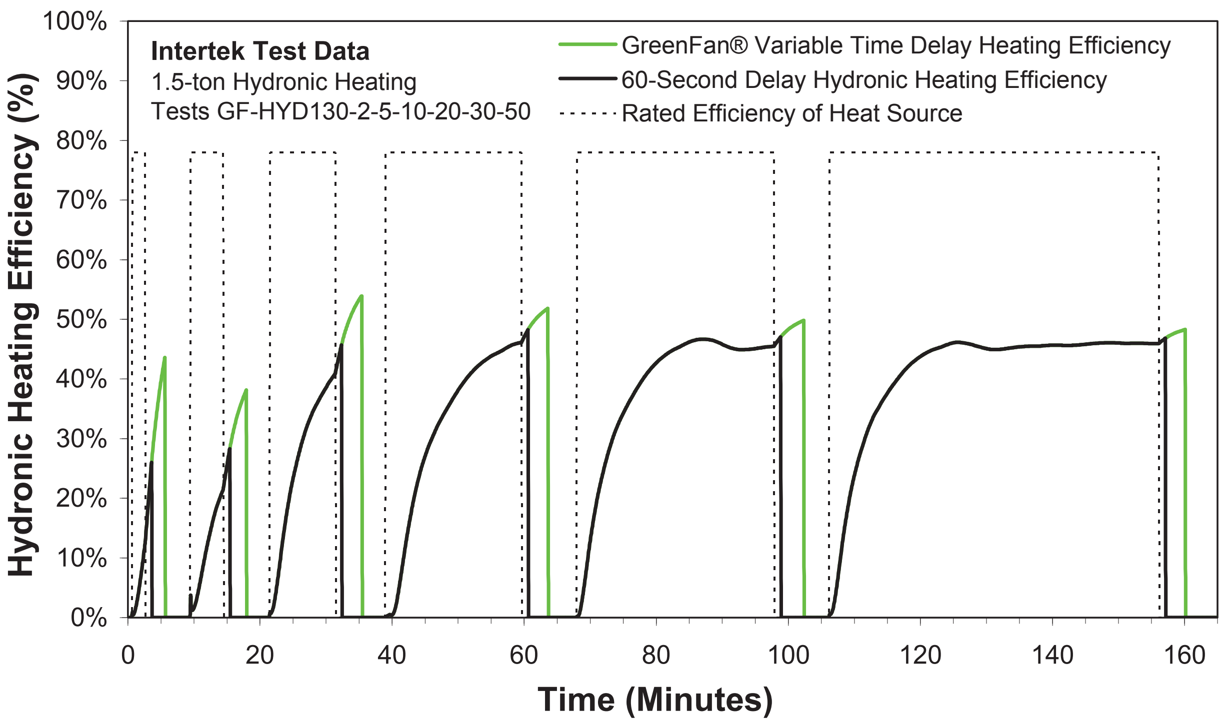
Hydronic Heating Tests with 130F Hot Water with 60-Second Delay and EFC™ Variable Delay

Heating tests for the 1.5-ton split-system hydronic heating system were performed at typical field conditions of 70F DB and 55F WB indoor and 47F outdoor temperatures with average 130F hydronic temperature. **Table 17** and **Figure 17** provide test results. For the baseline tests the indoor fan operated with 60-second time delay after the heat source turned off. With GreenFan® the indoor fan operated with variable time delay after heat source turned off. Each pair of tests used the same energy for heating. The GreenFan® EFC™ improved heating efficiency by 3.1 to 68.4% and provides heating savings of 3 to 40.6%. The maximum hydronic heating efficiency varies during heat source operation due hot water supply temperatures decreasing below the storage tank setpoint.

Table 17: Hydronic Heat Tests 130F HW GF-HYD130-2-50 – 60-Second and EFC™ Variable Delay

Description	Test 179	Test 180	Test 181	Test 182	Test 183	Test 184
Hydronic On Time (minutes)	2	5	10	20	30	50
60-Second Delay Hydronic Energy Input (Btu) [a]	970	2,365	4,548	9,185	14,102	23,893
60-Second Delay Heating Capacity (Btu) [b]	251	668	2,093	4,507	6,632	11,185
60-Second Time Delay Heating Efficiency [c=b/a]	25.9%	28.3%	46.0%	49.1%	47.0%	46.8%
GreenFan® Hydronic Energy Input (Btu) [d]	970	2,365	4,548	9,185	14,102	23,893
GreenFan® Delivered Heating Capacity (Btu) [e]	423	901	2,469	4,840	7,026	11,535
GreenFan® Hydronic Heating Efficiency [f=e/d]	43.6%	38.1%	54.3%	52.7%	49.8%	48.3%
GreenFan® Heating Efficiency Improvement [g=f/c-1]	68.4%	34.7%	18.0%	7.4%	5.9%	3.1%
GreenFan® Extra Fan Energy (kWh)	0.007	0.009	0.010	0.010	0.012	0.010
60-Second Delay Energy to Match GreenFan® [h=e/c]	1,633	3,186	5,367	9,864	14,939	24,641
GreenFan® Energy Savings (Btu) [i=h-d]	663	822	819	679	837	748
GreenFan® Heating Energy Savings [j=1-c/f]	**40.6%**	**25.8%**	**15.3%**	**6.9%**	**5.6%**	**3.0%**

Figure 17: Hydronic Heat Tests 130F HW GF-HYD130-2-50 – 60-Second and EFC™ Variable Delay



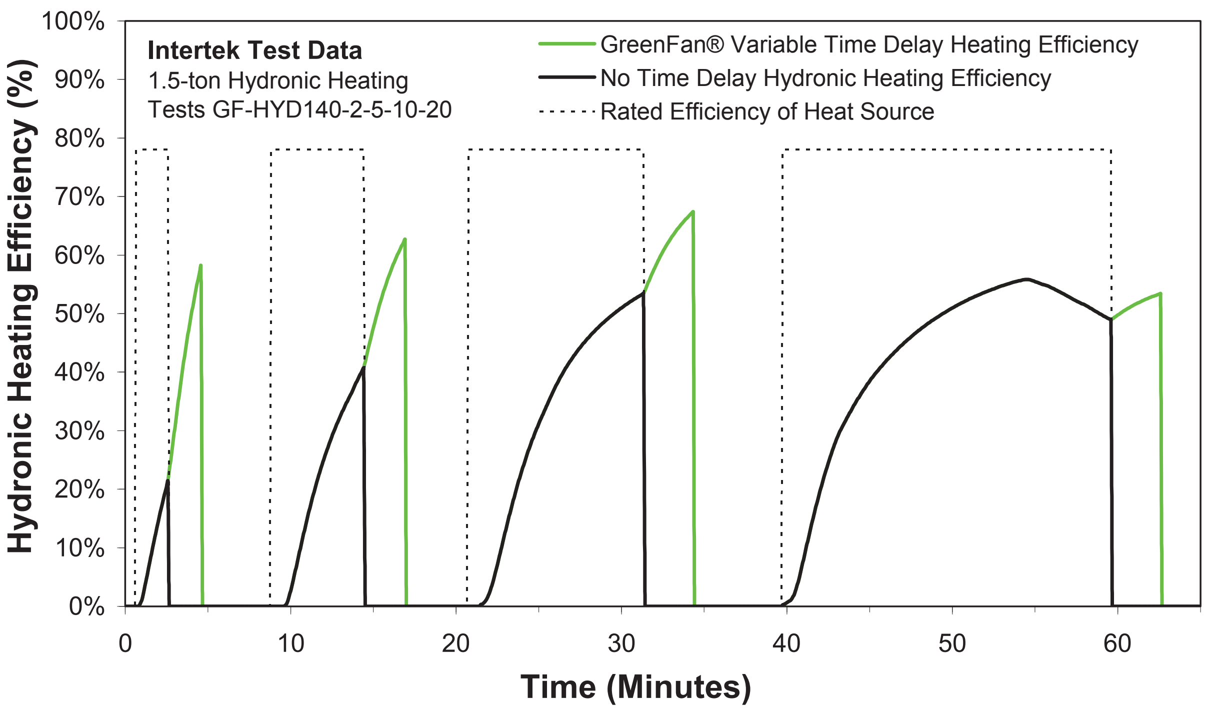
Hydronic Heating Tests with 140F Hot Water with No Delay and EFC™ Variable Delay

Heating tests for the 1.5-ton split-system hydronic heating system were performed at typical field conditions of 70F DB and 55F WB indoor and 47F outdoor temperatures with average 140F hydronic temperature. **Table 18** and **Figure 18** provide test results. For the baseline tests the indoor fan operated with no time delay after the heat source turned off. With GreenFan® the indoor fan operated with variable time delay after heat source turned off. Each pair of tests used the same energy for heating. The GreenFan® EFC™ improved heating efficiency by 9.1 to 172.5% and provides heating savings of 8.4 to 63.3%. The maximum hydronic heating efficiency varies during heat source operation due to hot water supply temperatures decreasing below the storage tank setpoint.

Table 18: Hydronic Heat Tests 140F HW GF-HYD140-2-50 – No Delay and EFC™ Variable Delay

Description	Test 185	Test 186	Test 187	Test 188
Hydronic On Time (minutes)	2	5	10	20
No Delay Hydronic Energy Input (Btu) [a]	874	2,507	4,433	9,540
No Delay Heating Capacity (Btu) [b]	186	1,020	2,368	4,668
No Time Delay Heating Efficiency [c=b/a]	21.3%	40.7%	53.4%	48.9%
GreenFan® Hydronic Energy Input (Btu) [d]	874	2,507	4,433	9,540
GreenFan® Delivered Heating Capacity (Btu) [e]	508	1,571	2,987	5,094
GreenFan® Hydronic Heating Efficiency [f=e/d]	58.1%	62.7%	67.4%	53.4%
GreenFan® Heating Efficiency Improvement [g=f/c-1]	172.5%	54.0%	26.2%	9.1%
GreenFan® Extra Fan Energy (kWh)	0.007	0.009	0.010	0.010
No Delay Energy to Match GreenFan® [h=e/c]	2,381	3,861	5,592	10,412
GreenFan® Energy Savings (Btu) [i=h-d]	1,507	1,355	1,159	872
GreenFan® Heating Energy Savings [j=(1-c/f) or j=i/h]	**63.3%**	**35.1%**	**20.7%**	**8.4%**

Figure 18: Hydronic Heat Tests 140F HW GF-HYD140-2-50 – No Delay and EFC™ Variable Delay



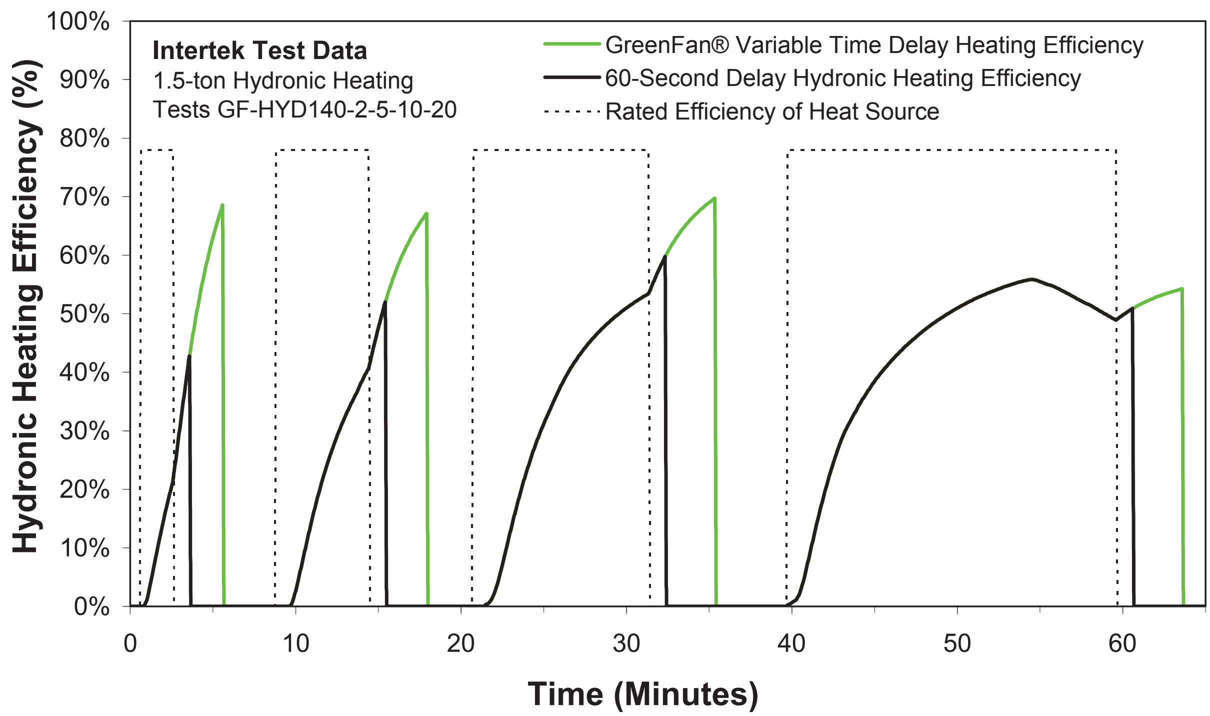
Hydronic Heating Tests with 140F Hot Water with 60-Second Delay and EFC™ Variable Delay

Heating tests for the 1.5-ton split-system hydronic heating system were performed at typical field conditions of 70F DB and 55F WB indoor and 47F outdoor temperatures with average 140F hydronic temperature. **Table 19** and **Figure 19** provide test results. For the baseline tests the indoor fan operated with 60-second time delay after the heat source turned off. With GreenFan® the indoor fan operated with variable time delay after heat source turned off. Each pair of tests used the same energy for heating. The GreenFan® EFC™ improved heating efficiency by 6.6 to 60.8% and provides heating savings of 6.2 to 37.8%.The maximum hydronic heating efficiency varies due to hot water supply temperatures decreasing below the storage tank setpoint causing the water heater to turn on and off during hydronic heating.

Table 19: Hydronic Heat Tests 140F HW GF-HYD140-2-50 – 60-Second and EFC™ Variable Delay

Description	Test 191	Test 192	Test 193	Test 194
Hydronic On Time (minutes)	2	5	10	20
60-Second Delay Hydronic Energy Input (Btu) [a]	874	2,507	4,433	9,540
60-Second Delay Heating Capacity (Btu) [b]	372	1,301	2,647	4,851
60-Second Time Delay Heating Efficiency [c=b/a]	42.6%	51.9%	59.7%	50.8%
GreenFan® Hydronic Energy Input (Btu) [d]	874	2,507	4,433	9,540
GreenFan® Delivered Heating Capacity (Btu) [e]	599	1,682	3,089	5,173
GreenFan® Hydronic Heating Efficiency [f=e/d]	68.5%	67.1%	69.7%	54.2%
GreenFan® Heating Efficiency Improvement [g=f/c-1]	60.8%	29.3%	16.7%	6.6%
GreenFan® Extra Fan Energy (kWh)	0.007	0.009	0.010	0.010
60-Second Delay Energy to Match GreenFan® [h=e/c]	1,405	3,240	5,173	10,174
GreenFan® Energy Savings (Btu) [i=h-d]	531	734	740	634
GreenFan® Heating Energy Savings [j=(1-c/f) or j=i/h]	**37.8%**	**22.6%**	**14.3%**	**6.2%**

Figure 19 Hydronic Heat Tests 140F HW GF-HYD140-2-50 – 60-Second and EFC™ Variable Delay



PERFORMANCE EVALUATION BASED ON INTERTEK TEST DATA OF THE GREENFAN® EFC™ INSTALLED ON HEAT PUMP AND HYDRONIC SPLIT-SYSTEMS

Conclusion

The following conclusions are provided regarding the performance evaluation tests of the patented GreenFan® EFC™ installed on a 1.5-ton split-system heat pump HVAC unit. Based on 20 cooling tests, the GreenFan® EFC™ provides cooling energy savings of 4.9 to 72.5% compared to zero fan-off time delay and 2.9 to 40.9% compared to 65-second fan-off time delay. Based on 48 heat pump heating tests, the GreenFan® EFC™ provides heat pump energy savings of 3.7 to 62.1% compared to no time delay and 3.1 to 30.9% compared to 65-second time delay.

The following conclusions are provided regarding the performance evaluation tests of the GreenFan® EFC™ installed on a 1.5-ton split-system hydronic HVAC unit. Based on 20 hydronic heating tests with 130 to 140F hydronic supply temperature, the GreenFan® EFC™ provides heating energy savings of 4.1 to 66.3% compared to no time delay and 3 to 40.6% compared to fixed 60-second fan-off time delay.

The GreenFan® EFC™ requires extra fan energy to recover and deliver additional sensible cooling or heating capacity from the HVAC system evaporator or heat exchanger to improve cooling or heating efficiency, lengthen off-cycles, and save cooling or heating energy. For cooling, the average fan energy increase per cycle with the GreenFan® EFC™ is 0.012 ± 0.001kWh or 16.2 ± 2.5% of cooling savings (i.e., 1 unit of extra fan energy provides 6.02 ± 0.56 units of cooling energy savings). For heat pump heating, the average fan energy increase per cycle with the GreenFan® EFC™ is 0.006 ± 0.0004 kWh or 9.2 ± 1.2% of heating savings (i.e., 1 unit of extra fan energy provides 10.9 ± 0.68 units of heating energy savings). For hydronic heating, the average fan energy increase per cycle with the GreenFan® EFC™ is 0.0095 ± 0.0006 kWh or 11.1 ± 1.4% of heating savings (i.e., 1 unit of extra fan energy provides 9.04 ± 0.57 units of heating energy savings).[4]

Based on 20 cooling tests, the GreenFan® EFC™ improved cooling efficiency by 44.8 +/- 2.1% and provided cooling energy savings of 23.3 +/- 0.7%. Based on 48 heat pump heating tests, the GreenFan® EFC™ improved average heating efficiency by 30.6 +/- 0.9% and provided average heat pump heating energy savings of 19 +/- 3.8%. Based on 20 hydronic heating tests, the GreenFan® EFC™ average heating efficiency by 41.3 +/- 2% and provided average hydronic heating energy savings of 22.7 +/- 7%.

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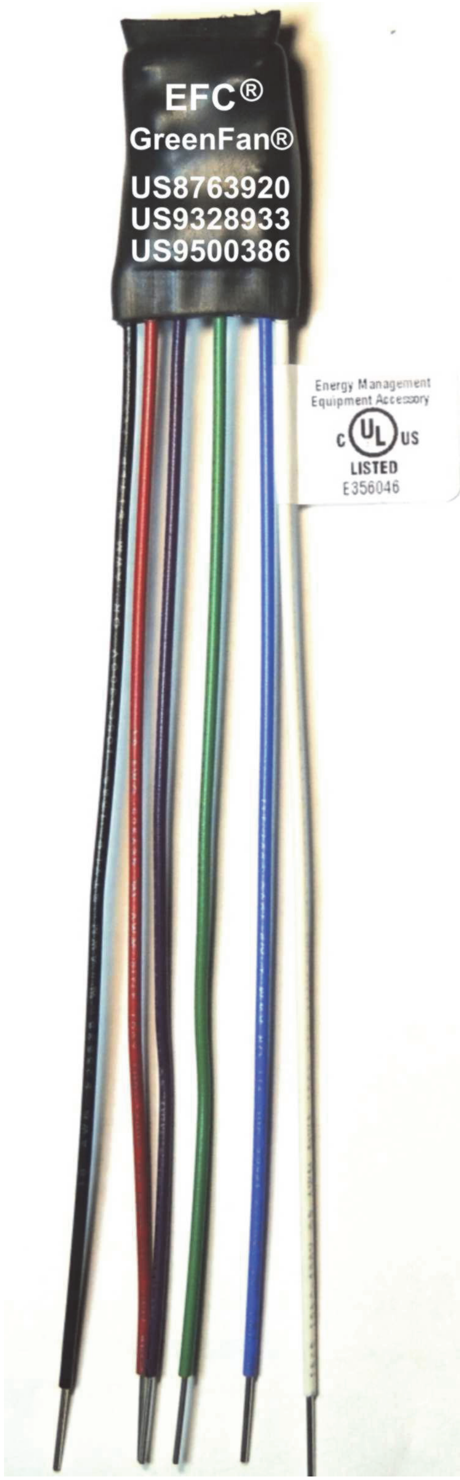
[4] The EFC™ extra fan energy for heating is valued at 10,354 Btu/kWh based on natural gas electricity generation. US Energy Information Agency (EIA) 2013. Average Tested Heat Rates by Prime Mover and Energy Source, 2007-2013. https://www.eia.gov/electricity/annual/html/epa_08_02.html).



- **GreenFan® EFC®** provides variable extended fan-off time delays to deliver more heating or cooling energy that would otherwise be wasted to improve thermal comfort, lengthen off-cycle times, reduce operation, and prevent evaporator coil icing.
- **GreenFan® EFC®** saves 15% on cooling and heating and EFC® workpaper documents 2.3 TRC.
- **GreenFan®** provides a 5-year warranty and typically lasts for the life of the HVAC equipment.
- **GreenFan® EFC®** is attached to low-voltage thermostat wires and does not connect to any high-voltage wires.
- **GreenFan® EFC®** installation takes 10 to 15 minutes and checks HVAC and thermostat operation.
- **GreenFan® EFC®** can be installed for free with incentives from California Utility ratepayers.
- **GreenFan® EFC®** provides high customer satisfaction for comfort and energy savings.

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Efficient Fan Controller™

greenfan®

Higher Efficiency - Less Wasted Energy

GreenFan® EFC® Improves HVAC Efficiency, Saves Heating and Cooling Energy and Increases Equipment Life

"Your Partner for Efficient Cooling and Heating"

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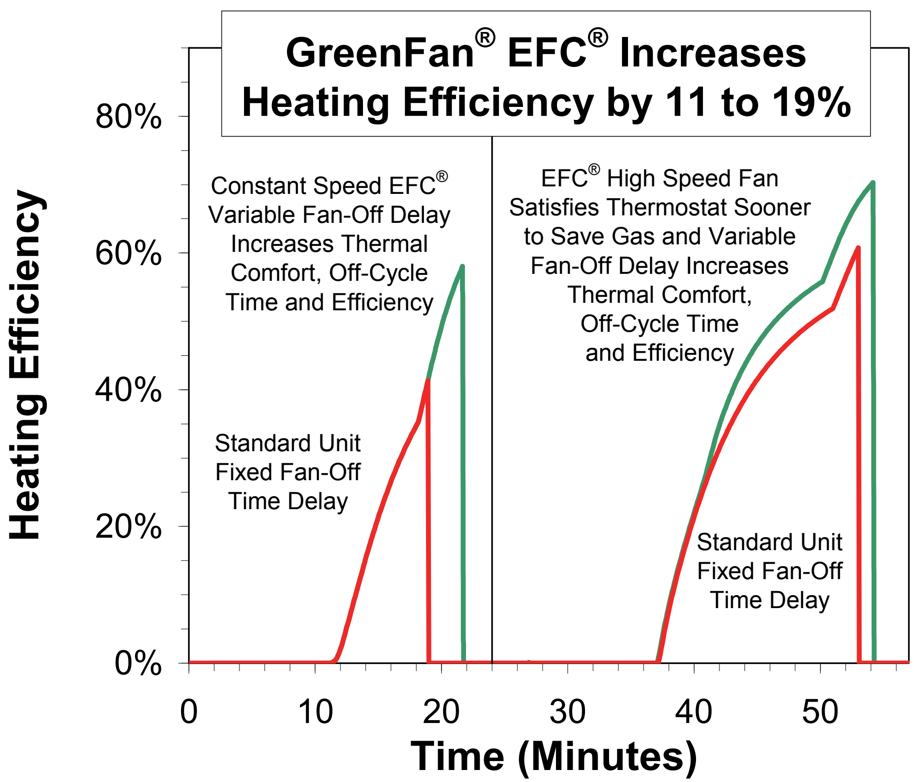
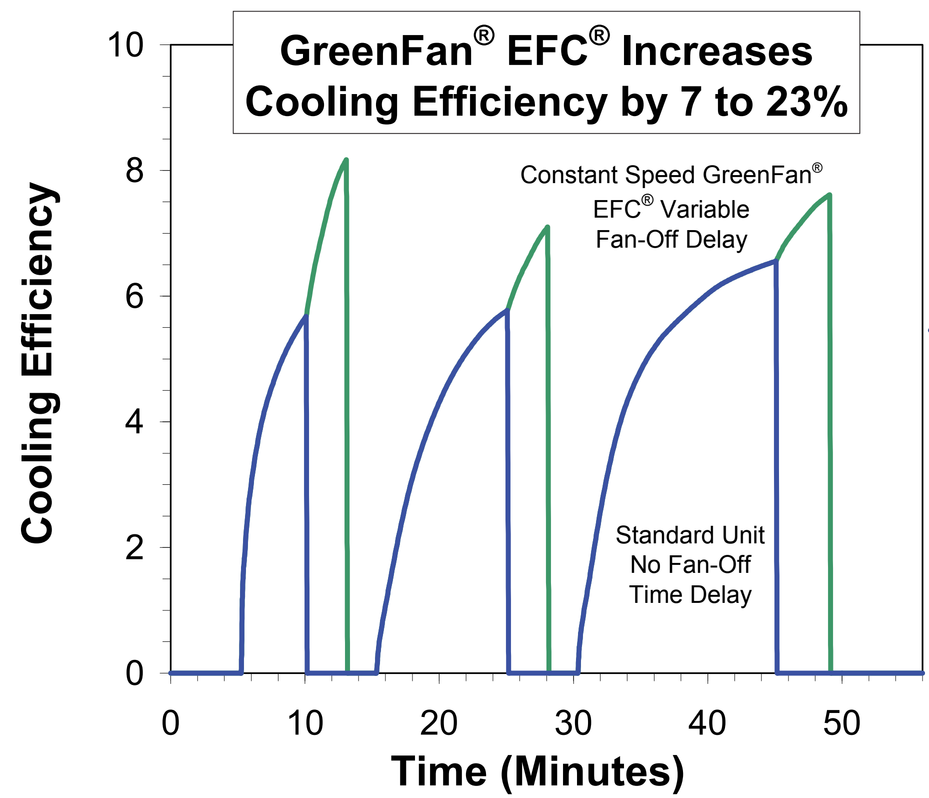
GreenFan® Efficient Fan Controller® Increases Thermal Comfort, HVAC Efficiency, Equipment Life and Energy Savings

Intertek®† tests show GreenFan® improves heating efficiency by 11 to 19% by recovering and delivering more heating energy from gas, heat pump or hydronic heat exchangers that would otherwise be wasted.

Intertek® tests show GreenFan® improves cooling efficiency by 7 to 23% by recovering and delivering more useful cooling energy that would otherwise be wasted. GreenFan® prevents evaporator coil icing.





†Intertek is an AHRI–Certified HVAC Testing Laboratory.