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HVAC

PACKAGED AIR CONDITIONER HEAT RECOVERY, COMMERCIAL

SWHC048-02

CONTENTS

MEASURE NAME

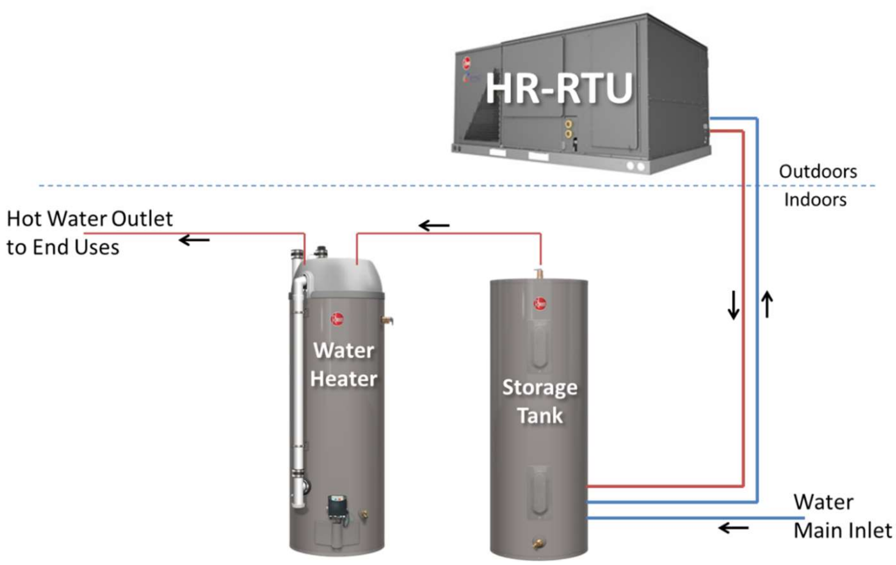
Packaged Air Conditioner Heat Recovery, Commercial

STATEWIDE MEASURE ID

SWHC048-02

TECHNOLOGY SUMMARY

Heat-Recovery from a packaged air conditioner rooftop unit (RTU) will reduce the energy required for water heating through the use of the waste heat from the RTU air conditioning cycle. The waste heat preheats the incoming water from the main; once the water has been preheated it is directed into a storage tank where it will be available upon demand. When there is hot water demand, the preheated water will route into the water heater to be raised to setpoint temperature.



Typical HR-RTU System Architecture

In a typical setting, waste heat that originates in the building interior is rejected via an air-cooled condenser in the RTU to the atmosphere. With an RTU with heat recovery capability, the heat is instead transferred via a refrigerant-to-water heat exchanger to the incoming water. This offsets the water heater natural gas consumption by having the RTU increase the main water temperature prior to entering the water heater.

The energy savings are proportional to the change in water temperature between the water main and the water heater inlet; this is the “free” heat from the RTU that would have been rejected into the environment. While the equipment, itself, is integrated in an RTU for space conditioning, this is a water heating measure. Savings as a result of this measure are directly dependent on the space cooling demand, which makes this a weather sensitive measure.

Currently, only 10-ton and 15-ton cooling capacity units are available in the market; the savings and costs developed for this measure are based upon a 10-ton cooling RTU unit.

Additional benefits associated with this measure include:

- *Increased water heating capacity:* A RTU with heat recovery increases the total hot water that can be provided by the existing hot water heater.
- *Backup water heating capabilities:* Should the building hot water heater fail, an RTU with heat recovery can provide hot water at up to ~125 °F between 80 kBtu/hr and 220 kBtu/hr, provided there is sufficient space cooling demand.[1]

MEASURE CASE DESCRIPTION

The measure case is defined as a packaged air conditioner with heat recovery capabilities, i.e., that is equipped with an air-to-water heat exchanger to preheat service hot water.

Measures Offerings

Statewide Measure Offering ID	Measure Offering Descriptions
SWHC048-01A	Heat-Recovery Rooftop Unit

BASE CASE DESCRIPTION

The base case is defined as a packaged air conditioner rooftop unit without an air-to-water heat exchanger.

CODE REQUIREMENTS

There are currently no federal or regional codes that impact heat recovery air conditioner rooftop units.

Applicable State and Federal Codes and Standards

Code	Applicable Code Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20	Section:1605.1 (c)	January 1, 2019
CA Building Energy Efficiency Standards – Title 24 (2019)	Section: 110.2	January 1, 2019
Federal Standards	None.	n/a

NORMALIZING UNIT

Each.

PROGRAM REQUIREMENTS

Measure Implementation Eligibility

[1] Rheem H2AC Rooftop Unit Product Brochure.pdf

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	Delivery Type	Sector
Normal Replacement (NR)	DnDeemed	Com
Normal Replacement (NR)	UpDeemed	Com
Normal Replacement (NR)	DnDeemDI	Com
New Construction (NC)	DnDeemed	Com
New Construction (NC)	UpDeemed	Com
New Construction (NC)	DnDeemDI	Com

Eligible Products

The installation of an air-to-water RTU air conditioner unit for a fast food restaurant that is capable of utilizing waste heat to preheat incoming water from the main. See Measure Case Description.

Eligible Building Types and Vintages

The savings developed for this measure are applicable for installations in a fast food restaurant facility with a gas water heating system.

Eligible Climate Zones

This measure is applicable in all California climate zones.

PROGRAM EXCLUSIONS

None.

DATA COLLECTION REQUIREMENTS

Due to this technology being new, there are currently no studies that document the energy savings benefits of preheating water with an air-to-water heat exchanger in a rooftop air conditioning unit (RTU). The emerging technology study, *Portfolio of the Future: Field Testing Report – Rheem H2AC at a Quick-Serve Restaurant,* summarizes results of a field test for which an RTU unit with heat recovery was installed and water temperature and water consumption data was monitored and recorded for 114 days.[2] The data recorded in the study is of good quality and accuracy, outlining all values required to yield an empirical savings value over the monitored period. However, because of limited data availability, further research is needed to associate a relation between hot water demand and air-conditioning load to increase the accuracy of savings.

USE CATEGORY

HVAC

ELECTRIC SAVINGS (KWH)

Not applicable.

PEAK ELECTRIC DEMAND REDUCTION (KW)

Not applicable.

GAS SAVINGS (THERMS)

Methodology

The annual gas unit energy savings (UES) of this measure was estimated by a regression as a function of cooling degree days (CDD) and pre- and post-installation data collected for 114 days of an air conditioning rooftop unit (RTU) with heat recovery installed at a quick-serve food restaurant in Anaheim, California.[3] Measurements were collected every 15 minutes for water main temperature, storage tank outlet temperature, water heater outlet temperature, and water consumption. As documented in the field test study, the daily UES is a function of the temperature difference between the incoming water from the main and the outlet water from the water storage tank; this temperature difference represents the energy that would have previously come from the natural gas fired water heating system. The pre-installation data confirmed that usage patterns did not deviate from typical levels after installation of the H2AC. (p.3)

The restaurant is open 24 hours per day, 7 days per week. The restaurant consumes approximately 520 gallons of 140 °F hot water daily. The hot water system is a standard storage tank gas-fired hot water heater with a thermal efficiency rating of 80%.

[2] Guernsey, M. (Navigant Consulting, Inc.). 2016. Portfolio of the Future: *Field Testing Report – Rheem H2AC at a Quick-Serve Restaurant.* Prepared for the Southern California Gas Company (SCG). July.

[3] Guernsey, M. (Navigant Consulting, Inc.). 2016. Portfolio of the Future: *Field Testing Report – Rheem H2AC at a Quick-Serve Restaurant.* Prepared for the Southern California Gas Company (SCG). July.

Regression Model – Sloped Section

	Value
Slope	0.08
Intercept	-0.05
Inflection	28.00
RSQ	0.35
Y = 0.08X - 0.05	

Cooling Degree base of 42°F

Regression Model – Flat Section

	Value
Slope	-0.01
Intercept	2.53
Average	2.30
Y = 2.3	

Cooling Degree base of 42°F

The CDD base of 42 °F that was to generate the regression was chosen for the following reasons.

- The typical 65 °F base is driven by outside temperatures. However, in a fast food environment, the thermostat will call for cooling prior to the outside temperature exceeding 65 °F . This is due to various internal loads in a fast food setting (i.e. multiple people, cooking equipment, electronics, and constant traffic opening doors).
- The Y-intercept in this regression model is close to zero with an inflection point of 28 CCD. This implies that at zero-degree days, there will be no gas savings. This is true for this measure. If the AC is off, savings are nonexistent.
- The weather data shows that for a base of CDD65 on March 25, 2014 there was zero CDD.[4] This implies that there should be no AC activity. However, there were savings and therefore AC load must have been present. From the 114-day test data, 1.67 therms were saved on March 25, 2014.[5] Applying the regression model and the CDD days from a base of 42 °F, the following was observed:[6]

  $$Y = 0.08 \times 19.3 - 0.05 = 1.5 \text{ therms}$$

  This conservative result shows the regression model will predict the actual savings fairly closely.

[4] Southern California Gas Company (SCG). 2019. “SWHC048-01 KFUL_CDD_65F.csv.”

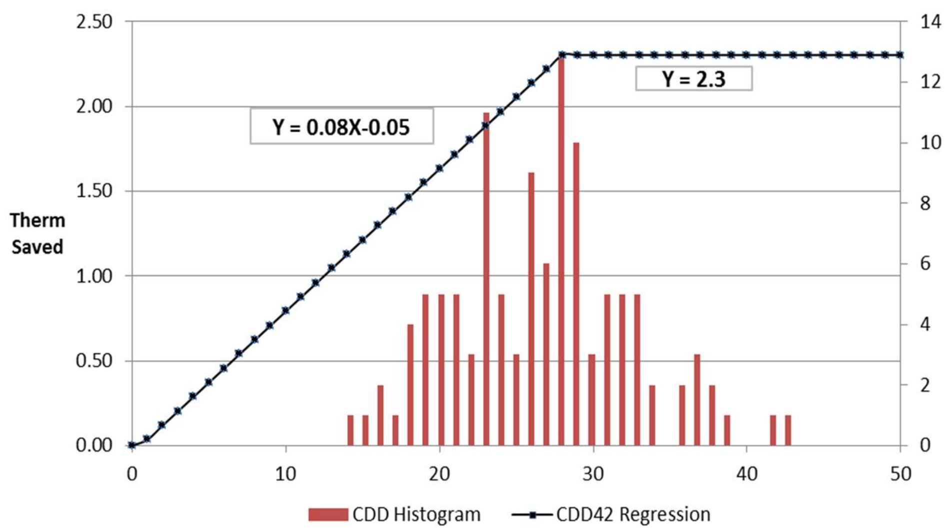
[5] Guernsey, M. (Navigant Consulting, Inc.). 2016. Portfolio of the Future: *Field Testing Report – Rheem H2AC at a Quick-Serve Restaurant.* Prepared for the Southern California Gas Company (SCG). July.

[6] Southern California Gas Company (SCG). 2019. “SWHC048-01 KFUL_CDD_42F.csv.”

- During a major interval during the test pilot, the AC operation status was recorded, and it was observed that it would cycle ON and OFF. There was not a single day in which the AC was OFF for the entire day.[7]

However, the regression savings are limited to an inflection point of 28 CDD. This point value was chosen to force the Y-intercept to be close to a value of zero for zero savings at zero CDD. Any value of CDD exceeding 28 will yield the same energy savings as 28 CDD. This was done to limit the amount of energy saved, otherwise savings will indefinitely increase linearly with CDD. This limitation was established due to the hot water demand, which depends on the facility daily traffic.

During the monitor period, 28 CDD was the maximum value that produced savings and also the highest CDD value. This relates water demand that needs heating and available heat to preheat it. Beyond this CDD value, the hot water demand volume and available heat are not modeled by the current data. The hot water demand could be much greater than the amount of heating that could be provided by this measure, therefore savings past 28 CDD are uniform. This is done by having two sections in the regression: slope and flat. The following plot represents the linear regression against CDD:



Gas Energy Savings vs Cooling Degree Days

Daily Unit Energy Savings

The regression model constructed from the field test data was used along with convective principles to estimate daily UES, as shown below.

$$UES_{daily,therm} = \left[\frac{m * C_p * \Delta T}{\eta * 100{,}000}\right]$$

$m = pounds\ of\ water\ used(lb_m) = gallons\ used\ x\ Specific\ weight\ of\ water$
$C_p = Water\ Specific\ Heat\ Capacity$
$\Delta T = Water\ Heater\ outlet - Storage\ Tank\ Outlet$
$\eta = Water\ Heater\ Efficiency$
$100{,}000\ Btu = Btu\ to\ Therm\ conversion\ factor$

[7] Southern California Gas Company (SCG). 2019. "SWHC048 Test Pilot Raw Data.xlsx."

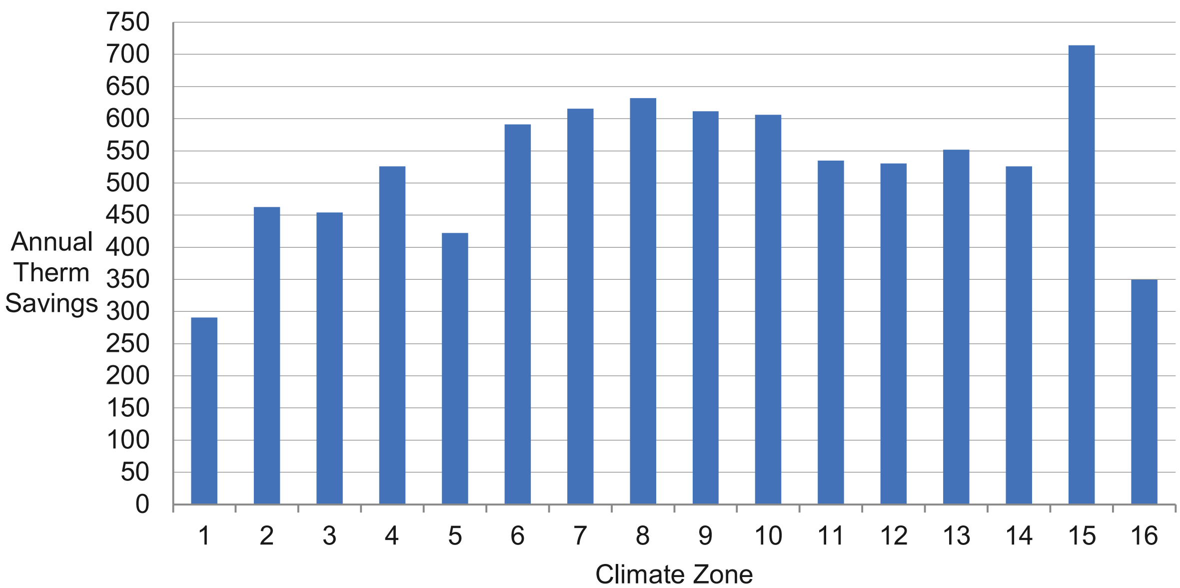
The inputs for the calculation used to estimate daily gas UES are measurements recorded from the 114-day monitored test period.

Daily UEC Inputs and Assumptions

Input	Value	Source
Gallons (gal)	Varies	Southern California Gas Company (SCG). 2019. *SWHC048-01 Energy Savings.xlsb*
Water Heater Outlet Temperature	Varies	
Storage Tank Outlet Temperature	Varies	
Water heater thermal efficiency (η)	80%	
Specific Weight of Water (lb_m/gallons)	8.33	*Constants*
Specific Heat Capacity of Water, Cp (BTU/lb_m×°F)	1	
Btu to Therm Conversion Factor (Btu/Therm)	100,000	

Annual Unit Energy Savings

The regression was applied to 8760 weather approved data by the CPUC.[8] The annual gas UES was calculated as the sum of the hourly gas energy savings obtained from the regression. Savings by climate zone are shown below.



Gas Energy Savings by Climate Zone

[8] CompareWeatherData-v4

Sample Calculation

For a sample calculation of March 22, 2014 with the following values.

$$Water\ use\ =\ 4\ gallons\ =\ 4\ gallons * 8.33\frac{lb_m}{gallons} = 33.32\ lb_m$$
$$Water\ specific\ heat\ capacity = 1\ \frac{BTU}{lb_m * {}^{\circ}F}$$
$$Water\ Inlet\ Main\ Temperature\ =\ 67\,{}^{\circ}F$$
$$Water\ Heater\ \Delta T\ =\ (144 - 67){}^{\circ}F\ =\ 77\,{}^{\circ}F\ (No\ HR - RTU)$$
$$Water\ Heater\ \Delta T\ =\ (144 - 90){}^{\circ}F\ =\ 54\,{}^{\circ}F\ (With\ HR - RTU)$$

For this instance, the heat recovery- roof top unit increased the water main temp by 23 °F, the savings are as follows:

$$Q_{therm:\,No\ HR-RTU} - Q_{therm:\,HR-RTU} = \left[\frac{m * C_p * \Delta T}{\eta * 100{,}000}\right]$$
$$= \left[\frac{33.32\ lb_m * 1\frac{BTU}{lb_m * {}^{\circ}F} * \ 77\,{}^{\circ}F}{0.80 * 100{,}000}\right] - \left[\frac{33.32\ lb_m * 1\frac{BTU}{lb_m * {}^{\circ}F} * \ 54\,{}^{\circ}F}{0.80 * 100{,}000}\right]$$
$$= 0.032 - 0.022$$
$$= 0.010\ therm.$$

All the recordings for March 22, 2014 as shown in the example were calculated and aggregated to yield a daily UES value. During this day a total of 4.2 therms were used, 1.80 of which were accounted to the HR-RTU as savings from preheating water by taking advantage of the AC cooling load.

A total gas UES of 237 therms was estimated over the entire test period of 114 days. The amount of energy used would have been 437 therms, 200 of which were accounted to the water heater. For this test period, the energy consumption was reduced by 54%.

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.

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

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

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 for a rooftop air conditioning unit with heat recovery are specified below. The estimated lifetime can be traced back to values adopted for the California PY 2001 energy efficiency programs.

Effective Useful Life and Remaining Useful Life

Parameter	Value	Source
EUL (yrs)	15	Pacific Gas and Electric Company (PG&E), San Diego Gas & Electric (SDG&E), Southern California Edison (SCE), Southern California Gas Company (SCG), California Energy Commission (CEC), Office of Ratepayer Advocates (CPUC ORA), and Natural Resources Defense Council (NRDC). 1998. *Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings from Demand-Side Management Programs.* Revised March 1998 and March 1999. Page 15. Pacific Gas and Electric Company (PG&E), San Diego Gas & Electric (SDG&E), Southern California Edison (SCE), Southern California Gas Company (SCG). 2000. "Proposed Effective Useful Life for Measures for PY2001 Program Elements. Report Issued Prior to Public Meeting. Response to Ordering Paragraph #8, Discussion Paper 2." September 5. California Public Utilities Commission (CPUC), Energy Division. 2008. "EUL_Summary_10-1-08.xls."
RUL (yrs)	-	n/a

BASE CASE MATERIAL COST ($/UNIT)

Base case material costs for this measure represent an average of cost data obtained from Portfolio of the Future (PoF) test pilot project conducted by Navigant Consulting, Inc. and from manufacturer/contractor discussions.[12] The actual base case material costs may vary depending on the distance between the water heater and the rooftop unit (RTU), various local labor rates, and the variations in markups and material costs.

Base Cost Material Cost Inputs (10-ton Unit)

Input	Cost per unit	Cost per ton
RTU	$5,000	$500
Curb adapter	$900	$90
Total	**$5,900**	**$590**

[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.

[12] Southern California Gas Company (SCG). 2019. "SWHC048-01 Cost Analysis.xlsx."

Guernsey, M. (Navigant Consulting, Inc.). 2016. Portfolio of the Future: *Field Testing Report – Rheem H2AC at a Quick-Serve Restaurant.* Prepared for the Southern California Gas Company (SCG). July. See Appendix B.

Vadnal, H. (Gas Technology Institute, GTE). 2015. "Rheem H_2AC ™ integrated Air and Water RTU." Presented at the ACEEE Hot Water Forum. February 22.

MEASURE CASE MATERIAL COST ($/UNIT)

Measure case material costs represent the average of cost data obtained from Portfolio of the Future (PoF) test pilot project conducted by Navigant Consulting, Inc. and from manufacturer/contractor discussions.[13] The actual measure case material costs may vary depending on the distance between the water heater and the rooftop unit (RTU), various local labor rates, and the variations in markups and material costs.

Measure Case Material Cost Inputs (10-ton Unit)

Input	Cost per unit ($)	Cost per ton ($)
RTU	$7,000	$700
Curb adapter	$900	$90
Storage tank	$1,000	$100
Total	$8,900	$890

BASE CASE LABOR COST ($/UNIT)

Base case labor installation costs were estimated from a Portfolio of the Future (PoF) test pilot project conducted by Navigant Consulting, Inc.[14]

Base Cost Labor Cost Inputs (10-ton unit)

	Cost per Unit ($/unit)	Cost per Ton ($/ton)
Rigging/placing/reconnecting power/etc.	$5,700	$570
Additional plumbing labor	n/a	n/a
Total	$5,700	$570

MEASURE CASE LABOR COST ($/UNIT)

Measure case labor costs for this measure are estimates that represent an average customer installation obtained from Portfolio of the Future (PoF) test pilot project administer by Navigant Consulting, Inc. in addition to manufacturer/contractor discussions.[15] The actual measure case labor costs may vary

[13] Southern California Gas Company (SCG). 2019. "SWHC048-01 Cost Analysis.xlsx."

Guernsey, M. (Navigant Consulting, Inc.). 2016. Portfolio of the Future: *Field Testing Report – Rheem H2AC at a Quick-Serve Restaurant.* Prepared for the Southern California Gas Company (SCG). July. See Appendix B.

Vadnal, H. (Gas Technology Institute, GTE). 2015. "Rheem H_2AC ™ integrated Air and Water RTU." Presented at the ACEEE Hot Water Forum. February 22.

[14] Southern California Gas Company (SCG). 2019. "SWHC048-01 Cost Analysis.xlsx."

Guernsey, M. (Navigant Consulting, Inc.). 2016. Portfolio of the Future: *Field Testing Report – Rheem H2AC at a Quick-Serve Restaurant.* Prepared for the Southern California Gas Company (SCG). July. See Appendix B.

[15] Southern California Gas Company (SCG). 2019. "SWHC048-01 Cost Analysis.xlsx."

depending on the distance between the water heater and the rooftop unit (RTU), various local labor rates, and the variations in markups and material costs.

Measure Case Labor Cost Inputs (10-ton Unit)

	Cost per Unit ($/unit)	Cost per Ton ($/ton)
Materials – piping, other misc. (incl. labor)	$2,500	$250
Rigging/placing/reconnecting power/etc.	$5,700	$570
Additional plumbing labor	See above	See above
Total Labor	$8,200	$820

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. These NTG values are based upon the average of all NTG ratios for all evaluated 2006 – 2008 commercial, industrial, and agriculture programs, as documented in the 2011 DEER Update Study conducted by Itron, Inc. These sector average NTGs ("default NTGs") are applicable to all energy efficiency measures that have been offered through commercial, industrial, and agriculture sector programs for more than two years and for which impact evaluation results are not available.

Net-to-Gross Ratios

Parameter	Value	Source
NTG – Commercial	0.60	Itron, Inc. 2011. *DEER Database 2011 Update Documentation.* Prepared for the California Public Utilities Commission. Page 15-4 Table 15-3.

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. *Energy Efficiency Policy Manual Version 5*. Page 31.

Guernsey, M. (Navigant Consulting, Inc.). 2016. Portfolio of the Future: *Field Testing Report – Rheem H2AC at a Quick-Serve Restaurant.* Prepared for the Southern California Gas Company (SCG). July. See Appendix B.

NON-ENERGY IMPACTS

Non-energy benefits 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	No
DEER Operating Hours	No
DEER eQUEST Prototypes	No
DEER Version	DEER2021, via READI v2.5.1
Reason for Deviation from DEER	DEER does not contain Heat-Recovery Rooftop Units
DEER Measure IDs Used	None
NTG	Source: DEER. The NTG of 0.60 is associated with NTG ID: *Com-Default>2yrs*
GSIA	The GSIA of 1.0 is associated with GSIA ID: *Def-GSIA*
EUL/RUL	Source: DEER. The value of 15 years is associated with EUL ID: *HVAC-airAC*

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Revision Complete Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision
01	10/31/2019	RMS Energy Consulting, LLC.	Draft of consolidated text for this statewide measure is based upon: WPSCGNRWH160726A-Rev00
	01/30/2020	Raad Bashar, SoCalGas	The comments from the CPUC ExAnte team requesting additional information on 12/27/2019, were addressed as follows: Building type was changed from Com to RFF and RSD and building HVAC type was changed to Any.
	5/27/2020	Eduardo Reynoso, SDG&E	Workpaper measure adoption by SDG&E, no changes to energy efficiency savings or cost. Updated Ex-ante Implementation data table. No other changes.
02	04/16/2021	Anders Danryd, SoCalGas	Updated NTG Ratio from ET-Default to Com-Default>2yrs, minor formatting changes, made calculations and sources easier to follow and more clearly labeled