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HVAC
**MULTIPLE CAPACITY UNITARY AIR-COOLED
COMMERCIAL AIR CONDITIONERS BETWEEN 65
AND 240 KBTU/H**
SWHC043-01

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MEASURE NAME

Multiple Capacity Unitary Air-Cooled Commercial Air Conditioners between 65 and 240 kBtu/h

STATEWIDE MEASURE ID

SWHC043-01

TECHNOLOGY SUMMARY

Multiple capacity unitary air-cooled commercial air conditioners (ACs) between 65 kBtu/h (5.4 tons) and 240 kBtu/h (20 tons) are capable of varying cooling capacity delivered to conditioned space and therefore are capable of achieving very high IEER ratings. This equipment is not currently captured by DEER measures and therefore, this is a non-DEER measure. The DEER commercial unitary air conditioner measures are designed to reward equipment with more efficient full-load energy efficiency ratio (EER) ratings than currently required by Title-24. These measures, by contrast, target equipment with both greater EER ratings than code and with much greater IEER ratings than required by DOE/Title-24. These measures target equipment with “advanced features”. The allowable methods to achieve “advanced features” include multiple speed indoor fans, and one of the following advanced compressor control strategies: (1) variable speed compressor(s), (2) multiple-step compressor(s), or (3) multiple compressors on a single refrigeration circuit (tandem compressors). In addition, units must meet specified EER and IEER requirements by size category.

This workpaper does not replace the DEER unitary air-cooled commercial air conditioner and heat pump workpapers (PA-specific PGECOHC128 and SCE13HC035, or statewide SWHC013) but rather supplements them by targeting equipment that uses advanced capacity control strategies to achieve very high IEER ratings. Savings for these units were created using manufacturer performance curves and other modeling inputs that reflect units sold in the market place, which was a recommendation to Finding #1 in the report “Impact Evaluation of 2013-14 Upstream HVAC Programs (HVAC1)”.¹

MEASURE CASE DESCRIPTION

The measure case is defined as unitary air-cooled AC equipment that meets the EER and IEER requirements shown below, and additionally contains the “advanced features” described in the table below. The advanced features are intended to capture units capable of superior part-load control strategies relative to code-minimum equipment. The measure size categories are described as follows: 65-134 kBtu/h includes equipment greater than or equal to 65,000 Btu/h but less than 135,000 Btu/h, and 135-239 kBtu/h includes equipment greater than or equal to 135,000 Btu/h but less than 240,000 Btu/h. Unitary commercial heat pumps and unitary air conditioners with electric resistance heating are not in the scope of this measure. Central plant systems, DHW systems, and package terminal AC units

¹ DNV-GL. (2016). Impact Evaluation of 2013-2014 Upstream HVAC Programs (HVAC1).

(units manufactured for installation through a wall or window and are usually less than or equal to 2 tons), are not eligible.

Description of Measure Names and Eligibility Requirements

Measure Name	Minimum EER	Minimum IEER	Advanced Features
65 – 134 KBTU/H. MIN EER = 12.0 and Min IEER 19.0, Air Cooled Unitary Air Conditioner DX Equipment with Advanced Features	12.0	19.0	Multi speed indoor fan and compressor must utilize one of: (1) variable speed compressor(s), (2) multiple-step compressor(s), or (3) multiple compressors operating on a single refrigeration circuit (tandem compressors).
135 – 239 KBTU/H. MIN EER = 12.0 and Min IEER 17.5, Air Source Unitary Air Conditioner DX Equipment with Advanced Features	12.0	17.5	

The “advanced features” component of the measure description was not present in the first version of this workpaper. They were added in response to the March 2018 CPUC disposition.² Additionally, the original version of the workpaper had tiers at roughly 14.0 IEER levels and 16.0 IEER levels. These tiers were eliminated to ensure no overlap with the current DEER unitary AC measures. Additionally, the original workpaper had measures for equipment between 240 and 760 kBtu/h, including package VAV (PVAV) systems. Due to CPUC feedback in the disposition, this size category was eliminated in this edition of the workpaper since the measures weren’t sufficiently differentiated from DEER measures in that size range.

BASE CASE DESCRIPTION

The base case is defined as code/standard-minimum efficient unitary air-cooled AC equipment. The code-minimum levels for the size categories contained in this workpaper are shown in **Error! Reference source not found.**

Description of Base Case Efficiency by Measure Name

Measure Name	Minimum EER	Minimum IEER
65 – 134 KBTU/H. Heating section = gas furnace	11.0	12.7
135 – 239 KBTU/H. Heating section = gas furnace	10.8	12.2

The first version of this workpaper modeled the base case with code-minimum eQuest input values and performance curves. In response to the CPUC disposition, the DEER base case is now being used in the energy models.

² <http://deeresources.net/workpapers>; disposition title: “Multiple Speed Unitary HVAC Units.”

CODE REQUIREMENTS

Unitary air-cooled AC equipment is regulated under the U.S. Department of Energy appliance standards program as well as the California Energy Commission’s building energy efficiency codes.

Applicable State and Federal Codes and Standards

Code	Applicable Code Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20 ^a	20 CCR §1605.1(c)(1), Table C-4	1/1/2018
CA Building Energy Efficiency Standards – Title 24	24 CCR §110.2, Table 110.2-A	1/1/2020
Federal Standards	10 CFR §431.97, Table 3	1/1/2018

^a Commercial unitary air conditioners are federally pre-empted, therefore Title 20 follows the federal appliance standards.

NORMALIZING UNIT

Per cooling ton.

PROGRAM REQUIREMENTS

Measure Implementation Eligibility

All combinations of measure application type, delivery type, and sector that are established for this measure are specified in **Error! Reference source not found..** 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	Delivery Type	Sector
NC (New Construction)	UpDeemed (Upstream Deemed)	Com (Commercial)
NR (Normal Replacement)	UpDeemed (Upstream Deemed)	Com (Commercial)

Eligible Products

Products eligible for this measure include the following characteristics:

For units from 65,000 Btu/h to less than 135,000 Btu/h rated capacity:

- ≥12.0 EER
- ≥19.0 IEER

For units from 135,000 Btu/h to less than 240,000 Btu/h rated capacity:

- ≥12.0 EER
- ≥17.5 IEER



For both size categories:

- Must contain advanced compressor capacity control (either a variable speed compressor, tandem compressors on a single refrigeration circuit, or multiple-step compressors)
- Must contain a multi-speed (three steps or greater) indoor fan
- Gas-furnace heating section (no requirements on thermal efficiency)
- Must be a commercial unitary air conditioner subject to 10 CFR §431.97

Eligible Building Types and Vintages

PG&E downloaded all of the 22 available building types from MasControl3 for the unitary commercial air-cooled air conditioning measures (NE-HVAC-airAC-SpltPkg-65to134kBtuh-12p0eer-wPreEcono, NE-HVAC-airAC-SpltPkg-135to239kBtuh-12p0eer).

PG&E's goal was to have an "Ex" (a DEER abbreviation for "existing median," used for normal replacement projects) and a New (for new construction) vintage. PG&E used the DEER2020 commercial building stock data provided by the CPUC to generate both the Ex vintage and Com building types.³ Building types and vintages are shown in the two tables below. The table below shows the rolled up vintages in the workpaper. Ex is a weighted average of four vintages: 2003, 2007, 2011, and 2015. MasControl3 only outputted the "sizing" INP files for the "New" vintage and therefore New was unable to be modeled by PG&E. Therefore, PG&E used the 2020 vintage as a replacement for "New" to be used for New Construction projects.

Building Types in Workpaper

No.	Code	Description
1	Asm	Assembly
2	Com	Commercial
3	ECC	Education - Community College
4	EPr	Education - Primary School
5	ERC	Education - Relocatable Classroom
6	ESe	Education - Secondary School
7	EUn	Education - University
8	Gro	Grocery
9	Hsp	Health/Medical - Hospital
10	Htl	Lodging - Hotel
11	MBT	Manufacturing Biotech
12	MLI	Manufacturing Light Industrial
13	Mtl	Lodging - Motel
14	Nrs	Health/Medical - Nursing Home

³ <http://deeresources.com/files/DEER2020/download/DEER2020-Building-Weights.xlsx>.

15	OfL	Office - Large
16	OfS	Office - Small
17	RFF	Restaurant - Fast-Food
18	RSD	Restaurant - Sit-Down
19	Rt3	Retail - Multistory Large
20	RtL	Retail - Single-Story Large
21	RtS	Retail - Small
22	SCn	Storage - Conditioned
23	WRf	Refrigerated Warehouse

Building Vintages Modeled

No.	Vintage
1	2003 ^a
2	2007 ^a
3	2011 ^a
4	2015 ^a
5	2020 ^b

^a Rolled up to “Ex” vintage

^b Used for new construction in place of “New” vintage

Building Vintages in Workpaper

No.	Vintage	MAT
1	Ex	NR
2	2020	NC

Eligible Climate Zones

This measure is applicable in all 16 California climate zones. PA-specific climate zone measure impacts were not created (i.e., an “IOU” climate zone associated with a specific PA). For climate zones that cross PA territory boundaries (e.g., CZ05 or CZ13), the PA with the highest population was used as the PA for that climate zone. The full list of PA-CZ affiliations is shown in **Error! Reference source not found.**

List of Primary PA by Climate Zone

Climate Zone	IOU Source
CZ01	PGE
CZ02	PGE
CZ03	PGE



CZ04	PGE
CZ05	PGE
CZ06	SCE
CZ07	SDGE
CZ08	SCE
CZ09	SCE
CZ10	SCE
CZ11	PGE
CZ12	PGE
CZ13	PGE
CZ14	SCE
CZ15	SCE
CZ16	SCE

PROGRAM EXCLUSIONS

Central chilled water hydronic systems and domestic hot water systems are not eligible.

DATA COLLECTION REQUIREMENTS

Data collection requirements are to be determined.

USE CATEGORY

HVAC

ELECTRIC SAVINGS (kWh)

Electric Energy Savings Calculations

PG&E extracted the relevant measures from MasControl3 and modified key input values in the measure case files to capture advanced controls. The eQuest parametric modeling tool was used to perform the simulations necessary (outlined in the table below) for calculating the measure savings estimates using manufacturer collected performance maps.

Summary of Parameters Modeled

Parameter	Quantity
Climate zones	16
Building types	22



Building vintages	5 ⁴
Equipment size categories	2
System types	1 (DXGF ⁵)
Tiers	1 base case + 1 measure case

There were 7,040 total simulation iterations. The following shows a breakdown of those runs:

- Unitary AC - 65-135 kBtu/h: 16 Climate Zones x 22 Building types x 5 Building vintages x 1 System type x 2 Tiers = 3,520 runs
- Unitary AC - 135-240 kBtu/h: 16 Climate Zones x 22 Building types x 5 Building vintages x 1 System type x 2 Tiers = 3,520 runs

To calculate savings, the total annual energy usage for the measure case was subtracted from the total annual energy usage of the base case. The base case equipment that was modeled for the DXGF equipment were simply the DEER base case models, which represent a two-speed unit with gas heat that meets Title 24 Standards for Large Unitary Equipment. The measure case models are nearly identical to the base case models except replacing a few key variables (i.e., the compressor EIR f(PLR) performance curve, the compressor minimum unload ratio, and the fan minimum airflow fraction) which represent the high-IEER equipment being modeled in this measure.

Raw data on energy usage for each building climate zone and building type is found in the savings worksheets (file named: "MCLU-eQuest-Outputs.xlsx") under the "Modeled Results and Calculated Savings" header in the Attachments. These worksheets show the savings calculations by measure using the commercial building type weighting.

Once savings were calculated for each building type, climate zone, and vintage, the savings were weighted to produce "roll-ups" of raw savings results. Detailed calculations for these weightings are shown in the "Commercial Building Type Weighting.xlsx" (see Attachments). The "commercial" building type is derived separately for new construction (represented by the 2020 vintage) and normal replacement (represented by the Ex vintage) projects. Both new construction and normal replacement savings are included and shown in the savings worksheets.

Discussion of eQuest Inputs and Performance Curves

Performance curves in eQuest are a function of dry-bulb outdoor air temperature (OATdb), wet-bulb mixed air temperature (MATwb), part load ratio (PLR), or a combination of the three. The PLR is defined as the ratio of the hourly load to the hourly capacity. The system delivers the full-load rated capacity at 1.0 PLR and half of the rated capacity at 0.5 PLR. The table below shows the full set of performance curves that eQuest uses to define DX equipment in the software. Though PG&E collected a full set of performance curves for each DX unit, ultimately only the compressor EIR f(PLR) curve was used for this workpaper because of guidance in the CPUC disposition. The disposition stated that DEER curves are only to be replaced when specific performance features are being modeled that DEER does not capture. Since the equipment in the scope of these measures are mainly more efficient than standard DX units due to

⁴ 2003, 2007, 2011, and 2015 vintages were modeled and combined into the "Ex" vintage using the DEER2020 building weights. The "New" vintage only produced the "sizing" files from MasControl3 so the 2020 vintage was used instead for New Construction.

⁵ DXGF is a DEER abbreviation that means "direct expansion (DX) with gas furnace."

the advanced part-load compressor capacity control, the compressor EIR f(PLR) curve is the only curve is the only one that needs to be changed from the DEER defaults.

DX Performance Curves in eQuest

Parameter	Independent Variables	Function Type	Function	Source of Curve in Models
Cooling Capacity	MATwb, OATdb ^a	Bi-Quadratic	$Z = a + bx + cx^2 + dy + ey^2 + fxy$	DEER
Sensible Capacity	MATwb, OATdb	Bi-Quadratic	$Z = a + bx + cx^2 + dy + ey^2 + fxy$	DEER
Energy Input Ratio	MATwb, OATdb	Bi-Quadratic	$Z = a + bx + cx^2 + dy + ey^2 + fxy$	DEER
Coil Bypass Factor	MATwb, OATdb	Bi-Quadratic	$Z = a + bx + cx^2 + dy + ey^2 + fxy$	DEER
Compressor Energy Input Ratio	PLR	Cubic	$Z = a + bx + cx^2 + dx^3$	Manufacturer
Cycling Loss	PLR	Cubic	$Z = a + bx + cx^2 + dx^3$	DEER
Outdoor Fan Power	PLR, OATdb	Bi-Linear	$Z = a + bx + cy$	Not Applicable ^b
Fan Energy Input Ratio	PLR	Cubic	$Z = a + bx + cx^2 + dx^3$	DEER

^aMixed Air Temperature (wet bulb) is also referred to as the entering air wet bulb or EWB. The Outside Air Temperature (dry bulb) is also referred to as the Outside Air Dry-Bulb or OADB.

^bBoth DEER2020 and this workpaper didn't use the outdoor fan power curve because the energy is contained within the compressor EIR value and associated part-load ratio curve.

The performance maps collected are specific to a particular AC unit. When collecting curves, PG&E compared individual curves to manufacturer spec sheets and third-party studies to ensure accuracy in the data and ensure curves followed expected trends given the technologies implemented. These performance curves dictate how the unit will operate under various operating conditions and greatly affect the performance differences between equipment of different efficiencies. For example, the cooling capacity performance curve defines how much capacity the system can deliver at a specific indoor and outdoor temperature combination.

Together, the performance curves and operating parameters can be used to determine the performance of the HVAC system at any condition. The operating parameters define the performance of the system at AHRI conditions while the performance curves serve as a factor to adjust the performance of the system based on the varying conditions. The output of the curve is expressed as a ratio between how the unit operates at the given condition compared to how it operates at ARI conditions. As an example, the calculation for the cooling capacity of the system can be found in Equation 1 (note that DOE-2 uses the term "ARI" since this is the prior name for AHRI).

$$\text{Cooling Capacity} = \text{Cooling Capacity at ARI} \times \text{Cooling Capacity } f(\text{MATwb}, \text{OATdb}) \tag{Eq. 1}$$

Although some performance data is available in manufacturer equipment catalogs (e.g. capacity curves as a function of OADB and EWB) most of the detailed performance data that was collected, including the curves as a function of part load, are proprietary. Thus, non-disclosure agreements (NDAs) between Energy Solutions and some manufacturers were required to receive this information.

To maintain a like-for-like comparison between the existing and revised models, updates were only made to the components of the DEER models dealing with the performance mapping of the HVAC system. Any components related to building design or system operation remained unchanged. **Error! Reference source not found.** contains a detailed list of the HVAC operating parameters and performance curves that were altered, as well as definitions for each parameter.

Modified eQuest Inputs and Performance Curves

Modeling Category	Type of Input	Modeling Value/Curve Name	Description
Coil Capacity/Control	Single value	Min Cycling Part Load Ratio (LowSpdCapRatio)	The minimum part load conditions that the system can cycle down to during cooling
Supply Fans	Single value	Min Fan Airflow Ratio (LowSpdCfmRatio)	The minimum fraction of design flow at full capacity that the supply fan will always deliver, even when the system is not in cooling mode.
Unitary Power (full-load)	Single value	Cooling Electric Input Ratio (CoolingEIR)	The EIR refers to the ratio of the system’s electric input power to its rated cooling capacity at AHRI conditions. The value of the EIR determines the system’s efficiency. EIR can also be defined as $1/COP$ with indoor fan contributions excluded or $1/EER_{compressor}$. Outdoor fan power is included in this value for these simulations, and the outdoor fan power (“CondWPerBtuh”) is set to 0 W/Btuh.
Unitary Power (part-load)	Performance curve	Cooling Electric Input Ratio as a function of part-load ratio (CEIR_fPLR)	A cubic function with part-load ratio as the independent variable and cooling fraction of full-load EIR as the dependent variable. EIR is normalized such that at 100% PLR, the EIR value is 1.0.

The reason why each of the four modeling inputs are changed from DEER is described below:

- Compressor minimum unload ratio: PG&E adjusted this value to account for the fact that the units being modeled can unload to less than 50% before having to cycle.
- Supply fan minimum airflow ratio: PG&E adjusted this value from the default of 0.66 which represents a two-speed fan down to 0.4 which represents a multi speed (three or more steps) fan with a lower fan speed setting for ventilation mode.⁶

⁶ The supporting documentation for the decision to use 0.4 can be found in the attached document titled “MCLU Fan Minimum Airflows.docx”

- Compressor electric input ratio (EIR): PG&E used the same full-load EIR value as the DEER 12.0 EER measure, since full-load EIR is essentially going to dictate the full-load EER of the AC unit, and the units in the measure case are also required to have a 12.0 EER. It should be noted that DEER combined the condenser fan and compressor energy into a single EIR value, a procedure which PG&E also followed.
- Compressor EIR as a function of PLR: PG&E replaced the default DEER curve with a manufacturer-derived curve in order to capture the advanced part-load efficiency of the unit being modeled. PG&E simulated a number of compressor control strategies and then selected the compressor EIR f(PLR) curves with median savings results for use in the final workpaper savings calculations.

CPUC Disposition and Subsequent Edits

The February 2018 CPUC disposition requested raw data used to generate these curves. This is not possible due to the fact that the curves came from thermophysical computer models. These highly accurate models are used to generate AHRI and U.S. DOE ratings and are calibrated using laboratory data. The models must be accurate since AHRI and DOE ratings are subject to third-party validation. As the ED mentioned in discussions with PG&E, different vendors use different techniques to achieve high part load ratings and therefore curves were not blended. Units from manufacturers were simulated and the models with the lowest efficiency ratings that still met the requirements were used to represent the tier. All modeling files are available to the CPUC upon request, but were not attached to the work paper due to size constraints (>40 GB of data). Data was collected that represent every “advanced feature” option in the measure description.

In the CPUC disposition, it was stated that cooling EIR calculations must be shown. It was also stated that the “as-modeled” EER must match the EER requirement in the measure description. Because the measures require 12.0 EER, the cooling EIR from the DEER measures at 12.0 EER is used for the measure case simulations. **Error! Reference source not found.** shows that the condenser W/Btuh value is set to zero, which is a change from the first version of this workpaper to bring the workpaper modeling methods into closer alignment with DEER. The supply fan minimum airflow settings were reduced from the DEER default value of 0.66 to 0.4 in order to represent a lower fan speed setting in ventilation mode that a multi-speed fan can achieve. The DEER default value of 0.66 represents a code-minimum two-speed fan.

The original version of the workpaper used different design airflow W/cfm values which correlated to the particular units being modeled in eQuest. The CPUC disposition noted that their research did not establish a definitive relationship between overall unit IEER and supply fan W/cfm, and therefore that value was held constant across the base to measure-case models. PG&E conducted additional research which confirmed this finding. Now, the DEER value for supply fan W/cfm is used in our measure case models. Our fan energy savings arise from the supply fan’s ability to reduce its speed during low demand or ventilation hours lower than a standard two-speed fan.

Though the DEER cycling loss performance curve is now used, the CPUC disposition pointed out that this curve only applies to the first stage of cooling and stated that the higher stage cycling losses should still be captured in the compressor EIR f(PLR) curve. As a result, PG&E modified its compressor EIR f(PLR) curve used for this modeling effort in accordance with the procedure outlined in the CPUC-supplied spreadsheet titled “Multispeed_PkgPerfMapDemo_2018_10_09.xlsx” (included as an attachment to this workpaper). The calculations to modify the manufacturer curve are shown in the spreadsheet titled “HigherStageCycLoss.xlsx” (also included as an attachment to this workpaper). Because PG&E is modeling tandem compressors on a single refrigerant circuit, when in higher stages of cooling, cycling losses should be lower than when the refrigerant is in the first stage of cooling because refrigerant is always flowing

through the system. A coefficient of degradation of 20% is used in the first stage of cooling (captured in the cycling loss performance curve) and a coefficient of degradation of 7% is used in higher stages of cooling. Both figures are used from CPUC guidance as shown in the spreadsheet “Multispeed_PkgPerfMapDemo_2018_10_09.xlsx.” The 20% value in the first stage of cooling is what DEER has traditionally used to represent the cycling loss degradation coefficient, and is also the value used in AHRI 210/240 when a cyclic test is not conducted.⁷ The 7% cycling loss value was negotiated between PG&E and the CPUC to represent the cycling loss in higher stages of cooling on a single refrigerant circuit.

The CPUC disposition also contained a request for more information on PVAV systems (including hot gas bypass at low loads). Because PVAV was only modeled in 20–63.3 tons, a size category which was eliminated for this version of the workpaper, addressing those topics is no longer needed.

PEAK ELECTRIC DEMAND REDUCTION (kW)

The DEER peak demand period as defined in DEER2020 was used to calculate peak demand for each model and subsequently used to calculate peak demand reduction for each measure case.⁸ The DEER2020 Peak Period Update changed the hours of the day, from 2 to 5 PM to 4 to 9 PM, but not the summer days by climate zone. The peak kW savings calculations were done following DEER procedures. The peak period is a three-day summer heat wave specific to each of the 16 climate zones. The three-day period for each climate zone is shown in the table below (assumes a 2009 simulation year).

DEER Peak Period Days by Climate Zone

Climate Zone	Peak Period Days
CZ01	September 16-18
CZ02, CZ03, CZ11, CZ12, CZ13, CZ16	July 8-10
CZ04, CZ06, CZ07, CZ08, CZ09, CZ10	September 1-3
CZ05	September 8-10
CZ14	August 26-28
CZ15	August 25-27

In accordance with DEER2020 guidance, the peak period for each day is now defined as the window between 4 and 9 PM. Therefore, PG&E used the combination of the peak period days between the hours of 4-9 PM to extract the average electricity usage from each simulation for both the base case and

⁷ http://www.ahrinet.org/App_Content/ahri/files/STANDARDS/AHRI/AHRI_Standard_210-240_2017.pdf.

⁸DEER2020 – Peak Period Update <http://deeresources.com/index.php#PkPeriod>;
<http://deeresources.com/files/DEER2020/download/CZ2010%20Peak%20Period%20Determination%20-%20v3.xlsm>

measure cases. The peak savings were calculated as the difference between the electricity consumption between the two cases over the specified time periods by climate zone.

GAS SAVINGS (Therms)

There are no gas savings associated with this measure.

LIFE CYCLE

The methodology to calculate the RUL conforms with Version 5 of the Energy Efficiency Policy Manual, which recommends “one-third of the effective useful life in DEER as the remaining useful life until further study results are available to establish more accurate values.”⁹ This approach provides a reasonable RUL estimate without the requiring any a priori knowledge about the age of the equipment being replaced.¹⁰ Further, as per Resolution E-4807, the California Public Utilities Commission (CPUC) revised add-on measures so that the EUL of the measure is equal to the lower of the RUL of the modified system or equipment or the EUL of the add-on component.”¹¹

The EUL and RUL specified below, are based upon version 2.5.1 of the DEER READI tool.

Effective Useful Life and Remaining Useful Life

Parameter	Value	Source
EUL (yrs) – measure	15	DEER READI v2.5.1
EUL (yrs) – host	15	DEER READI v2.5.1
RUL (yrs)	5	DEER READI v2.5.1

BASE CASE MATERIAL COST (\$/UNIT)

Base case equipment costs were collected via a survey of distributors. The full survey information is contained in an attached spreadsheet named “Unitary AC – High IEER Tiers IMCs.xlsx.” The information has been anonymized to protect business sensitive information.

Base Case Equipment Costs by Size Category

Equipment Size	Equipment Efficiency	Equipment Cost per Ton
65-134 kBtu/h (5.4-11.25 tons)	11.0 EER/12.7 IEER	\$746.50
135-239 kBtu/h (11.25-20 tons)	10.8 EER/12.2 IEER	\$705.46

⁹ California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 32.

¹⁰ KEMA, Inc. 2008. "Summary of EUL-RUL Analysis for the April 2008 Update to DEER." Memorandum submitted to Itron, Inc.

¹¹ California Public Utilities Commission (CPUC). 2016. Resolution E-4807. December 16. Page 13.

MEASURE CASE MATERIAL COST (\$/UNIT)

Measure case equipment costs were collected via a survey of distributors. The full survey information is contained in an attached spreadsheet named “Unitary AC – High IEER Tiers IMCs.xlsx.” The information has been anonymized to protect business sensitive information.

Measure Case Equipment Costs by Size Category

Equipment Size	Equipment Efficiency	Equipment Cost per Ton
65-134 kBtu/h (5.4-11.25 tons)	12 EER/19.0 IEER	\$902.84
135-239 kBtu/h (11.25-20 tons)	12 EER/17.5 IEER	\$938.93

Incremental Measure Cost (IMC) by Size Category

Equipment Size	Measure Case Efficiency	IMC per Ton
65-134 kBtu/h (5.4-11.25 tons)	12 EER/19.0 IEER	\$156.34
135-239 kBtu/h (11.25-20 tons)	12 EER/17.5 IEER	\$233.48

BASE CASE LABOR COST (\$/UNIT)

Base case and measure case labor costs assumed to be equal, and therefore cancel in the IMC calculation.

Full and Incremental Measure Cost Equations

Installation Type	Incremental Measure Cost
NR (includes ROB)	$(MEC + MLC) - (BEC + BLC)$
NC	

MEC = Measure Equipment Cost; MLC = Measure Labor Cost

BEC = Base Case Equipment Cost; BLC = Base Case Labor Cost

MEASURE CASE LABOR COST (\$/UNIT)

Measure case labor cost not collected because base case and measure case labor costs assumed to be equal.

NET-TO-GROSS (NTG)

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 relevant NTG values for all packaged and split system air conditioner and heat pump replacements are specified below.

Net-to-Gross Ratio

Parameter	Value	Source
NTG - commercial	0.65	Impact Evaluation of 2015 Upstream HVAC Programs (HVAC1), CPUC, DNV-GL, April 4, 2017, Page 38. DEER2020 READI v2.5.1 (NTG ID: NonRes-sAll-mHVAC-DX-up)

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. This GSIA rate is the current “default” rate specified for measures for which an alternative GSIA has not been estimated and approved.

Gross Savings Installation Adjustment

Parameter	GSIA	Source
GSIA - Default	1.00	California Public Utilities Commission (CPUC), Energy Division. 2013. <i>Energy Efficiency Policy Manual Version 5</i> . Page 31.

NON-ENERGY IMPACTS

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

ATTACHMENTS

1. Multispeed_PkgPerfMapDemo_2018_10_09.xlsx
2. HigherStageCycLoss.xlsx
3. MCLU-eQuest-Outputs.xlsx
4. Commercial Building Type Weighting.xlsx
5. Unitary AC – High IEER Tiers IMCs.xlsx
6. MCLU Fan Minimum Airflows.docx

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
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Modified DEER methodology	DEER methods used but with different input/performance curve values to capture high efficiency part-load AC equipment characteristics.
Scaled DEER measure	No
DEER Base Case	Yes
DEER Measure Case	No
DEER Building Types	Yes
DEER Operating Hours	Yes
DEER eQuest Prototypes	Yes
DEER Version	DEER2020, READI v2.5.1
Reason for Deviation from DEER	The workpaper follows the recommendation of the 2013-2014 HVAC1 Impact Evaluation, which says to “Use DEER estimates generally and focus workpaper efforts on EER and IEER combinations greater than DEER values. Detail the performance maps and additional features if any such as variable speed compressors, energy recovery ventilation, etc.” Therefore, performance curves that represented these higher efficiency units (e.g., units with tandem compressors on a single refrigeration circuit and variable speed compressors) were collected from the manufacturers to allow energy modeling and calculation of the savings for these units.
DEER Measure IDs Used	NE-HVAC-airAC-SpltPkg-65to134kBtuh-12p0eer-wPreEcono; NE-HVAC-airAC-SpltPkg-135to239kBtuh-12p0eer
NTG	Source: DEER2020, READI v2.5.1. The NTG of 0.65 is associated with NTG ID: <i>NonRes-sAll-mHVAC-DX-up</i>
GSIA	The GSIA of 1.0 is associated with GSIA ID: <i>Def-GSIA</i>
EUL/RUL	Source: READI v2.5.1. The value of 15 years is associated with EUL ID: <i>HVAC-airAC</i>

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Revision Complete Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision
0	8/31/2017	Peter Florin and Alex MacCurdy (Energy Solutions), Henry Liu (PG&E)	New workpaper. Not reviewed by Cal TF.
1	10/14/2019	Bryan Boyce and Garrett Hedberg (Energy Solutions), Henry Liu and Adan Rosillo (PG&E)	Incorporated 3/1/2018 CPUC Disposition requirements: Eliminated 240-760 kBtu/h size category, eliminated lower IEER tiers (due to concerns with DEER measure overlap), changed base case to DEER (originally was code-minimum manufacturer performance curve inputs), specified “advanced features” in measure requirements, changed all modeling parameters in measure case to DEER values except for specific equipment aspects being modeled (three-speed fans, advanced part-load compressor operation), added a cycling loss penalty into compressor part-load curve in higher stages.
1	11/15/2019	Bryan Boyce and Garrett Hedberg (Energy Solutions), Henry Liu and Adan Rosillo (PG&E)	Added an attachment “MCLU Fan Minimum Airflows.docx” that documents each manufacturer’s low airflow cutoff (i.e., ventilation mode cfm to full airflow cfm ratio) in response to CPUC feedback.