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MEASURE CHARACTERIZATION

Occupancy Fan Controller, Commercial

https://www.caetrm.com/measure/SWHC062/01-draft/

USE CATEGORY
HC - HVAC

COMMITTED

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Technology Summary

Occupancy fan control (OFC) detects when a conditioned building space is unoccupied, detects continuous fan operation (ON condition), and sets the fan operation from ON to AUTO wherein the fan is only operated when zone conditions call for cooling or heating. The OFC returns fan control to continuous operation during occupied periods per building occupancy for minimum outdoor airflow per ASHRAE 62.1. R1052 Energy savings are achieved based on a reduction of unoccupied supply fan runtime unless zone conditions call for cooling or heating. Reduction in unoccupied supply fan runtime can also prevent the introduction of unfavorable outside air into conditioned spaces through leaky economizer dampers, causing an unnecessary increase in space heating or cooling. Average economizer closed-damper outdoor airflow is 18 +/- 3% of total system airflow which meets or exceeds ASHRAE 62.1 minimum ventilation requirements for most buildings. R3168 When operating in AUTO mode, the OFC also provides a variable fan-off delay at the end of each cooling or heating cycle to over satisfy the thermostat, lengthen off cycle times, and save energy.

San Diego Gas & Electric (SDG&E) funded an Emerging Technologies (ET) Program study (ET17SDG8031) to evaluate potential energy efficiency benefits associated with occupancy-based thermostats for commercial buildings and reported 9.5 to 30% savings. R3223

Emerging Technologies

ETP FLAG (PROJECT NUMBER) (TEXT)	PROGRAM FUNDING YEAR (TEXT)	YEAR INTRODUCED TO PROGRAMS (TEXT)
ET17SDG8031	**2017-2021**	

Measure Case Description

The OFC measure comprises one or more occupancy sensor technologies to detect when a conditioned space is unoccupied, detect continuous fan operation (ON condition), and set the fan operation from ON to AUTO where the fan is only operated when space conditions call for cooling or heating. The OFC returns fan control to continuous operation during occupied periods per building occupancy for minimum outdoor airflow per ASHRAE 62.1. R1052

When operating in AUTO mode, the OFC also provides a variable fan-off delay at the end of each cooling or heating cycle to over satisfy the thermostat, lengthen off cycle times, and save energy. R2563 R2561

According to the Advanced Research Projects Agency-Energy (ARPA-E) occupancy-based HVAC control is the most cost-effective measure in the residential and commercial buildings with potential savings of 30% of HVAC equivalent to 2 to 4% of total annual US energy use across the U.S. power system. R2528

Offering ID

SYSTEM TYPE	STATEWIDE MEASURE OFFERING ID (TEXT)	MEASURE OFFERING DESCRIPTION (TEXT)
AC Only Unit	**A**	**OFC, AC only unit**
AC Unit with Gas Heat	**B**	**OFC, AC unit with gas heat**
Heat Pump	**C**	**OFC, heat pump**
Variable Volume AC Unit with Gas Heat	**D**	**OFC, variable volume AC unit with gas heat**

Base, Standard and Measure Cases

CASE	DESCRIPTION OF TYPICAL SCENARIO
Measure	OFC automatically detects when conditioned space is unoccupied, detects continuous fan operation (ON condition), and sets fan operation from ON to AUTO wherein fan is only operated when zone conditions call for cooling or heating. When operating in AUTO mode, OFC provides variable fan-off delay at the end of each cooling or heating cycle to over satisfy the thermostat, lengthen off cycle times, and save energy.
Existing Condition	Existing HVAC equipment with supply fan operating continuously during unoccupied periods.
Code/Standard	Not applicable

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Base Case Description

The base case is defined as the existing HVAC equipment with the supply fan operating continuously during unoccupied periods.

Base Case Descriptions

SYSTEM TYPE	STATEWIDE MEASURE OFFERING ID (TEXT)	EXISTING DESCRIPTION (TEXT)	STANDARD DESCRIPTION (TEXT)
AC Only Unit	**A**	**Supply fan operating continuously during unoccupied periods, AC only unit**	**Unoccupied fan control, AC only unit**
AC Unit with Gas Heat	**B**	**Supply fan operating continuously during unoccupied periods, AC unit with gas heat**	**Unoccupied fan control, AC unit with gas heat**
Heat Pump	**C**	**Supply fan operating continuously during unoccupied periods, heat pump**	**Unoccupied fan control, heat pump**
Variable Volume AC Unit with Gas Heat	**D**	**Supply fan operating continuously during unoccupied periods, variable volume AC unit with gas heat**	**Unoccupied fan control, variable volume AC unit with gas heat**

Code Requirements

The OFC measure is an add on equipment (AOE) measure not governed by either state or federal codes and standards. The 2022 California Building Energy Efficiency Standards (Title 24) Section 120.2(e) provides options, with occupancy sensor being 1 of 3 options with various exceptions, but does not have code requirements for supply fans heating and cooling operation during unoccupied hours. For specific occupancies and conditions, each space-conditioning system must be provided with controls that can automatically shut off HVAC equipment during unoccupied hours and shall have one of the following. (1) An automatic time switch with manual overrides same as lighting systems. (2) An occupancy sensor compatible with ventilation pre-purge. (3) A 4-hour timer that can be manually operated to start the system. Exception to §120.2(e)1: HVAC systems serving retail, malls, restaurants, grocery stores, churches, or theaters with 7-day programmable timers do not have to comply with the above requirements. R2191 Pre-K and K-12 schools are also exempt.

Most new building HVAC systems do not have a 24VAC occupancy sensor or dry contacts on lighting occupancy sensors to use for HVAC systems. Therefore, the OFC measure with a default 20-minute occupancy sensor delay is applicable to most existing and new buildings. The OFC will allow pre-purge with economizers since the AC Y signal is energized with pre-purge economizer outdoor air, and the OFC energizes supply fans when AC Y signal is energized even if the building is unoccupied.

The ASHRAE Standard 180-2008, *Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems,* may be used by Quality Maintenance (QM) programs as a guide for measure implementation. R722

Applicable State and Federal Codes and Standards

CODE	CODE REFERENCE	EFFECTIVE DATE
CA Appliance Efficiency Regulations – Title 20	None	n/a
CA Building Energy Efficiency Standards – Title 24	Section 120.2(e)	January 1, 2023
Federal Standards – Code of Federal Regulations	None	n/a

Program Requirements

MEASURE IMPLEMENTATION ELIGIBILITY

OFC comprises three measures which apply to most buildings with or without continuous fan operation when unoccupied. (1) OFC occupancy sensors detect when space is unoccupied and set fan control from ON to AUTO only operating fan during calls for cooling or heating to save 12%. (2) OFC provides variable fan-off delays after each cooling or heating cycle to save 7%. (3) OFC closes economizer dampers and saves 2%. If supply fan is not operated continuously when occupied, then OFC saves 14% on variable fan-off delays and closes economizer dampers when unoccupied to save 7% so total savings are 21% or equivalent. R3224

All combinations of measure application type, delivery type, and sector that are established for this measure are specified below. Measure application type is a categorization based on the circumstances and timing of the measure installation; each measure application type is distinguished by its baseline determination, cost basis, eligibility, and documentation requirements. Delivery type is the broad categorization of the delivery channel through which the market intervention strategy (financial incentives or other services) is targeted. This table also designates the broad market sector(s) that are applicable for this measure.

Note that some of the implementation combinations below may not be allowed for some measure offerings by all program administrators.

Implementation Eligibility

MEASURE APPLICATION TYPE	SECTOR	DELIVERY TYPE
AOE	Com	DnDeemDI
AOE	Com	DnDeemed
AOE	Ind	DnDeemDI
AOE	Ind	DnDeemed

ELIGIBLE PRODUCTS

Eligible OFC products receive wired or wireless signals from occupancy sensors in a building. Occupancy sensors may use one or more sensing technologies. 1) Passive infrared (PIR) technology detects occupancy by sensing the change in the surrounding thermal radiation based on occupancy. 2) Ultrasonic sensors emit high-frequency sound waves outside human hearing range and use the doppler effect of returning sound waves to detect occupancy. 3) Time of flight infrared sensors emit invisible infrared light and onboard software detects occupancy. 4) Camera-based occupancy sensors use image processing to activate and record detected occupancy. 5) Geofencing uses location based sensor (LBS) technology such as mobile phones, GPS, or radio frequency identification (RFID) to create a virtual boundary around a physical location to detect occupancy. Advanced occupancy sensors count people and provide accurate data for occupancy levels and space use.

When operating in AUTO mode, eligible OFC products also provide a variable fan-off delay at the end of each cooling or heating cycle to over satisfy the thermostat, lengthen off cycle times, and save energy. R2563 R2561 The OFC works with any sensor technology that can provide a 24VAC/VDC signal. The OFC and occupancy sensor manufacturers provide instructions for sensor placement, operation, adaptive functions, calibration, and settings. The occupancy sensors detect when a conditioned space building is unoccupied, detect continuous fan operation (ON condition), and set the fan operation from ON to AUTO where the fan is only operated when zone conditions call for cooling or heating. The OFC returns fan operation to continuous during occupied periods per building occupancy for minimum outdoor airflow per ASHRAE 62.1. Geofencing must be calibrated, and occupancy sensors must be placed to capture occupancy for each HVAC unit. Geofencing will be calibrated with a WIFI-enabled device placed in conditioned space and verified by installer. Occupancy sensors are verified by changing delayed off time selection to 30 seconds and verifying fan switches from ON to AUTO, and then setting to 20 minutes.

ELIGIBLE BUILDING TYPES AND VINTAGES

A list of eligible building types is provided below in the table labeled "Building Description and Models." This OFC measure is applicable for all existing non-residential buildings served by unitary direct expansion (DX) and split systems that do not serve process loads, with the following exceptions.

Measure offering C heat pump (cDXHP) excludes building type refrigerated warehouse (WRf).

Measure offering D Variable Volume AC Unit with Gas Heat (cPVVG) excludes building types assembly (Asm), primary school (EPr), relocatable classroom (ERC), grocery (Gro), light industrial manufacturing (MLI), fast-food restaurant (RFF), sit-down restaurant (RSD), big box retail (RtL), small retail (RtS), conditioned storage (SCn), and refrigerated warehouse (WRf).

Exemptions are based on modeled HVAC types which are not currently included in the modeled building prototypes.

ELIGIBLE CLIMATE ZONES

The OFC measure is applicable in all California climate zones.

Program Exclusions

There are no program exclusions.

Data Collection Requirements

Data Collection requirements are described in *DEER Resolutions E-5152* and *E-5221* with the objectives of: R1503 R2026

1. Better tracking of the installed equipment that received a rebate,
2. Ensuring that eligible measures are submitted in applications,
3. Proper evaluation and application of savings are performed per California EM&V Protocols, and
4. Cost effectiveness values are properly/correctly applied for each application/project.

DATA COLLECTION REQUIREMENTS	REQUIRED FOR DOWNSTREAM AND DIRECT INSTALL
Site ID - unique identifier for the shipping destination (upstream) or installed location (Midstream/Downstream/DI) of the incentivized equipment (e.g., site address)	Yes
Quantity per Site – Total units of incentivized equipment located at the site or project	Yes

DATA COLLECTION REQUIREMENTS	REQUIRED FOR DOWNSTREAM AND DIRECT INSTALL
Measure equipment ID[1] - unique identifier for each unit of incentivized equipment (e.g., serial number)	Yes
Measure equipment model number	Yes
Measure equipment manufacturer	Yes
Measure equipment energy efficiency rating	Yes
Base equipment fuel type (gas or electric)	Yes
Base equipment type (AC Only Unit, AC Unit with Gas Heat, Heat Pump, Variable Volume AC Unit with Gas Heat)	Yes
Climate Zone	Yes
Building Type	es

1. Exemptions to the equipment identifier requirement will be made for measure package offerings where leveraging a serial number or other practical unique identifier is infeasible. Exemptions will need to be approved by the CPUC in advance.

Electric Savings (kWh)

Measure developers used building energy simulations to derive base case and measure case unit energy consumption (UEC). As an overview, the energy models used a modified set of DEER2023 building prototypes and measure definitions. R2238 The DEER2023 prototypes used the MASControl3 system to generate individual models and run simulations with the DOE-2 engine (versions DOE-2.3-50i and DOE-2.2-R52o) over one typical year of operation with CEC CZ2022 weather files. The generated model files are typically compatible with eQUEST 3.65.7175. R1791 R2238 MASControl3 stored the results into SQLite database format. R1792 R2240 A set of scripts based on the DEER post-processing scripts calculated the peak demand and applied the DEER commercial building weights to reduce the data into tabular UEC values. R1794 R2241 The unit energy savings (UES) were calculated as the difference between the normalized modeled end-use energy consumption of the base case and measure case. Electric savings for the cooling variable fan-off delay are calculated using the measure UEC times the average percentage savings (or cooling EIR adjustment) based on Intertek test data discussed below.

The table below shows the predefined DEER TechIDs that were used as the starting point for developing the base and measure case models and the subset of models generated from the prototypes based on combinations of HVAC type and building type.

Subset of DEER Prototypes and Reference TechIDs

SYSTEM TYPE	HVAC TYPE MODELED	DEER PROTOTYPES	REFERENCE DEER TECHID
AC Only Unit	cDXGF with heating end-use zeroed out	All commercial	PkgAC_135to240
AC Unit with Gas Heat	cDXGF	All commercial	PkgAC_135to240
Heat Pump	cDXHP	All commercial except ERC, WRf	PkgHP_135to240
Heat Pump	cDXHP	ERC	PkgHP_55to65/AirEcono-OAT-ByVint
Variable Volume AC Unit with Gas Heat	cPVVG	Commercial buildings with variable volume prototypes (ECC, ESe, EUn*, Htl*, MBT, OfL, OfS, Rt3)	PVVAC_240to760

University and Hotel. On review of preliminary energy impacts developed for the SWHC009 measure package, it was observed that the batch of energy models applied the measure to terminal units (TUs) in addition to other HVAC systems in building types EUn and Htl, although it was meant to apply only to non-terminal HVAC systems within the model. R2239 The building total cooling capacity calculation excluded the terminal units. Hence, due to the mismatch, preliminary calculations for unit energy savings were overestimated for these building types. In the models developed for the current measure package iteration, the measure was applied only to direct expansion (DX) systems in these building types. In other words, the TU systems operate with the same parameters in the measure case as in the base case models. To normalize the electric savings, the cooling capacity of only the DX systems was considered, consistent with the application of the measure to HVAC systems in the model.

The reference TechIDs shown in the table above trigger the prototypes to generate HVAC system configurations that are used by DEER measures to represent pre-existing baseline cases, according to measure definitions in the MASControl3 workbooks for DEER2023. R1352 With the exception of the motel building type and education relocatable classroom building type with heat pumps, DEER prototypes for air conditioning (AC) and heat pump measures were created using the “135to239kBtuh” cooling capacity range. This capacity range allows prototypes to be generated for the widest range of building types. Variable Volume AC units were not available in the “110to134kBtuh” range and were created using the “240to759kBtuh” range. These pre-existing baseline definitions vary by vintage (using the VariTech feature in MASControl3), and may not meet current building energy codes for some vintages.

A methodology for base case and measure case models is provided next. Using the MASControl3 system, additional TechIDs can be specified to trigger modifications. The measure package developer created custom TechIDs for this measure to trigger the following modifications for base and measure case. R2238

Baseline and Measure Case Custom Tech IDs

DESCRIPTION	CUSTOM TECHID	SYSTEM:INDOOR-FAN-MODE	SYSTEM:FAN-SCHEDULE
DEER prototype default	(None)	(varies by building/space)	(varies by building/space)
24/7 Continuous Supply Fan Operation (base case)	SupplyFanBase	CONTINUOUS	Always on
Normal Fan Operation (measure case)	SupplyFanMsr	CONTINUOUS	Same as DEER prototype default

BASELINE ENERGY USE SIMULATIONS

The baseline models for the unoccupied fan control measures are simulated with a fault representing HVAC units in an as-found condition – in this case the fault is a supply fan schedule operating 24/7 incongruously with occupancy. To implement unoccupied fan control fault simulations, specific modifications to eQUEST keywords shown in the Baseline and Measure Case Custom Tech IDs table were performed on all system types serving conditioned spaces. The simulation setup document highlights these changes in detail. R2238

The following building types already utilize 24/7 occupied schedules in which case the modeled fault results in the same energy use as the measure scenario: hospitals (Hsp), motels (Mtl), and nursing homes (Nrs). These building types were therefore not simulated and can be reported as having zero energy savings.The SYSTEM:INDOOR-FAN-MODE keyword identifies continuous or intermittent supply fan operation during occupied periods. It is set as CONTINUOUS in both the baseline and measure case. The SYSTEM:FAN-SCHEDULE keyword assigns an ON/OFF schedule which requires the supply fan to follow occupied operation set by SYSTEM:INDOOR-FAN-MODE. An hour set to ON results in continuous supply fan operation during that hour while an hour set to OFF results in intermittent operation corresponding to calls for cooling or heating. The DEER value for SYSTEM:FAN-SCHEDULE varies by prototype but all employ schedules that align the supply fan occupied operation with the building occupancy schedules. The base case assigns the SYSTEM:FAN-SCHEDULE keyword value to “Hourly Report Schedule” which has all hours set to ON, resulting in 24 hours per day supply fan operation regardless of building occupancy.

MEASURE CASE ENERGY USE SIMULATIONS

The DEER prototypes were used as the reference models for the measure case buildings and are unmodified. Multifamily Common Area (MfmCmn) prototypes are modeled using same base and measure UEC values as Small Office (OfS) prototype.

The following tables describe the building types, building vintages, and climate zones modeled.

Building Description and Models

BUILDING TYPE	BUILDING TYPE CODE	MODELED
Assembly	Asm	Yes
Primary School	EPr	Yes
Secondary School	ESe	Yes
Community College	ECC	Yes
Relocatable Classroom	ERC	Yes
University	EUn	Yes
Grocery	Gro	Yes
Hospital	Hsp	No
Nursing Home	Nrs	No
Hotel	Htl	Yes
Motel	Mtl	No
Bio/Tech Manufacturing	MBT	Yes
Multifamily Common Area	MfmCmn	Yes
Light Industrial Manufacturing	MLI	Yes
Large Office	OfL	Yes
Small Office	OfS	Yes
Sit-Down Restaurant	RSD	Yes
Fast-Food Restaurant	RFF	Yes
Department Store	Rt3	Yes
Big Box Retail	RtL	Yes
Small Retail	RtS	Yes
Conditioned Storage	SCn	Yes

BUILDING TYPE	BUILDING TYPE CODE	MODELED
Unconditioned Storage	SUn	No
Refrigerated Warehouse	WRf	Yes

Climate Zones

CLIMATE ZONE	CLIMATE ZONE DESCRIPTION	MODELED
1	Arcata Area (CZ01)	Yes
2	Santa Rosa Area (CZ02)	Yes
3	Oakland Area (CZ03)	Yes
4	Sunnyvale Area (CZ04)	Yes
5	Santa Maria Area (CZ05)	Yes
6	Los Angeles Area (CZ06)	Yes
7	San Diego Area (CZ07)	Yes
8	El Toro Area (CZ08)	Yes
9	Pasadena Area (CZ09)	Yes
10	San Bernardino Area (CZ10)	Yes
11	Red Bluff Area (CZ11)	Yes
12	Sacramento Area (CZ12)	Yes
13	Fresno Area (CZ13)	Yes
14	China Lake Area (CZ14)	Yes
15	Blythe Area (CZ15)	Yes
16	Mount Shasta Area (CZ16)	Yes

VINTAGE WEIGHTED AVERAGE

Baseline and measure simulations used the DEER building vintages (below) for both customer average and code prototypes.

DEER Building Vintage Codes and Descriptions

DEER VINTAGE CODE	DESCRIPTION
V03	Existing building stock built between 2002 and 2005
V07	Existing building stock built between 2006 and 2009
V11	Existing building stock built between 2010 and 2013
V15	Existing building stock built between 2014 and 2016

DEER2020 vintage weighting tables and procedures were used to appropriately weight all measure electric and demand reduction savings according to each vintage per IOU, building type, and climate zone. R857 The summation of these weighted savings give the estimated savings for each measure offering.

Thermostat Options

Programmable thermostat

Case Options

DESCRIPTION	CODE	MODELED
Customer Average	CAv	Yes
2005 Code/Standard	C05	No
2008 Code/Standard	C08	No
2013 Code/Standard	C13	No
Market Average	MAv	No
Measure	Msr	Yes

DEER PROTOTYPE DISCUSSION

The *HVAC Impact Evaluation FINAL Report WO32 HVAC* conducted by DNV GL ("WO32 Study") evaluated gross energy savings and installation rates through activities including on-site field evaluations, sampling and monitoring the performance and energy use of units enrolled in the programs before and after CQM maintenance, and additional laboratory testing of existing HVAC units. The study highlights findings for key QPM treatments (and parameters) including, but not limited to, recognition of typical damper leakage characteristics, non-functional economizer conditions and performance, and adjusting refrigerant charge. R693

The economizer damper leakage observed during laboratory testing with supply damper perimeter gap sealed suggests that existing economizers generally allow 15% to 30% outdoor air flow with closed dampers, 20% to 35% outdoor air flow with the commonly applied "finger open" methodology for minimum ventilation, and 62% to 80% outdoor air flow with dampers completely open (pp.18-19). R3168 R2560 Additional laboratory and field tests indicate sealing supply and return perimeter gap provides fully closed OAF from 4 to 15% and fully open OAF from 88 to 96%. Models use 85% MAX economizer OAF which is average of 78 to 92%. R3224 The WO32 Study findings include as-found non-functional economizer conditions for which "approximately 74% of observed units in the programs after maintenance had economizer or make-up air dampers set to one or more fingers open after maintenance was completed." Intertek tests for 3-ton and 4-ton packaged rooftop units (RTUs) are used to evaluate energy savings for OFC variable fan -off delays with 35% outdoor airflow and 1 finger-open. R3168 R2560 Intertek tests were also performed with 18 to 30% economizer outdoor airflow which provided similar savings.

Considering that the energy savings results for the supply fan measure may be sensitive to damper leakage rate and considering the prevalence of non-functional economizers failing partially open as opposed to failing closed, it is important to document model assumptions for outdoor air flow. It is understood that DEER 2020 prototypes, developed after the 2014 WO32 Study, had incorporated the latest understanding of economizer performance and code requirements and had appropriately modeled outdoor air flow into the HVAC systems subject to the measure. The following keywords describe the typical outdoor air flow configuration in the models.

Model Keywords for Typical Outdoor Air Flow Configurations

MODEL KEYWORD	MODEL VALUE
ZONE:OA-FLOW/AREA	Varies by area type, 0.05 to 1.07 cfm/ft^2
SYSTEM:MIN-OA-METHOD	FRAC-OF-HOURLY-FLOW
SYSTEM:MIN-AIR-SCH	Hourly schedule varying from inactive to active at 5% minimum outdoor air. Confer parameter MinOANight in model templates.
SYSTEM:OA-CONTROL	Varies: FIXED and OA-TEMP
SYSTEM:MAX-OA-FRACTION	85% (confer parameter MaxOAFrac)
SYSTEM:ECONO-SCHEDULE	Hourly schedule, always available

ELECTRIC UNIT ENERGY SAVINGS FOR VARIABLE FAN-OFF DELAY

The electric unit energy savings (UES) for the variable fan-off delay for cooling and heating were calculated using the measure UEC times the average percentage savings (or cooling EIR adjustment) based on Intertek test data. Intertek tests were performed on a packaged rooftop unit with an economizer at 82F, 95F, 105F, and 115F outdoor air temperature (OAT) and air conditioning (AC) compressor operating times of 2, 5, 10, 20, 30, and 50 minutes. The cooling variable fan-off delays of 1.5 to 3.5 minutes are adjusted based on AC compressor ON and OFF cycle times. Intertek tests were performed on 3-ton and 4-ton packaged rooftop units (RTUs) with 35% economizer outdoor airflow based on actuator voltage set to 5.1V or 1-finger open including perimeter gap leakage. Intertek tests are based on the WO32 Study as-found condition which found "approximately 74% of observed units in the programs after maintenance had economizer or make-up air dampers set to one or more fingers open after maintenance was completed." R693 R3168

The Part Load Ratio (PLR) is calculated based on delivered cooling capacity in British thermal units (Btu) for an air conditioner (AC) or heat pump over an operating time period less than one hour divided by the AC or heat pump cooling capacity delivered for one hour.

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PLR = Cooling Load (Btu/hr) / AC Cooling Capacity (Btu/hr)
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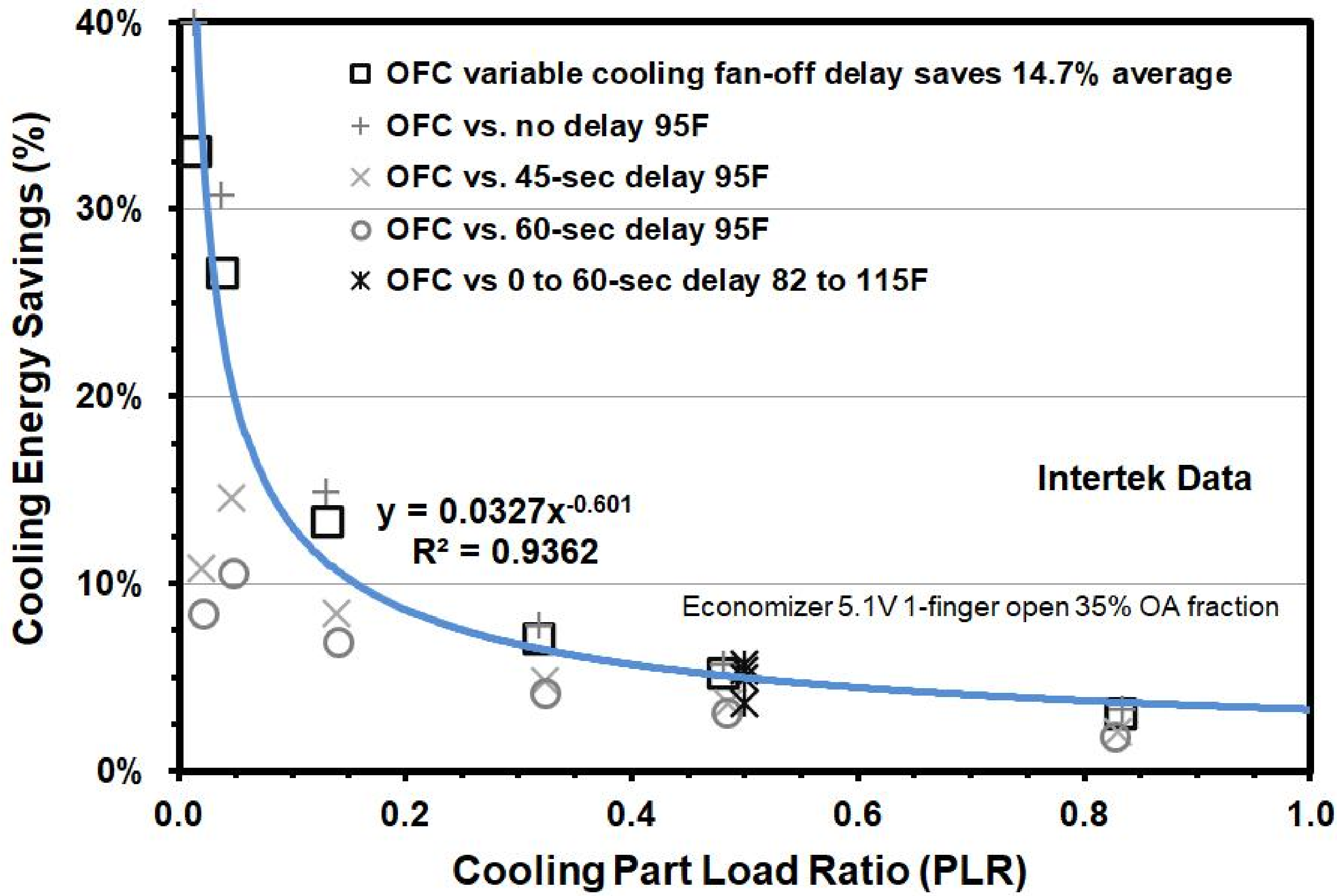
Intertek laboratory -test data and weighted average savings are plotted in the following figure which compares the OFC cooling energy savings versus part load ratio (PLR). R2563 The power function regression equation curve fit is shown on the following figure.

$$\text{Cooling Energy Savings (\%)} = 0.0327(\text{PLR})^{-0.601}$$



Cooling energy savings versus part load ratio (PLR)

The following table summarizes Intertek tests of the 4-ton RTU operating for 2 to 50 minutes at 95F OAT. The 3-ton RTU tests were performed with AC unit operating for 30 minutes at 82F, 95F, 105F, and 115F OAT. R2563 Savings are weighted based on 77% no delay, 11.9% 45-second delay, and 11.1% 60-second delay baased on a sample of 5582 AC units where 4298 units or 77% had no fan-off delay. R3139

Cooling Weighted Average Energy Savings vs. Part Load Ratio (PLR)

AC RUN TIME (MINUTES)	PLR	OFC SAVINGS VS. NO DELAY	OFC SAVINGS VS. 45-SEC DELAY	OFC SAVINGS VS. 60-SEC DELAY	WEIGHTED AVE. SAVINGS
2	0.01	40.0%	10.8%	8.3%	33.0%
5	0.04	30.8%	14.6%	10.5%	26.6%
10	0.13	14.9%	8.4%	6.8%	13.2%

AC RUN TIME (MINUTES)	PLR	OFC SAVINGS VS. NO DELAY	OFC SAVINGS VS. 45-SEC DELAY	OFC SAVINGS VS. 60-SEC DELAY	WEIGHTED AVE. SAVINGS
20	0.32	7.8%	4.8%	4.1%	7.0%
30	0.48	5.7%	3.6%	3.1%	5.1%
50	0.83	3.3%	2.1%	1.8%	3.0%
Ave. savings					14.7%

When operating in AUTO mode, OFC provides a variable fan-off delay at the end of each cooling cycle providing 14.7% cooling savings for AC only unit, AC unit with gas heat, and variable volume AC unit with gas heat. OFC variable fan-off delays at the end of each heating cycle provide 14.3% therm savings for AC only unit with gas heat and variable volume AC unit with gas heat. Interactive effects describes extra fan energy of 0.918 kWh/therm savings for heating variable fan-off delays after heating ON cycles. R2561
The average gas UES savings of 14.3% are in the Gas Savings section (below).

OFC Average Cooling EIR Adjustment, Cooling Savings, Heating EIR, Extra Fan Energy, and Heating Savings

BLDG HVAC	COOLING EIR ADJUSTMENT	COOLING SAVINGS	HEATING EIR ADJUSTMENT	EXTRA FAN ENERGY	HEATING SAVINGS
AC Only Unit	0.853 * base cool EIR	14.70%	NA	NA	NA
AC Unit with Gas Heat	0.853 * base cool EIR	14.70%	0.857 * base heat EIR	0.918 kWh/therm savings	14.30%
Heat Pump	0.853 * base cool EIR	14.70%	NA	NA	NA
Variable Volume AC Unit with Gas Heat	0.853 * base cool EIR	14.70%	0.857 * base heat EIR	0.918 kWh/therm savings	14.30%

INTERACTIVE EFFECTS (KWH) FOR HEATING VARIABLE FAN-OFF DELAY

Interactive effects (kWh) for the heating variable fan-off delay for the gas RTU are calculated using the following equation. This is the extra fan energy required for the heating variable fan-off delay after the base case fixed fan-off delays of 45-seconds or 60-seconds.

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Interactive Effects gas RTU (kWh) = −0.918 × (1−0.857) × UEC_ThermBase__heat
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The - 0.918 coefficient is the weighted average interactive effect adjustment (IE_HVAC__kWh_therm) based on the following table.

The 0.857 is the gas furnace heating EIR adjustment heating (heatEIRAdj__YrTherm) based on Intertek test data (see Gas Savings)
UEC_ThermBase__heat = Gas furnace UEC, measure (therm)

The following table summarizes extra fan energy of 0.918 kWh/therm savings for heating variable fan-off delays after fixed 45-second and 60-second base delays at 47F and 17F OAT. [R2561]

Extra Fan Energy (kWh/therm) for Variable Fan-off Delays after Heating ON Cycles at 47F and 17F OAT

AC RUN TIME (MINUTES)	PLR	45-SEC BASE 47F (KWH/THERM)	60-SEC BASE 47F (KWH/THERM)	45-SEC BASE 17F (KWH/THERM)	60-SEC BASE17F (KWH/THERM)	WEIGHTED AVE. (KWH/THERM)
2	0.01	0.369	0.482	0.437	0.578	0.466
5	0.04	0.628	0.703	0.770	0.884	0.746
10	0.12	0.807	0.870	1.005	1.120	0.950
20	0.29	0.946	1.002	1.260	1.387	1.149
30	0.47	1.034	1.091	1.123	1.195	1.111
50	0.83	0.985	1.032	1.055	1.271	1.086
Ave. kWh/therm						0.918

ELECTRIC UNIT ENERGY SAVINGS CALCULATIONS

The electric (UES) was calculated as the difference between the baseline and measure case UEC.

Annual Unit Energy Savings - Electric

EQUATION (KWH / YR)
$UEC\_YrkWhBase - UEC\_YrkWhMeas$

UEC_YrkWhBase = Annual unit energy consumption - electric, baseline (from each modeled fault weighted by the frequency distribution of the corresponding as-found condition) (kWh / yr ton)
UEC_YrkWhMeas = Annual unit energy consumption - electric, measure (kWh / yr ton)

The UEC was calculated as the sum of the modeled end-use energy consumption during heating (OFF), cooling (OFF), and continuous ventilation fan operation (ON) schedule.

Annual Unit Energy Consumption - Electric, Baseline

EQUATION (KWH / YR)
$UEC\_kWhBase\_\_heat + UEC\_kWhBase\_\_cool + UEC\_kWhBase\_\_ventFan$

> *UEC_kWhBase__heat = Average unit energy consumption - electric, baseline during intermittent fan operation with heating mode (kWh / yr ton)*
> *UEC_kWhBase__cool = Average unit energy consumption - electric, baseline during intermittent fan operation with cooling mode (kWh / yr ton)*
> *UEC_kWhBase__ventFan = Average unit energy consumption - electric, baseline during continuous fan operation mode (kWh / yr ton)*

The measure case UEC for each system type was calculated as the sum of the OFC measure case modeled end-use unit energy consumption during heating (OFF), cooling (OFF), and continuous ventilation fan operation (ON) schedule plus the fan-off delay savings using the following calculation.

Annual Unit Energy Consumption - Electric, Measure Case

SYSTEM TYPE	EQUATION (KWH / YR)
AC Only Unit	$(UEC\_kWhMeas\_\_heat + UEC\_kWhMeas\_\_cool + UEC\_kWhMeas\_\_ventFan) - (UEC\_kWhMeas\_\_cool \bullet (1 - coolEIRAdj\_\_YrkWh))$
AC Unit with Gas Heat	$(UEC\_kWhMeas\_\_heat + UEC\_kWhMeas\_\_cool + UEC\_kWhMeas\_\_ventFan) - (UEC\_kWhMeas\_\_cool \bullet (1 - coolEIRAdj\_\_YrkWh)) + (IE\_HVAC\_\_kWh\_therm \bullet (1 - heatEIRAdj\_\_YrTherm) \bullet UEC\_ThermMeas\_\_heat)$
Heat Pump	$(UEC\_kWhMeas\_\_heat + UEC\_kWhMeas\_\_cool + UEC\_kWhMeas\_\_ventFan) - (UEC\_kWhMeas\_\_cool \bullet (1 - coolEIRAdj\_\_YrkWh))$
Variable Volume AC Unit with Gas Heat	$(UEC\_kWhMeas\_\_heat + UEC\_kWhMeas\_\_cool + UEC\_kWhMeas\_\_ventFan) - (UEC\_kWhMeas\_\_cool \bullet (1 - coolEIRAdj\_\_YrkWh)) + (IE\_HVAC\_\_kWh\_therm \bullet (1 - heatEIRAdj\_\_YrTherm) \bullet UEC\_ThermMeas\_\_heat)$

UEC_kWhMeas__heat = Average unit energy consumption - electric, measureduring intermittent fan operation with heating mode (kWh / yr ton)
UEC_kWhMeas__cool = Average unit energy consumption - electric, measure during intermittent fan operation with cooling mode (kWh / yr ton)
UEC_kWhMeas__ventFan = Average iunit energy consumption - electric, measure during OFC intermittent fan operation mode (kWh / yr ton)
coolEIRAdj__YrkWh = Average cooling EIR adjustment for cooling fan-off delay (ratio)
IE_HVAC__kWh_therm = Interactive effects multiplier for extra fan energy required for heating variable fan-off delay (ratio)
heatEIRAdj__YrTherm = Average heating EIR adjustment for heating fan-off delay (ratio)
UEC_ThermMeas__heat = Average whole-building consumption for heating mode (Therm / yr ton)

Note that the reported building UEC is already the vintage-weighted average end-use unit energy consumption and is already normalized by the cooling tons.

Peak Electric Demand Reduction (kW)

Peak demand reduction was calculated based on similar methodology used to calculate electric unit energy savings (UES). The peak demand reduction was estimated using energy modeling software, DOE-2.3 (compatible with eQUEST version 3.65). The Database of Energy Efficient Resources (DEER) 2020 prototypes were developed for the CAv (Customer Average) case using MASControl v3.00.27, the .INP file was then imported into eQUEST and modifications were made to develop the base case and the measure case. (See Electric Savings.). R1791 (all building types except EUn and Htl) R2239 (EUn and Htl) Note that whereas annual electric energy (kWh) data extracted from building energy models were based on heating, cooling, and ventilation end-use loads, the hourly demand (kW) data extracted from models were inclusive of all electric loads within the building energy models. (This distinction was merely due to limitations of modeling and post-processing hourly data with the typical setup for DEER prototypes, and was not likely to impact the results.)

The demand reduction was estimated using the average hourly peak demand for the 15 hours of the DEER peak period from 4:00 p.m. to 9:00 p.m. during the three consecutive weekday period within the dates of June 1st through September 30th. R622 (OP 1) The DEER version adopted in D.12-05-015 uses a 3-day "heat wave" that occurs on consecutive days in June through September such that the three consecutive days do not include weekends or holidays, and where the heat wave is ranked by giving equal weight to the peak temperature during the 72-hour period, the average temperature during the 72-hour period and the average temperature from noon – 6 pm over the three days. R1503 Peak Demand Definition is corrected based on CPUC D.06-06-063 OP 1. Peak dates are linked to the weather files in conformance with the Database for Energy Efficiency Resources (DEER) peak definition. R1503 (pp. 16, A12-A14.)

PEAK ELECTRIC DEMAND REDUCTION UNIT SAVINGS CALCULATIONS

The peak electric demand reduction was calculated as the difference between the baseline and measure case demand, multiplied by a modeled savings adjustment. The measure case peak demand is further adjusted by the average cooling EIR adjustment for the cooling fan-off delay. The average demand is already the vintage weighted average building demand and is already normalized by the cooling capacity (tons). See the Electric Savings section. The modeled savings adjustment factor accounts for the setback override requirements. See the Data Collection Requirements section.

Peak Demand Reduction

EQUATION (KW)
$UEC\_YrkW\_\_base - \left(UEC\_YrkW\_\_meas \bullet coolEIRAdj\_\_YrkW\right)$

UEC_YrkW__base = Average demand for DEER peak period of customer average from each modeled fault weighted by the frequency distribution the corresponding as found condition (kW/ton)
UEC_YrkW__meas = Average demand for DEER peak period of measure (kW/ton)
coolEIRAdj__YrkWh = Average cooling EIR adjustment for cooling fan-off delay (ratio)

Gas Savings (Therms)

The gas unit energy consumption (UEC) was derived from modeled energy consumption and heating capacity based on the DOE-2.3/DOE-2.2R building energy simulation engine (compatible with eQUEST version 3.65.7175). R1791 (all building types except EUn and Htl) R2239 (EUn and Htl) Prototypes from the Database of Energy Efficient Resources (DEER) 2020 were used for the building energy simulations. See Electric Savings for details for the building simulation models. Gas savings for the heating variable fan-off delay are calculated using the measure UEC times the average percentage savings (or heating EIR adjustment) based on Intertek test data discussed below. Gas savings for the heating variable fan-off delay are calculated using the measure UEC times the average percentage savings (or heating EIR adjustment) based on Intertek test data. R2561 R2562

VINTAGE WEIGHTED AVERAGE

Baseline and measure simulations used the DEER building vintages (below) for both customer average and code prototypes.

DEER Building Vintage Codes and Descriptions

DEER VINTAGE CODE	DESCRIPTION
Ex	Non-Mobile Homes 2002 - 2016; default vintage for existing buildings
V03	Existing building stock built between 2002 and 2005
V07	Existing building stock built between 2006 and 2009
V11	Existing building stock built between 2010 and 2013
V15	Existing building stock built between 2014 and 2016
2020 (New)	New Construction (not yet built)

DEER2020 vintage weighting tables and procedures were used to appropriately weight all measure gas savings according to each vintage per IOU, building type, and climate zone. R857

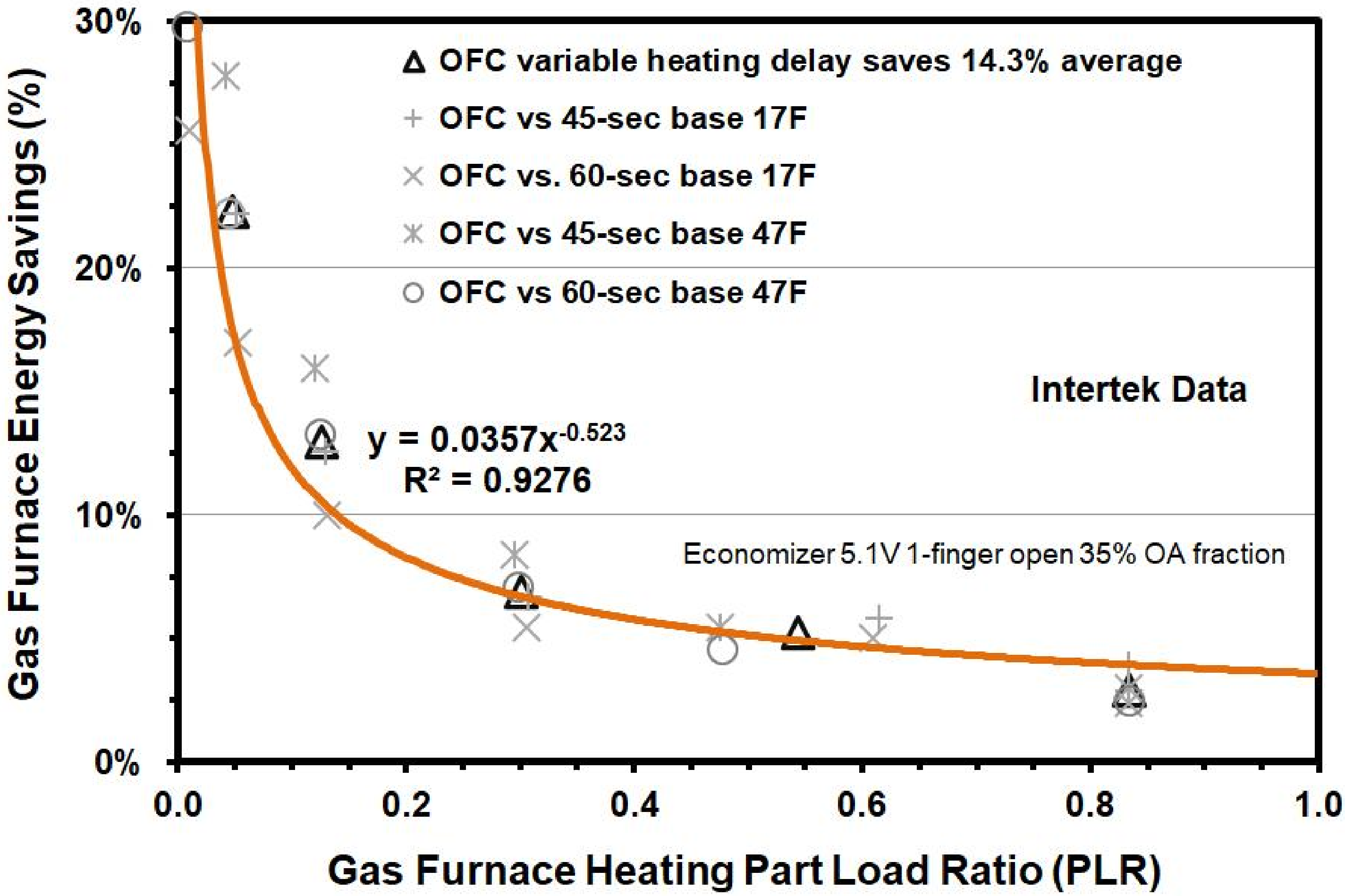
GAS UNIT ENERGY SAVINGS FOR HEATING VARIABLE FAN-OFF DELAY

The gas unit energy savings (UES) for the heating variable fan-off delay were calculated using the measure UEC times the average percentage savings (or heating EIR adjustment) based on Intertek test data. Intertek tests were performed on a packaged gas rooftop unit (RTU) with an economizer at 17F and 47F OAT and heating operating times of 2, 5, 10, 20, 30, and 50 minutes. The heating variable fan-off delays of 1.5 to 3.5 minutes are adjusted based on heating ON and OFF cycle times. Intertek tests were performed on 3-ton packaged RTU with 35% economizer outdoor airflow based on actuator voltage set to 5.1V or "1-finger" open including perimeter gap leakage. R3168 R2560 Intertek tests were also performed with 18 to 30% economizer outdoor airflow which provided similar savings. The heating Part Load Ratio (PLR) is calculated based on delivered heating capacity in British thermal units (Btu) for a gas furnace or heat pump over an operating time period less than one hour divided by the gas furnace or heat pump heating capacity delivered for one hour.

```
PLR = Heating Load (Btu/hr) / Gas Furnace Heating Capacity (Btu/hr)
```

Laboratory test data and weighted average savings are plotted in the following figure which compares the OFC gas furnace heating energy savings versus PLR with the following regression equation curve fit.

$$\text{Gas Furnace Heating Energy Savings (\%)} = 0.0357(\text{PLR})^{-0.523}$$



Gas furnace heating energy savings versus part load ratio (PLR)

The following table summarizes Intertek tests of the OFC gas furnace heating savings versus 45-second and 60-second fixed base delays and 47F and 17F OAT. Average savings are based on savings for no delay, 45-second delay, and 60-second delay. R2561 R2562

Heating Weighted Average Gas Savings (%) vs. Part Load Ratio (PLR) at 47F and 17F OAT

AC RUN TIME (MINUTES)	PLR	45-SEC BASE 47F	60-SEC BASE 47F	45-SEC BASE 17F	60-SEC BASE 17F	AVERAGE SAVINGS
2	0.01	45.4%	29.8%	40.5%	25.6%	35.3%
5	0.04	27.8%	22.2%	22.2%	17.0%	22.3%
10	0.12	15.9%	13.3%	12.5%	10.0%	12.9%
20	0.29	8.4%	7.1%	6.7%	5.4%	6.9%
30	0.47	5.4%	4.6%	5.8%	5.0%	5.2%
50	0.83	3.0%	2.5%	3.9%	2.4%	2.9%
Ave. heating savings						14.3%

GAS UNIT ENERGY SAVINGS CALCULATIONS

The gas unit energy savings (UES) were calculated as the difference between the baseline and measure case UEC.

Annual Unit Energy Savings - Gas

EQUATION (THERM / YR)
$UEC\_YrThermBase - UEC\_YrThermMeas$

> *UEC_YrThermBase = Annual unit energy consumption - therms, baseline (from each modeled fault weighted by the frequency distribution of the corresponding as - found condition) (therms / yr ton)*
> *UEC_YrThermMeas = Annual unit energy consumption - therms, measure (therms / yr ton)*

The gas UEC was calculated as the sum of the modelded end-use energy consumption during heating (OFF), cooling (OFF), and continuous ventilation fan operation (ON) schedule.

Annual Unit Energy Consumption – Gas, Baseline

EQUATION (THERM / YR)
$UEC\_ThermBase\_\_heat + UEC\_ThermBase\_\_cool + UEC\_ThermBase\_\_ventFan$

> *UEC_ThermBase__heat = Average unit energy consumption - therm, baseline during intermittent fan operation with heating mode (therms / yr   ton)*
> *UEC_ThermBase__cool = Average unit energy consumption - therm, baseline during intermittent fan operation with cooling mode (therms / yr   ton)*
> *UEC_ThermBase__ventFan = Average unit energy consumption - therm, baseline during continuous fan operation mode (therms / yr   ton)*

The gas measure case UEC for each system type was calculated as the sum of the OFC measure case end-use energy consumption during heating (OFF), cooling (OFF), and intermittent ventilation fan operation schedule plus the heating variable fan-off delay savings using the following calculation.

Annual Unit Energy Consumption – Gas, Measure Case

SYSTEM TYPE	EQUATION (THERM / YR)
AC Only Unit	$UEC\_ThermMeas\_\_heat + UEC\_ThermMeas\_\_cool + UEC\_ThermMeas\_\_ventFan$
AC Unit with Gas Heat	$(UEC\_ThermMeas\_\_heat + UEC\_ThermMeas\_\_cool + UEC\_ThermMeas\_\_ventFan) - (UEC\_ThermMeas\_\_heat \bullet (1 - heatEIRAdj\_\_YrTherm))$
Heat Pump	$UEC\_ThermMeas\_\_heat + UEC\_ThermMeas\_\_cool + UEC\_ThermMeas\_\_ventFan$
Variable Volume AC Unit with Gas Heat	$(UEC\_ThermMeas\_\_heat + UEC\_ThermMeas\_\_cool + UEC\_ThermMeas\_\_ventFan) - (UEC\_ThermMeas\_\_heat \bullet (1 - heatEIRAdj\_\_YrTherm))$

> *UEC_ThermMeas__heat = Average unit energy consumption - therm, measure during intermittent fan operation in heating mode (therm / yr   ton)*
> *UEC_ThermMeas__cool = Average unit energy consumption therm, measure during intermittent fan operation in cooling mode (Therm / yr   ton)*

UEC_ThermMeas__ventFan = Average unit energy consumption therm, measure during OFC intermittent fan operation mode (Therm / yr ton)
heatEIRAdj__YrTherm = Average heating EIR adjustment for cooling fan-off delay (ratio)

Note that the reported building UEC is already the vintage weighted average end-use unit energy consumption and is already normalized by the cooling tons. See Electric Savings.

Life Cycle

Effective useful life (EUL) is an estimate of the median number of years that a measure installed through a program is still in place and operable. Remaining useful life (RUL) is an estimate of the median number of years that a technology or piece of equipment replaced or altered by an energy efficiency program would have remained in service and operational had the program intervention not caused the replacement or alteration.

Per Resolution E-5152, if add-on equipment (AOE) is not directly installed on host equipment and can remain in place if host equipment is replaced, then AOE equipment full EUL can be used even if it exceeds host equipment RUL. R1503 Thus, the OFC full EUL will be used for this measure.

The EUL for the OFC are provided below. R240

Effective Useful Life and Remaining Useful Life

EFFECTIVE USEFUL LIFE ID	EUL DESCRIPTION (TEXT)	SECTOR (TEXT)	EUL YEARS (YR)	START DATE (TEXT)	EXPIRE DATE (TEXT)
ILtg-OccSens	**Occupancy Sensors**	**Com**	**8.00**	**2013-01-01**	

Base Case Material Cost ($/Unit)

The base case is the existing equipment; therefore, the base case material cost is equal to $0.

Measure Case Material Cost ($/Unit)

The measure case material cost was calculated as the average material costs from several online retailers and distributors. The average cost was normalized to per ton of cooling capacity, using 12.5 tons. R2621 For larger HVAC systems, OFC and occupancy sensors will be installed on each zone air handler.

Base Case Labor Cost ($/Unit)

The base case is the existing equipment; therefore, the base case labor cost is equal to $0.

Measure Case Labor Cost ($/Unit)

The measure case labor cost was calculated as the product of the 2022 RSMeans HVAC technician labor rate and the labor hours, derived from the 2021Q4 mechanical cost for installing the OFC on a 12.5 ton package HVAC system. R1720 R2621 Result was normalized to per ton of cooling capacity, using 12.5 tons.

Net-to-Gross

The net-to-gross (NTG) ratio represents the portion of gross impacts that are determined to be directly attributed to a specific program intervention. The NTG value adopted for this measure is designated specifically for emerging technologies by the California Public Utilities Commission (CPUC). R237 R3223

Net to Gross Ratio

NET TO GROSS RATIO ID	NTG DESCRIPTION (TEXT)	NTG ELECTRIC (RATIO)	NTG GAS (RATIO)	START DATE (TEXT)	EXPIRE DATE (TEXT)
ET-Default	**Emerging Technologies approved by ED through work paper review**	**0.8500**	**0.8500**	**2019-01-01**	

Gross Savings Installation Adjustment (GSIA)

The gross savings installation adjustment (GSIA) rate represents the ratio of the number of verified installations of the measure to the number of claimed installations reported by the utility. This factor varies by end use, sector, technology, application, and delivery method. R1270

Gross Savings Installation Adjustments - Default

GSIA ID	GSIA (RATIO) R1270
Def-GSIA	**1.0000**

Non-Energy Impacts

Non-energy impacts for this measure have not been quantified.

DEER Differences Analysis

This section provides a summary of inputs and methods based upon the Database of Energy Efficient Resources (DEER), and the rationale for inputs and methods that are not DEER-based.

DEER Difference Summary

DEER ITEM	COMMENT
Modified DEER methodology	No
Scaled DEER measure	No
DEER Base Case	No
DEER Measure Case	No
DEER Building Types	Yes
DEER Operating Hours	Yes
DEER eQUEST Prototypes	Yes, with modifications
DEER Version	2023
Reason for Deviation from DEER	DEER does not contain this type of measure
DEER Measure IDs Used	N/A

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